IPIC 2014

Conference Proceedings



1st International Physical Internet Conference

28-30 May 2014 | Quebec City, Canada

TOWARDS A SMART INTERCONNECTED ERA OF EFFICIENT AND SUSTAINABLE LOGISTICS, SUPPLY CHAIN AND TRANSPORTATION

Conference Host

UNIVERSITÉ LAVAL

IPIC 2014 Proceedings

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CargoFish: A Network Utility for Parcel Exchange

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Abstract: *An installed utility infrastructure for transportation of small parcels could replace operation of automobiles over streets and highways for these purposes, offering significant savings in energy, driver's time, road congestion, and accidents. A variety of existing municipal utilities are effective and economical instruments for dispatch, delivery, and/or removal of several of the everyday necessities of modern life: electricity, water, natural gas, sewer, telephony, and the Internet. This additional infrastructure will provide far more value than its cost, and benefit the financial backers as well as society at large.*

Keywords: *cargofish, physical internet, network, transportation, utility*

1 Introduction

Transportation of people and things is an essential element of modern society. Unfortunately, it is also a contributor to growing problems stemming from energy consumption. Much work is being done on finding less detrimental ways of effectively moving people and freight. CargoFish Physical Internet is focused on replacing the most inefficient "freight" movements presently in common use: driving a car to deliver or retrieve relatively small payloads, such as groceries, mail, etc. The idea is to create a new utility… an underground network of electric freeways for autonomous "trucks". This would allow home delivery of all manner of everyday essentials on a very low energy budget, at a high level of reliability and convenience, and in lieu of driving. Side effects will include reduced traffic congestion, energy consumption, and time lost to driving.

2 Background

Before recorded history, transportation likely seldom involved purposeful improvements to routes other than the "wearing in" of paths from repeated traffic. Since then several cultures developed roads, bridges, and harbors. These improvements made transportation easier by reducing the necessary effort per mile. Maximizing the economy of the prime mover remained the leading element of technological advances in transportation right through the canal boom and the birth of the railroad. Since the introduction of the steam engine though, and especially after widespread adoption of the internal combustion engine, prime mover efficiency gains took a back seat to other factors in transportation development. The age of oil provided cheap energy, which fueled its expanded use.

3 Body and Conclusion

In just the US, light trucks and cars are driven almost three trillion miles per year. This is half a light year, per year. A full fifteen percent of this driving is not for the purpose of moving any person, passenger driver, but for transporting some other payload. Examples of such other payloads frequently include groceries, prescriptions, and consumer packaged goods in general. Such movements are the most energy intensive activities of the modern age, in terms of how much is being expended versus how little could be.

For many other materials moved in great quantities, this is not the case. Utilities provide for driverless delivery of electricity, natural gas, and potable water. Sewer and storm drain utilities handle much of our waste removal. Finally, broadcast media, telephony, and the Internet provide for information exchange. Notably, each of these utilities transports its payload as a fluid, either literally or figuratively. No common utility, other than our road networks and the flow of traffic, handles any solid.

There are automated handling methods for solids in productive use. These include conveyor belt systems, such as sorting facilities for parcel services, manufacturing facilities, bulk materials at mines, terminals, and processing facilities. There have also been coal slurry pipelines. The most notable systems for moving solids are pneumatic tube systems. A ten inch diameter pneumatic tube system is in service at the Denver International Airport. Smaller diameter systems have been employed in a wide range of applications, such as NASA Mission Control Center, Houston. Over 2,600 hospitals in North America actively use systems installed by just the two top vendors: Swisslog and Pevco. On the neighborhood scale, there are systems available from Envac, for solid waste and recycle collection via twenty inch diameter vacuum tubes. These are installed at Disney World, FL, Roosevelt Island, NY, Montreal, CA, and in total about 600 locations throughout Europe and around the world.

The present use of systems employing pneumatic technology proves the economic viability of any similar system. A change in technology from pneumatics, to electrically energized tracks and motor driven capsule carrying vehicles would allow several advantages ensuring even greater usefulness and economic viability. Pneumatic tubes require path diverters and complex, coordinated central control. Independent autonomous carriers can select their own path along a network having a fixed geometry, which is much cheaper to install, operate, and maintain. Pneumatic tubes consume a high specific energy per payload weight, and/or volume. Motor driven traction drive vehicles can be designed to about as efficient as modern freight railroads. Pneumatic tube networks are difficult to expand, requiring additional blower “zones” to extend distances. A fixed track geometry system can be added on to as easily as building more roads into the existing road network. Pneumatic tube systems have limited capacity due to their high minimum headways between successive capsules, as well as the necessity to maintain path lineup because the prime mover is a blower acting from a fixed point on the network. A system populated by autonomous motor driven vehicles can achieve very high throughputs in comparison, due to the ability to operate at close following distances, and the ease with which the track can be energized.

Only a cursory analysis, which stops short of examining the details which determine the relative merits, could fail to conclude that the possibilities for a new transportation utility along these lines holds great promise.

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Towards a smart interconnected era
of efficient and sustainable
logistics, supply chains and transportation

May 28-30, 2014 - Québec City, Canada

Ex ante sustainability improvement assessment of city logistics solutions: learning from a simple interlinked pooling case

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Abstract: Improving the sustainability of city logistics involves the design and implementation of solutions that lead to improvements from social, environmental and economic perspectives. In this paper we focus on the ex ante sustainability assessment of city logistics solutions. For demonstration purposes, we rely on a simple fictitious city and investigate the implementation of alternative logistics pooling solutions. Using sustainability key performance indices, we contrast a centralized pooling solution relying on a single Urban Consolidation Center (UCC) with an interlinked pooling solution rather relying on a network of distributed UCCs. Key learnings are (1) the importance of rigorous ex ante sustainability assessment of proposed city logistics solutions, as the assessment investigated solutions revealed counterintuitive results, and (2) the importance of designing city logistics solution using an open interconnected systemic approach rather than a piecemeal approach, as a fundamental root cause of the results with the proposed alternative solutions was revealed by contrasting the foundations of their design to those inherent interconnected city logistics as prescribed according to the Physical Internet concept. This work is the beginning of a core project aiming to enable and to investigate the ex ante assessment of city logistics solutions for actual cities.

Keywords: *City logistics, Pooling, Urban Consolidation Centers, Sustainability evaluation, Interlinked pooling, Interconnected logistics, Physical Internet.*

1 Introduction

City logistics is the last link of complex supply chains that involve numerous stakeholders such as carriers, inhabitants and the public administration. It is a small part of the total distance traveled by products across supply chains, nevertheless it can represent up to 28% of the total transport cost (Roca-Riu and Estrada, 2012). Moreover, urban freight transport is estimated to induce between 16% and 50% of the overall air pollution made by transport activities in a city (Albergel et al., 2006). These numbers emphasize the importance of addressing urban freight transport in the management and planning of the city (COST 321, 1998). Furthermore, designing

an efficient urban transportation system facilitates small businesses, shops and boutiques, therefore improving the livelihood and livability of cities (Taniguchi et al., 2013).

Unfortunately, most public decision-makers are not knowledgeable enough about city logistics to tackle the adaptation of local public policies so as to better face these hurdles (Dablanc, 2007). They may ignore urban freight transportation issues to concentrate their effort on issues they perceive as having more direct repercussions on the life of inhabitants, such as public people mobility.

Furthermore, city logistics solutions are based on two principles, transportation multimodality and resource pooling, either independently or concurrently (Allen et al., 2007; Boudouin, 2006). In the context of a specific city, such solutions are currently usually established without any sort of scientific study. Generally, the conclusions are relying on a try-and-see method whose results are only known ex post. That makes it difficult to collect rational behavior to provide sustainable models for city and town planners to install innovative collaborative systems for urban freight transportation.

This highlights the need to help public decision-makers and city logistics solutions designers improve their knowledge and their potentiality assessment so they contribute better to the quest toward providing sustainable city logistics solutions notably relieving city freight induced traffic congestion and reducing the negative environmental impact of urban freight transport.

In this paper, in line with the recommendations of Taniguchi et al. (2003) and Russo and Comi, (2011), we contribute to addressing this need by demonstrating the potential offered by enabling model-based ex ante assessment of proposed city logistics solutions using a decision support system. Such a system aims to provide pertinent information beforehand when designing a city logistics project where stakeholders must think about “What will happen to the city and its inhabitants if we make this choice?”.

We focus on resource pooling centric solutions in order to demonstrate that using a rigorous and pragmatic “What if” model-based decision support system can help decision-makers assess the potential impact of proposed city logistics solutions. The pooling solutions addressed here are simple to conceptualize, being based on the implementation and exploitation of Urban Consolidation Centers (UCC), the most popular type of pooling solution in European cities to deal with city logistics issues (Chwesiuk et al., 2010). Other solutions like vehicle sharing have been studied by authors such as Thompson and Hassall (2012).

Using a simplified case study, we contrast the current situation first with a pooling solution exploiting a single UCC and then with a more elaborate interlinked pooling solution based on a network of distributed UCCs. We demonstrate that, even for such a simple case, assessing the relative sustainability impact of alternative solutions is not a trivial undertaking, yet does reveal intricate non-intuitive results. This emphasizes the critical importance of rigorous ex ante model based assessment capability, especially as the proposed solutions are to become more sophisticated in the future, such as those resulting from applying the Physical Internet concepts to enable smart interconnected city logistics (Montreuil, 2013). It also reveals the importance of tackling city logistics with an open interconnected systemic approach instead of relying on a piecemeal approach.

The paper is organized as follows. Section 2 introduces the simple fictitious city used in this paper. Then section 3 provides sustainability assessment of alternative centralized and

interlinked pooling solutions to city logistics. These are positioned relative to Physical Internet enables interconnected city logistics in section 4. Finally section 4 provides conclusive remarks and opportunities for further research.

2 A simple fictitious city

In order to get to the essence of our purpose without getting stuck with a specific city's peculiarities and details, we have selected to use a simplified fictitious city case, yet exhibiting basic characteristics of several cities around the world. We have studied several such cities, as Moscow and Paris depicted in **Erreur ! Source du renvoi introuvable.**.

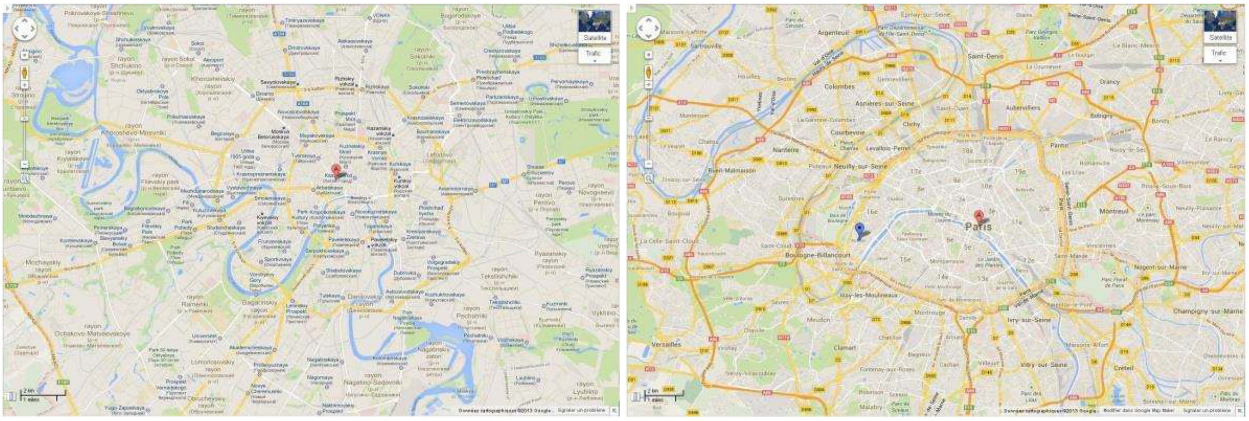


Figure 1: Cities of Moscow (left) and Paris (right)

We have built the simple city depicted in Figure 2 around four key characteristics, with no pretention that they are ubiquitous amongst world cities:

- An ellipse shaped city;
- With a river flowing through it, with a limited number of bridges;
- With multiple inbound/outbound roads across its periphery;
- With demand locations (pickup/delivery points such as retail stores, factories and homes) distributed through its area, yet with local concentrations.

Figure 2 purposefully does not portray specific roads through the city, as we used well known approximations for travel distance and time between locations (Gallez, 2000), taking into consideration that crossing of the river has to be done through one of the bridges.

We have then selected to take a snapshot of the logistics demand at a given time and to concentrate the case on how the set of specific demands was to be treated in a situation with no explicit city logistics solution put in place, and then with specific ones put in place.

In real life, at any given time, there is a stochastic mix of inbound flow of shipments needing to be delivered to city destinations, outbound flow of shipments needing to be picked up in city locations and gotten out to various out-of-city destinations, and an internal flow of intra-city shipments. We could have built a case with these three types of flow, yet it would have been hard to grasp visually. So we have opted to limit the case to deal only with inbound flows at the snapshot time. Readers can readily make up more complex variants for specific purposes.

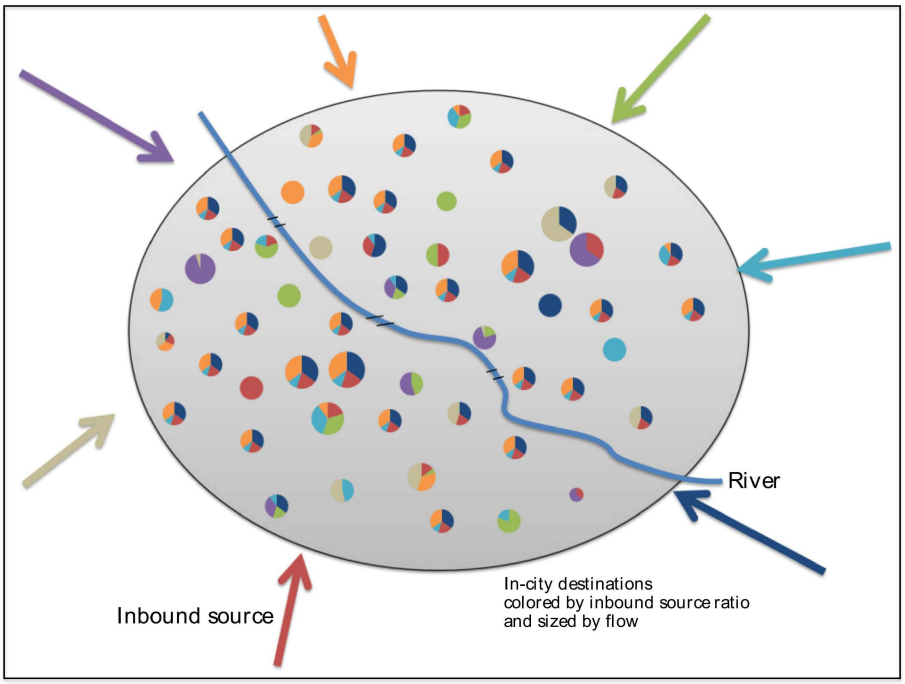


Figure 2: Illustrative simple city with punctual sources and destinations

At snapshot time, the case depicted in Figure 3 has seven out-of-city sources, represented by a specific color, from which shipments are to be delivered to client locations in the city. A total of 52 city destinations are to receive the goods delivered by the shipments. Destinations vary both in terms of the amount of goods they are to receive from which source, and the amount they are globally going to receive. This why, we have represented each destination as a pie chart of a specific size with a specific number of slices, each having a specific relative size. The inbound flows are represented as arrows, each pointing toward a specific entry point along the city circumference.

As a further simplification, we have constructed the specific demands so that the overall demand to be fulfilled from each out-of-city source fits in one carrier sent from the source toward the city, by default to enter the city through the entry point where its representative arrow is pointing. We have assumed that the city-inbound carriers are using city adapted trucks which have $40m^3$ of cargo space. One of these trucks contains ordinary 16 parcels whereas a semi contains 34 parcels in $94m^3$. In the following sections, the terms truck for $40m^3$ and semi for $94m^3$ will be utilized. In the aim of optimizing deliveries, we also mention vans which are utility vehicles with a $20m^3$ normally containing 8 parcels. Routing of vehicles takes into account their loading capacity. We assume that one delivery point receives its freight from one carrier in one time. Each delivery route is constructed by considering two parameters: the logic of delivery order and the quantity of freight that has to be delivered at different points. It is not possible to split a delivery in several routes.

We will subsequently define the alternative city logistics solutions through the way the overall set of shipments is to be dealt with to get each ordered good to its appropriate city destination.

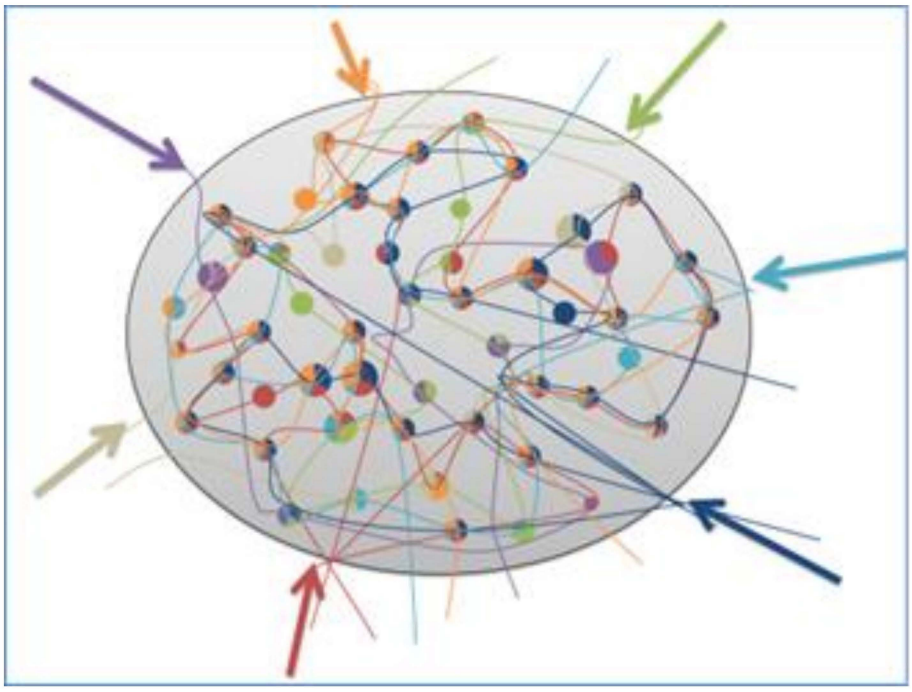


Figure 3: Current fragmented multi-source, multi-destination, multi-party city logistics base case

3 Assessing city logistics configurations

3.1 City logistics Key Performance Indicators

Three key performance indicators (KPIs) were selected to evaluate city logistics actions. The aim is to evaluate the impacts of one or more city logistics actions on a traditional city network. A lot of publications suggest indicators for transport and city logistics. We decide to choose among these indicators to quantify the performance based on obtaining a sustainable assessment of solutions. Evidently, the comparison between different solutions is just an initial step in the general evaluation process. The endgame of our approach is to encourage public decisions-makers to choose the best scenario for their city by knowing the differing impacts of their choices. Nowadays, sustainability is crucial because it reflects the long terms needs of society. The following indicators are basic and often used by others.

The first is the total travelled distance. This indicator is frequent in city logistics studies (Patier and Browne, 2010; Henriot et al., 2008; Ballot et al., 2012; Van Rooijen and Quak, 2010; De Assis Correia et al., 2012). Actually, distance can be perceived as a surrogate of cost for carriers. Distance is taken into account when calculating total transport cost. In addition, it can also be interpreted as a social indicator of working conditions for drivers. This KPI is measured by simply adding travelled distances by each vehicle.

The second KPI is the total travelled time. Certainly, time can be turned into costs, but it is also a sign of customer service quality either for the receiver or sender (Patier and Browne, 2010; Henriot et al., 2008; Ballot et al., 2012; De Assis Correia et al., 2012; Roca-Riu and Estrada, 2012). The total travelled time is an essential factor for timely delivery. This indicator is obtained by adding delivery times (driven and loading/unloading times) of each vehicle. For

senders, the delivery period is a criterion of choice. Users often purchase a service like "24h delivery". Thus it is important for transport companies to optimize delivery time. From the perspective of the last mile, the most beneficial organization is to deliver a maximum of stops per delivery rounds in a minimum time. Most often, senders (companies or private individuals) are looking for the best compromise between cost and time.

Finally, as in (Patier and Browne, 2010; Henriot et al., 2008; Ballot et al., 2012), the last chosen KPI is environmental, specifically the quantity of CO_2 emissions, which is the primary source of greenhouse gases (Albergel et al., 2006).

These three KPIs enable us to evaluate city logistics solutions under the scope of sustainability: social, economic and environmental.

3.2 Assessing the current situation

In order to provide a baseline for comparison, the KPIs must be assessed for the initial situation. To do so, routes have to be determined for each city-inbound carrier to deliver to their specific destinations in the city all the goods it carries.

Due to the relatively small size of the case and to the desire to reflect practical contexts, our approach to routing has been to assign the routing tasks to a knowledgeable engineer that had to interactively develop the routes, checking the satisfaction of capacity constraints while aiming to get routes with good KPIs. In further studies using larger data sets and more dynamic context, this simple approach would have to be replaced by the usage of vehicle routing exact or heuristic optimization techniques (e.g. Cordeau et al., 2007; Crainic et al., 2012; Taniguchi et al., 2012; Toth and Vigo, 2002).

The routing for the current baseline depicted in Figure 3 has achieved the KPI values reported in Table 1. Delivery the sampled inbound shipments has required a total travelled distance of 347 km, a total travel time of 29,9 h and 334 kg of CO_2 emissions. These values will be the basis of comparison to evaluate the opportunities offered by logistics pooling presented in the next section.

Table 1: Current situation assessment results

	Current situation
Total travelled distance	347 km
Total travelled time	29,9 h
Total CO_2 emissions	334 kg

3.3 Centralized pooling

In city logistics, the most popular type of pooling solution is the Urban Consolidation Center (UCC) (Browne et al., 2005; Chwesiuk et al., 2010). The overall logic is to have inbound and outbound city flows to be concentrated in UCCs, allowing efficient pooling when creating routes for pickup and delivery within the city. Most applications rely on a single UCC, what we here characterize as centralized pooling.

The use of UCC is claimed to have significant advantages, such as reduced noise, pollution, CO_2 emissions and congestion (Browne et al., 2011; Chwesiuk et al., 2010; Malhéné et al., 2012), especially due to the driving force of consolidation (Verlinde et al., 2012).

Nevertheless, these kinds of actions have also been demonstrated to have failed in many experiments (Courivault, 2004; Van Rooijen and Quak, 2010). Apparently, researchers have postulated to say that it is caused by the economical involvement: UCC implies flow disruption and increased synchronization costs; and as implemented there is little way to anticipate (Browne et al., 2011), which can produce secondary and harmful effects. More accurate forecasting may help resolve some major issues of UCC.

With its mix of pros and cons, single-UCC implementation has been selected for study in our conceptual city as it represents the most common example of UCC-based pooling. This provides an opportunity to quantify gains through the chosen KPIs, and then to compare with the current baseline. In our study case, an Urban Consolidation Center was implemented in the south of our simplified city, as shown in Figure 4.

The same method as in section 3.2 has been used to generate possible delivery routes. From a visual examination of Figure 4, some relevant observations can be made before calculating KPIs values. First, some carriers have to make a detour to deliver their freight to the UCC. On one hand it implies a higher distance to travel. On the other hand, the average speed in the periphery of the city is higher than inside the city. Second, visually it is obvious that flows are less jumbled than in the initial situation. Third, a total of 10 trucks enter the city vs. 12 in the initial system.

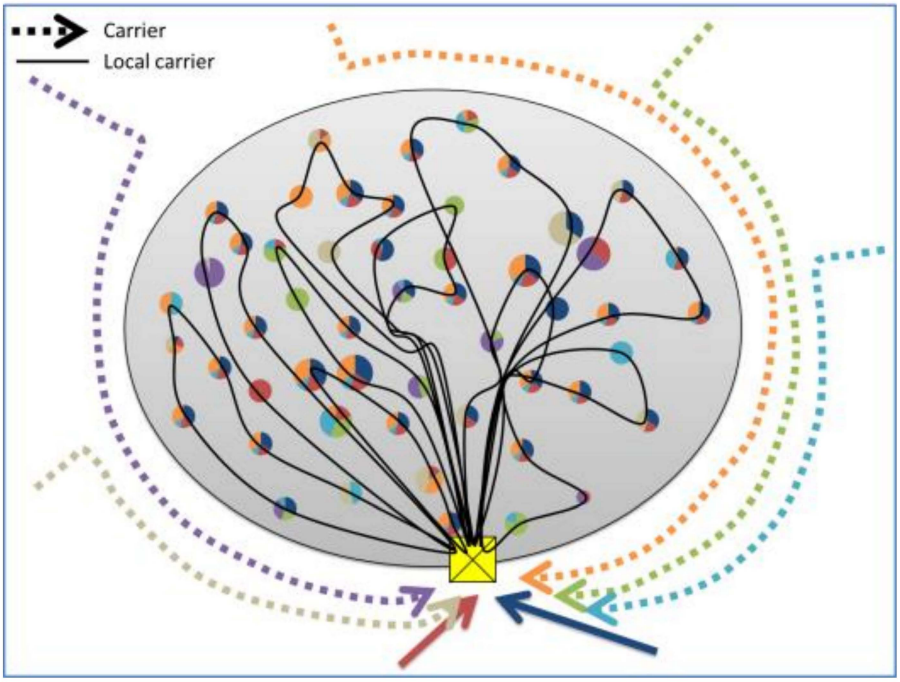


Figure 4: Centralized single-UCC pooling exploited in a simple city

Table 2: Centralized pooling assessment results

	Current baseline	Centralized pooling: KPI values	Centralized pooling: Difference with baseline
Total travelled distance	347 km	231 km	-33%
Total travelled time	29,9 h	14,5 h	-52%
Total CO_2 emissions	334 kg	226 kg	-32%

Table 2 provides the resulting value for each KPI. The first KPI studied is total distance. Even when carriers detour along the city periphery, a reduction of 33% of total travelled kilometers is observed. This is due to the fact that exploiting a UCC allows to construct pools of delivery points very close to each other, leading to efficient delivery routes. The detour make by each carrier is lower than the gain obtained by the pooling. So, the total distance is shorter. The total time is logically lower (-52%) because of the total distance but also because a part of this travel is made faster around the city periphery. Finally, the CO_2 emissions are lower (-32%) because we use less trucks with less travelled distance than in the initial solution. Note that here what is important is not the specific set of resulting KPI values, but the fact that for a known situation, the potential effect of one UCC has been quantified. It is necessary to remember the trend rather the values.

3.4 Interlinked pooling

With centralized pooling, using the single-UCC solution, most carriers have to make a detour to access the UCC. Nevertheless, there seems to be an improvement in efficiency than a situation without this kind of layout. This leads to two queries: How is it possible to avoid these detours? Will the result be even better if this is solved?

An intuitive idea is to shift from centralized pooling to interlinked pooling, multiplying the number of UCCs around the city in such a way that each inbound/outbound vehicle can drop off the freight on their round without an excessive detour. This is a well known approach theorized for city logistics, with a single-tier peripheral-UCC network or a two-tier UCC network for larger cities (Crainic and Sgalambro, 2014).

The interlinked pooling solution proposed for the city case study relies on the implementation of a single-tier network of three peripheral UCCs. This choice is based on the fact that they would represent the beginning of a network of interlinked UCCs shaping a regular layout around our elliptical city. As shown in Figure 5, the location of each UCC has been determined in order to reduce the travelled distance for each carrier when they drop off their freight.

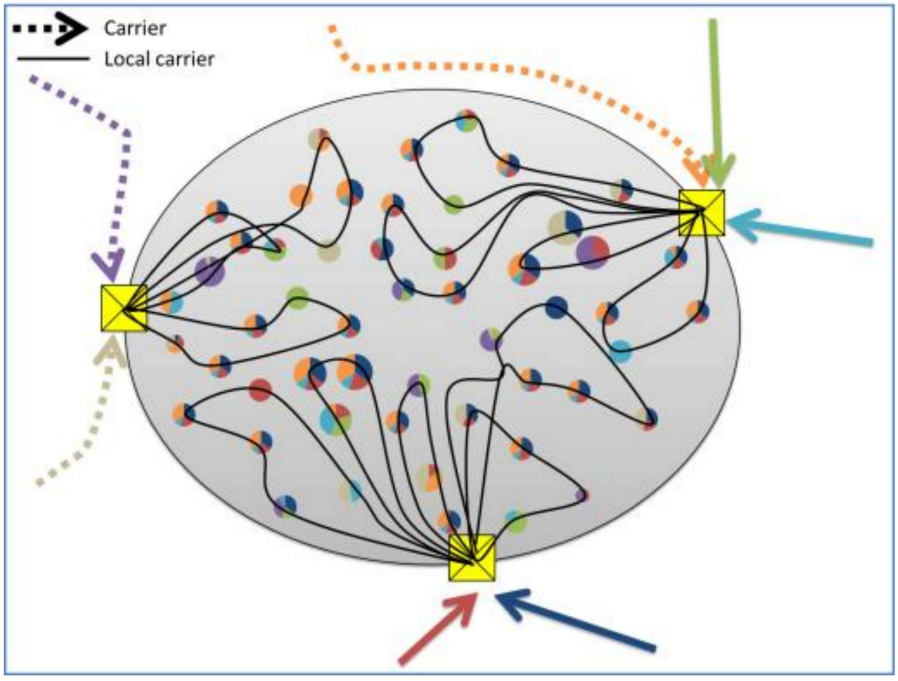


Figure 5: Interlinked three-UCC pooling in a simple city

Even though it graphically looks simple, the operation of such an interlinked solution needs to be explained further. In Figure 5, the red and dark-blue carriers both arrive at the south UCC. The freight from both carriers is split in three packs. The former have a destination that is nearest to the South UCC and will be routed through this UCC. The other two packs correspond to freight whose destination is respectively nearest to West UCC and the Northeast UCC. These packs are consolidated and shipped to their appropriate UCC. Routes are planned from each UCC, launched as soon as their associated freight is available at the UCC.

The KPI results obtained in this case for the proposed second solution are reported in Table 3. First, in general, the situation is better than the current baseline. The improvement is between 32% and 36% for each KPI. This is due to the pooling effect and a reduction of trips by drivers and vehicles. Pooling establishes rounds where each delivery point is close to others along the route. Finally the total distance is shorter, and the total travel time and CO_2 emissions are also reduced.

Second, it is interesting to compare this interlinked three-UCC pooling solution to the centralized pooling solution. The total travelled distance is essentially the same, yet achieved with a different repartition between inbound carriers and local carriers. Inbound carriers gain significantly in efficiency from a reduction of 63% on the total travelled distance. Yet the local carriers suffer an efficiency loss from an increase of 38% of their total travelled distance. Figure 5 shows the local routes to be shorter yet more numerous. The increase in local travelled distance is associated with the inter-UCC transfers explained earlier.

Total travelled time is also worse with 3-UCC than with 1-UCC because it implies additional disruptions with loading and unloading moments. Yet it is still significantly better than the solution without UCCs due to the lower distance and the pooling that delivers only once at each destination.

Finally, the CO_2 emissions are the same in both cases. This is caused by the detour made to dispatch the freight between UCCs as explained above. Trucks using the periphery, driving faster and emitting more, yet the lower distance travelled by carriers neutralizes this negative effect.

Table 3 Interlinked pooling assessment results

	Current baseline: KPI values	**Centralized pooling: KPI values**	**Centralized pooling: Difference with baseline**	**Interlinked pooling: KPI values**	**Interlinked pooling: Difference with baseline**
Total travelled distance	347 km	231 km	-33%	233km	-33%
Total travelled time	29,9h	14,5h	-52%	19,1h	-36%
Total CO_2 emissions	334kg	226kg	-32%	225kg	-32%

In this case, the interlinked pooling solution is more advantageous than the current baseline in the studied city but is less efficient time wise and less environmentally sustainable than a centralized pooling solution. Notably explainable by the introduction of extraneous inter-UCC transfers, these results are quite counterintuitive.

This should not be understood as a generic conclusion, but rather applicable to this single case study. Subsequent studies will be needed to assess whether the phenomenon would appear in numerous real cities. Yet the mere existence of a case where centralized pooling dominates interlinked pooling for city logistics is evidence that a more systemic approach is needed to insure improved efficiency and sustainability.

3.5 Towards Physical Internet enabled interconnected pooling

The Physical Internet initiative proposes an evolution of current logistics towards interconnected logistics (Montreuil, 2011), and more specifically from current city logistics towards interconnected city logistics.

The concept of Physical Internet (PI) uses the Digital Internet metaphor to change the art and the way to move, store, produce, supply and purchase physical objects. The objective is to enable order-of-magnitude improvements in logistics efficiency and sustainability.

PI can be defined as an open global logistics system founded on physical, digital and operational interconnectivity through standardized encapsulation, interfaces and protocols (Montreuil et al. 2013). PI couples multiple characteristics such as an open market for goods transportation, handling only world standard modular designed-for-logistics containers, open and shared transportation and distribution networks and facilities, vast community of users, supplier certification and ratings-by-users to drive logistics performance, as well as continuous tracking

and monitoring. A key aim of PI is to create a global interconnected network of logistics networks, a Logistics Web, where freight can be transported and stored in appropriately size modular containers through open facilities (e.g. hubs and warehouses). Indeed the Physical Internet can be seen as version 2.0 of worldwide logistics.

Recent studies have notably revealed a potential for over 30% reduction of induced costs and up to 60% reduction in greenhouse gas emission, with similar or better customer satisfaction (Ballot et al. 2012, Meller et al. 2012, Sarraj et al. 2014).

Open pooling is a component of the Physical Internet. Therefore the urban consolidation centers (UCCs) on which focuses this paper are in line with the interconnected logistics vision. Indeed, the Physical Internet would exploit all existing logistics facilities and transportation means adapted to interconnected logistics so as to enable open pooling of transportation, transshipment and storage means, and it would include new generations of PI-enabled logistics facilities.

Yet in a Physical Internet vision of city logistics, there would be much more than the simple act of pooling. Everything would be aligned towards efficient seamless interconnectivity: moving goods in smart modular PI-containers; crossdocking them through efficient, often multimodal, PI-hubs equipped with smart PI-container handling and storage technologies; transporting the PI-containers in green city-adapted transportation means across a city logistics backbone network entirely designed for easing interconnected logistics.

In an ultimate PI-context for our simple city, there would have been open pooling of inbound carrier loads well before their arrival to the city; the transfer time and cost of PI-container encapsulated goods at UCCs would have been much smaller; UCCs would have been embedded in a vast network of intra-city PI-hubs, from larger sizes in main peripheral intersections down to tinier drop-and-collect points across the city intra-city; vehicles would exploit green energy; and ubiquitous PI-container and PI-resource monitoring. Extra travelled distances, lost time for transshipment and greenhouse gas emissions would all be minimized.

Whereas the PI offers a target long-term vision, most city logistics initiatives tend to be strongly anchored in the present situation and to offer specific focused solutions, such as logistic pooling in UCCs. The small example used in this paper is revealing that such specific solutions may have unintended counterintuitive characteristics and effects. For example, preferring interlinked pooling to centralized pooling appears to be a great move, one could even say in line with PI. Yet as in current settings, all kinds of goods are transported and moved, the UCCs are usually not world models in terms of transshipment efficiency, information systems do not fully support open pooling with protocols, anticipation and optimization capabilities, etc., the end result may be that the perceived good move is not so good when implemented by itself.

Clearly, one cannot switch in a Big-Bang way from the current undersigned city logistics to a fully PI-enabled interconnected logistics. Modular containerization may not be achievable in the short term; budgets may limit the implementation of UCC-type hubs; etc. Phased transient implementations according to a multi-year roadmap, starting with easy-win steps, are needed. A key learning from this exploratory contribution is that such steps have to be designed using a systemic approach, definitely not piecemeal, and that assessment tools are needed to set expectations right and to allow tackling head-on counterintuitive effects of proposed solutions.

4 Conclusion and future works

A schematic and illustrative city has been used to better understand the impact of city logistics actions on the three sustainable development indicators: social, environmental and economic. This work assesses quantitatively for a small fictitious city the difference current non-designed city logistics and two alternative solutions based on a basic centralized and a more elaborate interlinked pooling. The results obtained are revealing as they show the former to be counter-intuitively dominating the latter.

The paper has provided insights on the importance of avoiding piecemeal solutions in city logistics and of rather proceeding through a systemic roadmap from the current situation towards ever more interconnected logistics.

The paper has also highlighted the need for an *ex ante* assessment method. Every city is different and a lot of parameters have to be taken into account to characterize a city. Nevertheless, some common ground can be found. In any case multi-source multi-destination logistics should be considered. The first step of such a method would be to establish the cartography of the current urban situation, the second step to evaluate the systemic impact caused by the implantation of one, or more, city logistics actions.

This study is a part of the ANNONA project, which is an ANR project (French Agency for the Research). The limited results from this first phase will be improved on in subsequent phases. The scope of city logistics actions will be enlarged and and dealt with in depth. Using illustrative fictitious cities as done here has its uses, yet in future works, real cities will also be modelled to insure the practicality and generic character of the approach, the tools and the results. Moreover, there is need for a prototype decision support system to be developed so as to enable obtaining *ex ante* assessments of city logistics actions impacts, a prototype to be used by researchers and urban decision makers alike.

Acknowledgements

The authors wish to thank Professor Christopher Yukna for some help in proofreading.

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Proposition of a potential fields approach to solve routing in a rail-road π-hub

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Abstract: *This paper deals with the promising domain of physical internet. It presents a study of the routing of π-containers in a rail-road π-hub. Since there are only very few works on the control of a π-hub, this paper aims to find the parameters that have a significant impact on the π-hub effectiveness. The parameters studied are the π-containers' size, their number of movements in the system, the numbers of conflicts between π-containers and the loading time of π-containers in trucks. After presenting the design of the π-hub studied and the routing approach used, this paper describes the simulator developed with the multi-Agent environment NetLogo. Then, the assumptions taken to study the system in critical situation and the simulation protocol are detailed. Finally, five sets of simulations are performed and discussed and a first way to improve the π-hub effectiveness is proposed.*

Keywords: *Physical Internet, Routing, Potential Fields, Rail-Road hub, π-hub*

1 Introduction

This paper is relevant in the recent, innovative and promising domain of the Physical Internet (Montreuil, 2013) which breaks with the usual approaches of the current logistic systems. (Montreuil, 2011, Sarraj et al., 2012) point out that the actual logistic systems are unsustainable economically, environmentally and socially. The aim is to reverse the actual situation on three points of view:

- From an economical perspective, the goal is to unlock significant gains in global logistics.
- From an environmental point of view, a reduction of the global energy consumption and of the direct and indirect pollution is expected.
- From a societal perspective, the goal is to enhance the quality of life of the different actors (e.g., truckers, logistic workers…) implied in the logistic systems.

Benoit Montreuil introduced the concept of Physical Internet (PI, denoted π) as a possible way to achieve this challenge and to build an efficient and sustainable logistics system.

As defined in (Montreuil, 2011): "The term, Physical Internet, employs a metaphor taken from the Digital Internet, which is based on routers, all transmitting standard packets of data under the TCP-IP protocol. A core enabling technology to make the PI a reality exploit is the encapsulation of goods in modular, reusable and smart containers, called π-containers. The π-containers range in modular dimensions from large to small. The ubiquitous usage of π-containers will make it

possible for any company to handle and store any company's products because they will not be handling and storing products per se. Instead they will be handling standardized modular containers, just as the Digital Internet transmits data packets rather than information/files."

At this point of development of the Physical Internet, the design of π-facilities, allowing the quick and flexible transfer of the π-containers has been rarely addressed (Montreuil et al., 2012; Ballot et al., 2012). Despite this, this issue is essential for the successful development of the Physical Internet. Among the facilities to design, the cross-docking hub (in analogy with digital internet, can be seen as a router) is a key point since efficient hubs and transit nodes should enable quick and synchronized transfer of π-containers which are the key elements in the Physical Internet network. Different modal transfers (e.g., road to rail, road to road, ship to rail) can be considered and impact not only the economical but also the environmental and social sustainability.

2 Road-rail hub presentation and current issues

The aim of a road-rail π-hub is to allow efficient transfers of π-containers among trains and trucks without dismantling of the trains. The figure 1 gives an example of a road-rail π-hub, inspired from the papers (Ballot et al., 2010; Ballot et al., 2012). Three large zones are distinguished:

- the "rail-road" zone where some π-containers are unloaded from the train present in the hub and loaded in trucks.
- the "rail-rail" zone where some π-containers are unloaded from the train and moved to be loaded in other trains.
- the "road-rail" zone where the π-containers are unloaded from trucks and loaded in a train.

In addition, several stocks are available to store the π-containers which cannot be treated at short term.

In the next parts of this paper, only the "rail-road" zone is studied. Only two sections of 5 wagons are located in the hub at each time. As depicted on the figure 1, the "rail-road" zone is situated in front of the section 1 and is composed of a sorting area and a maneuvering area. The aim of the sorting area is to sort the inbound π-containers and to route them toward the maneuvering area. This area is composed of a grid of π-conveyors, allowing moving π-containers in the four directions (front, back, left and right). The maneuvering area allows via a dedicated equipment to return the π-containers and to move them towards the different gates, where trucks are located.

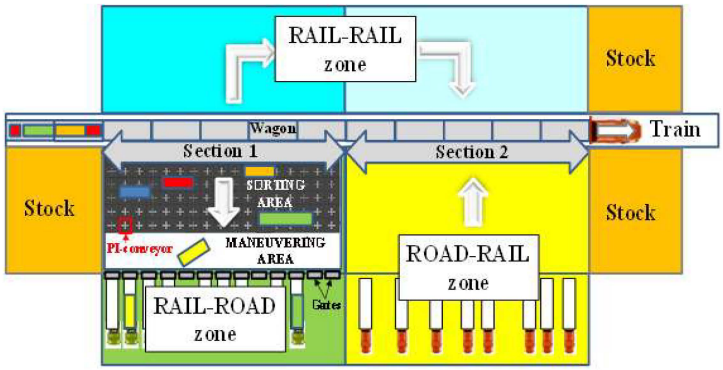


Figure 1: Example of a rail-road π-hub (from (Ballot et al., 2012))

The main performance objective of the "rail-road" zone is to realize smooth interconnections between trains and trucks services in shortest time. To manage the cross-dock, several issues must be treated:

- Allocation of the cargo to the trucks: this problem consists to choose the more appropriate loading of the trucks with the π-containers unloaded from the train.
- Scheduling of the trucks on the gates: the trucks must be located adequately in front of the different wagons to minimize the routing times. This problem implies to determine the succession of trucks on the gates to answer the following question "where and when the trucks should be located?".
- Routing of π-containers: once the π-containers have been unloaded, they are engaging in a sorting process that will get them to their destination trucks.

The control of the "rail-road" zone must deal with different degrees of variability and uncertainty: the flow of incoming π-containers can vary through time, both in terms of quantity, sizes and destination mix. In addition, two types of perturbations must equally be taken into account:

- The external perturbations: Considering a train coming from a precedent π-hub, the information relative to its load is forwarded upon its departure. However in case of perturbations on the rail traffic, another train can arrive before the expected train. The π-hub control must deal with this unexpected cargo, even if the trucks are not well located in front of the wagons.
- The internal perturbations concern mainly the possible perturbations on the conveying grid: some π-conveyors can be out of order due to breakdowns or curative maintenance operations.

In the present paper, the focus is put on the routing problem (without breakdowns of some π-conveyors) and an approach is proposed in the next section.

3 The proposed routing approach

At this point of development of the Physical Internet, very few research's works have addressed the routing problems in a π-hub (Ballot et al., 2012; Meller et al., 2012). In recent works (Furmans et al., 2010; Furmans et al., 2012, Gue and Uludag, 2012) have developed decentralized control for high-density storage systems based on π-conveyors. Other works (Gue et al., 2013; Mayer & Furmans, 2010) have proposed decentralized control to prevent deadlocks on a grid of π-conveyors. However these previous works deal with small-size goods that can be located on a unique conveying module. In the present routing problem, the complexity lies in the handling of different sizes of containers (occupying several π-conveyors at the same time).

From a control point of view, one possibility consists in exploiting the concept of "active" or "intelligent" products that can effectively contribute to solve the π-hub problems (Sallez et al., 2010). Over the last decade, the increasing growth of embedded technologies (e.g., RFID, smart cards, wireless communication...), associated with the concepts of ambient intelligence, has allowed the development of entities that are fully able to interact with their environment. The concept of "activeness" is proposed to increase informational, communicational and decisional capacities of a π-container. An "active" π-container is not only a « standardized » container with a cargo, but it plays an "active" role in the routing process.

The routing of π-containers inside the "rail-road" zone is managed by a Potential Field Approach (PFA). PFA comes from the mobile robotics (Khatib, 1986), where robots are attracted to their goal by attractive fields, while avoiding obstacles that emit repulsive fields. This concept has been used recently by our research team in manufacturing control with active products (Pach et al., 2012). In this paper, this concept is extended to manage the routing of "active" π-containers. To attract π-containers, trucks emit attractive potential fields. These fields are propagated through the grid of four-direction π-conveyors in a Cartesian way. While crossing a π-conveyor, potential fields are mitigated by the distance travelled. The figure 2a illustrates the propagation and mitigation mechanism with an initial field value of 100. If a π-conveyor is unavailable (e.g. broken or in maintenance), the fields are not propagated through the π-conveyor. Thus π-containers will naturally avoid this π-conveyor, as illustrated by the figure 2b.

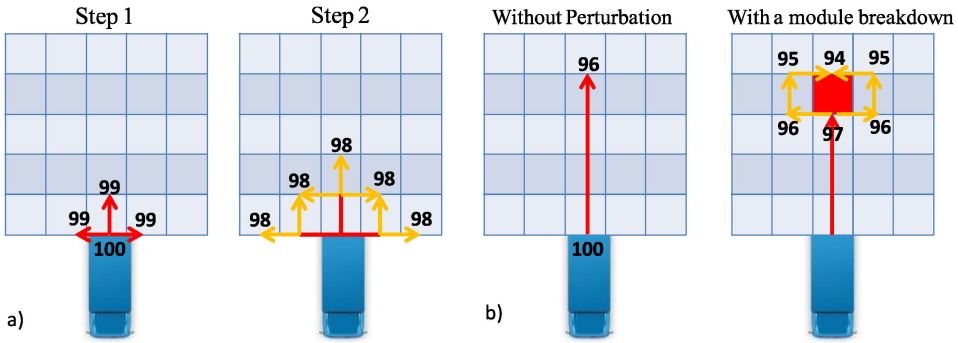


Figure 2a & 2b: Propagation and mitigation mechanism without and with perturbation

In this paper, internal perturbations are not considered. As there are only few works on the internal routing of π-hub, this paper will study different parameters to find parameters that have a great impact on the evacuation time. Moreover, as the goal is to test the robustness of the control approach, simulations have to study the worst situation. For example simulations have to define if the management of only small containers is more complicated than the management of only big containers.

To progress in the π-hub each π-container finds its path by following the attractive potential fields on the grid of π-conveyors. When a π-container is moving toward the next π-conveyor of its path, it emits a repulsive field on this π-conveyor. This field avoids other π-containers to move to this π-conveyor. The figure 3 illustrates this repulsive field emission by the C1 container.

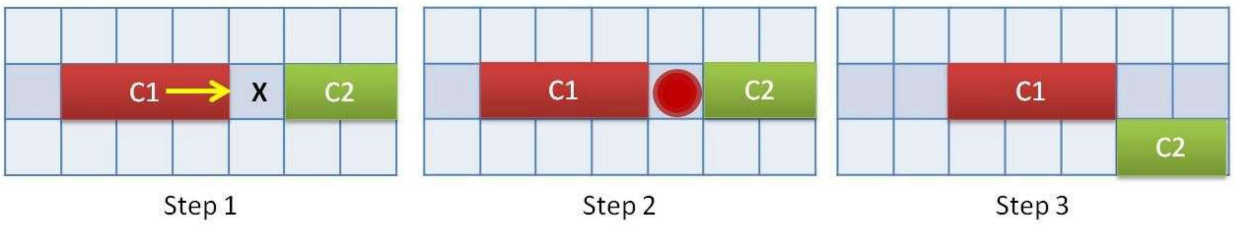


Figure 3: Repulsive potential fields

If a π-container cannot reach the next π-conveyor because of another π-container, it could moves in the other direction (horizontally instead of vertically or vice versa) or remains on its present location, if not possible.

The proposed mechanisms are evaluated via simulation studies. The simulation platform, protocol and results are presented in the next section.

4 Simulation study

This section presents the simulator developed for this paper, the simulation protocol followed and the obtained results.

4.1 Simulator overview

A simulator is used to study the validity of the routing mechanism. This simulator integrates all the realistic constraints like the size of the trains, trucks, π-conveyors and π-containers. It has been designed using the multi-agent environment Netlogo. The very popular and widely used NetLogo multi-agent simulation platform was chosen for its openness, ease of implementation, large community, comprehensive documentation and gratuity. Comparisons with other agent platforms confirm this choice. NetLogo is a high-level platform providing a simple yet powerful programming language and a built-in graphical interface. It was primarily designed for agent-based modeling of physically mobile individuals with local interactions in a grid space. NetLogo is also recommended for prototyping complex models. Figure 4 presents an overview of the simulator.

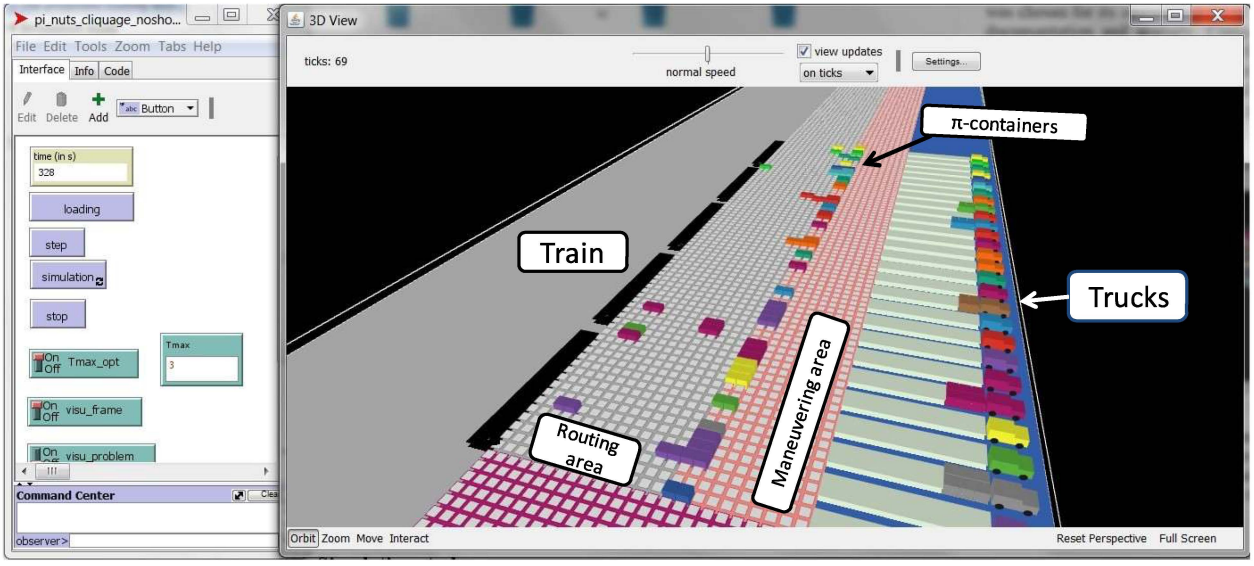


Figure 4: View of the simulator GUI

In this simulator π-containers and trucks are represented by agents with processing and decisional capabilities. The π-conveyors are modeled by other agents allowing the propagation of potentials fields through the grid. The composition of the train, the π-containers' destinations and the trucks' locations are defined by input files.

4.2 Simulation Protocol

In a normal configuration the unloading rate of the train is around 30% (assumption taken in the final layout in (Ballot et al. 2012)) and the size of containers is between 1.20m and 12.00m. The allocation mechanism optimizes the placement of trucks in front of the containers to load.

However, as the aim of this paper is to study the effectiveness and the robustness of the routing mechanism, it is tested in critical conditions (see assumptions).

Performance indicator

The main performance indicator measured in the simulations is the evacuation time. It represents the time between the unloading of the first π-container from the train and the loading of the last π-container on its truck.

Assumptions

Several assumptions are taken, especially to put the system in critical conditions.
1°) Wagons are always full of π-containers with no empty places.
2°) The unloading rate of wagons to the rail-road hub is set at 100%.
3°) Trucks are positioned randomly in the π-hub. This situation represents the worst perturbation considered, when a train is delayed and another train enter the π-hub while the trucks are already positioned for the delayed train. Thus the system should solve an unknown problem reactively.
4°) π-containers are all unloaded in the same time from wagon to the system.
5°) The loading into trucks takes two minutes: one to rotate the π-container in the maneuvering area and one to load it into the truck.
6°) The time to move a π-container from one π-conveyor to another is set to four seconds.

Protocol

A train is generally considered composed by 30 wagons. In a π-hub each section (e.g. road-rail or rail-road) manages simultaneously 5 wagons. Thus each simulation performed manages a set of 5 wagons to unload. Simulations use a random placement of the trucks into the π-hub. To have significant results, each simulations set contains 20,000 simulations randomly generated. The simulation protocol is divided into five simulations sets as depicted in figure 5.

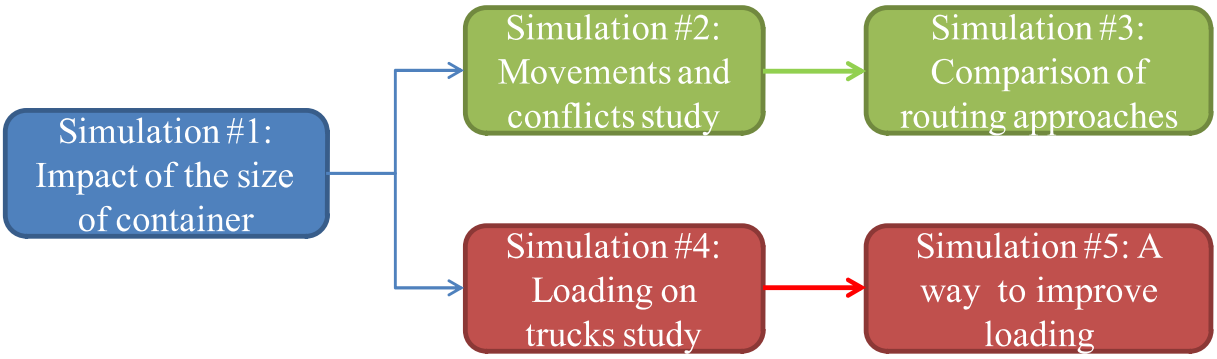


Figure 5: Simulation protocol

Simulations set #1: impact of the π-containers' size. Simulations are first performed to study the impact of the size of the π-containers on the evacuation time. The aim is to find the worst case to use for the next simulations of the paper. Three simulations sets, containing 20,000 runs each, are performed with, first 15 π-containers of 1.20m (minimum size of π-containers), second with 5 π-containers of 3.60m and finally with 1 π-container of 12.00m (maximum size) and 1 π-container of 6.00m. These configurations ensure that the 18.00-meter wagons are filled.

Simulations set #2: impact of π-containers' conflicts and movements. The aim of this simulations set is to study the point of optimizing the management of conflicts between π-containers (i.e. two

π-containers want to go to the same π-conveyor in the same time) or their movements through the system. Thus these two parameters are monitored and their variations compared to the evacuation time.

Simulations set #3: study of two different routing approaches. To confirm the results of the simulation #2, this simulations set compared the results obtained with two different routing approaches. The first one is called "conflict solving" approach. It manages the conflict when they occur (like in the first two simulations sets). The second one is called "conflict avoiding" approach. It allocates the first line of the π-hub for the π-containers moving from right to left and the second line for the ones that move from left to right. Thus there is no conflict to manage.

Simulations set #4: study of loading on trucks. As the loading on trucks takes two minutes, it could be a bottleneck. This simulations set aim to study the correlation between the number of π-container in each truck and the evacuation time. If these two variables are correlated the loading will be important to study. Simulations are also performed with artificial lower loading times (1'30 and 1') to study the impact on the evacuation time.

Simulations set #5: a first way to lower loading times. As the loading time seems to be very important in the simulations, the simulations set #5 proposed a first way to lower this time without any change of technology or π-hub structure.

4.3 Simulation Results

This section presents the results of the simulation protocol presented in the previous section.

Simulations set #1

The simulations set #1 studies the impact of the π-containers size on the evacuation time. For each size, 20,000 runs were performed and results are presented Table 1. The first column contains indicators related to the total evacuation time. Column #2, #3 and #4 presents the results respectively for 1.20-meter π-containers, 3.60-meter π-containers and 6.00-and-12.00-meter π-containers.

Table 1: π-containers size study's evacuation time

Evacuation Time (sec)	1.20m	3.60m	6.00m & 12.00m
Average	963	614	620
Standard Deviation	122	70	91
Min	664	436	380
Max	1744	1132	1156

Using small π-containers (1.20m) is more difficult to manage than big π-containers. Indeed, there are more interactions between π-containers and there are bigger waiting queue for the loading on trucks. For the biggest π-containers, results are near the ones of 3.60-meter because when they are in the waiting queue, they block several trucks and delay the loading of nearest π-containers. For the next simulations set, the size used for π-containers is 1.20m to study the worst case as already stated.

Simulations set #2

The simulations set #2 studies the relation between the number of π-containers' movements and conflicts and the total evacuation time. Figure 6 illustrates this study by representing the evacuation time as a function of, first, the number of conflicts, and then the number of movements.

It seems that there is no high correlation between the evacuation time and the numbers of conflicts or movements. The correlation coefficient is 0.017 for the number of conflicts and 0.065 for the number of movements. Thus to lower the evacuation time, optimizing the solving of conflicts or the movements of π-containers is not a priority.

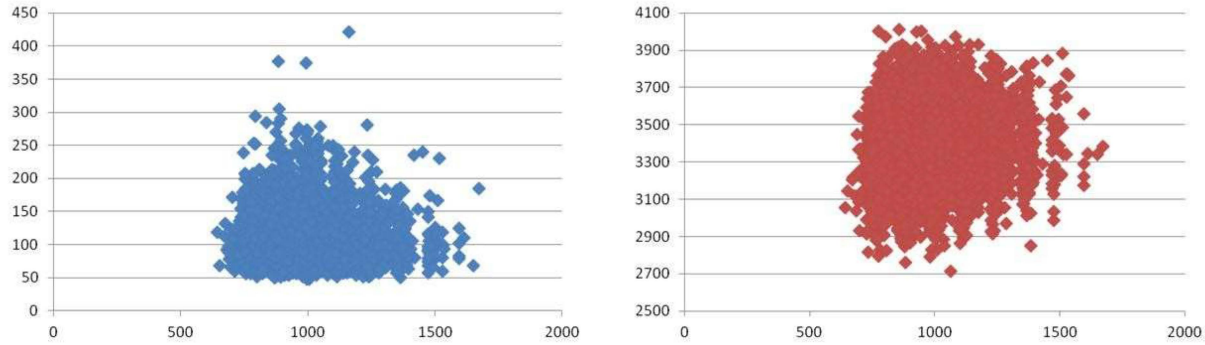


Figure 6: Evacuation time as a function of conflicts and movements

Simulations set #3

The simulations set #3 studies two different routing approaches. The aim of this simulations set is to confirm the results obtained by the simulation set #2. The first approach, called "conflicts solving", manages the conflict when they occur. The second one, called "conflicts avoiding", allocates different lines of π-conveyors in the π-hub for the π-containers moving from right to left or left to right. Table 2 sums up the results of this simulations' set.

Table 2: Comparisons of routing approaches

Evacuation Time (sec)	Solving Conflicts	Avoiding Conflicts
Average	955	963
Standard Deviation	122	122
Min	644	664
Max	1728	1744

The results obtained are very close for the two approaches even if they are completely different. For the average evacuation time for 20,000 runs, the difference is 8 seconds that represents 0.83%. The standard deviation is the same. Minimum and maximum are different but not significant because of the configuration of trucks that is defined randomly. Thus the routing approaches do not have a great impact on the evacuation time. In the following simulations the

approach used is the "conflicts avoiding" approach because it is less resource-consuming and implies faster simulation time.

Simulations set #4

The simulations set #4 studies the impact of the loading on the evacuation time. Indeed, the loading time (that takes 120 seconds) could be a bottleneck for the system. To study this, simulations count the number of π-containers sent in each truck and save the maximum number. If the loading has a major impact on the total time, this number should be correlated to the evacuation time. Figure 7 presents results obtained for a sample of 200 simulations (for readability reason).

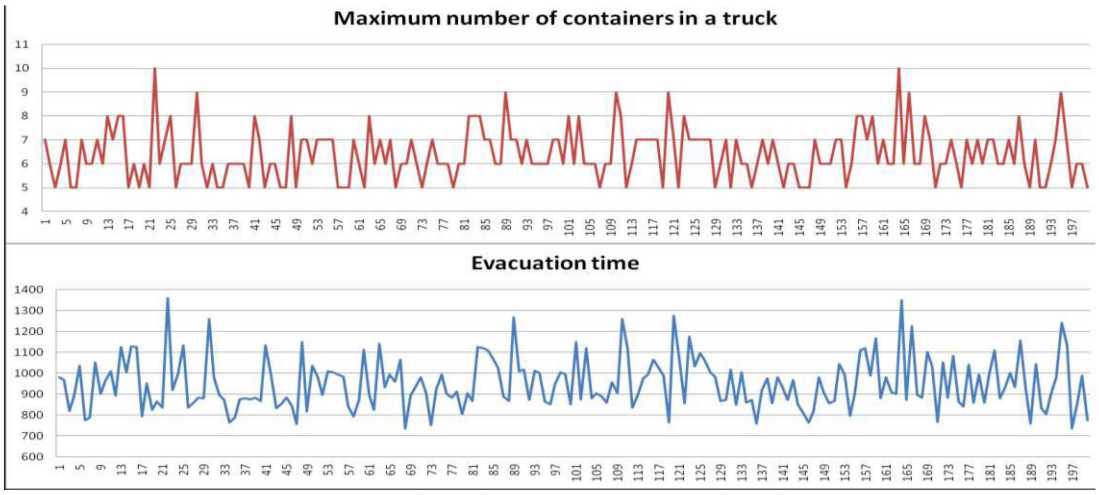


Figure 7: Maximum number of containers in a truck and evacuation time

At a first sight the two graphs seem correlated. To confirm this assumption, Figure 8 presents a graph representing the maximum number of π-containers as a function of the evacuation time.

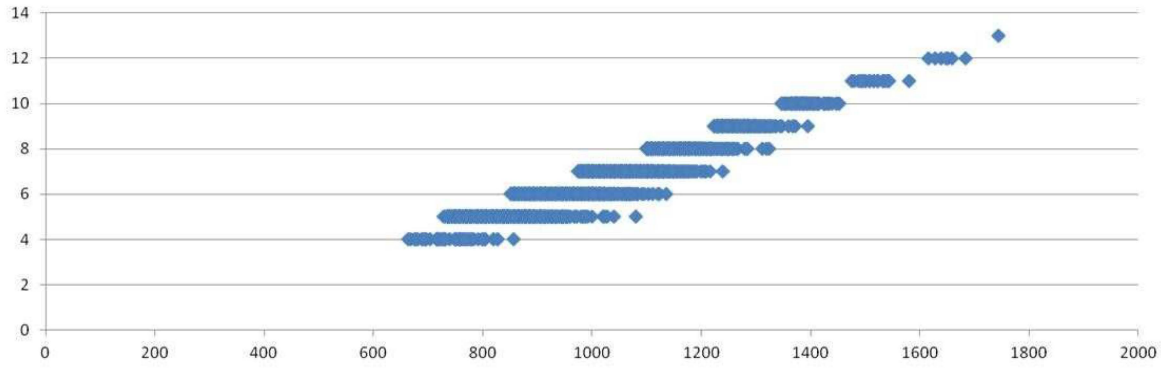


Figure 8: Correlation between Maximum number of containers in a truck and evacuation time

This graph shows that there is a correlation between evacuation time and number of π-containers. The number of π-containers determines a stage of values. Being in a stage of values determines an interval of reachable evacuation times. To lower the evacuation it seems be interesting to study the loading time.

Moreover, in the worst case, if the number of π-containers moving to the same truck is too high, the waiting queue in front of the truck can block all the system. Figure 9 illustrates this problem of large waiting queue.

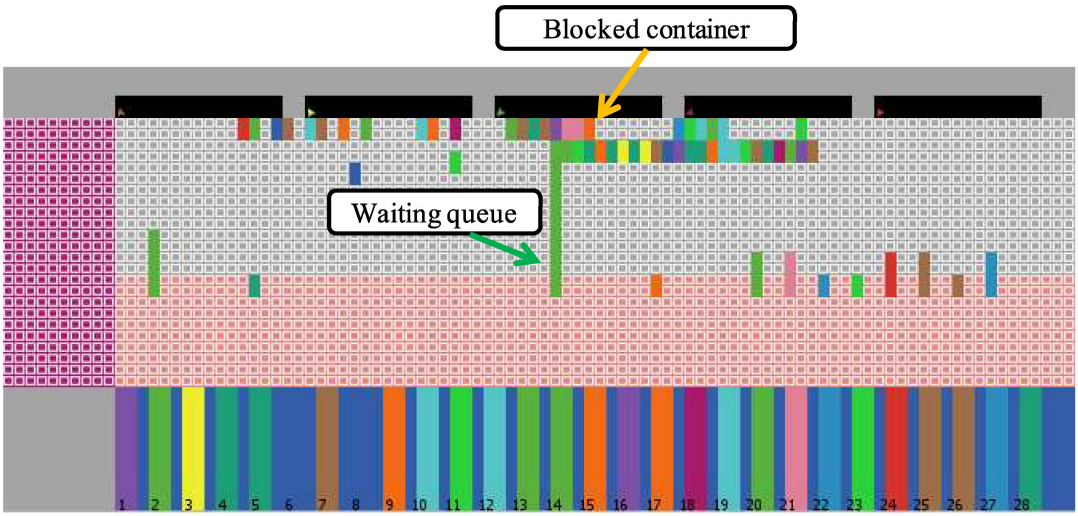


Figure 9: Illustration of the waiting queue problem

The waiting queue in front of the truck #14 reaches the first lines and so blocks the containers that move from right to left. Then the blocked orange π-container that wants to go to the truck number 15 cannot go down and it blocks the π-containers moving from right to left. Thus, until the loading of three green containers in truck 14 (around 6 min), the system is blocked. Thus to optimize the management of the π-hub and to lower the evacuation time, the first problem to study is: how the loading time of a set of containers can be reduced?

To reduce the loading time two solutions can be proposed. The first one is a technological improvement able to reduce practically this time for each container. Table 3 presents the results obtained with the actual loading and maneuvering time (2') and with lower times: 1'30 then 1'.

Table 3: Simulations with lower loading times

Evacuation Time (sec)	2' loading time	1'30 loading time	1' loading time
Average	963	787	605
Standard Deviation	122	92	55
Min	664	580	468
Max	1744	1384	1092

These results confirm the link between loading time and evacuation time. While using a 1' loading time, the evacuation time is lower by 30%. However, a change of technology can implies a high initial investment and is not easy to implement.

The second solution is to assemble many small π-containers before the loading and to load them at once. In π-hubs a mechanism allows to regroup containers that are going to the same directions. This paper proposes a solution based on this mechanism to take many π-containers and load them instead of one.

Table 4 presents the results obtained for the "take-many" loading solution.

Table 4: Simulations with the "take-many" solution

Evacuation Time (sec)	« Take-one » Solution	« Take-many » Solution
Average	963	679
Standard Deviation	122	40
Min	664	544
Max	1744	1076

This solution reduces the evacuation time by around 30%. Moreover it also greatly reduces the standard deviation (40 sec instead of 122) and implies a more homogeneous evacuation time. As this approach can efficiently tackle larger waiting queue, solutions with important evacuation time are greatly reduced, like illustrates by the maximum evacuation time obtained (1076 sec instead of 1744). Thus the loading was really a bottleneck for the system. While a change of technology could be expensive, this first solution is efficient and do not cost anything. However, this is still a first step and the "take many" solution could be enhanced by fine-tuning parameters like the number of π-containers grouped, the time waited by π-containers before cancelling the grouping, for instance.

5 Conclusion

This paper presented a study of the internal functioning of a rail-road π-hub. This paper focused on the rail-road part that manages the unloading of a train, the routing of π-containers and the loading into trucks. Another paper is proposed in the conference to deals with the problem of allocation of trucks.

As there are few works on the internal routing of π-hub, this paper proposed to study the impact of different parameters on the evacuation time without internal perturbation in the system. However, as the goal is to test the robustness of the control approach, the system is tested in critical situation with the maximum number of π-containers to manage (i.e. the smallest containers) with trucks not positioned correctly.

Simulations presented in this paper have shown that, in the configuration proposed by (Montreuil et al., 2012), the loading is the bottleneck of the system. Thus before optimizing the routing approach used, the loading time should be studied. That is why, this paper proposed a solution using the actual technology, to reduce this loading time.

The next works should focus on different points. First the solution proposed could be optimized by fine-tuning some parameters (number of π-containers grouped, the time waited by π-containers before cancelling the grouping). Second, internal perturbations should be generated to prove the efficiency of the Potential Fields Approach in a disrupted environment. And third, the routing approach could be studied one more time. Indeed, after the loading problem resolution, change on routing approach could have more impact on the evacuation time, and so it could be interesting to optimize this approach.

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The Physical Internet concept for libraries: a first set of ideas

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Abstract: *Libraries experience a declining readership base due to developments in e-books and the internet. At the same time governmental subsidies are highly reduced. However, cultural and societal constraints enforce libraries to keep up with a high service level and offer a full assortment to its customers. Historically, this was done by offering a full assortment in each library branch. However, floating collections, central storage and other logistics solutions might help libraries to reduce costs and at the same time keep service levels high. We note that potentially the decline of library usage will dampen in the future with the next generation that seems to care less about ownership. It is more about being able to read than to own books. This might improve the attractiveness of libraries. In this paper we study the potential of the physical internet concept for Dutch libraries to enable a smoothly operating library system being able to keep up its standards.*

Keywords: *libraries, floating collections, central storage, logistics, service level, cost reductions*

1 Introduction

Libraries struggle with decreases in governmental subsidies ([1]) and a declining readership. At the same time, libraries aim to continue to offer a full assortment and a high service level in the library system as a whole. Currently, several interesting developments in the Dutch library system can be noted. In 2013 a new IT system was introduced that enlarges the online visibility of books for readers dramatically. Readers are now able to see what title is available in what library in the country. The next step will be to allow online ordering and home delivery of books in a country-wide system. On a local level, libraries that started to share their IT/online system noted that the demand for books from other locations increased strongly, which at the same time created sustainability concerns due to the increased transport of books between branches. A clear advantage of this new IT system is the opportunity to use information on transaction data to

improve book movements, book purchasing and storage by allowing for real time decision making. We will explore the opportunities for the PI concept by using data from this IT system.

Research projects that the authors performed with libraries since early 2000 have shown us that libraries deal with many logistics challenges. In literature, studies typically deal with purchasing decisions and budget allocation (e.g., [2]), customer analyses (e.g., [3]), optimization of logistics operations at a single branch (e.g., [4]), warehouse operations for libraries (e.g., [5]) and transhipment operations between libraries ([6]). In analysing the Dutch public library system we notice a strong analogy with the evolution of supply chains and logistics as graphically represented by [7]. The library system currently unites aspects of different supply chain evolution levels. One of the current ideas in the Dutch system is to introduce one or more central storage facilities which is an idea at the Integrated level of the Supply Chain evolution. For the aspects that are at the atomistic level, a step towards the integrated level could bring advantages in costs and otherwise. However, for the aspects at the Collaborative and Interconnected levels, this may direct developments away from best path. Many companies are currently struggling to change from an Integrated structure to a Collaborative structure. Libraries already have a Collaborative structure that they can easily improve and expand upon. In this light, enhancing collaboration and interconnectiveness is more likely to yield the desired results.

An important constraint in implementing the PI concept is scalability. At this point, it can be concluded that in The Netherlands, borrowing of books has gone down in the past years with 25%. Clearly, the system itself will not disappear, however, the focus and size need to be altered and result in a smaller system designed for storage and reviewing with a high accessibility instead of a system purely designed for lending. Librarians aim for the following aspects: 1) at all times demand of readers should be fulfilled; 2) support should be offered to help readers in finding quality books that readers otherwise may not have found or read; 3) keeping up the societal role in offering a wide portfolio for readers with different interests, both being members of the library as well as visitors. In designing the PI system for libraries those objectives should be met.

The goal of this paper is to formulate a PI-vision towards an efficient and sustainable library system from a social, economic and environmental perspective. From a *social perspective* the aim is to improve by an order of magnitude readership accessibility for each citizen by offering the opportunity for finding and getting the right items in a fast, smart, reliable, convenient and affordable way. Secondly, to exploit the library system to invigorate local communities and the overall society. From an *economic perspective* the aim is to reduce by an order of magnitude the economic burden of maintaining a national library system. From an *environmental perspective*, the aim is to reduce by an order of magnitude greenhouse gas emissions, pollution, energy consumption, materials waste, induced by both the library system and the overall readership.

In section 2 we introduce the library system and potential changes in more detail. In section 3, we propose 12 different ideas varying from purchasing, assortment, inventory management and transportation decisions. In section 4, we report the results of a SWOT analysis that has been performed on several of those ideas by a group of librarians. Section 5 presents conclusions.

2 The Dutch Library system

A library system typically consists of several library organizations scattered throughout the country. Given the size, those organizations are organized at the level of a city, region or province. Every library organization has a group of branches where customers can borrow books, and do other activities. Membership cards enable users to borrow books of all branches of a library organization. If a book is not available in a specific branch, a customer can reserve the item and/or order it from another branch in the same network. Also inter-library-organizations flows of books can be noted for more specific items that are only available at a limited number of libraries. Different types of branches can be distinguished: full service branches, self-service branches, branches at schools, library busses and so on. The type of branch used typically depends on the amount of members and items borrowed, available capacity and staff, costs and available income.

As an illustration of the changes and trends impacting library systems, we summarize some relevant statistics on the Dutch library system [8] :

- In the period 2000-2013 the number of library branches (including service points with limited opening hours) has decreased from a maximum of 1130 in 2002 to 1035 in 2013.
- In the period 2010-2012 8% of the libraries has closed 1 or more branches.
- The average distance between a citizen and a library is currently 1.5 km in a high-density areas and over 2.5 km in lower-density areas [9].
- 79.2% of the inflow of money for libraries consist of subsidies of local government.
- 80% of the Dutch libraries has to deal with reductions in subsidies. Direct impact can be seen in the reduction of the number of activities offered to the public, the size of the assortment and the amount of staff hired in the front office.
- One third of the libraries expects to change some of its branches in self-service branches.
- Approximately 25% of the libraries has decreased the amount of opening hours.
- The total number of items borrowed in 2012 was 39.7 million compared to over 180 million per year in the period 1992-1998.
- The number of visits to a library is decreasing. In 2012 the association of Dutch libraries reported a total number of visits of 64.4 million per year. In 2005 86.1 million visits were counted.

Most of the customers visit a branch of a library to borrow a book. Online borrowing of books has been introduced. Typically, customers visit a library branch to pick-up and return their item. In low-density areas where branches have been closed, we note that pick-up locations at self service libraries and retailers are being introduced. Home deliveries are seldomly made. In The Netherlands online purchase of books already account for 37% of the purchases [10]. This might been an indication that also for online borrowing a market might exist.

We will focus on the following aspects that can be changed in a library system to obtain the objectives mentioned in Section 1.

- Assortment per location
- Number of copies per title in the system and/or at a location

- Introduction of “central” storage facility/i.e. where books are stored and shipped. Typically, customers can not visit those locations. Advantages of central storage include lower costs for land and daily operation.
- Close/shrink/add/expand branches in cities where typically land and building prices are high. Shrinking the assortment in branches might open opportunities for other activities in the building.
- Staffing
- Pricing of services. Different copies have different costs (e.g., waiting for a local book is cheaper than having a book shipped from elsewhere)

Based on those aspects, we formulate a set of ideas which together can be seen as a first PI-vision for the library system.

3 PI for the library system

In this section, we discuss several ideas which together form the base for introducing the physical internet initiative into the Dutch library system. For each idea, we explain the main reasons for implementing the idea as well as the relevant research and implementation issues.

Idea 1. Book purchase based on life expectancy of a book
Library books have a limited life due to wear and tear and readers' interests. We note a strong link with the newsvendor problem. However, in this case a more complex situation exists due to the dependency among book titles. Keeping track of inventories will be important in implementing this concept. Data should be collected for each title and all copies on the books’ life expectancy. This can be measured based on borrowing rates and number of borrowing.

Idea 2. Internal book market
If a library branch wants to buy an extra copy of a book, they currently buy a new book and apply binding in hardcover. The life time of this book is approximately 20 times of borrowing. We propose the following new alternatives:

- Check for superfluous copies at other branches and transfer them to the right branch. The maximum *transfer price* can be calculated as follows:
    - *transfer price* = (price of a new book*number of borrows)/(max.borrows), where
    - *max.borrows* equals the expected number of future borrowing (minimum of lifetime, or expected demand).
- Buy second-hand from e-bay and the like

Idea 3. Profiling
Libraries have a lot of information on their customers from transaction data. Additionally, surveys or online questionnaires can be used. Big data analyses on reader profiling can help in managing assortment in branches dynamically and providing (online) advice/tips to the customers (e.g., like Amazon.com: "people who bought this, also bought.....). Matching those transaction data analyses and survey outcomes with Bisnode data enable detecting patterns for geographical areas, which help to predict preferences of people before they can be observed. We suggest to profile readers based on the following information:

- Previous borrowing
- Asking whether they liked the book they read
- Asking what they would like to read
- Social media profiles

Furthermore, we suggest to add an *online voting mechanism* to be used as an additional base for new purchases done by the library. Transaction data analyses can track the quality of the votes of a customer by tracking if a person that voted for a book also borrowed the book. If not, a library might opt to count the vote of the person less the next time that this person votes.

Idea 4. Pricing of services

The type of service a person wants from a library might differ per age group, service level, and customer priority. Libraries already have partly differentiated membership feeds in place based on promised service levels for assortment at a specific branch. However, if a book is not present at the location where the reader is, then a reader can place a request to have the item shipped to the right location. Typically, a fixed price is charged. We suggest to determine the price for shipping books to a reader dynamically, based on:

- Transportation cost
- Expected time of availability of the book at the location (e.g. if currently borrowed)
- Opportunity cost (if available elsewhere, what is probability that someone comes to the branch where the book is and borrows it there, thus giving an equal number of borrowings, at a lower cost)

Idea 5. Assortment planning

Most library branches do their own assortment planning. Operating in a library system provides the opportunity to make assortment decisions on a network level. Each library then will have the option to look at its own assortment and designate books based on three dimensions. Namely, (1) keep (2) try to sell (3) throw away. Secondly, for a book in the first or second category, the location needs to be selected from the following options: (a) here (b) anywhere in network, (c) not here.

Consequently, each book can be categorized as follows:

- Mine; lots of demand; must be stored in my building
- Mine; rare/valuable/specialty; must be stored in my building
- Mine; can be stored anywhere in country; do not throw away (i.e., if nobody wants it, the library is willing to store the book itself)
- Transferable; for the right price any other library can have it; otherwise keep.
- To get rid off; if no other library wants it, then throw away.

To use the outcomes on a network level, each library branch needs to add valuation to books in each category individually, based on librarians interest, and members preferences and profiles. Secondly, a market can be opened to bid for books (refer also to idea 2).

Idea 6: Managing stock versus owning it
Cooperation at a network level enables libraries to keep a variety of stock and enable readers to use stock at other libraries in the network. Key characteristic is that libraries reach a mutual consent on sharing stock and consequently make the shift from ownership of stock to jointly managing stock on a network level. Each library can search for their added value in the network to also reach a level of differentiation. To reach a high service level for customers on a network level, we suggest to distinguish between the following types of stock:

- *Fashion stock*: often borrowed books which are owned by and located at the library branch.
- *General stock:* regularly borrowed books which are owned by and located at the library branch, tailored to local audience (e.g., school books).
- *Specialized stock:* a collection of books about a certain topic (e.g., fantasy books, or books about the Dutch waterworks). Located all together at a certain library. Ownership of books may be diverse.
- *3PL stock*: Floating collection, which is either owned or not. That may be stored at a certain branch or elsewhere, depending on space, cost, and borrowing patterns.

Specialized stock will attract readers to that library. These books are infrequently borrowed when considered from a country perspective, but due to aggregation may constitute a large part of activity at the library.

Idea 7. Add commercial storage facilities to the network
As a direct consequence of the 3PL stock mentioned in idea 6, library networks might consider commercial storage facilities for books that libraries want to keep, but of which demand is low. In other words, studies might be performed if long term storage of slow movers at a central, commercial location is a viable option. For those books, typically customers tend to be patient and do not require short lead times for delivery.

Idea 8. Social transport of books
Transport operations between branches are performed to deliver books to match customer orders and to return books to their owners. Short distances between branches of a single organization as well as longer distances between the main branch of two or more organizations are being executed. Transportation costs are high. Nationwide transport typically is being outsourced to a mail company or logistics service provider. We suggest to involve readers in this transportation process and to dynamically assign transport jobs to service providers. To this end we see the following potential elements as part of *social transport of books*:

- Putting out open requests for moving books from one location to another or for moving books closer to their destination in the network.
- Requests for free transportation can be posted to volunteer readers or volunteer companies/organizations.
- Requests for paid transportation can be posted to transport companies or readers, offered price may vary based on urgency (price may consist of reader benefits).

Refer to [11] for more information on potential options for social transport.

Idea 9. Distributed pick-up and return
New types of library branches are being introduced. To enable online ordering and borrowing books, locations have to be introduced where reserved books can be picked up and returned. Interesting opportunities lay in extending the traditional library network with, for example, grocery stores, railway stations, post offices, school and so on. In the province of Zeeland in the Netherlands, a small network has been set-up where customers can pick-up items at the local grocery store. In Haarlem a railway station library has been opened for commuters to pick-up books to read on their way to work [12]. On a broader scale, typical network design questions as what are good locations, what are opening hours desired and how to transfer books, need to be answered. Next to that, the function of the location need to be determined (see also idea 10). Just a pick-up/return location for reserved items, fashion stock available (e.g., top 10 in stock), or a wider assortment to also enable selection of a book at the spot.

Idea 10. Unbundling service offerings at locations
Currently, most locations offer all options, namely:

- books stored to browse and borrow by readers
- Reading materials available for all citizens.
- Pickup of reserved books
- Book returns
- Personal advice
- Reading areas

From a network perspective the type of services offered in branches might differ. An important question from this perspective is what is the best set of offerings at which locations? Next to that, the question arises how to transform each current location to, or introduce new locations for these offerings?

Idea 11. Exploit service automation
Several initiatives for service automation can be noticed. AS/RS systems for storage and sorting systems in library warehouses can be used. Next to that, vending machines can be introduced in the library network to dispense books to readers at shopping centers, supermarkets, railway stations and so on. Drop-box locations for returns need to be located at the same location to enable an easy return process. E-books usage is expected to increase and library customers see a high potential for libraries offering e-books borrowing to read at home. Another option might be to offer an electronic copy of books (as ebook or Google books style) at each library for browsing or reading purposes.

Idea 12. Temporary Exhibits

Librarians can start temporary exhibits of themed books, like museums have exhibits to extend their added value to the network. Books can be temporarily sent to the exhibiting library and sent back after the exhibit, if desired, or remain there since an increased demand may be expected at that location. Readers may borrow exhibited books, or may order them from the network if multiple copies are available in the country, as to keep the set of books intact for the exhibit.

4 SWOT-analysis

The ideas described in Section 3 have been presented to an audience of Dutch librarians at November 1, 2013 in Apeldoorn, The Netherlands. A SWOT-analyses was performed where by means of group-wise discussion, three out of the 12 concepts were analyzed. Each group presented the results to enable responses of the other groups. The outcomes are presented below.

Idea	Strengths	Weaknesses	Opportunities	Threats
Idea 6. Managing stock versus owning it	Customer will be more successful in a shorter time	Might result in a network with branches that cannot offer a collection to a customer	Increased access to a broader assortment	All directors need to be aligned Budget owners (i.e., local government) might not like the idea that "their" books are not stored in "their library"
Idea 2. Internal book market	Changing ownership of books can already be supported by the IT system	Organization of the concept Local government is not ready for such a concept	Assortment to offer to customers much larger Digitalization of fast-movers at first	Digitalization might make this concept excessive
Idea 5. Assortment planning	Right books at right location for the right users	At the same point in time customers might ask for similar books which specifically for frequently asked items might be a problem	Better service for a customer	Way how financial structure is being organized

5 Conclusion

In this paper we presented our vision on aspects of the Physical Internet concept for Dutch libraries by proposing 12 ideas. Implementation of one or more of these ideas might contribute to meet social, economic and environmental goals and to enable a smoothly operating library system which is able to keep up its standards. A SWOT analyses has been performed by Dutch librarians on several of the presented ideas. It can be concluded that the librarians expect that customer service will increase with the mentioned concepts. The main bottleneck for introducing ideas for the PI concept for libraries seem to be in the current financial structures. About 80% of the budget of libraries is made available via local governments. These governments measure the spending of the subsidies partly through the visibility in the local library branches of the books that were actually purchased from the subsidy, which hinders free exchange of books between libraries on a national scale. Methods and convincing arguments should be derived to show the added value of sharing stock among a large network of libraries to reach higher service levels against lower costs.

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Acknowledgements

This study was supported by a grant of the Dutch Institute for Advanced Logistics (Dinalog).

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May 28-30, 2014 - Québec City, Canada

Comparison of the Conventional, Physical Internet, and Hybrid Logistic Systems

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Abstract: *The purpose of this study is to compare the performance of Conventional (CO), Physical Internet (PI), and a Hybrid (HY) logistic systems in a road network. For a comparison of these three logistic systems, a series of Key Performance Indicators (KPIs) such as total number of container packing and unpacking instances required, total driving time, etc. are proposed. The comparison presented in this work is carried out through Monte-Carlo simulation in which loads are generated randomly and three optimization models are run sequentially to optimize the CO, PI, and HY logistical networks. The values for KPI's are collected and the process is repeated. In this study, we do assume that all loads are present at the start of a period. At the end of the period, all loads should have been transported and all trucks are back at their start positions. Compared to CO, HY, and PI benefits from a lower total driving time required to transfer all the loads from sources to destinations across the network. However number of the instances containers require loading and unloading is higher in PI compared to CO and HY.*

Keyword: *Physical Internet Cost*, *Logistic Systems Cost*, *Logistic Optimization*, *Truck Routing*, *Truck Scheduling.*

1 Introduction

The purpose of this study is to compare the performance of Conventional (CO), Physical Internet (PI), and a Hybrid (HY) logistic systems. These logistic systems perform the material handling activities differently. A number of Key Performance Indicators are used to compare the overall performance of these logistic systems. The followings, are the KPIs used in this study:

- Total Number of the loading and unloading
- Total driving time required to carry all the loads to their final destination
- Total Number of the trucks
- Average diving time per truck required
- Cost comparison of the Logistic System (CO, PI, HY)

This comparison take place on road network approximately identical to Eastern Canada's major roads network. As it will be shown in section 2, the major Canadian cities East of Ottawa create the nodes of this road network.
To calculate KPI values, a Three Phase Optimization Framework (TPOF) is built using Python and GLPK. TPOF is fed by a Random Data Generation Module (RDGM). RDGM generates a number of loads to be carried from a source to a destination. Each load with a specific source and destination and size is called a request. Number of requests generated in RDGM is used as a parameter to simulating the traffic level in the network. List of the generated requests then is fed into TPOF for optimizations in the next steps. Numerical values of the KPI introduced are calculated and collected gradually as each step of optimization is executed. Finally, after the work of the optimization framework is completed, all of the KPI required for overall comparison of the logistic policies get numerical values.
In this study, we do assume that all loads are present at the start of a period. At the end of the period, all loads should have been transported and all trucks are back to their home nodes.
It should be noted that in this study, the term "container" is referred to what encapsulates PI loads. Containers are placed over a trailer and are pulled by a truck. Section 5.2 illustrates the PI loads chosen.

1 Literature Review

Although PI is a fairly fresh subject, the literature is extensive and covers a very wide area ranging from supply web simulation to functional design of PI facilities.
The global sustainability grand challenge issue is addressed in (Montreuil, 2011). Statistics about the weak performance of the current logistic systems are presented and then global unsustainability symptoms are listed. Physical Internet vision is introduced in 13 points. Encapsulating merchandise in standard PI-container sizes and moving from point to point transportation to distributed multi segment transportation are among the 13 points in the PI vision that created the major building blocks of this study.
A road based PI facilities introduced in (Meller, Montreuil, Thivierge, & Montreuil, 2012) are extensively used in this study. Proposals for functional design of PI facilities for road based transit centers, road-rail hubs, and road based cross-docking hub are presented in (Meller, Montreuil, Thivierge, & Montreuil, 2012) , (Montreuil, Meller, Thivierge, & Montreuil, 2012), and (Ballot, Benoit, & Thivierge, 2012). Each of these studies show the facility components, introduce a set of key performance indicators, and actual simulation models. At the end of these studies the performance results under various conditions are identified and areas worthy for future research are proposed.

2 Road Network

This study focuses on transportation within a simplified Eastern Canadian road network. As shown in Figure 1, 11 cities in Eastern Canada are the nodes in the network. Being a large urban area, and for better simulation of traffic flows, Montreal is represented by two nodes: Montreal

East and Montreal West. Figure 1 shows only the logical connection of the nodes in the network and is not to scale. The network shown in Figure 1 is a tier 4 *Intra-country inter-state network*, as described in (Montreuil, 2011)

The Canada West node represents the rest of the Canadian road network to West. Similarly, Ontario North, and Ontario South nodes represent the north, and south Ontario road networks as one single node. The traffic going to and from Canada West, Ontario North, and Ontario South will pass from these three nodes. In the same fashion, the traffic to and from United States will pass from three nodes called US Border Gate 1, 2, and 3.

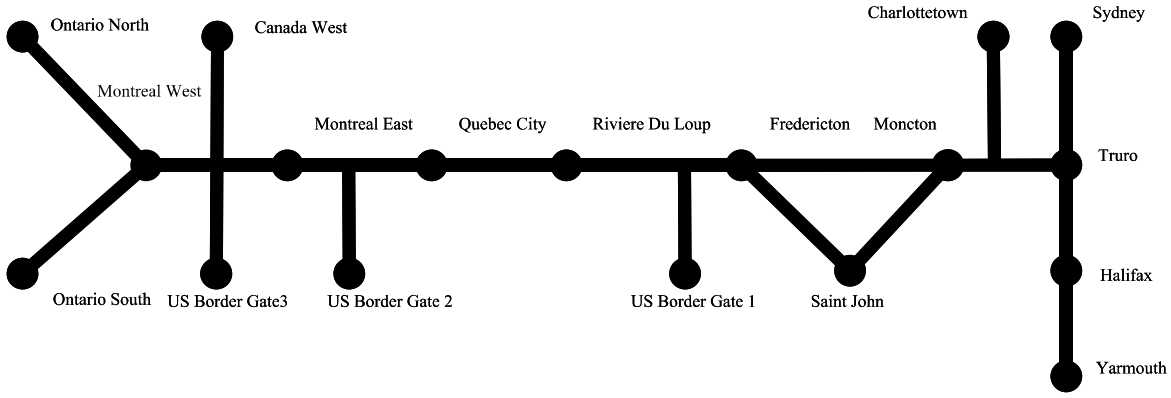


Figure 1- Eastern Canada Road *Network*

2.1 Door To Door Logistics System

In this logistics system, at each source node, a request is packed into a container with all other requests going to the same final destination. As an example, a containers carrying requests from Yarmouth to Quebec City will be loaded in Yarmouth and only unloaded when it arrives at its final destination in Quebec City.

2.2 Physical Internet Logistics System

In this logistics system, at the at a source node, a requested is packed in a container with other requests. A container then is transported to a PI node with a Road Based PI Transit Center (Meller, Montreuil, Thivierge, & Montreuil, 2012). The load, therefore, goes from an origin node to one or more PI Transit Centers before reaching its final destination through the PI Transit Center of the destination cluster.

This network has five PI Transit Centers (represented by red squares) in Truro, Fredericton, Quebec City, Montreal East, and Montreal West. Each of these PI Transit Centers represents a cluster of nodes as shown in Figure 2. As an example, a request going from Yarmouth to Quebec City will be loaded into a container in Yarmouth, unloaded and loaded into other containers in Truro and Fredericton, and finally transported to Quebec City.

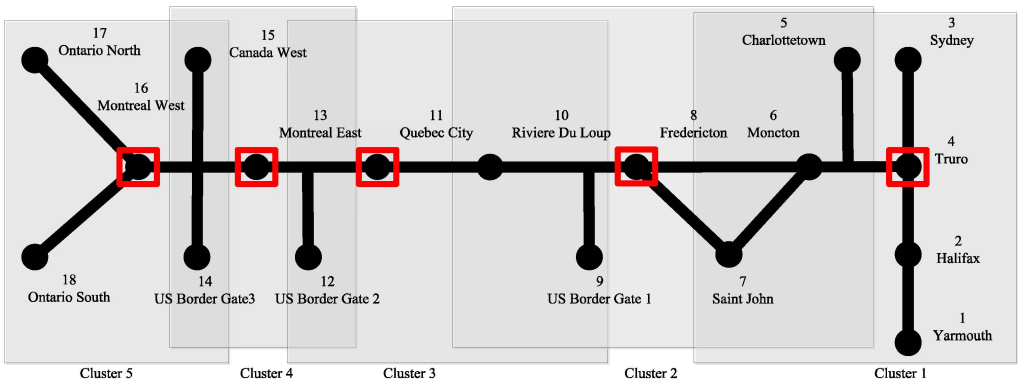


Figure 2- PI Road Network

2.3 Hybrid System Logistics System

In the Hybrid system a request at a source node is packed into a container with other requests. The container is then transported to the source cluster's PI Transit Center. In the PI Transit Center, the request is packed with all the other requests going to the same final cluster destination. The container then is transported to the destination cluster's Transit Center, where the request is unloaded and loaded with all the requests going to the same final destination node. As an example, a request going from Yarmouth to Quebec City will be loaded into a container going from Yarmouth to Truro. In Truro the request is unloaded and loaded to another container leaving to Quebec City. Then the container carrying the request will be transported directly to Quebec City.

3 Three Phase Optimization Framework

TPOF includes three optimization models working in series fashion. The first optimization model in TPOF is called *Packing*. The Packing model reads the list of the generated request from RDGM and packs them into containers. The purpose of this optimization step is to find the minimum number of the containers required to transport all the requests (or loads) from their initial location or source to their final destination. The second optimization model in TPOF is called *Routing*. The Routing model reads the result of the first optimization model and finds a series of Node sequences. These sequences of nodes determine the order in which resource (ex. trucks) should transport containers from a node to another node until containers reach their final destination. The sequence of nodes visited by a resource carrying different containers is called a *route*. Routes are created such that first and last node visited by a resource in the Route coincide. In other words, each route created by the Routing models is a loop. Model three in TPOF is called the *Scheduling and Cost* model. This model reads the list of the routes created in Routing model and treats each route as a unique job that should be assigned to a truck. The Scheduling and Cost model works similar to a generalized assignment problem to find the minimized cost of performing all the routes with the given set of the resources. Figure 3, is an illustration of how RDGM and TPOF are connected together.

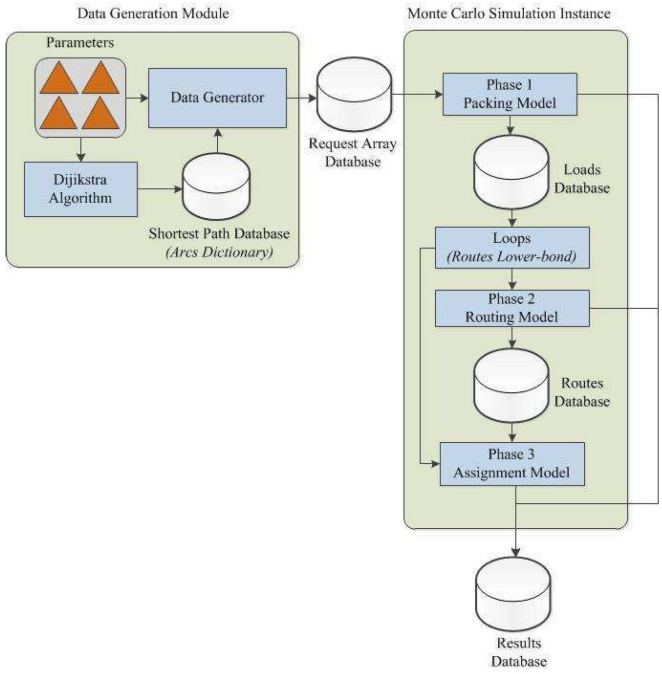


Figure 3 - RDGM and TPOF

4 Experiments

Six different experiments were performed to investigate the performance of logistic policies under various scenarios. The major differences among these experiments is originated from the following two factor:

1. Distribution of the load sizes chosen to enter into the TPOF
2. Number of requests generated for each source - destination pair which determines the traffic level in the network

Load Sizes

As stated in (Montreuil, 2011), globally accepted and standard PI load sizes are yet to be determined. In our study, we allowed the load (or request) sizes to be one of 1, 0.5, 0.25, or 0.125 of a 40 foot container.

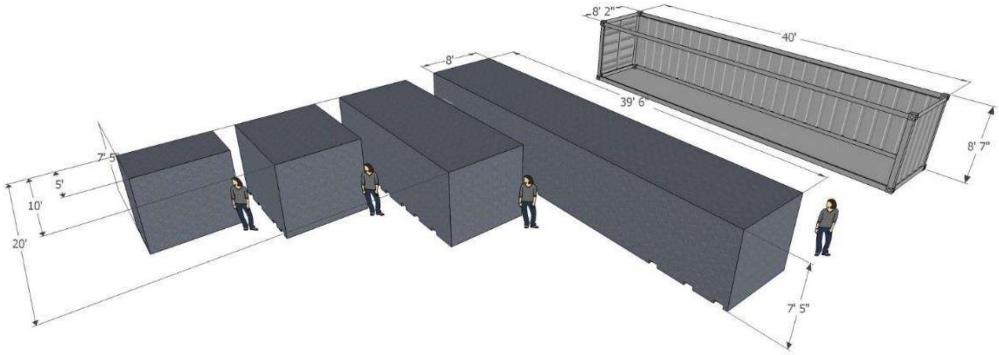


Figure 4 - PI Loads and a PI Container

Low Traffic Normal Loads (LTNL)

In low traffic experiment, EDGM generates two random load sizes for every possible source-destination pair. Possible source destination pairs are determined by the logistic policies. The probability distribution of the loads chosen in this experiment is shown as follows:

$$P(0.125) = \frac{8}{15}, P(0.25) = \frac{4}{15}, P(0.5) = \frac{2}{15}, P(1) = \frac{1}{15}, P(0) = \frac{1}{15}$$

Implied total number of requests generated in this experiment is 612 for CO, 1700 for PI, and 1250 for HY.

Moderate Traffic Normal Loads (MTNL)

In Moderate traffic experiment, EDGM generates five random load sizes for every possible source-destination pair. Possible source destination pairs are determined by the logistic policies and are identical to one in Low Traffic experiment. The probability distribution of the loads chosen in this experiment is identical to the one used for Low Traffic Experiment.

Implied total number of requests generated in this experiment is 1530 for CO, 4250 for PI, and 3125 for HY.

High Traffic Normal Loads (HTNL)

In High traffic experiment, EDGM generates ten random load sizes for every possible source-destination pair. Possible source destination pairs are determined by the logistic policies and are identical to one in Low, and Moderate Traffic experiments. The probability distribution of the loads chosen in this experiment is also identical to the one used for Low Traffic Experiment.

Implied total number of requests generated in this experiment is 3060 for CO, 8500 for PI, and 6250 for HY.

High Traffic Large Loads (HTLL)

Similar to High traffic experiment, in High Traffic Large Loads experiment, EDGM generates ten random load sizes for every possible source-destination pair. The probability distribution of the loads chosen in this experiment is shown as follows:

$$P(0.125) = \frac{1}{15}, P(0.25) = \frac{2}{15}, P(0.5) = \frac{4}{15}, P(1) = \frac{8}{15}$$

Similar to High Traffic experiment, implied total number of requests generated in this experiment is 3060 for CO, 8500 for PI, and 6250 for HY.

High Traffic Small Loads (HTSL)

Similar to High traffic experiment, in High Traffic Small Loads experiment, EDGM generates ten random load sizes for every possible source-destination pair. The probability distribution of the loads chosen in this experiment is shown as follows.

$$P(0.125) = \frac{8}{15}, P(0.25) = \frac{4}{15}, P(0.5) = \frac{3}{15}, P(0) = \frac{1}{15}$$

As it can be seen, the difference between Large Load and Small Load experiments comes from the difference in probability of selecting larger or smaller loads as load sizes Similar to High Traffic experiment, implied total number of requests generated in this experiment is 3060 for CO, 8500 for PI, and 6250 for HY.

Random Traffic (RD)

Random Traffic Experiment is performed to investigate the effect of varying traffic levels in different section of the network on the overall performance of the logistic policies. The distribution of the load sizes chosen for this experiment is similar to the Low, Moderate and High Traffic experiments. Number of loads generated for each source- destination pair varied randomly between values of 6 to 14 in this experiment.

5 Results

As stated, the comparison presented in this work is carried out through Monte-Carlo simulation in which loads are generated randomly and three optimization models are run sequentially to optimize the CO, PI, and HY logistical networks. The KPI's are collected and the process is repeated. Figure 5, is an illustration of how these simulation are ran for each logistic policy and results are collected in the results database. Six instances of data for each experiments introduced were generated.

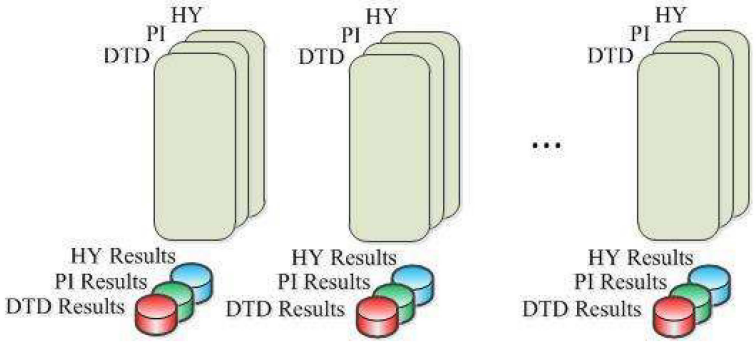


Figure 5 - Monte Carlo Simulation Instances

Figure 6, illustrates the aggregated results collected from the first phase of TPOF. Graphs show number of packing and unpacking instances required to transport all the loads. From these results, one can conclude that number of packing and unpacking instances is higher in PI compared to HY, and CO. Therefore, in terms of volume and number of material handling activates, CO performs superior to HY, and PI.

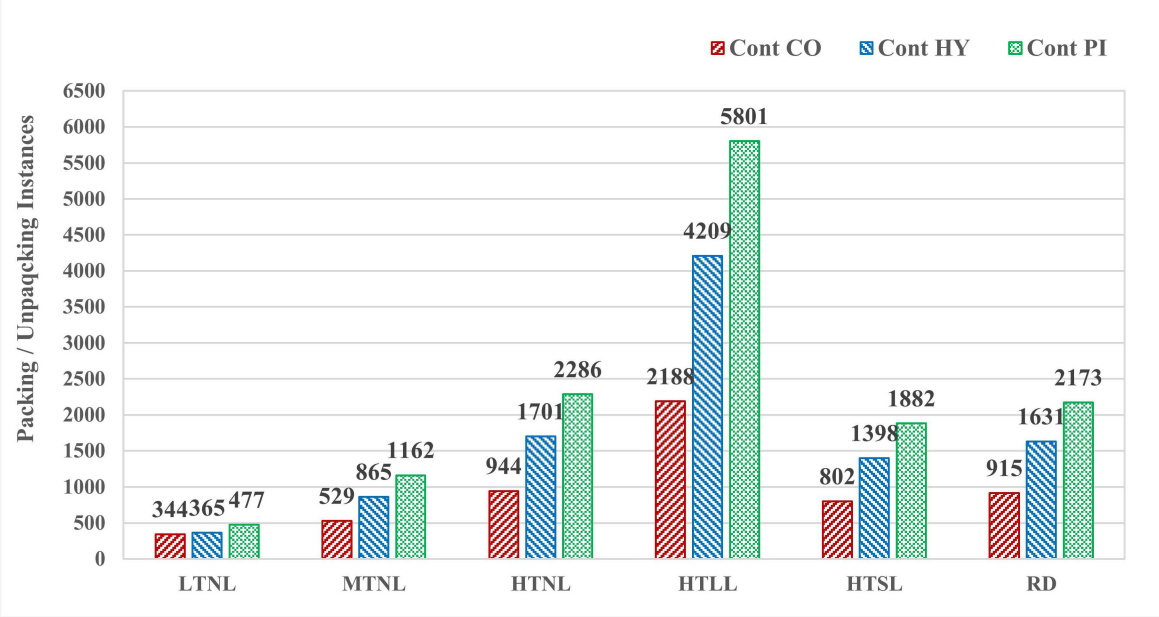


Figure 6 - Packing / Unpacking Instances

Figure 7, shows the aggregated routing time results of experiments collected from the second phase of TPOF. Graph shows the routing time required to transport all the loads from sources to destinations is smallest in PI, followed by HY, and CO.

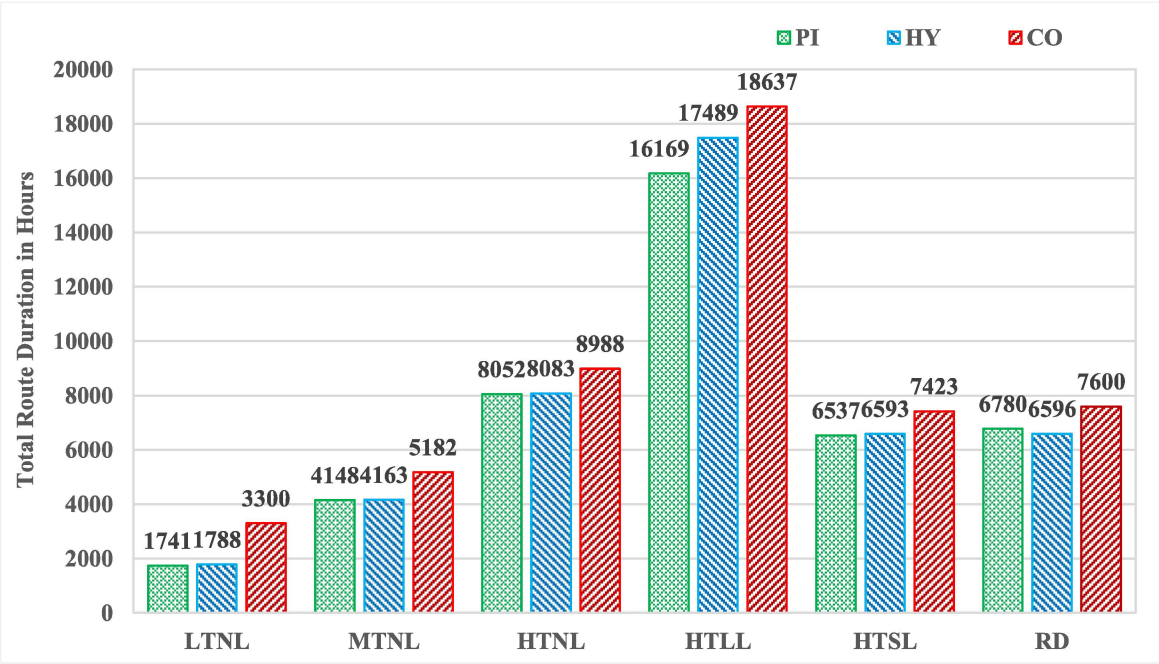


Figure 7 - Average Routing Time of Experiments

Table 1, and Table 2, shows the results generated in phase three of TPOF. One of the major differences of PI with CO logistic systems is that drivers usually work on short routes and are able to return home at the end of a 14 hours driving shift. The following two tables show an approximately consistent, major difference across the logistic policies in terms of percentage of

drivers who can go back home at the end of a day. These drivers are assigned to "Short Haul" routes. As driver does not need to sleep while enroute, trucks assigned to short haul routes do not require to have sleep compartment and are more economical to operate.

Table 1 - Scheduling Results with Fixed Load Size

	Low Traffic			Moderate Traffic			High Traffic		
Policy	PI	HY	CO	PI	HY	CO	PI	HY	CO
Trucks in Service	102	64	64	183	136	92	528	371	227
Long Haul	6	21	52	19	41	75	11	86	140
Short Haul	96	43	12	164	95	17	517	285	87
Total Enroute Hours	1,434	1,797.2	3,510.7	3,205.0	3,830.2	5,051.5	6,661.8	7,948.8	10,206.2
Total Driving Hours	1,402	1,469.2	2,743.2	3,191.1	3,256.6	4,212.1	6,525.8	6,636.8	7,574.2
Avg Hours on Duty	14.06	28.08	54.85	17.51	28.16	54.91	12.62	21.43	44.96
Avg Hours Driving	13.75	22.96	42.86	17.44	23.95	45.78	12.36	17.89	33.37
% Drivers Back Home	94.1%	67.2%	18.8%	89.6%	69.9%	18.5%	97.9%	76.8%	38.3%

Similar trends observed in the table above are repeated in the following table too. Therefore one can conclude the impact of PI logistic systems on drivers' social life has a lower magnitude compared to HY, and CO logistic policies.

Table 2 - Scheduling Requirements with Fixed Traffic Level

	High Traffic, Small Loads			Random Traffic			High Traffic, Large Loads		
Policy	PI	HY	CO	PI	HY	CO	PI	HY	CO
Trucks in Service	413	224	168	428	322	210	529	477	429
Long Haul	20	66	116	18	86	138	153	242	233
Short Haul	393	158	52	410	236	72	376	235	196
Total Enroute Hours	5,579	6,375.7	8,487.7	5,682.7	7,715.5	9,877.8	14,837	18,916	22,596
Total Driving Hours	5,443	5,319.7	6,319.7	5,506.7	6,339.5	7,269.8	14,637	15,556	16,868
Avg Hours on Duty	13.51	28.46	50.52	13.28	23.96	47.04	28.05	39.66	52.67
Avg Hours Driving	13.18	23.75	37.62	12.87	19.69	34.62	27.67	32.61	39.32
% Drivers Back Home	95.6%	70.5%	30.9%	95.9%	73.3%	34.3%	71.1%	49.3%	45.7%

6 Total Costs of Logistic Policies

Cost of the logistic systems are calculated by considering the results generated from phase one and phase three of the TPOM. Phase two has no direct effect on the costs as the results generated at phase two are sent to phase for further routing and scheduling calculation. The following shows what the contributing factors are to the total cost of the logistic system:

$$Total\ Cost = (Model\ 1) + (Model\ 3)$$
$$Total\ Cost = (Material\ Handling) + (Operational\ Cost + Social\ Cost + Fix\ Cost)$$

In this study, the Material Handling cost is defined as the total cost incurred for packing and unpacking of a one single container inside a transit center. In other words, the measurement unit for Material Handling cost is dollar per container. As there is no real PI transit center existence, the actual material handling cost cannot be estimated accurately. Therefore a cost ratio is defined to show material handling cost in relation with operation cost. Operation cost of using a truck per hour is approximately $200 (RAY BARTON & ASSOCIATES, 2006). Therefore for example a cost ratio of two set the Material Handling Cost at $400.

$$Cost\ Ratio\ = \frac{Material\ Handling\ Cost}{Operational\ \ Cost}$$

A current material handling cost in conventional logistic system is around $150 for a 40 foot container. This cost includes unloading and loading pallets from one container to another container. Material handling cost of $150 sets the cost ratio to 0.75. This cost ratio is shown by a vertical dashed line in Figure 8. Figure 8 shown the total logistic policy cost as a function of cost ratio defined. As cost ratio increases the tendency of PI to be the lowest cost logistic policy decreases. This is because PI is more sensitive to material handling cost compared to HY, and CO. At the cost ration of 1.5 or higher CO and PI change places and CO becomes the lowest cost logistic policy.

Figure 8, shows the total cost of logistic polices in High Traffic Large Loads scenarios (or experiments). For the other scenarios, total cost of logistic policies can be calculated and shown in the same fashion. It should be noted that, a similar trend holds for the total cost of logistic policies in other experiments. Overall, in all the scenarios for low material handling costs, PI is less expensive than HY, and CO. As material handling cost increases, PI's tendency to be the cheapest logistic policy decreases. For higher material handling costs, CO becomes a less expensive logistic policy.

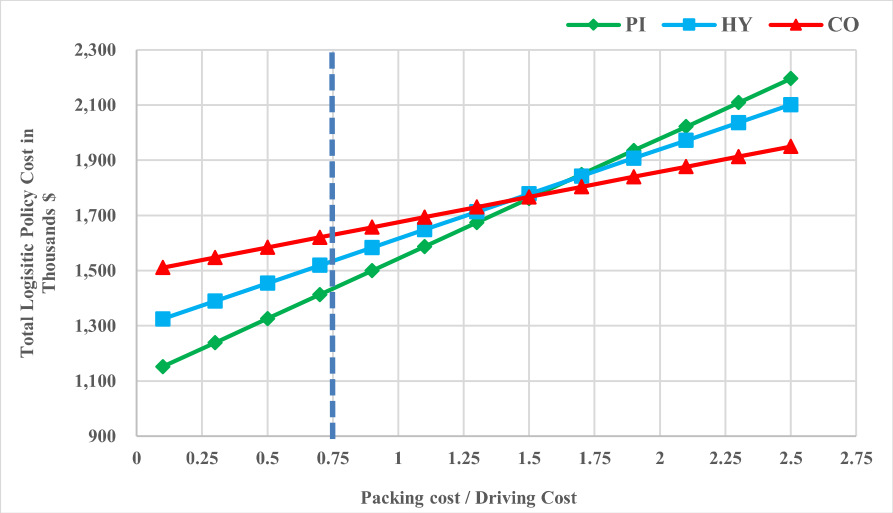


Figure 8 - Total Logistic Cost for HTLL

7 Conclusion

The three phase optimization framework was shown to be an effective method of investigating the overall performance of the logistic policies in this study. By comparing the CO, PI, and HY logistic policies using the three phase optimization methodology, a major trade of was observed between the total number of the instances containers requiring loading and unloading and total required driving time to carry loads from sources to their final destinations. Compared to CO logistic, HY, and PI benefits from a lower total driving time required to transfer loads from sources to destinations across the introduced road network. However, number of the instances containers require loading and unloading is higher in PI, and HY compared to CO. In other words, PI, and HY decreases the work done by drivers and increases the work done in PI transit center. The cost performance of each of these logistic policies varies under various traffic and load selection scenarios. In networks with low traffic PI showed to be a superior logistic policy followed by HY and CO. As traffic level increased the cost superiority of PI became very dependent on the work efficiency of the PI transit center.

Success of PI logistic system highly depends on the efficiency of PI transit center. Without efficient PI transit centers, PI logistics policy will not reduce the total cost of logistic activities. However, from an environmental point of view, PI and HY logistic policies will result in substantial decrease in logistic system's carbon foot print due to driving activities, and reduce the trucks traffic on the roads. Moreover, the social impact of truck driving on social life of truck drivers is less in PI, as a siginificant proportion of drivers are assigned to jobs with durations of one day or less.

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Library operations in low-density areas

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Abstract: Low-density areas with a population decline are confronted with the need to close down library branches. As a response to this trend, libraries start to work together in an interconnected network of libraries to maintain a specific service level for their members. Studies show that typically a significant increase in interlibrary transportation operations can be noticed. In this paper, we analyze the effects of closing down library branches and propose sustainable options for interlibrary transport operations. Transaction data and geographic information system analyses help to study the effects on customer behavior. Social transport is proposed as a way to involve volunteers and members of the library in performing the transport themselves. A SWOT analysis performed to study the potential of social transport by means of using public transport to deliver books to their destination. At the end, we formulate a sketch of a framework for initiating a pilot of this concept.

Keywords: *libraries, logistics, transport operations, transaction data analyses, GIS analyses, pilot study*

1 Introduction

In the Dutch library system we note that lately many library branches had to close down mostly due to the economic crisis and at the same time cuts in governmental subsidies. Specifically, this trend can be noticed in low-density areas that experience population decline. Library branches in these areas have responded to these developments by working together in an interconnected network of libraries. For example, in the province of Groningen, members can check stock levels of each library online and borrow and return books at a branch of their preference. In general, in such an interconnected system interlibrary reservations and borrowing results in a significant increase in interlibrary transportation operations. At this stage these transport operations are performed in a rudimentary functional way. From a sustainability perspective more efficient and effective transport operations might be designed, which is the focus of this paper.

In practice and literature several initiatives are being studied. One of those initiatives is called "Book-your-Book" as implemented by the library network in the province of Zeeland [1]. Many libraries have been closed in this province lately. The remaining interconnected network of libraries still offers a large assortment to members. Those members can order online the book(s)

of their preference and select a specific pick-up and delivery point, such as a supermarket in their own city. Important logistics questions in this context are the number and type of locations and opening hours and the organization of the transportation between the branches, and pick-up and delivery points. Academic research in this area focuses on transport operations between libraries (e.g., [2]), assortment decisions in library networks (e.g., [3]) and optimization of logistics processes (e.g., [4] and [5]).

Social transport is being introduced as one of the ideas in introducing the Physical Internet Initiative for Dutch Libraries ([6]). This can be seen as a way to dynamically assign transport requests to companies and volunteers. A sustainable way to transport books might be to have volunteers use public transport to deliver books at the right destination. Cargo Hitching is proposed as an idea to integrate passenger and freight transportation to enable efficient and effective delivery of people and small to medium freight flows by either using modes for public transport or freight transport [7]. In the Dinalog R&D project Cargo Hitching the logistics challenges of implementing this concept are studied. The focus is both on city distribution as well as low density areas. Specifically in low density areas, implementation of integrated passenger and freight transport might maintain public and freight transportation at socially, and economically acceptable levels.

The goal of this paper is to study effects of closing library branches and options to offer sustainable and economically sound transportation operations in interconnected library networks. The outcomes might be used for a potential pilot study to be performed in The Netherlands. In Section 2 we analyze the effects of library closures in the Dutch library system by means of transaction data analyses and GIS analyses in the province of Groningen. In section 3, we present the results of a SWOT analysis and discussion sessions with representatives of governmental and societal organizations. In Section 4 we present a framework outlining potential steps to design pilot studies for using public transportation for shipping library books. Section 5 presents conclusions.

2 Effects of closing library branches

We use the library network of the province Groningen in The Netherlands to study the effects of closing library branches. The province Groningen is in the north of the Netherlands and has one large city, named Groningen as well and contains 23 municipalities (see Figure 1). Per January 1, 2014, the province has 582,640 citizens which is 3.5% of the total population of The Netherlands. The size of the province is 2960 km^2, which is 7.1% of the Netherlands and its surrounding waterways. This means an average of 196.8 citizens per km^2 in Groningen compared to an average of 405 citizens per km^2 in the Netherlands [8]. Overall, in The Netherlands we notice a growth in the number of citizens. Forecasts show that around 2040 the population will stabilize and that the number of households will decrease from 2046 onwards. However, some municipalities and regions are confronted with a shrinking population already. In the province of Groningen this is the case for the municipalities Appingedam, Delfzijl, Eemsmond and Loppersum. Prognoses show that many municipalities in the countryside will follow [9]. Many facilities disappear in those areas. It can be noticed that usage of public transport has significantly decreased and less public transport services are being offered [10]. At the same time delivery routes to individual customers and retailers typically contain longer distances with fewer stops in low-density areas [11].



Figure 1: Municipalities in the province of Groningen (source: Province of Groningen)

The province of Groningen has a library system in which members can visit any library and borrow and return books at any library, not necessarily being the same. In 2012 the library received over 2.8 million visitors. In total 6.4 million items (e.g., books, magazines, dvds) were borrowed in that year. Many of the libraries in Groningen operate under a retail-concept formula with the aim to attract more visitors and improve customer satisfaction. Next to regular libraries, library busses visit more remote areas and several libraries were opened in schools [12]. We selected one area in the province of Groningen, De Marne, to perform our analyses on library transaction data. In this region several library branches were closed. As a result, we could analyze the effects of closing libraries on customer behavior.

The dataset and library network can be described as follows:

- Period 2009-2011
- Transaction data Region De Marne in province of Groningen
- 5 library branches (Eenrum, Leens, Zoutkamp, Ulrum and Kloosterburen; see Figure 2)
- 3 stops of library busses (Pieterburen, and 2 in Wehe-den-Hoorn, see Figure 2)
- At the end of 2010 the 3 stops of the library busses and the branches in Zoutkamp, Ulrum and Kloosterburen were closed.
- The library of Leens increased the opening hours from 6.5 in 2009 to 18 hours by the end of 2011. The assortment of this library was increased as well as that the retail-concept was introduced.
- The opening hours of the library in Eenrum decreased from 6 to 4 hours by the end of 2010.
- Over 3 years 3173 unique members are counted. In the analyses, we only study members in a specific year that borrowed at least 1 item in that year.



Figure 2: Region De Marne with libraries in the province of Groningen in 2009

Per member we can obtain the following information from the dataset:

- Date of Birth
- Zip code
- Start date of membership and if applicable end date of membership
- Number of visits to each branch
- Frequency of borrowing books
- Distance to each library

The average age of a member of the library in this region is 30.51 years. Approximately 48% of the members is between 0 and 17 years old. Approximately 30% of the members is 45 years and older. On average a member borrowed 51 items in 2009, 49.1 in 2010 and 42 in 2011. A decrease in the number of libraries might result in borrowing less items per active member. On average, a member has to travel a longer distance up to a library to borrow a book. In the period 2009-2011 for more than 52% of the members the library that they visited most to borrow items has been closed. Based on the data analyses we conclude that the probability that a member ends his/her membership increases with 5.27% if the library that is visited most by this member has been closed. If we take the age of a member into account, we note that for the group of members with an age over 65 this probability increases with 9.65% [13].

The library of Leens is in the year 2011 in this region the library with the longest openings hours and the largest assortment. Geographic analyses can be used to study the relation between the location where members live and what library they visit most often. Figure 3 shows the amount of transactions being performed in the library in the city of Leens by customers living in surrounding regions in the years 2009, 2010 and 2011. The analyses show that the density of transactions increases over time and that members travel over longer distances to visit a library. No changes were noted in the library in Eenrum.

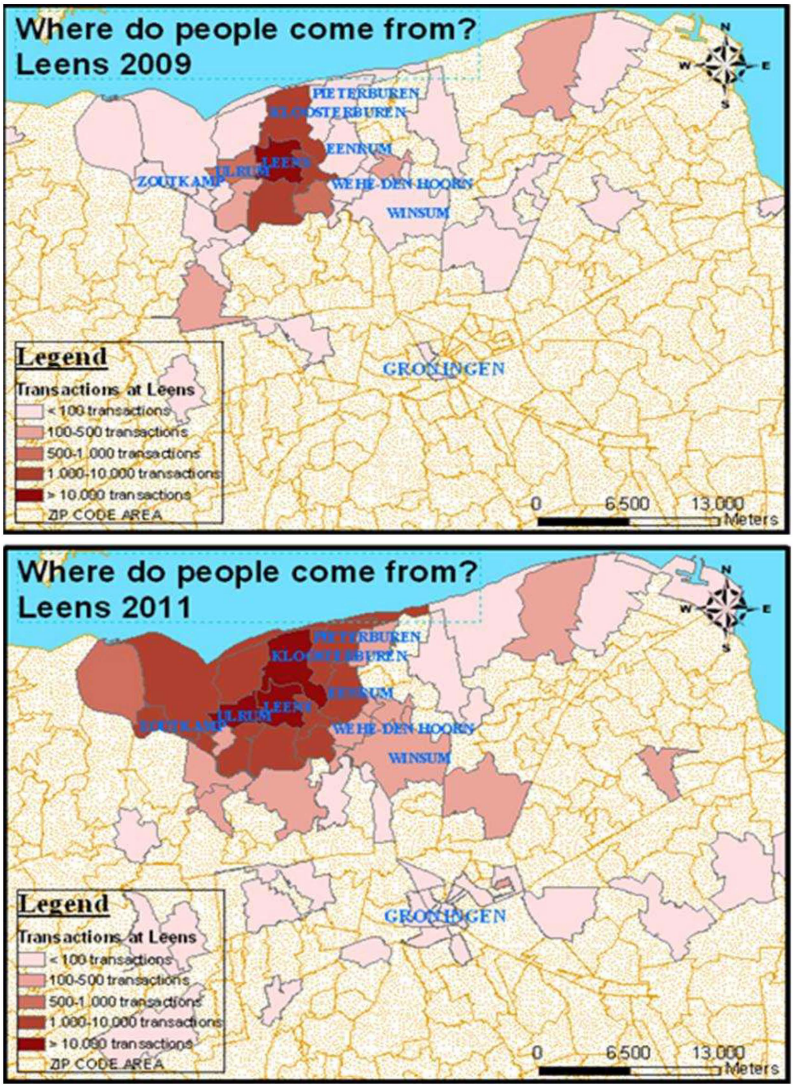


Figure 3: Transactions at Leens in surrounding regions (source: [14])

Based on the results of the data analyses in a typical low-density area in the province of Groningen, we conclude that as a result of closing library branches a significant increase in the probability that people discontinue their membership can be noted. Members typically borrow less items and travel over longer distances to visit the library of their choice. The library with the longest opening hours, a larger assortment and a new layout observed an increased number of members from surrounding areas.

3 SWOT Analyses

As a first step in working towards a pilot to test smart ways of transportation of library books between library branches we organized a workshop. The main idea was to get a good overview of constraints, challenges and objectives in implementing new ideas, such as Cargo Hitching. The outcomes can be used in deriving the characteristics of a successful pilot.

A workshop on the concept of *Cargo Hitching* was organized in which 25 people participated, representing governmental organizations (cities and provinces), health and child organizations. The workshop had the following design: 1) presentation on the concept of Cargo Hitching or social transport; 2) composition of four groups where we assigned people based on their professional experience to one of the four pillars of a swot analysis, namely strengths, weaknesses, opportunities and threats; 3) group-wise discussion on the assigned pillar; 4) presentation of the outcomes by each group; 5) selection per pillar of the three main points.

Below we present the outcomes for each category and the main points are highlighted in italic [15].

Strengths	**Weaknesses**
1. *People and resources meet each other* 2. *Much knowledge / power available in own residents* 3. *Short lines and granularity* 4. Importance of own citizens, individually and collectively 5. People take own responsibility and at the same time the right service can be offered	1. *There is little urgency to change the current organization* 2. *Many partners (complex and usually expensive)* 3. *Competences of employees* 4. Available networks will not cover the total area 5. Public transport has fixed time schedules 6. Potential loss of employment 7. There is no demand or market opportunity; business models of companies might disappear 8. Potential loss of speed in deliveries 9. Necessary conditions and availability of facilities 10. Social networks might solve it themselves 11. Expectations of people (customers might be spoiled: "I want it now".) 12. Local production/suppliers might form a threat
Opportunities	**Threats**
1. *Adding new facilities to the region* 2. *Increase social cohesion* 3. *Much cheaper and more efficient* 4. Creation of new jobs 5. More sustainable solution 6. Integration of different target groups 7. Exchange of facilities 8. Increase of mobility in area 9. Clear picture on all freight and passenger flows	1. *Companies might not be willing to share knowledge* 2. *Governmental regulations* 3. *Distribution of profits* 4. *Who will do the required investments?* 5. Participation of citizens 6. Collective versus individual needs

4 Conceptual Framework for a pilot study

Currently, the authors of this paper are exploring the opportunities for introducing a pilot in the province of Groningen to analyze the options to integrate passenger and freight transportation. More specifically, we will test the options to introduce social transport of library items potentially integrated with other freight flows in low-density areas by means of public transport (e.g., trains and busses). In this section, we provide a sketch of the steps to be performed before a pilot can be initiated. The outcomes of the SWOT analysis have been used to formulate these questions. We distinguish in this conceptual framework between research questions and choices to be made. Literature studies, analyses of freight and passenger flows, interviews and workshop meetings can be used in each of the steps mentioned. During the pilot phase both the concept of social transport via public transport as well as the design of this framework will be tested.

Steps to be performed are:

1. Perform a stakeholder analysis to get a clear picture on the stakeholders, their roles and relationships.
2. What opportunities and what resistance do stakeholders offer in introducing this concept?
3. What modes of transportation will be most successful (bus, train, taxi, ...)
4. What scenario(s) will be most successful (e.g., one village, multiple villages, a region; B2B and/or B2C; type of products)?
5. What village(s) will be most successful (e.g., based on number of citizens, presence of local retailers/web shops, accessibility by public transport, ...)
6. What network configuration is needed (e.g., locations for bundling and decoupling of products, IT systems)?
7. What flows of freight and passengers can be distinguished in the network derived in step 6.
8. What organizational decisions need to be made?
9. What changes in IT systems are needed?
10. How to design contracts, and divide investments and profits?

Based on discussions during the SWOT analysis (see Section 3) and with stakeholders, we conclude that the performance of the concept can be measured by the following aspects:

- costs
- service to the customer (e.g., lead time, reliability)
- option to keep the level of facilities in a certain area at the same level (e.g., public transportation that is being offered, number of stores)
- option to attract new flows of goods that were not profitable before introduction of the concept

5 Conclusion

The number of library branches in low-density areas in The Netherlands has significantly reduced. Studies on a library system in a low-density area with a decline in population in the province of Groningen show that many members are affected by library closures. The probability of discontinuing their membership increased significantly, specifically for the people over 65 years old. Members in the network tend to borrow less books and drive longer distances. Libraries work together in interconnected library network to keep up their service standards and offer their members a comparable assortment as before the closures. It is known that in these networks inter-library flows increase resulting in more transportation operations. In this paper we study the potential of the concept of social transport performed by volunteers using public transportation to transport library books potentially integrated with other freight flows. In other words, integrating freight and passengers flows as being introduced by the concept of Cargo Hitching. A SWOT analysis in Section 3 shows the potential of this concept. The outcomes have been used to provide a sketch of steps to be performed before a pilot of this concept can be initiated.

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Acknowledgements

This study was supported by a grant of the Dutch Institute for Advanced Logistics (Dinalog).

We thank L. Baardman, A.J. Uit het Broek, J. Chen, T.R. Dijk, N.W. Koning and J. van der Kroef for performing some of the data analyses reported in this paper.

Appendix

Participants workshop SWOT analysis

Organisation	Function
NBN	unknown
Adviescommissie Wonen	unknown
Concreet en Vos	Program- and projectmanagament
Fusiegemeente De Friese Meren	Coordinator Villages
Gemeente Dongeradeel	Alderman
Gemeente Franekeradeel	Mayor
Gemeente het Bildt	Alderman
Gemeente Menameradiel	Policy Officer
Gemeente Oldambt	Policy Officer
Grontmij	Senior Advisor
Kabelnoord	Innovator
Kennisplatfrom Kindvoorzieningen Noord-Groningen	Projectleider
Leeuwarden vrij-baan	Advisor Communication
Oosterlengte Zorgketen voor Oost-Groningen	Manager Care at home
Provincie Drenthe	unknown
Provincie Fryslân, Netwerk Noordoost	unknown
Provincie Groningen	Policy Officer Public Transport
Provincie Groningen	Member Government Province
Senior beleidsmedewerker, secretaris ovvf	Senior Policy Officer
STAMM CMO	Senior advisor
Stichting Herrie.nu	unknown
Uitgeverij media-totaal noord	Editor
ZORG INNOVATIE FORUM	Advisor Business Support
ZORG INNOVATIE FORUM	Project- & Subsidy advisor
ZuidOostZorg	Policy Officer

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A rail-road PI-hub allocation problems: model and heuristic

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Abstract: *A rail-road π-hub allocation problem is considered. A set of π-containers must be transferred from wagons to outgoing π-trucks using the rail-road π-sorters. The problem is identified and formulated as a special bin packing problem. The containers are assimilated to items to be packed, and the Bins are the trucks. The main performance objective is defined as the aggregation of two criteria to be minimized: the number of used trucks and the distance covered by each container to arrive at dock destination. Different scenarios are constructed and tested to show the efficient of proposed methods.*

Keywords: *rail-road allocation, physical internet, bin packing, linear model, heuristic.*

1 Introduction

The Physical Internet (PI, π) is defined as an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols (Meller et al., 2012). In this structure, goods are shipped in containers like data packets in the Digital Internet, where networks are connected using standard packets of data under the TCP-IP protocol. (Montreuil et al. 2010) proposed three key types of physical elements to exploit the Physical Internet: π-containers, π-movers (π-vehicles, π-carriers, π-conveyors and π-handlers) and π-nodes (π-transits, π-switches, π-bridges, π-sorters, π-hubs, π-composers, π-shops, π-bridges...). The mission of the π-hub is to transfer π-containers from the incoming π-movers to the outgoing π-movers.

Several scientific issues are defined in (Ballot et al, 2010; Montreuil et al., 2012; Sarraj et al., 2012):

- π-facilities design allowing a quick and flexible transfer of the π-containers,
- π-containers design and definition,
- modular containers impact on shipped volume,
- open network impact on the freight distribution,
- ….

The first mentioned issue is essential for the successful development of the Physical Internet but it has been rarely addressed. The π-containers are defined as the key element in the Physical

Internet network. The cross-docking hub is one of facility to be designed. Efficient hubs and transit nodes should provide a quick and synchronized transfer of the π-containers.

(Ballot et al., 2012) presented a specific road-rail hub which aim is transferring containers from truck to train and vice-versa; and from a train to another train. The road-rail π-hub has three main problems to resolve:

- The road-rail problem: some π-containers must be transferred from π-trucks to wagons using the road-rail π-sorters.
- The rail-rail problem: some π-containers must be transferred from wagons to other wagons using the rail-rail π-sorters.
- The rail-road problem: the π-containers must be transferred from wagons to outgoing π-trucks using the rail-road π-sorters.

In this paper, the third problem which is the "rail-road" problem is considered. The main performance objective of the "rail-road" zone is to minimize the time to interconnect trains and trucks services. To manage the cross-dock, several issues must be treated:

- Allocation of the cargo to the trucks: the appropriate assignment of unloaded π-containers from the train to the available trucks must be defined.
- Scheduling of the trucks on the gates: the trucks must be located adequately in front of the different wagons to minimize the routing times. This problem implies to determine the schedule of trucks on the gates to answer the following question "where and when the trucks should be located?"
- Routing of π-containers: once the π-containers have been unloaded, they must be routed to their destination trucks.

This paper focuses on the allocation and scheduling issues. It is organized as follows. In section 2, the problem is described. Third section presented a mathematical formulation of the problem. A heuristic based approach is proposed in section four. Computational results and experimentations are exposed in section five. Finally a conclusion and perspectives are addressed.

2 Problem description

2.1 System elements

The rail-road hub is composed of π-containers, π-movers and π-nodes defined as follow:

- π-containers: In the framework of π, goods are encapsulated in modular containers. All containers have the same width and height (section 2.4*2.4m^2) but with various lengths. There are six different lengths 1.2m / 2.4m / 3.6m / 4.8m / 6m / 12m. The containers which have the same destination must be grouped. Also, every container has a priority p. Three types of priority are defined: urgent, normal and no-urgent.
- π-movers: There are three types of movers used in the rail-road hub: π-vehicles, π-carriers and π-conveyors. The π-vehicles are represented in the trucks and train. The length useful of π-truck is 13.2m and the width useful is 2.4m. Then, the π-carriers are

represented in the π-wagons. The number of π-wagons is 30, the useful size of π-wagon is 18m and the total size of π-wagon is 20m. Also, the size of π-conveyors is 1.2*1.2m^2.

- π-nodes: There are many π-nodes represented in the rail-road hub such as π-sorter and π-store. The π-sorter is a π-node that receives π-containers from inbound trucks or wagons and must sort them in order to ship each of them to a specified outbound trucks or wagons in a specified order. Also, π-sorter can integrate a network of π-conveyors. The π-store is a π-node having the mission of storing π-containers during a time windows.

2.2 System description

The rail separates the π-sorters in two sections: the above section is devoted to load/unload containers from a train to another train. Then the below section is composed of two other sections: the left section "section 1" is devoted to unload containers from wagons to trucks and the right section "section 2" is devoted to load containers from trucks to wagons. Each of these sections is manipulated by blocks of 5 wagons. The distance between two trucks is 1m or 1.25m, so each wagon can be processed by 5 or 6 trucks. We suppose that the number of trucks per section is about 28 trucks (Figure 1).

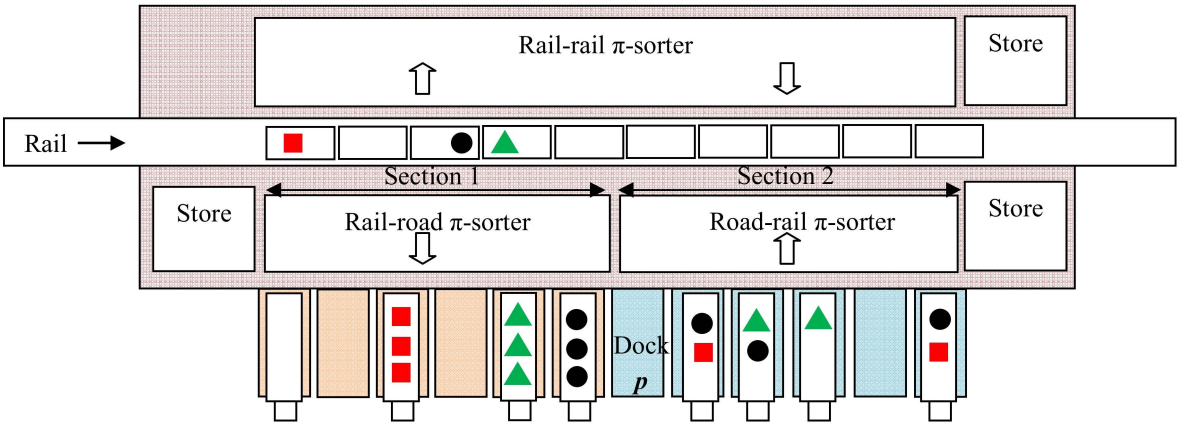


Figure 1: the Road-Rail π-Hub

When the train arrives to the π-hub, it carries a set of containers. Every container has three possibilities:

- Stay at the same wagon in order to be transferred to another π-node (cross-dock, road-rail hub…)
- Be transferred to the rail-rail sorters to be loaded in another train.
- Be unloaded in the rail-road sorters and transferred to the trucks.

Our study is focused on the last possibility. These containers can be affected either to a next destination or to a specific truck according to the nature of the container. The assignment of trucks to the docks must be done before the arrival of the train (the contents of wagons are known two hours before the arrival of the train).

Each container is unloaded from wagons to routing area using the conveyors. Then, in some cases, when there is no sufficient number of trucks, the container will be transferred to the storage area. After that, it returns to the routing area and finally the container is loaded to the

truck. If the whole truck is loaded, it lives the hub. Else the container stay at the truck until the whole truck is loaded or the delay of waiting time is attained (Figure 2).

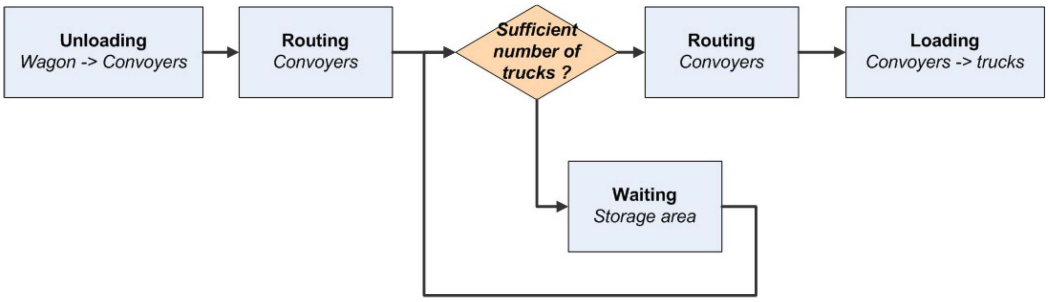


Figure 2: The path of container in the rail-road problem

Our purpose is to determine the "best" assignment of the trucks to the docks and the "best" assignment of the containers to the trucks in order to minimize the number of used trucks and the distance covered by each container to arrive at dock destination.

3 Problem formulation

The problem can be viewed as a Bin Packing problem (Bekrar et al., 2010). The containers are assimilated to items to be packed, each item i length l_i, ($i=1,..,n$). The Bins are the trucks with a uniform capacity K.

However, many specific constraints are to be considered:

- The position of both containers and trucks affected to docks are changing over the time.
- The position of trucks to docks is important in aim to minimize the moving containers on the routing zone.
- For simplification, the containers are considered with the same priority.

The following parameters and variables are used in the model.

Data and parameters:

n: number of containers positions.
M: number of docks positions.
D: number of destinations. $d(i)$ is the destination of container i.
l_i: length of the container i,
T : number of periods in the planning horizon.
K : capacity of trucks.
F : the set of available trucks.
mid_i: is the position of the middle of the container i according to the axe of the containers delimited by the block rail-road.
mid_p : is the position of the middle of the dock p according to the axe of the docks

Variables:

$$x_{ic}^{t} = \begin{cases} 1 & \text{if the container i is assigned to the truck c at time t} \\ 0 & \text{otherwise} \end{cases}$$

$y_{pc}^{t} = \begin{cases} 1 & \text{if the dock p is assigned to the truck c at time t} \\ 0 & otherwise \end{cases}$

$U_c = \begin{cases} 1 & \text{if the truck c is used} \\ 0 & \text{otherwise} \end{cases}$

d_{ip}^{t}= the distance covered by the container *i* at position mid_i to reach the dock *p*.

Objective:

Two criteria are fixed to be minimized: the number of used trucks and the distance covered by each container to arrive at dock destination. These two objectives are aggregated by a parameter α that varies between 0 and 1depending on the user choice.

$$Min\ Fct\ =\ \alpha * (\sum_{c=1}^{F} U_c) + (1-\alpha) * \sum_{t=1}^{T} \sum_{p=1}^{M} \sum_{i=1}^{n} d_{ip}^{t} \quad (1)$$

Subject to:

$$\sum_{c=1}^{F} \sum_{t=1}^{T} x_{ic}^{t} = 1, \forall i = 1,..,N \quad (2)$$

$$\sum_{i=1}^{n} l_i * x_{ic}^{t} \leq K * U_c, \ \forall t, c \quad (3)$$

$$\sum_{c=1}^{F} y_{pc}^{t} \leq 1, \forall t, p \quad (4)$$

$$\sum_{t=1}^{T} \sum_{p=1}^{M} y_{pc}^{t} \leq 1, \forall c \quad (5)$$

$$\sum_{p=1}^{M} y_{pc}^{t} \geq x_{ic}^{t}, \forall c, i, t \quad (6)$$

$$U_c \geq x_{ic}^{t} \forall c, i, t \quad (7)$$

$$if\ d(i) \neq d(j), \text{then } x_{ic}^{t} + x_{jc}^{t} \leq 1, \forall i, j, t, c. \quad (8)$$

$$\sum_{t1=t+1}^{T} y_{pc}^{t1} \leq K * U_c - \sum_{t0=1}^{t} \sum_{i=1}^{n} l_i x_{ic}^{t0} + min(l_i), \forall i, t, c, p \quad (9)$$

$$if\ x_{ic}^{t} + y_{pc}^{t} = 2, then\ d_{ip}^{t} = \left| mid_p - mid_i \right| \ \forall t, i, p, c \quad (10)$$

$$x_{ic}^{t}, y_{pc}^{t}, U_c \in \{0,1\}, \quad \forall t, i, p, c \quad (11)$$

$$d_{ip}^{t} \in R, \forall i, p, t \quad (12)$$

Constraints (2) ensure that each container should be assigned to only one truck at the same time *t*, while constraints (3) are truck capacity which bounds the amount of containers affected to a truck. Constraints (4) affect to each dock at most one truck in the same time while constraints (5)

ensure that a truck cannot be affected to more than one dock. Constraints (6) ensure the relationship between decisions of the assignment of containers, trucks and the docks: when a container is assigned to truck for a destination, a dock should be assigned to this truck. Constraints (7) assume that if a container is affected to a truck, the later is used. To fix the destinations, constraints (8) ensure that when two containers have different destinations, they cannot be assigned to the same truck. Constraints (9) express as when a truck is full at time t, it should free the dock at time $t+1$. Constraints (10) compute the distance covered by container i to reach the dock p follows: two axes, one for containers and the other for docks, are considered. Each container has a position on the container-axis (mid_i) and each dock has a position on the docks-axis. The simplest distance that we consider is the absolute value of the difference between the position of container and the position of dock to which it is affected (see Figure 3).

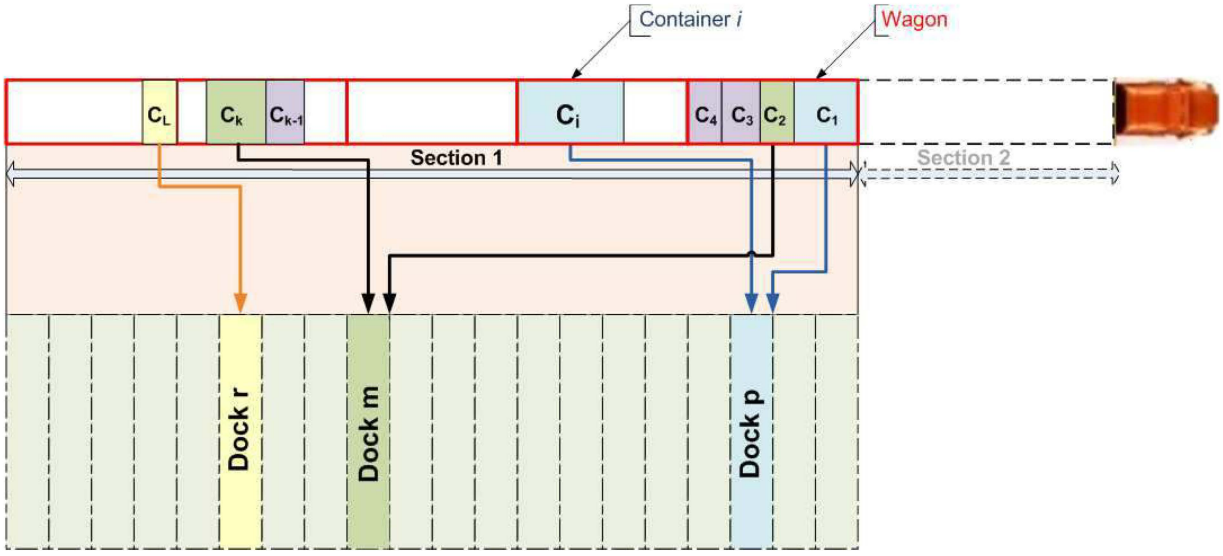


Figure 3: computing the distance between a container and a dock

4 Heuristic-based approach to rail-road π-hub allocation problem

In this section, a heuristic based method, named ***Best Fit Grouping Heuristic (BFGH)***, is proposed in order to find good solution in reasonable time for the *rail-road π-hub allocation problem*. The BFGH heuristic consists of four steps and is presented in the figure 4. Some notations are used and defined in next paragraph.

Notations

K : is the capacity of truck.
d_c : is a destination of the container c.
Nm: is the number of containers in the group m
m_d: is the group of containers with the same destination d.
M_d: is a set of groups of containers for destination d (a set of m_d).
l_c: is a length of container c.

lg_m: is the length of containers in the group m ($lg_m = \sum_{c \in m} l_c$).
res_m: is the remaining capacity in the wagon after putting the group m ($res_m = K - lg_m$).
mid_c: is the position of the middle of the container c according to the axe of the containers.
Avg_m: is the average of containers positions of the group m. $\mathbf{Avg_m = \sum_c^{Nm} mid_c / Nm.}$

The heuristic consists of four steps. The first step is for selecting randomly a destination not yet treated and determining all containers for the selected destination. In the second step, the containers are grouped satisfying the capacity/longer of truck in a set of groups M_d. In the third step, the solution obtained at the previous step is improved by the reassignment of the containers that minimize the number of used trucks. Finally in the fourth step, the groups of containers are assigned to the nearest dock according to the average position of containers (*Avg*).

4.1 Illustrative example

In order to better explain the BFGH heuristic, we introduce an example for which the assignment computation of the first destination is detailed.

Table 1 presents an example of the distribution of containers in wagons. In this example, in order to explain the method, we will limit to only one train r_1 and one block of the train b_1. The block includes 5 wagons and each wagon is composed of a set of containers with different lengths l_c, destinations d_c (we have three possible destinations) and their middle mid_c (according to the axe of containers).

Table 1: distribution's example of containers in wagons

Train ***r***	r_1																	
Block ***b***	b_1																	
Wagons ***w***	w_1		w_2				w_3			w_4					w_5			
Containers ***c***	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}	c_{17}	c_{18}
Length l_c	6	12	1,2	4,8	6	6	2,4	3,6	12	1,2	2,4	2,4	6	6	3,6	4,8	4,8	4,8
d_c	d_1	d_2	d_3	d_1	d_3	d_1	d_1	d_3	d_1	d_1	d_1	d_2	d_3	d_2	d_1	d_3	d_2	d_3
mid_c	3	12	20,6	23,6	29	35	41,2	44,2	52	60,6	62,4	64,8	69	75	81,8	86	90,8	95,6

Best Fit Grouping Heuristic(BFGH)

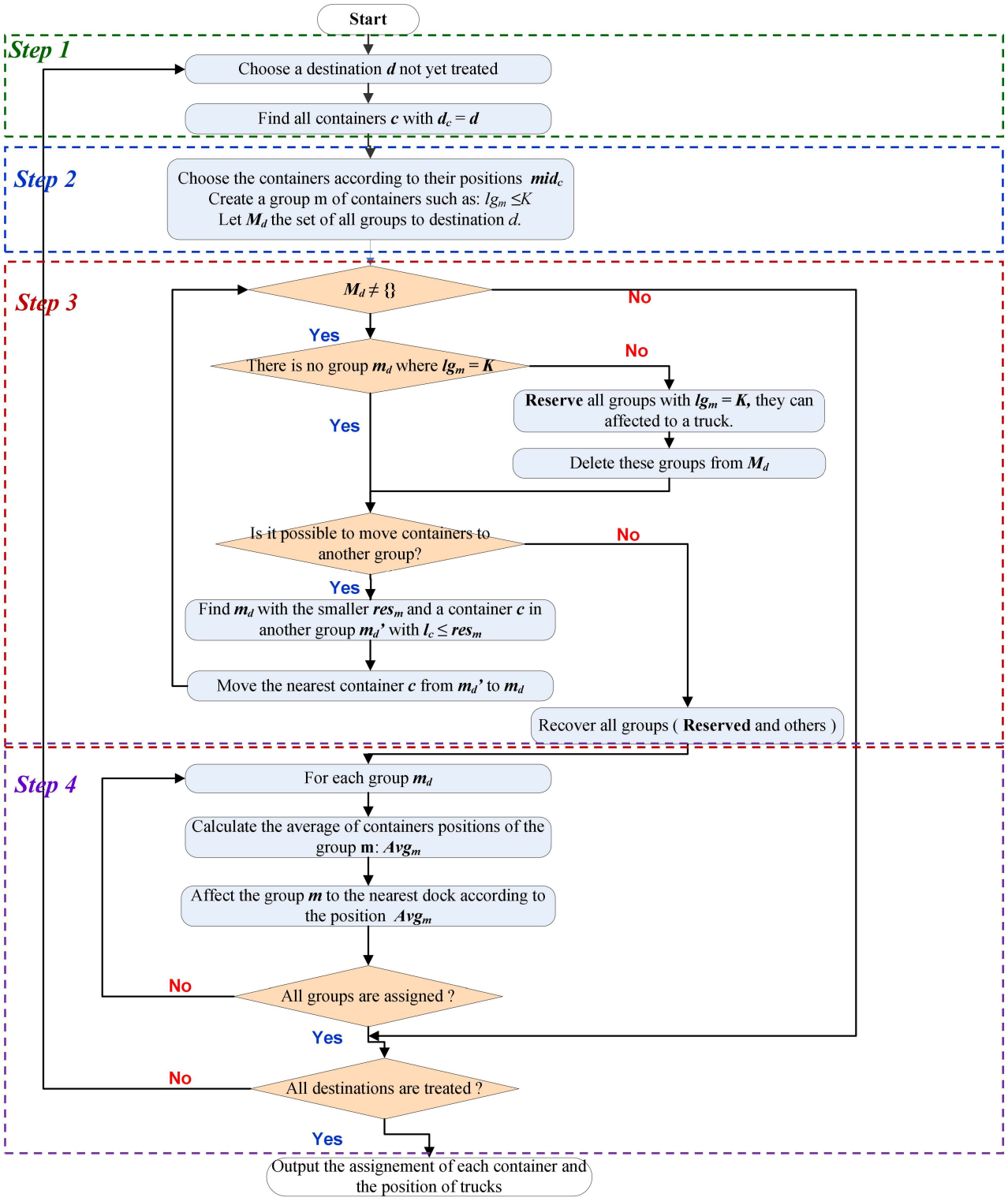


Figure 4: Best Fit Grouping Heuristic flow chart

The running of the BFGH heuristic

The different steps of the BFGH heuristic are detailed in the following.

Step 1: Select destination and containers

- Choose the destination $\boldsymbol{d_1}$ which is not yet treated.
- Define all containers with $\boldsymbol{d_c}=\boldsymbol{d_1}$ which are c_1, c_4, c_6, c_7, c_9, c_{10}, c_{11} and c_{15}.

Step 2: Grouping containers

- Choose the containers according to their positions $\boldsymbol{mid_c}$ on the containers axe.
- The list of container is $\{c_1, c_4, c_6, c_7, c_9, c_{10}, c_{11}, c_{15}\}$.
- Create the set of groups $\boldsymbol{M_d}$. Each group $\boldsymbol{m_d}$ of $\boldsymbol{M_d}$ is a set of containers.
- Thus, we have three groups. $\boldsymbol{M_{d1}}=\{\{c_1, c_4\},\{c_6, c_7\},\{c_9, c_{10}\},\{c_{11}, c_{15}\}\}$ (see Table 2).
- The length of each group $\boldsymbol{lg_m}\leq\boldsymbol{K}$.
- $\boldsymbol{res_m}$ is the remaining length to reach the capacity **K** of the truck.

Table 2 : initial set of groups of destination d1

m_d	1		2		3		4	
#container	c1	c4	c6	c7	c9	c10	c11	c15
Length l_c	6	4,8	6	2,4	12	1,2	2,4	3,6
lg_m	10,8		8,4		13,2		6	
res_m	2,4		4,8		0		7,2	

Step 3: Improve the solution

- Reserve the group 3 which have $\boldsymbol{lg_3}=\boldsymbol{K}$ and delete it from the set $\boldsymbol{M_d}$.
- The m_d with the smaller $\boldsymbol{res_m}$ is $\boldsymbol{m_1}$ and we look for a container that can complete this group. There is container $\boldsymbol{c_7}$ in the group $\boldsymbol{m_2}$ with $l_7\leq res_1$.
- Move the container c_7 from the group $\boldsymbol{m_2}$ to the group $\boldsymbol{m_1}$ and repeat ***Step3***.
  We note that we accept to move container from a group to another only if this move helps to fill the whole truck ($lg_m=K$) or to minimize the number of groups. This condition avoid infinite loop in the computation.
- The result of step 3 is represented in Table3.

Table 3: final groups of destination d_1

m_d	1			3		4		
containers	c1	c4	c7	c9	c10	c11	c15	c6
l_c	6	4,8	2,4	12	1,2	2,4	3,6	6
lg_m	13,2			13,2		12		
res_m	0			0		1,2		

Step 4: Assign containers to docks

- Calculate the average $\boldsymbol{avg_m}$ of the group 1:
  $avg_1=(mid_{c1}+mid_{c4}+mid_{c7})/3=(3+23,6+41,2)/3=22,6$.
- Find the nearest dock to the abscissa 22,6. The chosen dock is $dock_7$.
- Repeat ***step 4*** for all groups created in step3
- If there are more destinations not yet treated, then go to ***step 1***.

The final assignment for the example is presented in figure 5. Three trucks are used with an average loading rate of 90.90%.

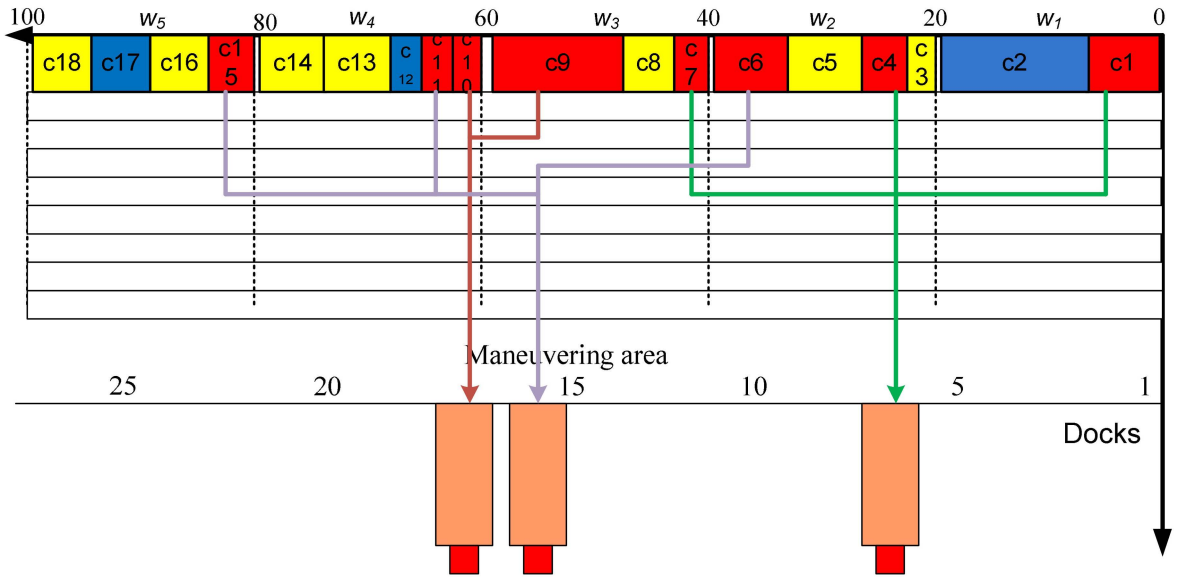


Figure 5: Assignment of containers with BFGH for the example

5 Experimentations and results

In order to validate the two proposed approaches, the linear model is implemented using Concert Technology of IBM Cplex. The heuristic is implemented in Java using a PC with processor Intel(R) Core(TM) i3 CPU 2.53GHz and 4Go of RAM.

The two approaches are tested on randomly generated instances as follows:

- The number of containers n is chosen from the set {60, 90, 140},
- The number of destinations D is chosen among the values : {4, 6, 10, 15},
- For each container, we generate its length uniformly among the different possible lengths {1.2, 2.4, 3.6, 4.8, 6, 12}. The amount of containers lengths in a wagon should be less than the length of the wagon.
- For each container, we generate a destination uniformly in [1, D].

The model can solve only small instances, for this, in this paper only results obtained by the BFGH heuristic are presented in table 4. Note that the BFGH heuristic takes few seconds to reach the solution.

To evaluate the efficiency of the heuristic, we check the mean loading rate (LR) of the trucks after assignment. If this rate is high, it implies that a minimum number of trucks to deliver the containers is used.

Table 4: Results of BFGH on randomly generated instances

D	N	#Trucks	LR
4	60	30	65%
	90	40	68%
	140	48	76%
6	60	39	58%
	90	47	60%
	140	53	65%
10	60	44	42%
	90	53	48%
	140	68	50%
15	60	48	41%
	90	64	40%
	140	78	42%

As we can see in Table 4, the loading rate of trucks is around 70% when the number of destinations is low. However, when the number of destination increases, the loading rate decreases. In one hand, this result can be explained by the fact that when the number of destination increases, it is difficult to fill whole trucks. In the other hand, these low rates concern the generation of instances. For example, in the instance with 15 destinations and 60 containers, for the destination d_7 only one container with length equal to 4.8 is proposed. This leads to a rate of 36% which affects the average rate. For future tests, we will fix bounds for the number and length of containers for each destination.

6 Conclusion and perspectives

In this paper, the allocation problem in the rail-road physical internet context is considered. This problem concerns the allocation of both containers to destination docks and docks to trucks. After detailing the specifications that show interesting and special constraints, a linear model and a heuristic based method are proposed to deal with problem. Two objectives are fixed, minimizing the number of used trucks and distance covered by containers in the routing zone.

Linear model and heuristic approach are implemented and tested on randomly generated instances. The linear model can only solve small instances when BFGH heuristic can solve all instances in few seconds. The results obtained by BFGH shown a loading rate around 70%. We

are working to improve the model by adding some valid inequities. It is planned also to relax some constraints to obtain good lower bound to compare with the heuristic.

More constraints, such us the whole destinations list for each container, will be considered in the future work. More objectives will be also used which implies the use of other techniques, like metaheuristics to solve the problem. Perturbations and uncertainties will be defined and integrated to test approaches in real-world context.

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May 28-30, 2014 - Québec City, Canada

Impact of resource sharing of freight transportation

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Abstract: This article will present the impact of resource sharing of freight transportation network. Based on some Physical Internet's key features, this model is developed as a few steps before the full implementation of the Physical Internet Network. In order to verify it impact, we use the platform Netlogo to implement and simulate the resource sharing transportation model and the traditional transportation model. After all those stages, we compare and analysis the results between the two models. The results indicate that the resource sharing transportation improve the financial, operational, social and environmental performance of a transport operation, more than the traditional model.

Keywords: *physical Internet, resource sharing, multi-agents simulation, logistics, road transportation, business models, consolidation, hub, performance Indicators.*

1 Introduction

In an increasingly global world, optimizing the flow of materials and products is an activity that concerns everyone involved, from industry, consumers, to road users. In this context, companies must provide transportation services for a variety of products, seeking to meet the principles of sustainable development while minimizing operational costs. It is based on these rules and requirements that the emerging concept of Physical Internet (PI, π) was initiated. The Physical Internet is an innovative, ground-breaking transportation philosophy. Its principles are based on the assumption that current logistics networks are unsustainable. Therefore, one of the basic assumptions of a PI network is the sharing of infrastructures, including transportation hubs, warehouse, hauling capacity, containers (trailers), among its participating members.

The Physical Internet is an innovative, ground-breaking transportation philosophy. Its principles are based on the assumption that current logistics networks are unsustainable. Therefore, one of the basic assumptions of a PI network is the sharing of infrastructures, including transportation hubs, warehouse, hauling capacity and trailers among its participating members. In this context, the deployment of a PI network inevitably leads to a deep reorganization of logistics and transport networks as well as the resources. In addition, according to Montreuil (2011) the PI has a huge impact on how goods are purchased by consumers around the world, how they are designed, produced and distributed to cities and families). The PI is based on 13 general characteristics. Ballot (2010) shows that these characteristics may be divided into principles of operations (tools, accountability, systems, openness and universality) and principles of organization (interconnection, consistency, accessibility to the network, singularity, encapsulation, agents, hiring and certification). Montreuil (2010) introduces that besides the sharing of physical resources and information, other important aspects of the PI involve the

design and the use of the modular containers of various sizes, of the hub and the PI facilities (e.g., for cross-docking, sorting, inter-modal handling), and of the vehicles carrying or handling the loads.

Based on some of those PI general characteristics, this paper is founded on the collaborative transportation system between its agents for increasing and optimizing the efficiency of a distribution transportation system. (van Weele 1999, Meller 2012) discovered that the collaborative logistics refers to the practice of two or more organizations collaborating to increase the logistics performance of each organization, within a certain balance of power between them. The collaborative transportation in the wood industry in Norway shown the potential backhaul trips reduced by 15 percent the empty trucking distance and by 6 and 7 percent the transportation cost. Peetijade (2012) affirms that manufacturing process planning also can reduce energy use in transportation by joining transportation process with other manufactures.

This collaborative transportation has as fundamental principle the resource sharing. It means the assets of the network, like the trailers, and the trucks and truckers that will be shared between all players (hubs). According to Polenske (2004), in collaborative agreements, the firms tend to gain unique and often unequal access to some of these resources. And for Ferrer (2010), this can explain the motivation of firms to collaborate to not only improve performance by reducing costs but also by expanding and controlling the market.

Supported by those assumptions, this paper will present a comparison between traditional and shared resource freight transportation. Both models will be implemented in a simulation platform using NetLogo, and tested in various condition and scenario configurations. The results will be analyzed and compared between the models by some social, financial, environmental and operational performance indicators.

The paper is set out as follows. Initially, we present the transportation models, then the concept of agent-based technology and presents further details and parameters of the simulation. In the fourth section it's the experiments, its designs, the simulation models, and the analysis of the results. The last section presents the conclusion.

2 Transportation models

This section introduces the characteristics and the implementation of the transportation models. The first sub-section is the resource sharing model, and the second one is the traditional transportation model.

Both models use the same network. The hubs' locations are based in Quebec, Ontario and New England major cities. They are therefore located using their latitude and longitude data, and the distances of each arc are determined using the Mercator projection. So the availability of trucks at each hub is also based on the size of population, with the larger cities having more trucks.

The trailer demand generation is based on the population of each city, because every city has a hub. It is understood that the cities with the highest population will demand more products and the origin of such transport is random. Each trailer has a capacity of 40 tonnes, and those transportations network only consider Full Truck Load (FTL) transportation.

The used truck will be a road train, and it will travel at a speed of 100km/h. The determination of speed is important to calculate the travel time of each arc.

On a different token, transport fees are calculated using two different elements. First, the fee contains a fixed cost and variable costs. The variable cost is a function of the number of kilometers traveled ($/km.trailer). This is a simplification of reality in which costs in North America are calculated according to complex tables, and a function of the origin and destination states. In this version of the simulation model, the notion of priority is only associated to the delivery date. In other words, trailers at a hub waiting for a truck to be transported to their next hub are prioritized solely according to their delivery date. Other scheduling rules will be tested in a future version of this model. Similarly, different classes of priority (e.g., 24h delivery, 48h delivery) will also be implemented.

2.1 Resource Sharing Transportation Model

We decide present a resource sharing transportation model because the literature suggest that among the different coordination mechanisms in the supply chain, sharing is a dimension increasingly sought to maximize the benefits and minimize the risks that arise from inter-firm relationships (Varamaki and Vesalainen 2003, Xu and Beamon 2006). So Lambert and Cooper (2000) affirms that in a competitive business, like the trailer transportation, its success depends on their ability to manage and share resources such as information and assets, costs and risk within their networks of players.

Organizations enter into close relationships such as collaboration to not only share risks and rewards, but also to share coordination costs and also resources (Gulati and Singh 1998, Dyer and Chu 2003, Ferrer 2010). Ferrer (2010) introduces the rationale for establishing relationships involves an understanding of finding ways to make the relationship efficient, the extent to which coordinating the costs offsets the benefits of the relationship.

2.1.1 General hypothesis of the model

This section presents the general hypothesis used to develop the proposed resource sharing transportation model, and ultimately, the simulation model. One of the hypothesis is that each arc has a distance of no more than 3 hours of transportation in order to allow drivers to make a round-trip in 8 hours (traditionally a day of work), and the truckers have 8-hour shifts distributed randomly within the day, according to the normal distribution. Most truckers have day shifts, although the transportation network operates 24 hours. As we have already said, the hubs' locations are based on the Québec, Ontario and New England major cities. Others hypotheses are that the trucks can haul 1 or 2 trailers, like a consolidation, (**Erreur ! Source du renvoi introuvable.**).

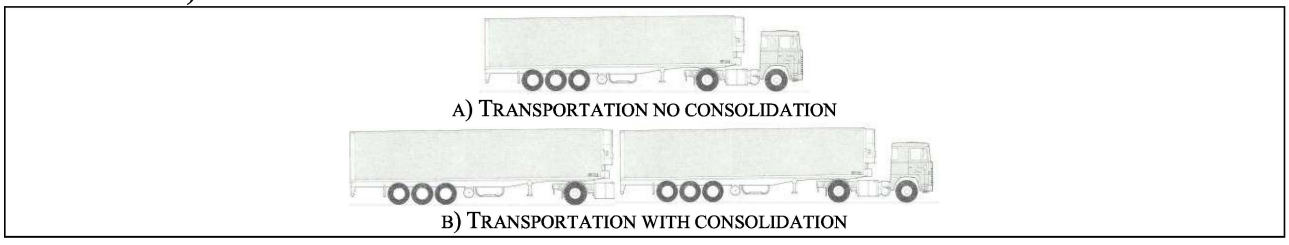


Figure 1: Modes of transportation

The general functions and operations are described in the next sub-section.

2.1.2 General resource sharing transportation network model

Based on the previous hypothesises, in this model, companies need to send a full trailer (i.e., trailer) to their customers. In order to do so, they express their need to the nearest hub (referred to as the origin hub), which is responsible to find a truck willing to transport their trailer. Transportation needs contain a specific number of trailers (i.e., 1 or 2 trailers) to transport to a destination (referred to as the destination hub), and a delivery date.

In this proposed model, routes are planned both in a centralized and decentralized manner. In other word, when a trailer arrives at a hub, this hub calculates the fastest routes towards the final hubs. To do so, it considers all possible routes through the entire network. However, only the road segment to the next hub is actually planned and implemented. When the trailer arrives at the next hub, the route is similarly planned again, and so on and so forth until the trailer reaches the final destination hub. In order to calculate the fastest routes towards the destination, hubs use the Dijkstra algorithm (i.e., shortest path) based on the total transportation time, which includes the travel time and the processing time for handling trailers in the hubs along the routes. The processing time for handling trailers is dynamically estimated by each hub taking into account the handling capacity of the hub and the number of trailer to process. This estimated waiting time is regularly updated and communicated to all hubs in order to let them know dynamically the processing time trailers have to wait. In other words, instead of calculating the shortest route to destination, routes are calculated based on the shortest time to achieve the final destination taking into account the actual congestion in the different hubs.

Along the same token, in order to model the natural ability of a resource sharing transportation network to improve truck efficiency, instead of returning with no trailer to their origin hub, trucks have the possibility to wait for an opportunity to haul another trailer on their way back. More specifically, truckers have two levels of willingness to wait for another trailer for backhauling. At the first level, they return as soon as the initial trailer is delivered, and general, they return hauling no trailer (referred to as empty return). At the second level, trucks wait for another trailer to haul up to 1 hour, thereby increase the probability of returning to their origin hauling a trailer.

When a trailer arrives at its destination, if there is enough time left in the work shift of the trucker, the truck can be assigned to another trip to transport another trailer to the origin hub of the truck. In other words, when a trailer is delivered, its management is not tackled in this model. This aspect of the model will eventually take into account a more detailed description of the last miles delivery of trailers. This will include the option of leaving the trailers at its final destination, which will be different of the destination hub.

In the business model proposed in this simulation model, the origin hub, to which demand is expressed, is paid by the client, and it gives a portion of its revenue to the intermediate hubs used to transport the trailer. The payment to the intermediate hub is based on fixed transit costs (i.e., cost of processing the trailer). This transit cost is calculated as an average cost per trailer carried to an intermediate hub, which includes the cost of handling trailers, the cost of storing trailers, and the cost of planning (i.e., administrative cost).

In the sub item 4.1.1, we present a resource sharing-based transportation network models implemented in the NetLogo agent-based simulation platform.

2.2 Traditional Transportation model

The first difference between the two models is the creation of trucks. Indeed, first of all, the amount per hub depends only of the size of the city and of its position in the network. It will of course keep the same total of trucks across the network to enable a comparison of the results of the two models.

In the traditional model, we consider that the trips are associated with a single trailer. A trailer will be transported by the same truck from its origin to its destination. The truck doesn't stop in the intermediate hubs and may do the backhauling to not return empty.

Unlike resource sharing model, trucks do not belong to a single hub, but belong to a zone that has several hubs. These are actually hubs lying within "Zone_km". So when looking for trailers, trucks can fetch trailers in other hubs of their area. The trucks cannot do the consolidation.

Transportation planning is fully centralized. That is, the original hub plans the full trip until the load reaches the final hub.

The next Section introduces the concept of agent-based technology and presents further details of the simulation.

3 Simulation model

This section first introduces the notion of agent-based technology, which is the technology used to implement this transportation model. Next, the general architecture of the agent-base simulation is presented. Finally, a last sub-section is dedicated to parameters definition

3.1 Multi-agents Systems

According to Frayret (2012), Multi-Agent Systems (MAS) technology involves different technological paradigms and models that are used to create intelligence as an emergent feature of the complex interactions of, often simple, entities referred to as software agents. MAS technology is useful for simulating different systems related to economics, social sciences, as well as biological and engineering sciences. Conte (1997) affirms that it is particularly useful where the structure of a system of simulation can be modeled as a network. With MAS technology, it is possible to implement and simulate systems and environments in order to explore future scenarios, explore potential alternative decisions, and determine probable outcome and trends (Axelrod 1997). It is also possible to model entities with simple behavior with predefined responses to stimuli, or entities with much more complex behaviour capable of intelligently apply rules or goal-oriented actions according to non-programmed situations.

Based on Madejski (2007), MAS technology can also be used as a heuristic technique to optimize decision problems, which are naturally distributed, complex, modular and heterogeneous. For the purposes of optimization, MAS technology is used in conjunction with a "physical" or "functional" decomposition of the problem to address. In the first case, agents represent physical entities (e.g., workers, machine tools, resources, vehicles) involved in a

specific problem to be solved. This general modeling philosophy is used in the specific modeling of this transportation system.

In terms of computational time, agent-based approaches may offer some advantages due to their ability to divide problems into sub-problems. However, the computational advantages may be offset by the need of frequent interaction between agents, in order to coordinate their activities in accordance with a given coordination paradigm; or optimization approaches have generally higher computational complexity. However, they have no cost of communication, as they are characterized by high centralization (Barbati, Bruno et al. 2012). In brief, MAS technology is relevant when the problem size is large, the domain is modular in nature, and changes in that domain structure are common. Consequently, MAS technology is appropriate for modeling supply chain management problems, which are naturally distributed and complex (Ahn and Lee 2004).

3.2 Systems general architecture

In the proposed agent-based model, these transport network, trucks and hubs are modeled as agent, while routes, routes segments and trailers are simple objects with no behaviour. They communicate with each other through shared global data and variables. Such simple communication architectures have three main advantages (Shen, Norrie et al. 2007): (1) they enable the use of separate, independent knowledge sources (separate agent can use and process this information independently); (2) they provide a shared memory space; and (3) they enable the use of parallel asynchronous processing. Having a separate, an independent knowledge sources allow the replacement of knowledge sources or extension by a simple addition of new software agents. Similarly, a shared memory space contains all data, hypotheses, and contextual information used to solve problems. Finally, knowledge sources can be distributed over several independent processors sharing a common memory, allowing for a simple form of parallel processing, which may increase the efficiency of the overall process.

Thus, this model is based on the interaction of various components (i.e., agents and objects), each having various levels of autonomy (i.e., control over its own actions) and different perception (i.e., ability to perceive certain information) of the environment. Agents are divided into external (i.e., customers) and internal (i.e., hubs, trucks/trucker) agents. As mentioned earlier, routes, routes segments and trailers are objects, which represent the structure of the data to be used by the agents. Unlike agents, objects do not make decisions. They are created dynamically as needed.

The general control architecture of this agent-based simulation is a dynamic quasi-heterarchy. In other words, hub-agents dynamically propose road segments to sub-set of truck-agents (i.e., trucks that are dynamically available at the hub), who can accept or refuse the job. Because trucks move from one hub to the other, they are under the dynamic quasi-supervision of many hubs according to the jobs they accept to do. Furthermore, as mentioned earlier, hubs exchange information about their dynamic processing time in order to guaranty a certain level of coordination and load balance throughout the network of hubs. In this architecture, each type of agents has a specific function/role, and limited information, as specified by their individual functions and behaviours described previously.

3.3 Parameters definition

In order to analyze the feasibility and the performance of the proposed transportation models (resource sharing and traditional), two virtual models were implemented and simulated using an agent-based simulation tool. More specifically, we designed a virtual network based on general shipping data between the Canadian provinces of Quebec and Ontario, and the U.S. states of Rhode Island, Massachusetts, New Hampshire, Pennsylvania, Vermont, Maine, and New York. According to RITA (2012), these states and provinces accounted for 16.13% of the value of the trade between the two countries in 2010. Similarly, Canada (2012) presents that the Canadians highways transported 82.7 million tonnes in exports and imports in 2009, which represent 82% of the 2010 road's trade between the two countries. Therefore, we estimated that 82% x 82.700.000 x 16.13% = 10.94 million tonnes of goods are moved by truck in this region. Considering that a trailer has a capacity of 40 tonnes, this region moved almost 28 million trailers. Therefore, based on the hypothesis presented earlier, which states that demand for trailer transportation is based on population, we extrapolate the average demand for each city/hub, by splitting the 28 million trailers proportionally. Therefore, larger cities generate higher demand for transportation.

After demand was estimated for each hub, we similarly estimated the fleet size and the hubs' capacity to process trailers. In order to follow the same logic, the number of trucks at a hub is directly proportional to the population size. As the trips in traditional transport are directs, without stops at the intermediate hubs, the hubs' capacity are only considered for the resource sharing transportation model. Concerning the hubs' capacity to process trailer, the problem is rather different, and as important as defining fleet size. Indeed, if there is not enough capacity to process trailers, performance will be artificially low. Therefore, in order to make sure that each hub possesses enough, although reasonable, process capacity, a different approach was used. More specifically, due to the characteristics of a resource sharing network, the number of trailers/trailer passing through any hub depends on both the size of global demand and the centrality of its position in the network. In order to take this into account, we estimated the centrality of each hub using the number of road leading to them. Therefore, both capacities were chosen in order to represent a realistic transportation network with a capacity that is in a state of equilibrium with demand. The capacity is fixed during each simulation runs. The next section presents the various scenarios that were simulated, and discuss the general results obtained.

4 Experiments

In this section, the general design of experiment for resource sharing and traditional transportation are introduced. Next, the key performance indicators used to analyse the performance of the transportation network are presented. Finally, results follow and a discussion of these results concludes.

4.1 Design of Experiment

In order to study the performance of various configurations of such a transportation network, we selected two configuration parameters that are the same between the models: demand level and fleet size. The first parameter is fixed at 10% of the total demand and the second is fixed at 100% of the total fleet.

4.1.1 Resource Sharing Transportation Model

The following parameters belong exclusively to the resource sharing model. The first parameter concerns the notion of consolidation. As mentioned previously, if a truck can consolidate, it can haul two trailers per trip. Otherwise, it can only haul one trailer. Based on Meller (2012), the first level of consolidation is 49%; the second level is 57%, and the third level is 65%. In all three cases the percentage of the fleet (randomly generated) can haul two trailers.

The second parameter studies the impact of the trucker's willingness to wait before he comes back hauling a trailer at a hub. We established two levels of willingness to wait: no willingness to wait and willingness to wait between 0 and 1 hour.

4.1.2 Traditional Transportation Model

The traditional model's exclusive parameter is linked to the backhauling; the Zone_Km. It means that each trucker can search for a trailer before returning to his original area. The first zone is 100km, the second 150km, and the last one 200km (Fig. 2).

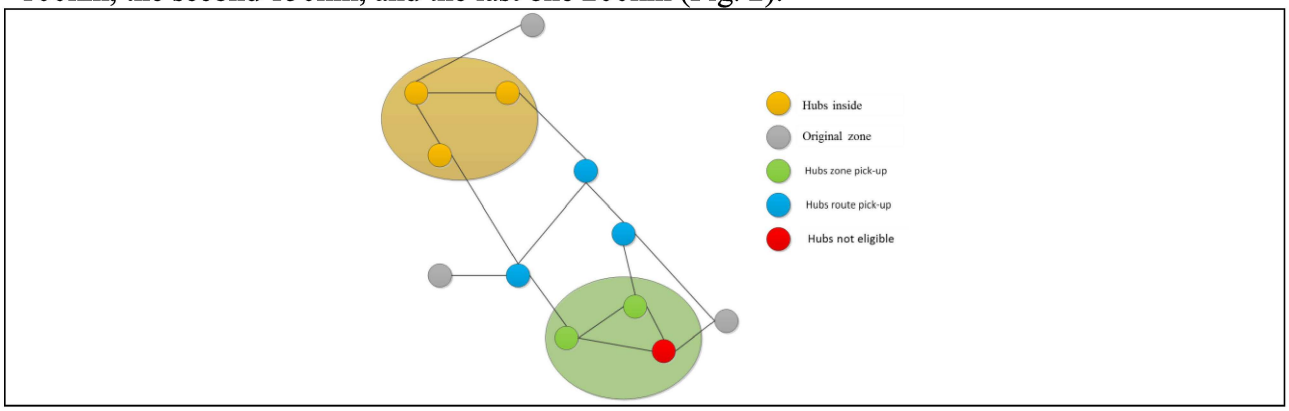


Figure 2: Zone_KM Diagram

The factorial plan of these preliminary experiments leads to 18 scenarios for resource sharing and 3 scenarios for the traditional model, as shown in Tables 1 and 2. Each of these scenarios was simulated 100 times for a total of 2100 simulation runs.

Table 1: Resource Sharing Scenarios

Consolidation	Fleet size	10%		50%		100%	
	Willingness to wait / Demand	[0]	[0,1]	[0]	[0,1]	[0]	[0,1]
49%	1%	1	2	X	X	X	X
	5%	X	X	3	4	X	X
	10%	X	X	X	X	5	6
57%	1%	7	8	X	X	X	X
	5%	X	X	9	10	X	X
	10%	X	X	X	X	11	12
65%	1%	13	14	X	X	X	X
	5%	X	X	15	16	X	X
	10%	X	X	X	X	17	18

Table 2: Traditional Transport Scenarios

Fleet size	100%		
Zone_Km Demand	100km	150km	200km
10%	1	2	3

4.2 Key performance indicators

This section describes the different measures and performance indicators used to analyze the scenarios. These variables were directly programmed in the NetLogo platform and accumulated during the entire simulation horizon. These measures include logistic performance indicators, cost indicators, social indicators, as well as environmental indicator. Logistic performance indicators include:

- Number of trailer in transit (i.e., both trailers in standby in a hub and trailer traveling between hubs);
- Number of empty and loaded trucks (whether or not trailers are consolidated with another trailer);
- Total distance traveled empty and loaded (km);
- On-time delivery (Fillrate) and maximum, minimum, and average delay.

Social performance indicator is mainly represented by the percentage of time spent at home per trucker and compared with real data to known best conditions.

Along the same token, several authors (Pels and Rietveld (2000); Novaes (2007); Bowersox, Closs et al. (2008)) consider that cost comparison constitutes a way to understand and determine transport efficiency. However, according to Alvarenga and Novaes (2000), it is also necessary to compare service times, damaged good rate, as well as delivery errors. Still, Ballot and Fontane (2008) affirms that it should considered the cost of downtime caused by a rupture of stock. Taking this into account, this paper presents four other performance indicators. First, the total cost is calculated as the sum of the fixed transportation cost, the variable transportation cost and the processing cost in hubs. The fixed cost is allocated to each transport demands, covering the costs of trucks (i.e., fleet maintenance, depreciation, insurance) and administrative costs. The variable cost is calculated as a rate $/km traveled per trailer, including fuel costs per km and the remuneration of truckers. Next, the transit cost is calculated as an average cost per trailer, including the cost of maintenance and storage of trailer and administrative costs.

Finally, the environmental performance indicator is represented by the amount of GHG emissions and compared to known conditions. This KPI was calculated according to statistics corresponding that an average road train emission is 2.7 Kg GHG per liter (Canada 2012).

4.3 Results and discussion

First of all, we are comparing and analyzing the resource sharing transportation with the traditional transportation. After, we analyze other resource sharing simulation scenarios.

Each scenario was simulated 100 times, and we used the average results. We simulated an eight days experience, including one day as warm-up. So, we have one week experience for each

scenario. To validate the results, we did the variable analyze test, and all the results were accepted.

4.3.1 Traditional vs Resource Sharing Transportation Model

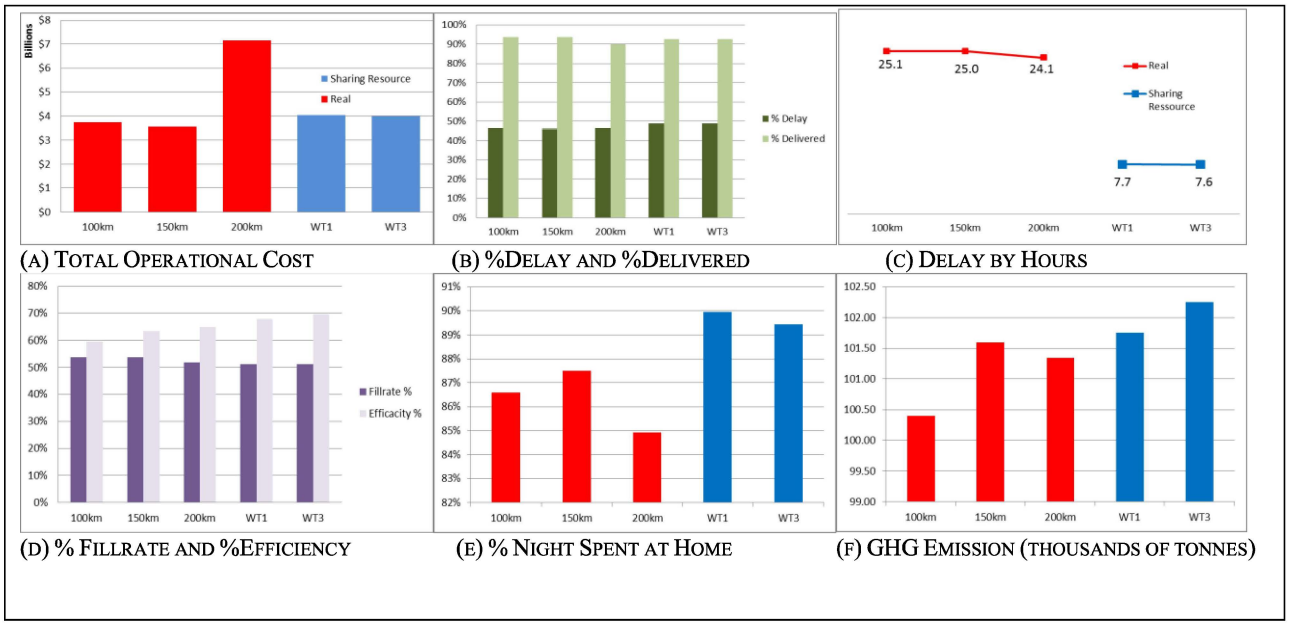
The first step to compare the results was to validate the traditional model. So, based on Meller (2012), 75% of the fleet (randomly generated) that can do the backhauling, we compare the percentages of empty trips by distance and by paths (Table 3), and it's logical to accept the traditional model, because comparing the KPI results with the literature, we see that all the results are around 25%.

Table 3: Processing capacity and fleet size of each Hub

KPI/Scenario	10-100-100	10-100-100	10-100-100
% Empty Trip by Distance	27.91%	22.02%	26.97%
% Empty Trip by Paths	28.15%	23.71%	24.66%

The name of the scenarios is composed by the percentage of demand (10), the percentage of the fleet (100) and the value of Zone_Km (100, 150, or 200).

After validate the traditional model, we compare those three scenarios with the resource sharing scenarios: 10% of demand, 100% of fleet, and the percentage consolidation level by literature 57% (Meller 2012), and we change the willing time (1 or 3). So, the resource sharing scenarios are: 10-100-57-1 and 10-100-57-3.



(A) TOTAL OPERATIONAL COST (B) %DELAY AND %DELIVERED (C) DELAY BY HOURS

(D) % FILLRATE AND %EFFICIENCY (E) % NIGHT SPENT AT HOME (F) GHG EMISSION (THOUSANDS OF TONNES)

Figure 3: Traditional and Resource Sharing Results

Figure 3 shows the positive impact of the resource sharing model. The first graph is financial KPI, the total cost (a), and because of the increase of the km searching a trailer for the backhauling, the average of the traditional model is higher by 20% of the resource sharing model. The next one is the Delay and Delivered percentage (b); the results are almost the same, but by analyzing this one with the third graph, the delay by hours (c), we see that the traditional models have more late delivery (25 hours) than the resource sharing models (7 hours). The fourth

graph shows the fillrate and efficiency, and despite the little decrease of the results of the resource sharing for the fillrate, the resource sharing scenarios have better result concerning the efficiency, in average 8%. The next one is the social KPI, the percentage of nights spent at home per trucker, and based on the characteristics of the distributive transportation; the trucker makes shorts trips, so the resource sharing is more social friendly than the traditional transport. The last one is the environmental KPI, the resource sharing scenarios generate more GHG than the traditional transportation because the GHG emission calculation is based on the gas consumption and the consolidation consumes more gas than the no consolidation transportation.

However, the worst environmental results, the resource sharing scenarios have better results than the traditional transportation. Founded on this conclusion, in the next sub-section we show the analysis of the resource sharing scenarios based on the parameters already presented.

4.3.1.1 Resource Sharing Transportation Model

To compare each scenario with each other, we selectively computed and compared the average value of specific scenario in order to illustrate the impact of specific configuration parameters. First graph is the financial KPI (the total cost); second, the operational (the percentage of delay and delivered, the percentage of fillrate and efficiency), the next one is the social KPI (the percentage of night spent at home), and the last one is the environmental KPI (the GHG emission). They are respectively analyzed with respect to consolidation level and fleet size (see Figure 4Figure 3).

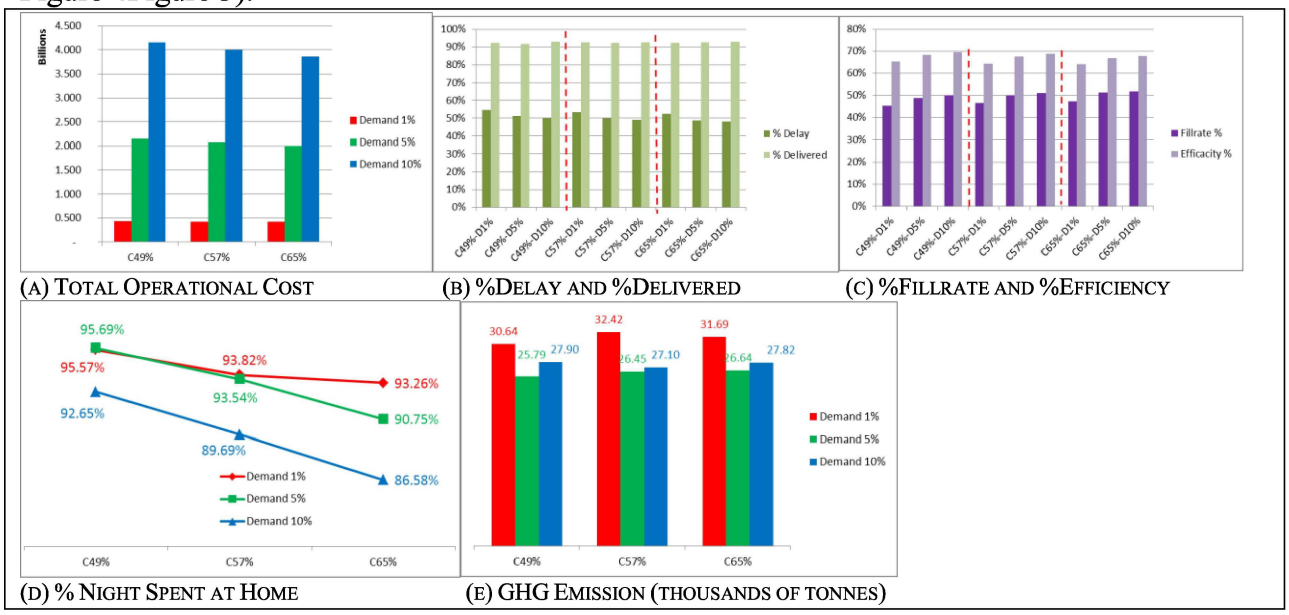
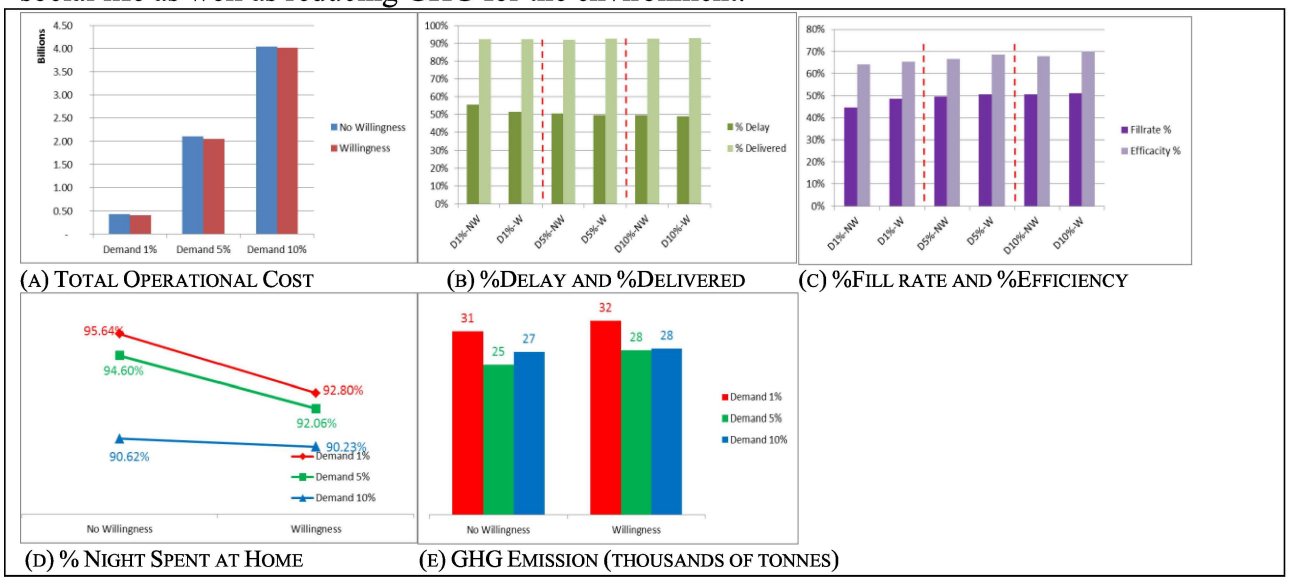


Figure 4: Resource Sharing Results analyzed with respect to consolidation level and demand

Figure 4Figure 3 shows the positive impact of consolidation (i.e., the ability to use a truck to haul simultaneously two trailers) on total cost, fill rate, efficiency, delay, delivered, the portion of night spent at home, and GHG emission. All these performance indicators, except the efficiency and GHG emission, seem to have a rather linear impact. However, concerning the efficiency and GHG emission, the demand has a mayor impact than the consolidation because of the increase volume of transport demanded. Concerning the portion of night spent at home, the consolidation

has a huge impact because the system doesn't need to use so many trucks to transport only one trailer. Therefore, these results prove that consolidation, as advocated by the resource sharing philosophy, is an ideal means of improving efficiency, lowering cost, improving the truckers' social life as well as reducing GHG for the environment.



(A) TOTAL OPERATIONAL COST (B) %DELAY AND %DELIVERED (C) %FILL RATE AND %EFFICIENCY

(D) % NIGHT SPENT AT HOME (E) GHG EMISSION (THOUSANDS OF TONNES)

Figure 5: Resource Sharing Results analyzed with respect to consolidation level and willingness to wait

Figure 5**Erreur ! Source du renvoi introuvable.** presents a similar analysis with respect to, again, consolidation level and willingness to wait. Granted that higher level of willingness to wait improve the probability of being able to have the opportunity for a truck to go back to its origin hauling a trailer, but as the willing to wait (1 hour) is small, the willing to wait are better results, but they are almost equal for the no willingness to wait results. The deltas of the results of each KPI are less of 3 %; so the difference may not be statistically significant. Therefore, a more in-depth analysis needs to be done to investigate this aspect. Indeed, both strategies affect positively performance, as willingness to wait directly improves back hauling opportunities (i.e., less empty returns), and consolidation improves transportation efficiency (more trailers transported per truck).

4.4 Future development

Several aspects of these simulations models will be improved. First, the simulations were designed in a way that trailers disappear from the simulation when they are delivered in the destination hub. Therefore, the first aspect to be changed is to improve trailers delivery as well as the management of trailers after delivery in order to return them to the origin hub.

Trailer management is important because once delivered at destination, trailers have an existence that affects the use of the transportation capacity. They also play a role during the last mile delivery and the temporary storage of goods at their destination. Along the same line, trailers are owned, rent and maintained. They are an integral part of the transportation service for which the owners receive contributions. Therefore, as mentioned earlier, the modeling of the last mile delivery must be improved. It is also very relevant to study as it mostly concerns urban freight transportation, which is a complex problem for medium and large cities all around the world.

Along the same line, we improve the traditional transportation model to allow the fleet to do the consolidation from the original hub to the destination hub. At least, it allows to compare the consolidation results and to watch the impact of the consolidation to the traditional transportation results.

As the results of the willingness to wait were very similar, we are increasing the waiting time to two hours, instead of the actual one hour. We believe that a mayor gap will produce disparity numbers for the KPIs.

Another interesting analysis concerns the assessment of the agility of such a transportation network to handle disturbances, such as the temporary out of business of a hub. For instance, the simulation of the removal of a hub in various conditions would allow the designer to better understand the design parameters that affect the most significantly the agility of the network to quickly recover from various types of disruptions.

Along the same line, other business models will be studied with similar means of simulation. In the model presented in this paper, hubs are independent business tied together by a business model. The next business model studied will be the one of an integrated transportation company that possesses a private PI network. This model assumes that, instead of hub being independent and partners within some sort of coop, they are now members of a single integrated company sharing the same network. Here, the responsibilities of the company include explicitly the management of containers/trailers, including their maintenance and their replacement. Another responsibility of the company is to prevent an unbalanced distribution of trailers on its network. Therefore, the management of empty trailer will have to take into account the transport of empty trailer to hubs with high demands. The most typical example of unbalanced container traffic in a macro scale proportion is the one happening between the U.S.A. and China.

Another business model worth studying include a company that rents trailers to be used throughout a large PI network made of several integrated companies and independent hubs simultaneously (a network of networks). The responsibility of such a company is to only manage the trailers and lease them to the hubs and integrated companies. In this model, the remuneration of such a company will have to be calculated accordingly.

5 Conclusion

The Physical Internet (PI) is a ground-breaking transportation philosophy. It provides a very innovative way to redesign and operate the transportation industry all around the world. Its principles are based on the assumption that current logistics networks are unsustainable.

The study presented in this paper provides an analysis of various performance indicators of a simple implementation of the PI philosophy. To do so, this article presents a freight transportation model based on the resource sharing methodology. As suggested by the PI general principles, this model is based on the distribution of road transportation services. Based on this idea, instead of hauling trailers from origin to destination using a single tractor, freight is hauled from hub-to-hub, using different tractors allocated to one specific hub. This model also considers the possibility to consolidate two trailers into a road train. The impact of the resource sharing and distribution transport on drivers' working conditions is significant, as they only offer their service within a limited area. This model also offers the ability to adjust transportation flows according

to hubs' waiting time to process trailers. This model was implemented into a simulation platform using NetLogo, and tested in various conditions of demand and design configurations.

The results indicate that resource sharing transportation improves the financial, operational, social and environmental performance of a transport operation, more than the traditional model, so it's important to the following developments of physical internet methodology.

The resource sharing results show that both consolidation (i.e., the ability to use a truck to haul simultaneously two trailers) and willingness to wait to improve the probability of an opportunity of backhauling have a positive impact on total cost, fillrate, efficiency, delivery, delay, the portion of nights spent at home, as well as GHG emission. However, willingness to wait seems to have a more significant positive impact than consolidation.

Finally, this paper also presents some research direction to both improve the model and design new business models related to further implementation of the PI philosophy.

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Shopfloor Logistics Management using RFID-enabled Big Data under Physical Internet

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Abstract: *Physical Internet has been widely used for upgrading the logistics and supply chain management integrating the Internet of Things technologies. This paper is motivated from a real-life company that uses the RFID for facilitating its shopfloor logistics management under Physical Internet. A ubiquitous shopfloor logistics environment is created by RFID devices and wireless communication standards which are able to generate immense data. The RFID-enabled shopfloor logistics Big Data carry invaluable information and knowledge that could be used for supporting advanced decisions like logistics planning and scheduling. A framework is proposed to excavate the knowledge and some practical KPIs are defined for examining various manufacturing objects like workers, WIP inventory, etc. Experiments are carried out for evaluating the mined knowledge. It is observed that task weight is primarily considered in the logistics decision-making. Key findings and observations are summarized as the managerial implications that could be used for guiding end-users when making logistics decisions.*

Keywords: *Physical Internet; RFID; Big Data; Logistics Management; Shopfloor.*

1 Introduction

Physical Internet, in logistics, is a global system based on physical, digital, and operational interconnectivity by the using of encapsulation, interface, and protocols (B. Montreuil, 2012). The Initiative's manifesto of Physical Internet is "Transforming the way physical objects are handled, moved, stored, realized, supplied, and used by applying concepts from Internet data transfer to real-world shipping processes, aiming to towards global logistics efficiency and sustainability." (Ballot, Montreuil, & Thivierge, 2012; Benoit Montreuil, 2011). Current year, great attentions have been paid upon the Physical Internet due to the innovative and advanced concept of encapsulating goods in smart, sharing data in the Digital Internet, and shipping adaptively and efficiently. In the United States, National Science Foundation (NSF) funded a research project conducted by Center for Excellence in Logistics and Distribution (CELDi), aiming to establish a logistics system gain efficiency of the Physical Internet (Meller & Ellis, 2012). At the European level, the Modulushca project was to achieve the first genuine contribution to the development of interconnected logistics in close coordination with North American and international Physical Internet Initiative (Hakimi, Montreuil, Sarraj, Pan, & Ballot, 2012; Benoit Montreuil, Meller, & Ballot, 2013). In Asian Pacific area, an initiative project

called AUTOM leading by the University of Hong Kong was carried out to ease the cross boundary logistics between Hong Kong and Guangdong province in 2008 (Huang, Zhang, Chen, & Newman, 2008).

This paper is motivated by a real-life case from out collaborative industrial partner who has been used radio frequency identification (RFID) technology for supporting its shopfloor logistics management over 10 years. The company is Huaiji Dengyu Auto-Parts (Holding) Co., Ltd, which is specializing in producing engine valves with over 30 years history. There are around 1,000 RFID readers and 10,000 tags deployed on the manufacturing shopfloors. Thus, all the RFID identified resources are converted into smart manufacturing objects (SMOs) which are able to sense, interact, and execute in Physical Internet. Through adopting RFID technology in its shopfloor management, logistics within the entire manufacturing factories has been updated to a level that is accurate, real-time, and controllable (Dai et al., 2012).

Within the Physical Internet-based shopfloor management, huge amount of RFID-enabled logistics data have been captured and collected. Such data are created automatically and immensely along with the production carrying on. Invaluable information or knowledge carried by these data is of great wealth for the company to support senior or advanced decision-makings such as internal logistics optimization, advanced production planning and scheduling, etc. However, the characteristics of RFID-enabled logistics data bring several challenges to mining the implicit knowledge. In the first place, the volume of such data is so huge that RFID technology is able to generate thousands pieces of data within a second. It is challengeable to transmit, storage, and query the datasets using traditional database tools. Secondly, each piece of RFID data is so abstract that it may be consisted of several attributes like EPC, job ID, user ID, and machine ID. These attributes should be further interpreted, thus, the pieces of data could be readable. Thirdly, the RFID data are so complex that because there are large numbers of RFID events, each of which may involve in a worker, a machine, a job, a location, a time, a production logic, and a material. Thus, spatial-temporal with n-dimensional perspectives of RFID logistics data add the difficulties in discovery the knowledge.

Big Data, referring to a collection of datasets so large and complex that it is difficult to handle by using on-hand database management tools or traditional processing approaches, may be used for address the above challenges. Big Data usually contains datasets beyond the capacity of commonly used in software/tool to capture, curate, manage, and process the data under a tolerable elapsed time (Snijders, Matzat, & Reips, 2012). As the data floods faced by our digital daily life, Big Data has been widely studied from both academia and practitioners (Abbott, 2013; Bughin, Chui, & Manyika, 2010; Davis & Ratcliffe, 2012; Lynch, 2008; Manyika et al., 2011). Unfortunately, research on Physical Internet-based big data is scarcely reported that partially because both these fields are at its infancy.

This paper aims to fulfill the gaps by taking the application of RFID-enabled Big Data under Physical Internet for shopfloor logistics management as an example. Several research questions are concentrated upon:

- How can we establish a framework to process the RFID-enabled Big Data under Physical Internet so as to finally excavate significant knowledge to support shopfloor logistics management?

- What KPIs could be defined in the Physical Internet-based manufacturing shopfloor so as to examine the performance of various SMOs like logistics operators, machines and their workers?
- Based on the KPIs, what mechanisms or rules could be used to optimize the shopfloor logistics from the massive RFID-enabled Big Data under Physical Internet?

In order to answer these questions, this paper proposes a Big Data approach framework to address the RFID datasets by using suitable models or algorithms to cleansing, compressing, classifying, and interpreting the RFID-enabled shopfloor logistics data, defines some KPIs according to the practical concerns, as well as compares different rules used in the case company to work out the decent strategies given different situations or objective functions.

This paper is organized as follows. In section 2, an RFID-enabled shopfloor logistics management system based on Physical Internet is introduced. Section 3 illustrates the RFID Big Data in shopfloor logistics management in terms of data structure and data transmission. Section 4 discusses the experiments and managerial implications. Section 5 concludes this paper by giving our findings and future work.

2 RFID-enabled Shopfloor Logistics Management System Using Physical Internet

This section reports on the RFID-enabled shopfloor logistics management system (SLMS) based on the Physical Internet concept. First of all, an RFID-enabled ubiquitous logistics environment on manufacturing shopfloor is introduced in terms of the deployment of Auto-ID devices and wired or wireless facilities. After the deployment, traditional shopfloor logistics could be converted into Physical Internet-based logistics supervision and visualization, improving the visibility and traceability. Secondly, an RFID-enabled SLMS is demonstrated to cooperate with the hardware devices for enabling the logistics related decision-makings.

2.1 RFID-enabled ubiquitous logistics environment on manufacturing shopfloors

This section demonstrates the RFID-enabled ubiquitous logistics environment on manufacturing shopfloors. Figure 1 shows the RFID-enabled ubiquitous logistics environment, which is based on a typical hybrid flowshop production mode. There are n production stages, each of which is equipped with m_n identical machines. Machines are able to work parallel so that the production could be continuous. The materials are organized in the form of batches that each batch contains 180 pieces in a basket. A basket (as a task or a job) passes from stage *1* to stage n strictly. The warehouse is responsible for distributing the required raw-materials to the first stage and receiving the finished products. The RFID-enabled ubiquitous logistics environment could be established through three steps: deployment of RFID facilities on shopfloor, creation of a ubiquitous logistics environment, and Physical Internet-based logistics operations.

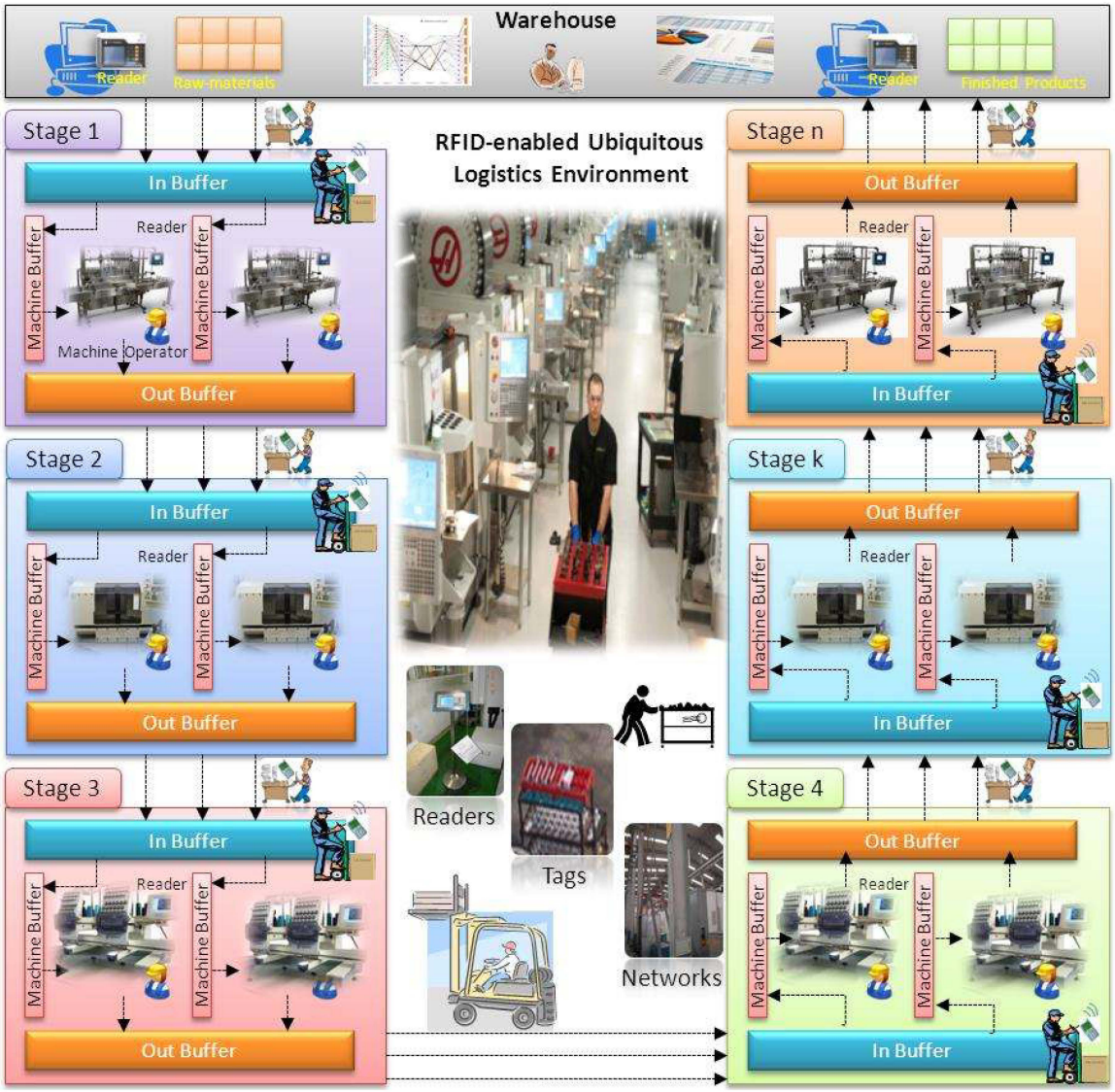


Figure 1: RFID-enabled Ubiquitous Logistics Environment

2.1.1 Deployment of RFID Facilities on Shopfloor

The deployment of RFID facilities on shopfloor is carried out given the logistics flow among different production stages. Firstly, in warehouse, two RFID readers are deployed. One is in raw-material preparing area. It is responsible for binding the RFID tag on each batch. The other one is deployed in finished products receiving area. It is responsible for killing and recycling the tags. Secondly, on production shopfloors, two types of RFID reader are used. Each machine is equipped with a stationary reader, which is able to facilitate the materials' hand over and processing. Mobile readers are distributed to external and internal logistics operators, who are responsible for moving the batched materials among different stages and for moving materials from in buffer to machine buffer, then from machine buffer to out buffer within a stage respectively. Thirdly, tags are deployed to batched materials and workers. For batched materials, each basket (batch) is attached a RFID tag. For various workers, they are carrying a RFID-enabled staff card. Once the RFID facilities are deployed on the production shopfloor, they are

turned into smart logistics objects (SLOs), which are able to sense, act, and behave according to the predefined logistics logics (Zhong et al., 2013).

2.1.2 Creation of a Ubiquitous Logistics Environment

Once the SLOs are created, the next step is to build up a wireless communication standard for enabling the SLOs to connect, cooperate, and carry out the logistics operations in a ubiquitous environment. The wireless approaches like WiFi, 433Hz Wireless manner, Zigbee, and BlueTooth could be used given different considerations such as investment of hardware devices, etc. Take the 433Hz wireless manner for an example, the base station is deployed on the shopfloor walls or the pillars given the signal coverage. Each base station will connect two antennas so that the major logistics areas could be covered without any gaps. With the cooperation of SLOs and wireless standards, the ubiquitous logistics environment will generate immense data along with the logistics operations.

2.1.3 Physical Internet-based Logistics Operations

Within the RFID-enabled ubiquitous logistics environment, the Physical Internet concept is adopted to facilitate the logistics operations. The Physical Internet-based logistics operations are detailed as follows:

(1) A warehouse manager makes the material requirement plan (MRP) in a SAP, which decides how many batches should be prepared for the daily jobs.

(2) A warehouse worker uses the reader deployed in raw-material preparing area to bind the RFID tags to various batches, which are converted into SLOs.

(3) An external logistics operator uses a mobile RFID to detect the batches that should be delivered and moves them to the in buffer at first production stage.

(4) In the first production stage, an internal logistics operator carries a mobile reader to sense the required materials from specific machines and move them from in buffer to machine buffer. The material hand over operation will be carried out on the stationary reader deployed at each machine.

(5) An internal logistics operator uses the mobile reader to detect the completed materials at a machine in stage *1* and then moves them to the out buffer.

(6) An external logistics operator utilizes a mobile readers to find the materials and then delivery them to the in buffer at next processing stage.

(7) In the next processing stage, the above steps (3)~(6) will be repeated until the end of the processing stage.

(8) At the stage n, an external logistics operator uses a mobile reader to detect the finished products and moves them to the warehouse, where a stationary reader is utilized for killing and recycling the tags.

From the above operations, all the logistics operations are facilitated by the RFID devices and rationalized by the Physical Internet concept. The data generated from the Physical Internet rationalized logistics behaviors and operations are captured to form a closed-loop. These immense data could be used for shopfloor logistics management such as prediction of material delivery trajectory, evaluation of logistics performance, etc.

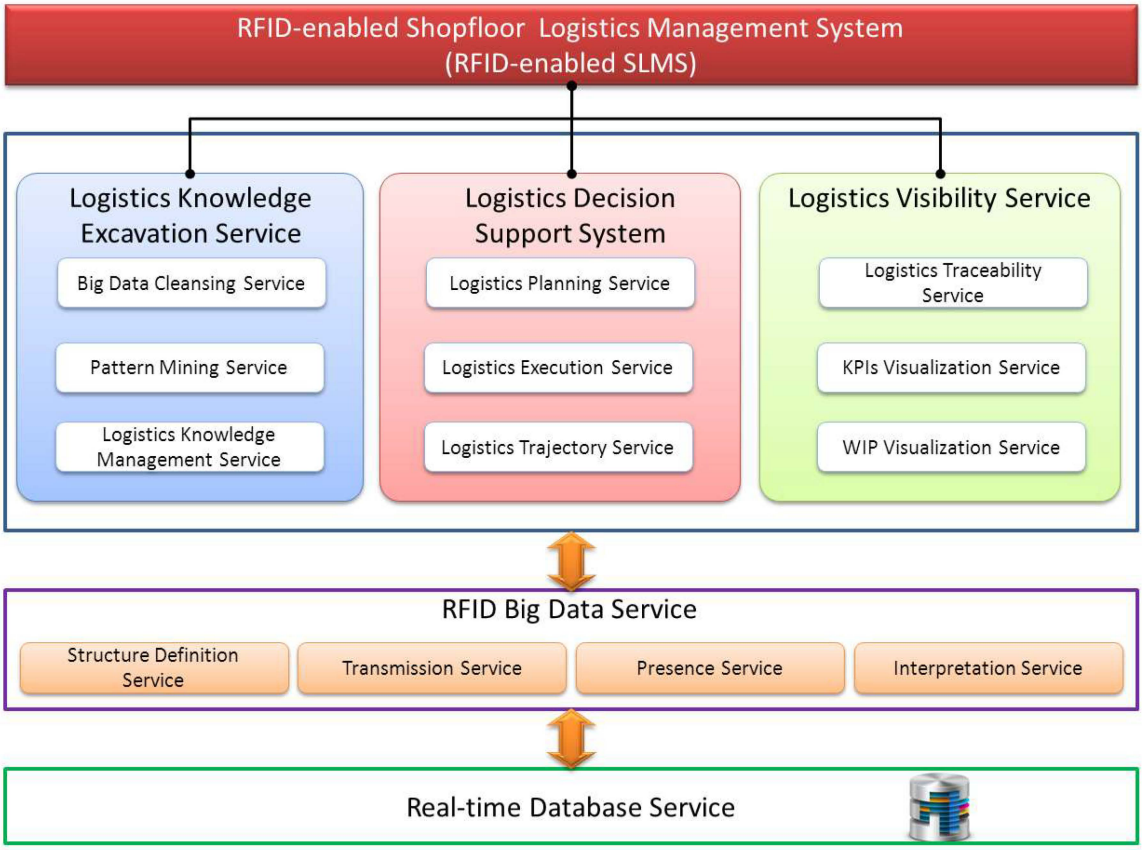


Figure 2. Overall of the RFID-enabled SLMS

2.2 RFID-enabled SLMS

Figure 2 shows the overall of the RFID-enabled SLMS. There are several key services, which are realized through web services based on the cloud architecture. In the first place, the overall architecture is designed as an infrastructure as a service (IaaS) so that this system would be deployed and established easily. Secondly, RFID-enabled SLMS is designed as a platform as a service (PaaS), thus, end-users are able to carry out the secondary development when new functions needed. Thirdly, the modules and functions are designed and developed as software as a service (SaaS) so that the application modules or software could be installed in the cloud and the end-users are able to access the software from cloud clients.

There are several key services in RFID-enabled SLMS. From the bottom to top, they are real-time database service, RFID big data service, logistics knowledge excavation service, logistics decision support system, and logistics visibility service.

Real-time database service is responsible for managing the logistics data generated from the frontline sites. The end-user is database manager who uses this service to monitor, store, and analyze the logistics data in a real-time basis.

RFID big data service is responsible for handling the real-time generated RFID immense data. It is designed specifically for database manager so that he or she is able to define the data structure, to supervise the data transmission, to identify the data presence, and carry out the data

interpretation. This service thus has four main sub-services for facilitating the typical users to fulfill the daily operations.

Logistics knowledge excavation service is responsible for mining the invaluable information or knowledge from the huge RFID-enabled shopfloor logistics data. Its main users are senior managers or key decision-makers. This service uses suitable models and algorithms encapsulated as web services so that they could be for dealing with different situations. It has several major sub-services: big data cleansing service is designed for tidying up the data sets since there are large number of noise data in the RFID-enabled shopfloor logistics data; pattern mining service is developed for discovering invaluable information or knowledge to support shopfloor logistics decision-makings; and logistics knowledge management service is proposed to conduct the mined information and knowledge in proper presentation or format.

Logistics decision support system is responsible for carrying out various resolutions. Its key users are logistics decision makers like planners, managers, and shopfloor supervisors. It has three main sub-services. Logistics planning service is designed for making the logistics plans that determine who executes the tasks at what time from which locations. Logistics execution service is designed for supervising the tasks' execution twining with the real-time information from SLOs. Logistics trajectory service is designed for reviewing the material moving paths so that more precise manufacturing decisions like production planning and scheduling could be achieved.

Logistics visibility service is responsible for visualizing various perspectives related to the shopfloor logistics. The main users are senior managers or CEO. There are several sub-services. Logistics traceability service is designed for visualizing the materials' life cycle from very beginning of the raw-materials to the end of the finished products. KPIs visualization service is used for examining the machine utilization, performance of various logistics operators, efficiency and effectiveness of the logistics trajectory, etc. WIP visualization service is designed for real-time monitoring the WIP statuses at different stages and buffers.

3 RFID Big Data in Shopfloor Logistics Management

This section presents the RFID big data used in shopfloor logistics management. The RFID-enabled big data is processed by a suitable framework that is shown in figure 3, which includes several key procedures. Firstly, the RFID data structure should be defined since the shopfloor logistics is extremely complex, not only in large involvement of manufacturing objects, but also in dynamic logistics logics. Thus, the RFID devices identified workers, machines, and objects have decent attributes to present their behaviors and keep the data generated. Secondly, the transmission mechanism should be worked out in terms of data presentation, transfer protocol, and data interpretation. Thirdly, a RFID big data warehouse is established so that the immense data from frontline logistics sites could be centrally managed. The warehouse uses real-time processing to handle data operations to preserve data consistency and transactions efficiently. Fourthly, RFID Big Data processing steps, each of which is equipped with suitable models or algorithms, are designed for various purposes such as cleansing, classification, compression, pattern excavation as well as standardization and expression. Finally, the discovered information or knowledge could be used for supporting various applications in logistics management. Thus, end-users such as managers, logistics planners, shopfloor supervisors etc, are able to make more precise and reasonable decisions given the data or knowledge-driven applicable practices. The crucial procedures are detailed illustrated in the following sub-sections.

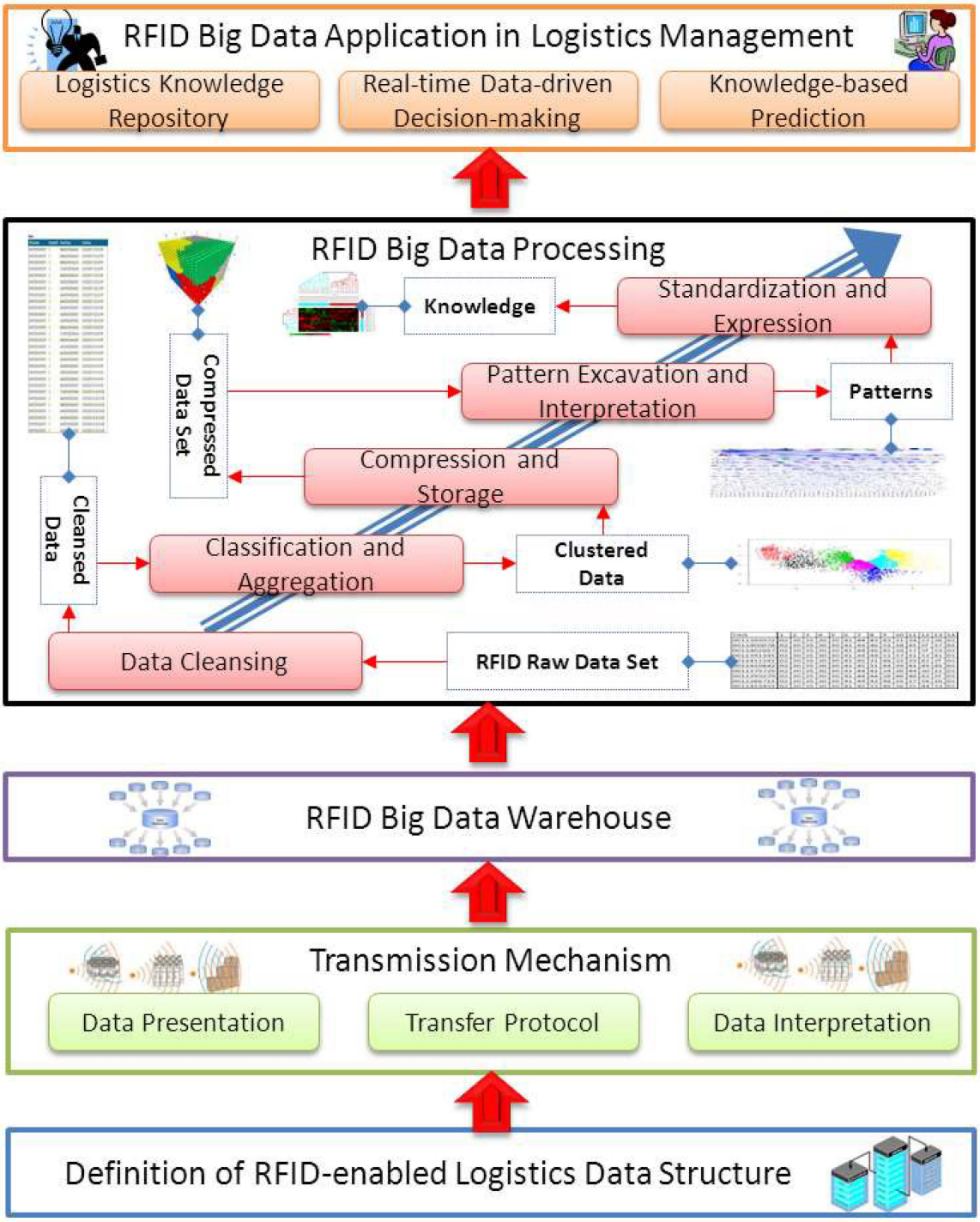


Figure 3. A Big Data Processing Framework for RFID-enabled Shopfloor Logistics Management

3.1 Data structure of RFID-enabled logistics

The data structure of RFID-enabled logistics includes five major objects, which are workers, machines, materials, tasks, and behaviors. Worker is defined as $< WorkID, Name, UserCard, WType, Level, Status, ShopfloorID >$, where $UserCard$ is a EPC

staff number that uniquely identifies a worker; $WType$ denotes the worker categories like machine operator, logistics operator, inspector, etc; $Level$ reveals the worker's skills or expertise; $Status$ presents the availability and $ShopfloorID$ indicates which processing stage he or she will work on.

Material is defined as $< MaterialID, Des, MType, Location, Quantity, TagEPC >$, where Des is a description of the materials; $MType$ illustrates the material type such as common, imperative, or special; $Location$ shows where the materials are stored; and $TagEPC$ is a unique code once the material is bound by a RFID tag.

Machine is defined as $< MachID, MachType, TeamID, Status, LineID, TermiAddr, Capacity >$, where $TeamID$ indicates which team is responsible for looking after the machine; $Status$ shows the machine current situation like working, under repairing, maintaining, or breakdown; $LineID$ describes which line the machine is belonged to; $TermiAddr$ is a unique code of the RFID reader deployed on the machine.

Task is defined as $< TaskID, MaterialID, Quantity, MakeType, StartDate, DueDate, Weight, InstrID, BatchCard >$, where $MakeType$ indicates make-to-order or make-to-stock; $Weight$ shows the task priority; $InstrID$ is an instruction that describes which manufacturing stages the task has to pass; $BatchCard$ shows the RFID tag attached to a batch, which is regarded as a task or a job.

Behavior is defined as $< BehaviorID, BType, Operator1, Operator2, Location, OccurTime, BatchCard, Des >$, where $BehaviorID$ presents the identified number of a occurred behavior; $BType$ indicates the behavior categories such as picking up, handover, receiving, etc; $Operator1$ and $Operator2$ records the involved workers; $Location$ demonstrates where this behavior happens and $OccurTime$ shows the exact time; $BatchCard$ is the RFID tag attached to the involved material in this behavior; Des is a description that keeps some important information or remarks.

3.2 Data transmission

After the definition of different key data structure, how to transmit the data within RFID-enabled ubiquitous logistics environment will be considered. This section reports on the data transmission in terms of data presentation and interpretation in a wireless network.

3.2.1 Data presentation

The data presentation includes two types of protocol. One is for transmission between readers and tags so that the data could be easily written into tags. And it could be erased when the tag is reused. The protocol is defined as *Start (1) Address (1) CID (1) Step (1) InfoLen (4) XXXX Check (4) End. Start* is defined as Char (1), which is the second character in ASCII. *End* is defined as Char (2) that is the third character in ASCII. *Address* is an EPC code which is presented as hexadecimal character. *CID* presents the functionality whose value ranges from Char (10) to Char (255). *Step* indicates the details of the functionality and the value ranges from Char (10) to Char (255). *InfoLen* uses four bit hexadecimal characters, whose range is 0000~FFFF, determining the maximum length of the data could reach 65535 characters. *XXXX* describes the contents of the data which will be transmitted. *Check* is a verification code which is calculated

by 'and' operator with *FFFF* and all the ASCII value of all characters except *Start* and *End*. A specialty should be paid attention to that the total contents could not exceed over 8000 characters. That may cause the jam between readers and tags due to the limited memory.

The other protocol is for the transmission between readers and wireless devices like base stations. The escape character in this protocol is Char (3) in ASCII. The contents include 0~9, A~Z, a~z, +, -, ',' '.' and 'enter'. Since it is not a focus in this paper, more information could be obtained from a published paper (Dai and Zhong 2009).

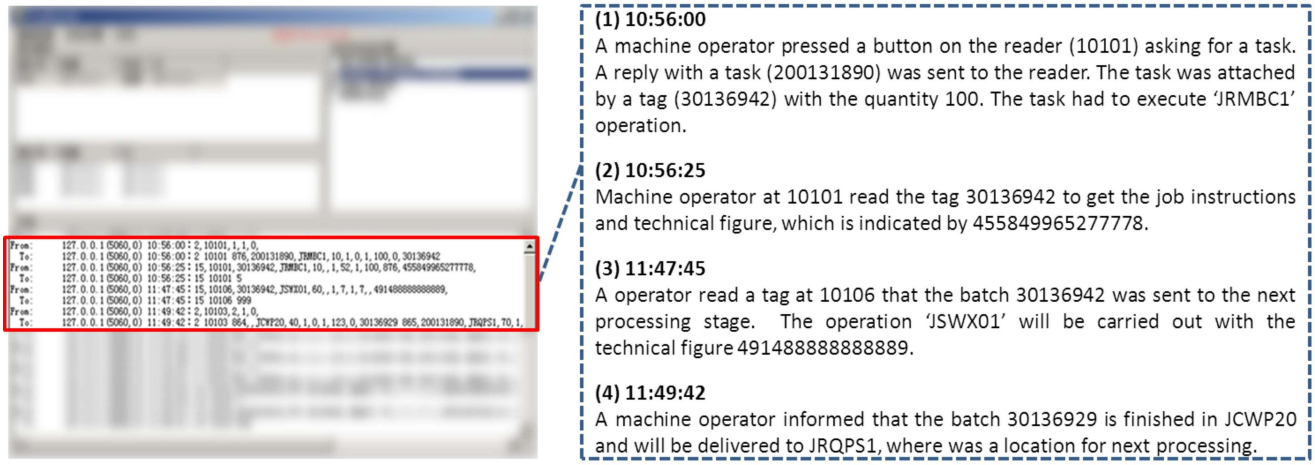


Figure 4. An Example of Data Interpretation from Real-life case

3.2.2 Data interpretation

This section illustrates the data interpretation through a real-life case. Figure 4 shows the transmission and interpretation service used in our collaborative company. Take a batch (30136942) in the time interval [10:56:00, 11:49:42] for an example, the interpretation is demonstrated in the right side. The interpretation is based by the predefined escape characters for data transmission under the Physical Internet based shopfloor logistics environment.

3.3 Logistics management using RFID-enabled Big Data

Based on the RFID Big Data from shopfloor logistics, the management is facilitated by several KPIs which are specifically designed for evaluating and examining the performance of various logistics objects as well as predicting the logistics trajectory within the RFID-enabled ubiquitous environment. Three major KPIs are used in this paper for these purposes. Given a logistics behavior $b_{ij} = (BID, BType, Op1, Op2, Location, Time, Batch, Next)$, the performance of logistics operator, average delivery time of a batch, and waiting time for movement is defined as follows.

Performance of logistics operator. Given a logistics operator Op_k, the performance is defined as the total batches he or she operated within a time interval: $\frac{\sum_{i=1}^{m}\sum_{j=1}^{n} b_{ij}\,|_{Op_1 = Op_k \in OP}}{Time_{mn} - Time_{11}}$.

Average delivery time of a batch. For a set of batch B, the completion time is $Time_{mn}$ and the start time is $Time_{ij}$, Let N denotes the total number of batches in B, the average delivery time is defined as $(Time_{mn} - Time_{ij}) / N$.

Waiting time for processing. Let $Time_{ik}$ denotes the time a batch enters into a shopfloor buffer, $Time_{is}$ denotes the time this batch is processed by a machine at stage i, the waiting time for processing is $Time_{is} - Time_{ik}$. The total waiting time is $\sum_{i=1}^{n} (Time_{is} - Time_{ik})$, which could be used for calculating the WIP inventory (the total number of batches in a buffer within a time interval).

The KPIs are obtained after processing the RFID big logistics data, which could be used for supporting advanced decision-makings like logistics planning and scheduling, logistics prediction, etc.

4 Experiments and Discussions

This section discusses the experiments which are carried out for evaluating the mined strategies used in the shopfloor logistics decision-making from the RFID-enabled Big Data. Using the Physical Internet concept, the shopfloor logistics management based on the RFID Big Data is examined. Key findings and lessons from this research are summarized as the managerial applications which could be used for guiding various end-users in practical implementations.

4.1 Experiments

This paper reports on the experiments from the following procedures. First of all, the collection of the data is from our collaborative company who has been using RFID technology for supporting its shopfloor logistics control over 10 years. There are about 1,000 RFID readers deployed in the manufacturing sites and 10,000 tags are daily operated. It is estimated that, given the data structure defined, the scale of data will reach 30.899T per day. For simplicity with generality, the experiments extract the data from 2010 to 2012 with specific 16,777,216 pieces of RFID data. The extracted data is used to figure out the logistics rules what are widely used in the company.

Secondly, the RFID big data is used for mining the rules so that which rules or strategies could be used under what situation so as to optimize the logistics control. Five rules are mined and examined. They are rules based on order, material, due data, task weight, and FIFO. Given two logistics tasks $Task1, Task2$, the rules could be expressed as follows, omitting the actual decision trees.

If $Task1.Weight > Task2.Weight$, *then execute* $Task1$;

If $Task1.Weight == Task2.Weight$ *and* $Task1.OrderID == Task2.OrderID$ *and* $Task1.Material == Task2.Material$ *and* $Task1.DueDate < Task2.DueDate$, *then execute* $Task1 \prec Task2$;

If $Task1.Weight == Task2.Weight$ *and* $Task1.OrderID == Task2.OrderID$ *and* $Task1.Material == Task2.Material$ *and* $Task1.DueDate == Task2.DueDate$ *and* $Task1.InTime < Task2.InTime$, *then execute* $Task1 \prec Task2$;

The mined rules imply that task weight is primarily considered in the logistics decision-making. If both tasks have the same weight, tasks from the same customer order with the same materials will be considered. After that, due date is used for sequencing the logistics tasks. If all the attributes of two tasks are same, FIFO will be carried out.

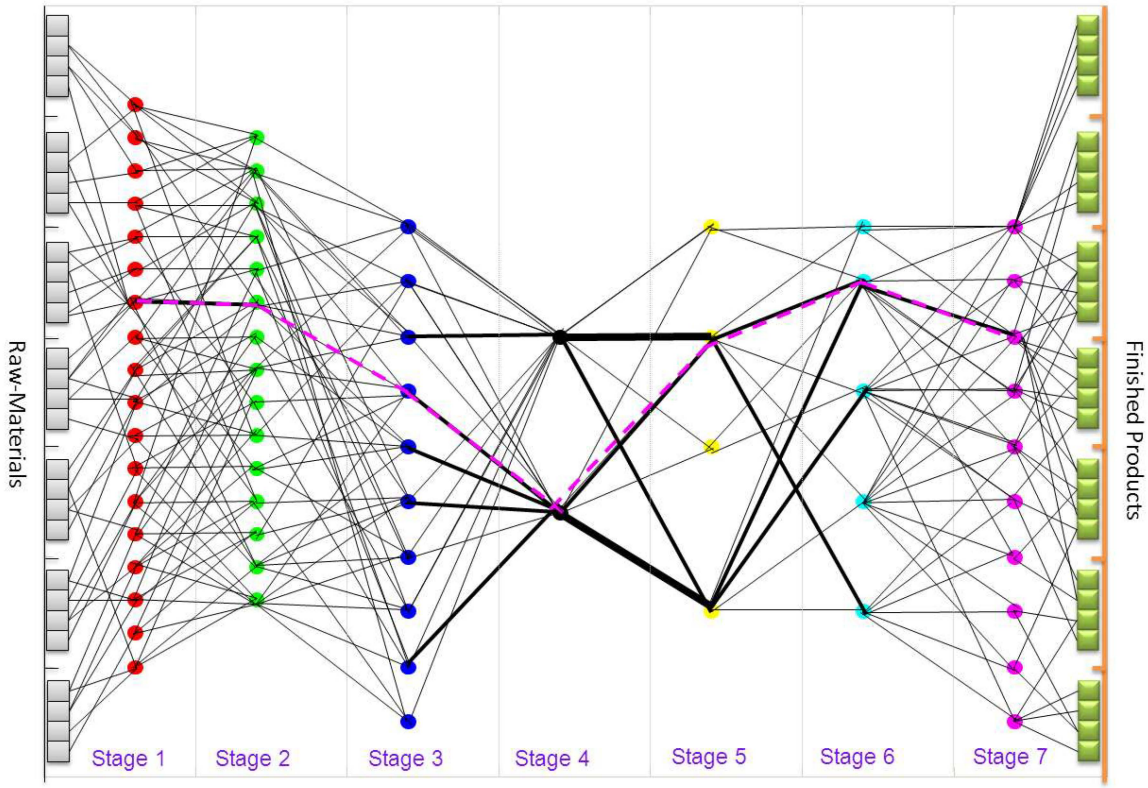


Figure 4. Frequent Logisitcs Trajectory

Thirdly, a 1000 pieces of RFID data are used for mining the frequent logistics trajectory. In this experiment, 7 processing stages are involved and each stage is equipped with certain number of machines. The raw-materials are batched and passing all the processing stages. After that, they will be produced into finished products. 10 logistics operators are for carrying out the logistics tasks. 4 are external logistics operators and the others are internal logistics operators.

Figure 4 shows the results using RFID-enabled shopfloor logistics big data to discovery the frequent logistics trajectory. It is observed that a frequent logistics trajectory is $< M_{1,7}, M_{2,6}, M_{3,4}, M_{4,2}, M_{5,2}, M_{6,2}, M_{7,3} >$. The average delivery time from stage 1 to 7 is 38.45 minutesand the average time waiting for processing is 16.78 minutes without considering the machine processing time at various stages. The performance of the logistics operators is $< 2.37, 2.65, 2.44, 2.65, 3.02, 2.77, 2.74, 2.12, 2.44, 2.56 >$, from which it is found that the fifth logistics operator has the best performance.

It is observed that the maximum waiting time for processing is on stage 5 that because there are only 4 processing machine with limited capacity while, in stage 4, two machines are with unlimited capacity. That causes the bottleneck within the processing stages. Meanwhile, the WIP inventory in the bottleneck stage will be high comparing with other processing stages.

4.2 Managerial implications

Findings and lessons from this research could be converted into managerial applications so that the end-users are able to make their logistics decisions more precise and reasonable when facing large number of RFID logistics data.

Firstly, the KPIs are defined and designed for evaluating various production objects like logistics operators, machines, etc. The historic KPIs could be used for determining the optimal workers, machines, and logistics path when carrying out logistics plans and schedules.

Secondly, the mined rules from RFID-enabled shopfloor logistics big data could be used for logistics operators to deal with various situations when carrying out the logistics plans and schedules. These rules are twined with the RFID devices like mobile readers, thus, the order picking and material delivery will be eased that because the rules are converted into logistics logics in the back-ground system which guides the logistics operators to execute the tasks.

Thirdly, using the approach proposed in this paper, the logistics could be predicted in advance. Therefore, it is important for the senior managers to make advanced decisions like recruitment strategy. Additionally, the logistics trajectory could be visualized which is helpful to work out logistics resolutions much easier.

5 Conclusion

This paper introduces a shopfloor logistics management under the concept of Physical Internet. The management uses RFID-enabled Big Data which are from a ubiquitous logistics environment that created by deploying RFID readers, tags, and wireless communication networks within the production shopfloor. The data structure and transmission is reported in the ubiquitous environment. A framework for mining the invaluable information and knowledge is introduced and various KPIs are defined to evaluate the logistics performance.

Several contributions from this paper are significant. Firstly, the creation of a RFID-enabled ubiquitous logistics environment in a real-life company under the concept of Physical Internet is realized. The creation integrates the practical applications and principles from Physical Internet so that the lessons from this case could be followed by other manufacturing companies who are contemplating to implement the RFID-enabled solutions. Secondly, a suitable framework is figured out to process the RFID-enabled shopfloor logistics Big Data. Different data structures, interpretation, data processing algorithms or models could be embedded into the framework so that it could be easily extended under different applications. Thirdly, under the Physical Internet-based shopfloor logistics management, some KPIs are defined to evaluate different manufacturing objects from the RFID-enabled Big Data. The findings are converted into managerial guidance which could be used for supporting logistics decision-makings in practice.

The future research directions could be carried out from several aspects. In the first place, a mathematical model will be built up to illustrate the logistics problems in the real-time RFID data driven Physical Internet. Thus, the theory perspectives of Physical Internet could be enriched. Secondly, as the increasing of RFID-enabled logistics Big Data, it is necessary to study the procedures to compress, store, process, and visualize these data so as to fully make the advantages from the valuable assets. Finally, the RFID-enabled logistics management system could be extended from two dimensions. One is synchronization both the computer-based platform and mobile phone-based application so that end-users are able to use their smart phones

to carry out the daily operations. The other is extension of this system to other applicable fields like third-party logistics companies, public warehouse, and industry parks. The principle of Physical Internet is able to be widely utilized in suitable areas.

Acknowledgement

Authors would like to acknowledge 2009 Guangdong Modern Information Service Fund (GDIID2009IS048), National Natural Science Foundation of China (51105081, 51305376), Industry-University-Research Cooperation Key Project of Guangdong Science and Technology Commission (2011B090400409), Guangdong College Talent Import Scheme (2011), Guangzhou Pearl River New Star Fund Science and Technology Planning Project (2011J2200017) and HKU small project funding (201309176013, 201209176052).

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The Role of Peri-Urban Networks in Building Efficient and Sustainable Distribution Systems

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Abstract: *It is now a common practice to use optimization models in the context of city logistics in order to enhance the efficiency and sustainability of current transportation systems. A large part of these models have been dedicated to the improvement of freights routing and transhipment operations using the current structure of the cities network. With the recent manifest of the Physical Internet appealing for more connectivity, sharing based practices and collaborative approaches, this paper proposes a conceptual framework to support logistics decision-making processes in urban contexts. It is based on building novel integrated models considering the strategic, tactical and the operational levels, and anticipating as precisely as possible the expenses generated by operating the subsequent decisions. In addition, it builds on the fact that current operations dynamic and the inherent uncertainty have to be shaped using optimization or simulation approach under uncertainty. An illustrative example on the city of Bordeaux in France is provided to argue in favor of the urgent need to redesign the current network for more efficiency and sustainability.*

Keywords: *Freight Distribution, Sustainability, Urban and Peri-urban Networks, City Logistics.*

1 Introduction

Nowadays, companies are often confronted to a two-speed distribution practice: large deployment with high volumes for more efficiency and costs rationalization; and last miles deployment with low volumes for more responsiveness and an increased service level. Whereas this strategy is clearly justified from an economic perspective due to economies of scale, consolidation and leanness guiding principles, it is not necessary appropriate from environmental, societal and resiliency perspectives. These latter are nowadays subject to a growing interest from practitioners, but several facts underline the failure of current companies to have distribution networks succeeding to well manage them (Montreuil 2011; Crainic 2008).

Two classes of literature have emerged in the recent years toward sustainability in distribution operations within the supply chain (SC): Sustainable SC practices in a closed system (i.e. for a single operating company); and city-logistics oriented practices for a collaborative set of companies or shareholders. In the former class of literature, the crucial issue is the minimization of ecological footprint of the company by improving SC forward operations based on the

minimization of the CO2 emissions or the energy consumption. A recent review on sustainability and social operations practices is presented in Tang and Zhou (2012). With regards to the class of literature dedicated to city logistics, several contributions have been proposed within the last years to set the specific context of city operations, the shareholders objectives and the involved decision-making processes, with the aim to propose logistic solutions improving the current unsustainable situation. City logistics corresponds to a system characterized by an optimized consolidation of loads of different shippers and carriers within the same delivery vehicles and the coordination of freight transportation activities within the city (Ananda et al. 2012; Crainic, 2008; Toh et al., 2009). Recently, tactical planning models (Crainic et al., 2009) and transportation models (Crainic et al., 2004; Hemmelmayr et al., 2012) have been proposed to cope with a number of real urban contexts. In these latter works, the two-tiers modeling framework proposed for city logistics, underlines the important role of peri-urban structural resources to connect distribution operations to urban areas. In addition, the systemic view of city operations points-out the crucial need for collaborative and sharing-based practices.

On the other hand, several works have recently underlined the performance of horizontal collaboration in distribution by sharing transportation and warehousing resources among the partner companies. Pan et al., (2013; 2014) illustrated, using a national context, how retailers could improve the efficiency and sustainability of long-haul transportation when collaborating. Meller et al., (2012) presented quantification of the effects of interconnectivity through horizontal collaboration on sustainability and profits. Sohrabi et al., (2012) proposed a formal SC design model for shared distribution operations and discussed its extension toward an open distribution network. This open distribution network, designed under the Physical Internet framework, is the global set of openly interconnected physical, digital, human, organizational and social actors and networks (Montreuil, 2011). It aims to fulfil the worldwide dynamic and evolving needs for ever more efficient and sustainable distributed deployment and accessibility of goods. However, to the best of our knowledge, only few works have investigated in depth this type of collaboration and tried to explicitly model it in a city logistics context.

According to that, our research interest is to consider the Physical Internet framework in order to investigate the interconnectivity potential of current closed distribution networks in the line of city logistics context. We foresee that peri-urban areas could play a key role to cope with the challenges of demand dynamics management and of more sustainability pursuit.

The reminder of the paper is organized as follows. Section 2 is dedicated to the problem statement where the case of the city of Bordeaux is considered to illustrate the framework, the issues and the challenges of our work. In Section 3, we present our solution methodology for the design and exploitation of sustainable distribution and mobility webs. The conclusions and avenues for future research are discussed in Section 4.

2 Problem Statement

When inspecting the decision-making process behind distribution operations, one notices that it refers to SC decisions on location, allocation, inventory management and transportation and it appeals for taking into account uncertainty and integrated decisions' models. More explicitly, this problem addresses the following issues: i) locating facilities in a context of uncertainty to shape the future capabilities of the network in terms of resources; ii) defining the inventory management mission of each of the open facilities to optimize capacity; iii) determining how these facilities could be used to meet efficiently the future transportation needs. However,

current models, only partially consider the inherent uncertainty related to the decision process, do not adequately integrate the functional issues of the problem, and do not exploit all the potential of horizontal collaborations. For instance, much of the literature focuses on discrete models for locating warehouses, under static and deterministic environment (Revelle et al., 2008). Also, little work on the join location-inventory problem (Shen et al., 2003) or location-routing problem (Nagy and Salhi, 2007) under uncertainty has been done. Moreover, the importance of the resiliency and flexibility capabilities for supply chain networks is rising (Sheffi, 2005; Klibi et al., 2010), but they have not been considered yet in the context of city logistics.

Faced with the current shortcomings of decision support models, the objective of this research work is to propose a methodological framework that enables to develop:

- A resilient peri-urban and urban distribution network, which allows coping with risky situations, deploying and storing products through open storage and distribution facilities.
- A web of efficient and sustainable intra-urban mobility, which is dedicated to move goods across infrastructure, vehicles, transit hubs and open multimodal options.

2.1 Fundamental issues

The notions of distribution and mobility webs refer to the new organizational approach based on the physical Internet, and require considering some logistics innovations as granted:

- All physical objects that require repeated handling operations through the Physical Internet are encapsulated with modular, ecological and smart containers (π-containers) whose sizes are worldwide standardized.
- Smart π-containers are interconnected to digital platforms of the Physical Internet so that their location can be almost known every time, for instance.

In this context, vehicles, handling and inventory systems, and logistics centers have to be designed and implemented to facilitate the storage and transport of π-containers through the mobility and distribution webs in an efficient and inexpensive way. The development of distribution and mobility webs in peri-urban and urban areas is a great challenge, given the extent of currents needs – the portion of city traffic dedicated to urban freight logistics is approximately between 9% and 15% when the occupancy rate of city roads related to urban freight transport exceeds 30%. Moreover, the legislative and fiscal pressure leads to restrict or regulate the city access to only a few types of vehicles, and sets the key question about the positioning of Distribution Centers (DC) and small-sized warehouses in urban zones given the high property tax to be paid.

The main issues in deploying distribution and mobility webs can be synthetized in the conceptual example of Figure 1. As illustrated in the left hand side of Figure 1, the disposition, the density and the size of the urban demand zones (population, shops, businesses), which are the final destinations for π-containers, are the key drivers for the distribution problem. The right hand side of Figure 1 illustrates conceptually the typical DC and transshipment points and their connecting lanes that must be deployed to insure an adequate coverage to such area.

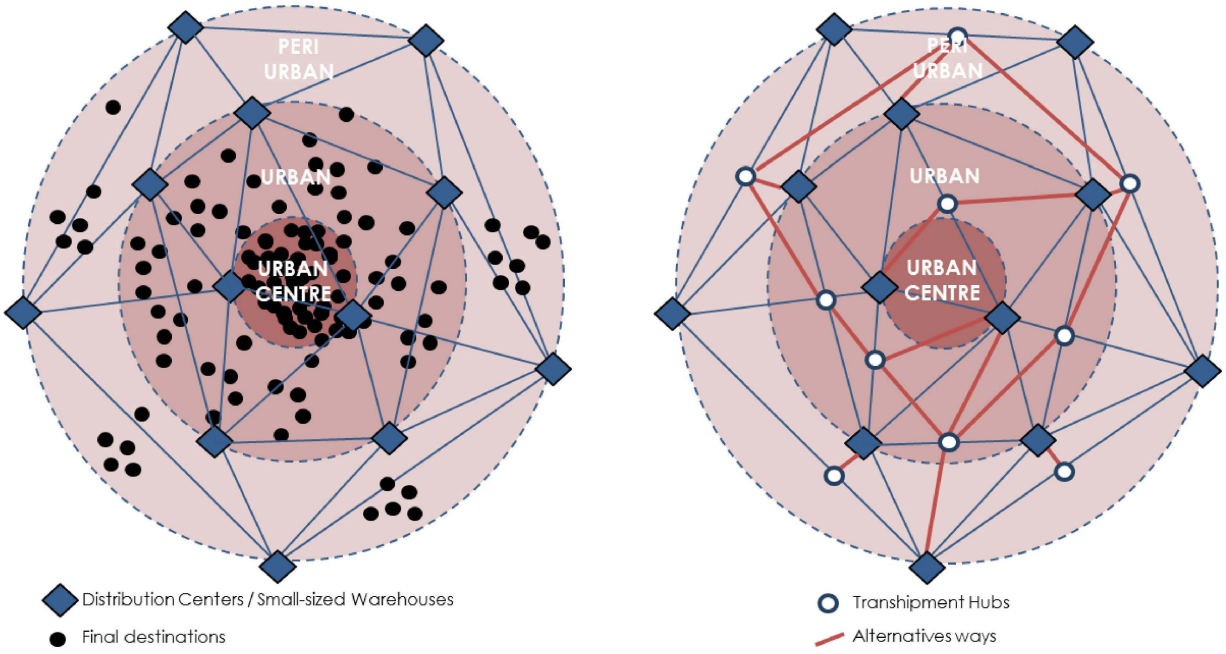


Figure 1: A generic example of Web Distribution in Urban Zones

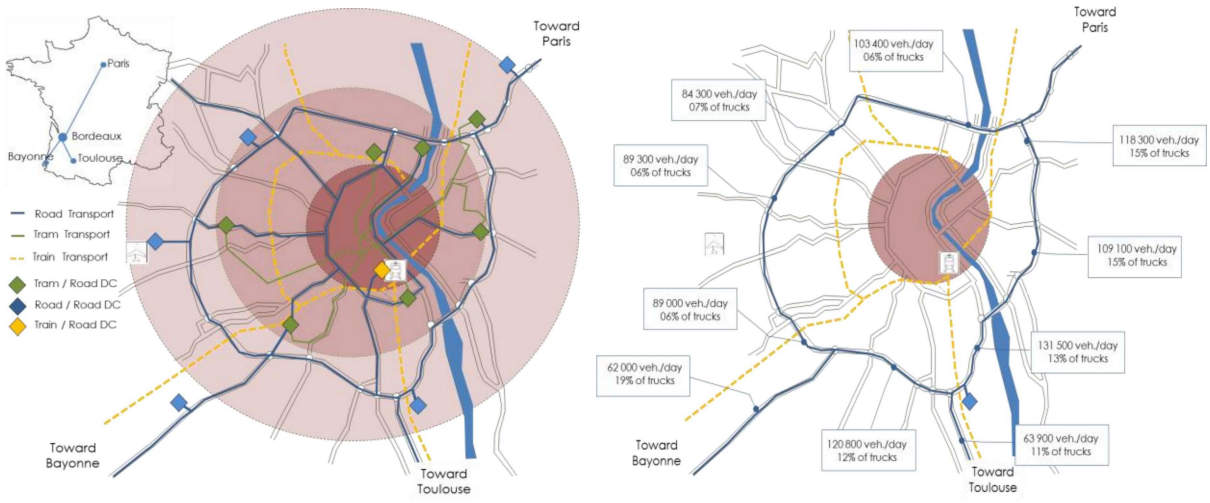
In contrast, areas with massive population favor the development of social and private housing, these decisions leading to note a lack of space for locating warehouses close to the final ship-to points. DCs with high storage capacity are situated in peri-urban zones whereas small-sized warehouses are expected to be located in urban areas in order to facilitate a multimodal freight distribution requiring transshipment between transport modes.

An efficient freight transport will be only possible if storage and transshipment intra-urban points are adequately located and connected, and offer alternatives roads and vehicles choices (in terms of energy modes and capacities) in organizing the movement of π-containers. The efficiency will be observed by measuring the impact of such transportation organization on:

- Reduction of the traffic congestion and the roads occupancy rate,
- Improvement of the customers' service rate,
- Optimization of loads of vehicles
- Reduction of CO2 emissions
- Reduction of global logistics costs for stakeholders.

2.2 An illustrative case: the city of Bordeaux

In order to illustrate the concepts discussed above, a typical urban context is considered hereafter as an example. The city of Bordeaux (Figure 2a) has plethora of stores, restaurants and service enterprises of all sizes concentrated in urban zones frequently visited by the population; the vehicles' access to this area is increasingly restricted, considering the existence of popular pedestrian zones and numerous small streets that limit traffic, gauges of vehicles that can be used and make difficult handling and unloading operations.



a) The current multi-modal network *b) The importance of trucks traffic on bypass*

Figure 2: The context of the city of Bordeaux

Many DCs (represented by blue diamonds in Figure 2a) already exist in peri-urban areas of Bordeaux, including 3 freight zones nearby the different highways that serve other major cities such as Paris, Toulouse and Bayonne. Bordeaux benefits from the existence of a railway network, with a central station located in the city center, of an international airport and of a sea port in the north of the city.

Furthermore, Bordeaux has currently an efficient public transport network composed of numerous lines of buses and a modern tramway system organized in a star form (green lines in Figure 2a). This network is currently dedicated to the persons' transportation. This network would be an efficient support to urban freight logistics if these transport modes could be shared with passenger's service.

Road traffic around the town is channeled through two arterial roadways: an "intra-muros" ring road surrounds the city center, allowing an easy access to the historic part of Bordeaux and the service of neighboring cities. A main ring road provides a global bypass of cities with high population density belonging to the urban community of Bordeaux, and is connected to highways, taking part in the definition of a major South-North road corridor between Spain and countries of Northern Europe. A recent investigation has evaluated the importance of trucks traffic of this bypass (Figure 2b).

Figure 3 depicts the current network deployed to distribute freights in the urban area of the city of Bordeaux. In contrast with the key issues cited above, it underlines 3 major drawbacks:

1) The absence of temporary storage or cross-docking points within the urban area
2) The lack of connectivity lanes between the platforms located in the peri-urban zone
3) The shortage of usage in multimodal transshipment and transportation options

All these characteristics seem to prove that the city of Bordeaux would be an excellent field of investigation to deploy efficient and sustainable webs of distribution and mobility, considering the specificities of the city layout.

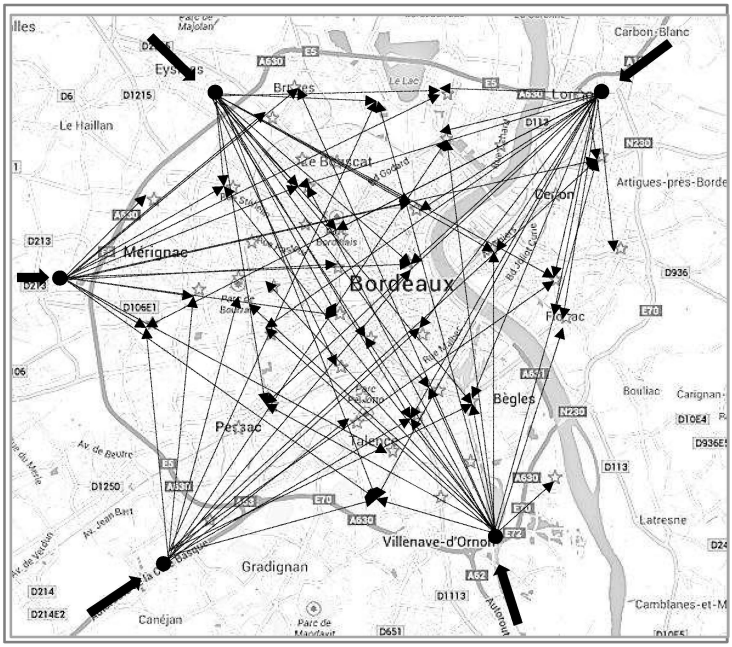


Figure 3: The status-quo network for urban freight distribution

3 Solution Methodology

To meet the objectives mentioned above, our aim is to develop decision support tools that explicitly address the issue of effective connectivity, sustainability and resiliency in an intra-urban context by adopting a generic methodology based on Schneeweiss' distributed decision-making framework (Schneeweiss, 2003). The methodology enables the design of mathematical models under uncertainty and integrated decisions among strategic to operational decision levels. It also fits well with hierarchical solution approaches using optimization and/or simulation.

Accordingly, in order to develop high quality decision-making models for the design of distribution and mobility networks, it is essential to anticipate when making these decisions, the future environment under which these networks will operate. The concept of anticipation is a key concept due to its impact on the quality of the solution and thus the robustness of the network to deploy. From a methodological perspective, the main issues are how to integrate resiliency into planning approach under uncertainty and how to develop integrated hierarchical models and solving approaches for effective solutions. From a functional perspective, the main issues are: i) how to append interconnectivity in current distribution practices, ii) how to consider practical constraints arising in an inter-site and intra-urban context, and iii) how to develop novel indicators in regards to ecological and social performance.

3.1 Deployment of an efficient and sustainable Web Distribution

The proposition for the deployment of an efficient and sustainable Web Distribution is based on the development of a set of hierarchical decision models to link the sites belonging to the network of Distribution Centers or warehouses based on the anticipation of the network operations. More specifically, such an approach implies to integrate the operational inventory management policies with the dynamic deployment of these inventories in time along the tactical

planning horizon. The problem associated to the design of a Web Distribution involves decisions on the location of a set of interconnected sites, defined as π-DCs, configured to receive, handle, group, store and ship π-containers. Furthermore, this problem implies decisions based on capacities in terms of flow and space, and the definition of activities related to the π-DC. At this decisions level, it appears essential to consider the strategic deployment of inventories within the Web Distribution in terms of the stock levels to be maintained and the mission of π-DC to supply, transfer and distribute π-containers through the network. The hierarchical decision-making framework proposed to design the deployment of the Distribution Web is illustrated on the left side of Figure 4. This framework underlines the impact of the Web Distribution design process on the management activities in the time. The anticipation process related to the costs and the estimated incomes in the Web Distribution influence directly the design decisions of π-DCs. This strategic/tactic decision-making framework will allow integrating the main characteristics of inventory management problem during the design phase of a Web Distribution. The development of this framework is based the following complementary three steps:

i. The location of a network of π-DCs considering the impact of usual inventory management policies.
ii. The development of dynamic inventories deployment strategies in a multi-echelon π-DCs network based on demand planning and forecasting methods.
iii. The design of a Web Distribution of π-DCs in a context of non-stationary demand based on dynamic inventories deployment strategies.

The characteristics of these three activities are illustrated on the right side of Figure 4.

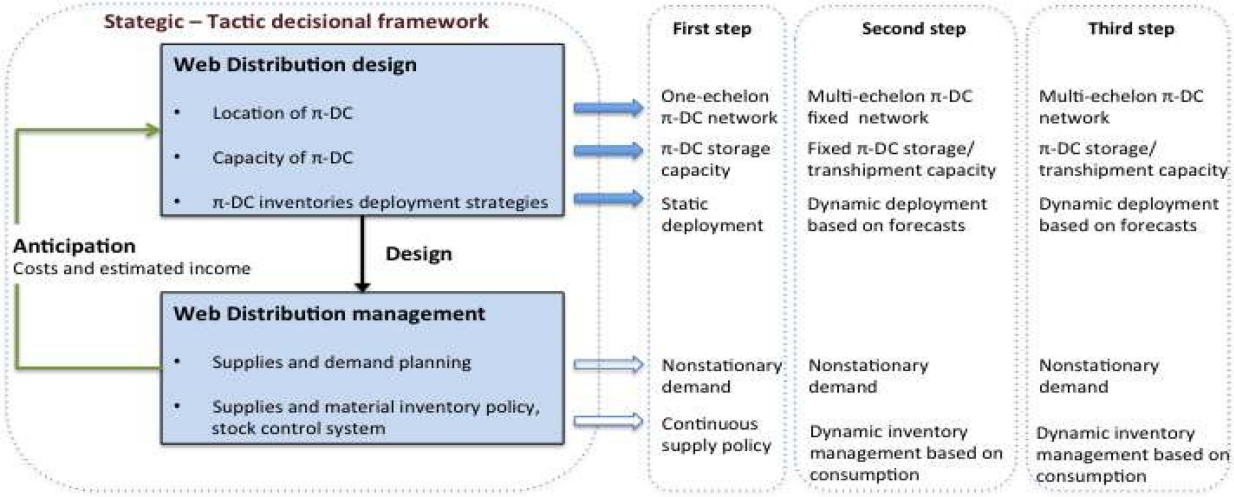


Figure 4: Decision-Making Framework for the deployment of a Distribution Web

The objective of the first step of the proposition is the location of one-echelon π-DC network and the determination of the associated capacity by considering the impact of usual management policies in terms of inventories and supply activities. This implies the development of a π-DC location model integrating periodic stock control decisions on a multiannual horizon. Based on the hierarchical decision-making framework presented in Figure 4, this consists in formulating an integrated location-inventory model as a stochastic program, including random variables in the demand that is as assumed to be non-stationary. The resolution method of this model will use the Sample Average Approximation (SAA) method, which is an approach for solving stochastic

optimization problems by using Monte Carlo simulation technique. The validation of the model developed will be made through a realistic study inspired by a peri-urban context.

The second step of the proposition has for objective the dynamic deployment of inventories from a set of predetermined π-DCs with fixed capacity on a tactical horizon planning. This necessitates the definition of a hierarchical decision model for the allocation of inventories in the π-DCs network and the anticipative decisions of inventories movements between π-DCs. These anticipative movements of inventories in the distribution network aim to improve the response time by linking π-containers and demand zones while benefiting from the inter-sites transfer consolidation. The demand is supposed non-stationary; this model involves the development of several strategies of demand anticipation based on forecast methods for demand and inventory management. Furthermore, this requires the proposal of a tactical planning structure under uncertainty which will characterize the dynamic environment for decision-making inventories deployment. Scenarios of non-stationary demand and π-DC capacity disturbances will characterize the Web Distribution environment.

The third step of the proposition aims to develop a π-DC location model in a multi-echelon network with decisions on capacity and inventories in a context of non-stationary demand. In order to anticipate the demand and improve the response time, forecasts techniques will be used involving dynamic movements of inventories in the time and in the space. The difficulty associated to this model necessitates defining inventory management policies in a multi-echelon network where the demand is non-stationary and the capacity must be determined. Another difficulty is the integration of decisions concerning the anticipated inventory control policies at the decision level of the π-DC location.

3.2 Enabling and exploiting a global and sustainable mobility web

This sub-section is dedicated to the presentation of π-hubs location model (mid-term decisions) for efficient transport and distribution of π-containers in urban and peri-urban areas at various levels of abstraction (timescales). A π-hub can be defined as any physical site with storage capacity exploited within the mobility web to create alternative points of routing; for example, an intermediate delivery point (pick up points in urban and peri-urban areas) is considered as a short-lived storage place for π-container. In this context, exploiting a mobility web include direct customer delivery or freight transshipment (mobility of π-containers by several vehicles / modes). To solve this category of problem a hierarchical approach with third level of decisions is considered as follow:

- Strategic decisions of π-hubs location by aggregating transport decisions (characterization of multiple meta routes based on a multiannual non stationary demand).
- Tactical decisions of π-hubs responsible for loads and capacities allocation, this level is based on the estimation of π-hubs activities in order to route π-containers.
- Operational decisions of routing for the validation of location-allocation models integrating uncertainties translating the risks associated to the routing activities of π-containers.

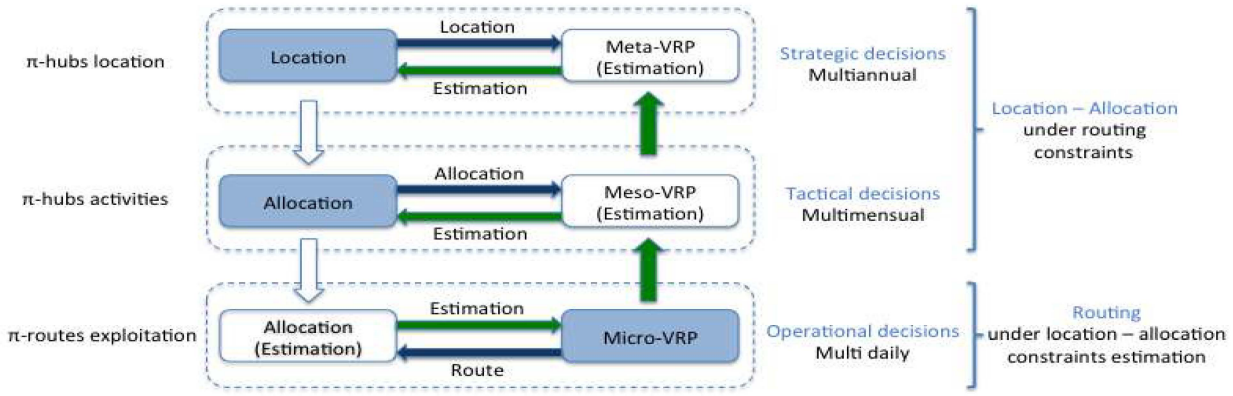


Figure 5: Enabling and exploiting a mobility web

In this problem, the planning decisions of location-allocation are considered in a cyclic way characterized by random events that define the future customers demand. The proposed resolution approach integrates location and transport under uncertainties. To find an adequate balance between all the desired dimensions of performance, numerous experiments will be tested based on models with various strategies of resilience and coverage area. Emphasis will be put on the hierarchical problem modelling based on an approach of Set Partitioning and on the development of heuristics adapted to the hierarchical structure of the problem.

4 Conclusion

Our aim in this article is to present in detail the main tasks associated to the proposition of a Physical Internet decision support tools in a peri-urban and intra-urban context. In this article, the decision support tools in a peri-urban and intra-urban context is decomposed according to the following four main tasks: i) modeling and illustrating current city-logistics practices, ii) deploying an urban and peri-urban distribution web that is efficient and sustainable, iii) exploiting an open and global mobility web in an urban and peri-urban context, and iv) estimating the impacts of the webs approaches by the development of a dedicated simulation environment. The tasks and their relationships will be presented and discussed in order to propose a methodological framework starting from the needs expression until the experimentations via simulations.

Currently, the data collection and gathering is finalized and the mathematical models are under development. The next steps of this project are the fine-tuning of the proposed models and the solutions production and evaluation for the city of Bordeaux and other potential applications.

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Towards a Traceability Solution in the Canadian Forest Sector

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Abstract: *Radio Frequency Identification (RFID) is an enabling technology that promises to create value through greater visibility in the forestry wood value chain network, higher product velocity, more efficient transportation management and improved quality control. However, it is still not clear how these objectives can be fully achieved. In this paper, we propose an ICT framework called "FTrace" for implementing a traceability system in the forestry wood supply chain based on Internet of things concept. Internet of things uses RFID technology to connecting objects. In the forest sector case object is wood and any product based on wood after transformation. FTrace will help some specific partners in the value chain to track the origin of wood, control information of raw material utilization, trace production progress and track the transportation process. FTrace solution increase collaboration between the different supply chain actors through tracing the business processes execution, orchestrating different providers, integrating the different IT application used throughout the wood process and offer a scalable traceability system. The proposed architecture will also provide managers with meaningful information allowing them to track and trace wood at different process stages (cutting tree, collecting wood, production, sales, etc.) to achieve a more competitive advantage. FTrace is tested in the Canadian forestry context.*

Keywords: *Internet of things, Traceability, RFID, Forest Supply Chain.*

1 Introduction

In forestry, the wood is treated generally as raw materials and it is graded at the final stages of production. Significant savings can be achieved if the right quantity, type, and quality of wood are available for the final product that is best adapted for so that unnecessary decommissioning is minimized and the yield of the desired product is maximized. Better overall control of the information and material flows might optimize the efficiency of production in the forestry network and minimize environmental impact [1]. The key for implementing this control is the identification and traceability of the wood products through the value chain. As an example, the Chain of Custody (CoC) certification for forest and wood products ensures that the forestry and

wood products come from certified, well-managed forests and their authenticity as they travel through the supply chain from processing to the customer. According to the International Organization for Standardization (ISO), in the ISO 9000-2005 standard [2], traceability is defined as "the ability to trace the history, application or location of that which is under consideration". From product identification, we are able to trace some important data related to this product. Several technologies have been used for tracking wood. They include conventional and special paint markings smart cards, barcode tags, and Radio Frequency Identification (RFID) tags. RFID technology has a number of advantages when compared to the other marking methods in the forestry: line of sight is not needed, the reading can be done over a distance allowing highly automated identification, the transponders are not sensitive to dirt or moisture, and there are a large number of unique identification codes or memory for coded data. In addition, [3] stated that RFID could be the best tool for the identification of wood.
Although RFID is an enabling technology that promises to create value through greater visibility in the forestry wood value chain network, higher product velocity, more efficient transportation management, improved quality control, and reduced human error; it is still not clear how these objectives can be fully achieved. Moreover, there is still no consensus on how the information system should be developed to address with success the basic traceability issues in the forest sector. To better understand and validate the potential use of RFID technology in this sector, more recently some research projects have been made in relation with the use Information and Communication Technology (ICT) systems to enhance forestry traceability. The Indisputable Key project [4] is one of these initiatives. They propose an ICT system for data collection from different providers in the value chain in order to offer an efficient supply chain management [5]. However, the proposed architecture is unable to capture a dynamic process management. In fact, they don't clearly specify how adding new actors (providers) is possible in the system after the operation of the forestry supply chain. Another important initiative is the "Seamless Operation of Forest Industry Application" (SOFIA). SOFIA is a platform that optimizes contractors order logistic management and developed in the forestry sector in Finland [12]. It's an innovative proposal of ICT solution for forestry, but it remains preparatory project and there is no validation proof of this platform in industry.

In this paper we propose an extensible ICT framework called "FTrace" that offers a dynamic process management and a unified data communication for tradable information through the forestry supply chain providers that enhance traceability. FTrace support Internet of things concept by using RFID technology to collect information about wood products. This architecture helps some specific partners in the value chain to track the origin of wood, control information of raw material utilization, trace transformation and production progress and track the transportation process. The proposed architecture will also provide managers with meaningful information allowing them to track and trace wood at different process stages (cutting tree, collecting wood, production, sales, etc.) to achieve a more competitive advantage. The proposed solution is tested in the Canadian forestry context and demonstrates the additional value of creating a sustainable wood value chain. The remaining of this paper is organized as follows. In section 2, we introduce the research problem. In section 3, related works are discussed. Proposed approach and a real time tracking architecture is put forth and discussed in details in section 4. Conclusion and future works are presented in section 5.

2 Problem Description

The forestry wood supply chain considered in this paper is illustrated in Figure 1. This figure show the different stages in the wood production process, starting from the extraction of the forest raw material and finishing by sale to a consumer [6]. In addition, for simplification purposes, the proposed wood supply chain is composed of four types of providers: Harvest Units, Log Sort Yards, Sawmills and Retailers. To extract the raw material from the forest, the tree is felled and cut to logs by a "Harvester". A "Distribution agent" transfers the logs to the "Log Sort Yard" to collect wood. Thereafter, the logs are transported to the Sawmill. In the "Sawmill", logs are sawn, drying, sorted, finished and then transported to the retailer for sale to Clients.

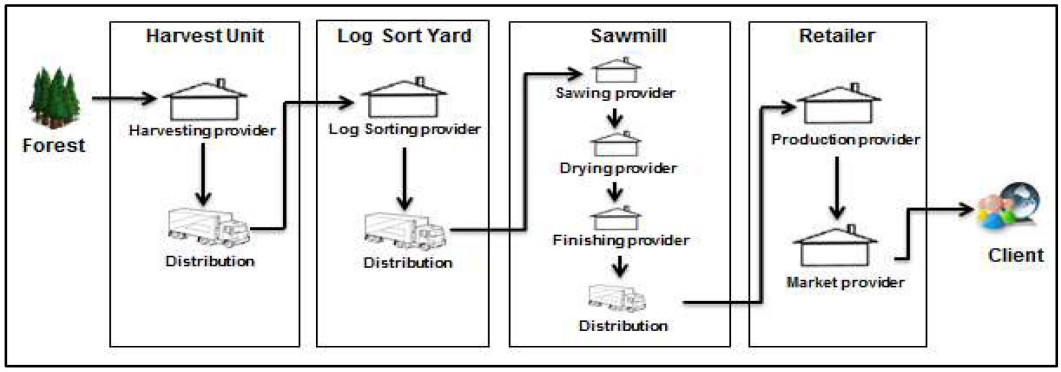


Figure 1: Forestry wood supply chain

The forestry wood supply chain is a complex process. In fact, each provider involved in the wood supply chain can take independent decisions. Moreover, wood characteristics and some specific measurements collected at each step of the wood chain process are diverse. The heterogeneity of information lead to some synchronization issues regarding the information exchanged between partners. Based on an extensive literature review, we can assume that it's a big challenge to make the connection between the information exchanged between partners and have reliable information that meets the customer's needs. Traceability and identification of assets can be a solution to this [1, 6-8]. Traceability in the supply chain presents a clear potential that might help to ensure quality control and legality of the product. It is used in different manufacturing and services applications such as Apparel, Consumer packaged goods (CPG), healthcare, logistics, Manufacturing, Defense, Pharmaceutical, etc. Different standards and norms have been developed in different areas to ensure reliable traceability systems such as the global traceability standard for healthcare used in the medical sector [9], ISO 22005 feed and food traceability standard [10] and the JIS (JISx0510) to track car components in Toyota plants [11], etc.

Although the literature about traceability based on RFID is well developed in different industrial applications [12-16], we are not able to find a clear and well-defined traceability standard or a framework for its implementation in the forest sector. This is why we should define and clarify the traceability concept in the forest sector. Indeed we have to establish the basic requirements

for a traceability system in the forest sector. These requirements include wood identification, definition of traded information structure and availability of this information among forestry stages.

To achieve this objective, the challenge is to define a generic ICT traceability system to manage information exchange between partners. The new system will ensure interoperability between partners and communicate reliable information to the traceability system for a dynamic process execution. The new system should provide a dynamic and generic platform with a unified data communication between different providers involved in the traceability process. Thus, the main objective of this study is to discuss a visionary approach and develop a generic and interoperability traceability platform in order to track forest wood during its operation, transportation, processing and in its distribution chain, from the forest to the final consumer. This platform creates an information link between the final wood-based product and the forest from which the woods was collected and answer the following questions: How to exchange information? What kind of information that should be exchanged? And how we can ensure interoperability among partner's systems?

3 Related work

Traceability is essential to increase the value of supply chain operations. There are several traceability definitions in the literature. For example, in [17], the author defined traceability as the tracking of dynamic interactions between process and objects. Moreover, traceability provides means to verify the chain of custody and the origin of the timber [1]. [6] defined traceability as a process of systematic practice and information traded among different providers in the chain to be able to preserve the product identity and its origin. [7] cited that traceability is the way by which we can make information available at different stages along the forestry-wood production chain. Finally, GS1 defines traceability as the ability to trace the history, application or location of that which is under consideration [18].

Traceability is important for many reasons such as wood value chain maximization [19]. It increases the end product quality by optimal use of resources when allocate the right raw material for the right final product [20]. [1, 17] state that traceability improves control during the wood processes in the supply chain by providing the accurate and complete information about the wood origin. Indeed, traceability minimizes waste and environmental impact while increasing profitability and earnings [1, 7, 20]. In [21], the use of a simulation model to analyze improvements by collecting reliable traceability data throughout all wood value chain demonstrate the importance of traceability. From the previous research, it is clear that traceability definition might be different and context dependent.

Thus, in this research we define traceability as following: "Traceability can be defined as the monitoring of traded information between processes and wood from their origin to their destination". More specifically, to locate a product, we must link information and wood

movements though the forestry supply chain from origin to destination to be traced back. Implementing traceability in the forestry value chain requires that several technologies are combined and integrated to operate as a system [20]. ICT traceability system is the core of traceability concept. Movement detection of each product in different process stage requires the implementation of ICT architecture to collect reliable information. In the literature, we can find different models to implement an ICT architecture in different type of supply chain [13] such as freight transportation networks [22], food chain [23, 24], and bulk grain supply chain [25]. For example, a framework of traceability called Traceability for Complex Systems (TraCS) proposed by [26]. This approach applies heterogeneous techniques to integrate an extensible traceability framework. Nevertheless, they provide a poor integration with users because they must make these decisions themselves throughout traceability process. TraCS is tested in an example drawn from a system to control chemical reactions at a catalyst plant. In [25], the authors present a traceability system in the bulk grain supply chain. They use the Extensible Markup Language (XML) for information exchange (e-information) and a relational database for data management. By using XML and a relational database, the author simplify the traceability concept, but this is not enough to offer an extensible and interoperable traceability system.
The ICT penetration in the forest sector is still very low [5]. SOFIA is one of the platforms that optimize contractors order logistic management developed for the forestry sector in Finland [12]. It ensures a sustainable ICT infrastructure for forestry operations. The SOFIA platform integrates several technologies including Service-Oriented Architecture (SOA), agent technologies and the Semantic Web for allowing integration and interoperability. It's an innovative proposal of ICT solution for forestry, but it remains preparatory project and there is no validation proof of this platform in industry. In [6], the authors proposed a forestry traceability model and they present basic requirements to manage information of the wood supply chain from the Amazon Forest. They use SOA to manage traceability. The Indisputable Key project develop an ICT traceability system to manage forestry supply chain based on RFID identification [4]. However they don't take into consideration the dynamic and the interoperability aspects in the proposed traceability system.

To create an efficient ICT traceability system in the Canadian forest sector, we identified some basic requirements inspired from the previous projects and from collaboration with our research partner. Thus, the traceability requirements are composed of three basic elements:

- **Provider's (type) identification**: For an effective traceability system, we have to identify production process stage in forestry supply chain and type of generic actors whose product goes through. The proposed wood supply chain is composed of four types of providers: Harvest Units, Log Sort Yards, Sawmills and Retailers.
- **Product identification**: Product identification is required in traceability to make reliable information available about different process stages. Automated identification in forestry eliminates multiple measurements needs and repeated inventories of wood [1]. We can find a variety of labeling technologies for wood identification such as conventional paint

and chisel labels, hammer branding, tracer paints, barcode tags, chemical and genetic fingerprinting and RFID [27]. Many previous researches affirm that RFID is the most appropriate to be used for wood identification in forestry [1, 6, 27, 28]. Indeed [19] claimed that RFID could be a good candidate to replace marking stamps, at the same time as possibly enabling the transfer of valuable information in the logistic chain of the forest industry. So, the ICT system should be able to handle different labeling technologies.

- **Communication information standard**: The third traceability required is the communication standard. It is a set of standard information that specifies product information exchange with the different supply chain partners. Examples of communication standards in forestry sector are eFIDS, GS1, StanForD and Papinet. eFIDS (e-Forestry Industry Data Standards) is a metadata standard for traded information within forestry industry. It is based on no named exchanged XML documents among supply chain which leads to a conflict of documents. The GS1 provides traceable data matrix that depends on product types and contractual relationship, and it's divided in public and private information [18]. StanForD (Standard for Forest machine Data and Communication) is used to control harvesting as well as monitoring the production of harvesters and forwarders [29], and it's used in Indisputable KEY project. PapiNet standard is an open standard that anyone can contribute to [30]. It supports the forest industry business areas. StanForD and PapiNet use XML technology to represent the information. These standards will remain independent but each one could support the other. However PapiNet standard is used for exchanged information between providers or StanForD used into the forest for sending information from harvesters and forwarders to the first receiver of data. PapiNet and StanForD represent two complementary standards. In our project, we combine these standards presented in section 4 for defining a global communication standard.

4 Traceability Proposed System

4.1 Forestry information system

In this article, we propose an ICT forest traceability system called "FTrace". FTrace is developed to collect information from forestry supply chain providers, and then use it effectively in order to trace wood material throughout the supply chain. The system offers also the possibility to understand, evaluate the forest value chain and take the right decisions. This system is composed of three modules (see Figure 2):

- Module 1: Traceability business processes.
- Module 2: Business application.
- Module 3: Web portal.

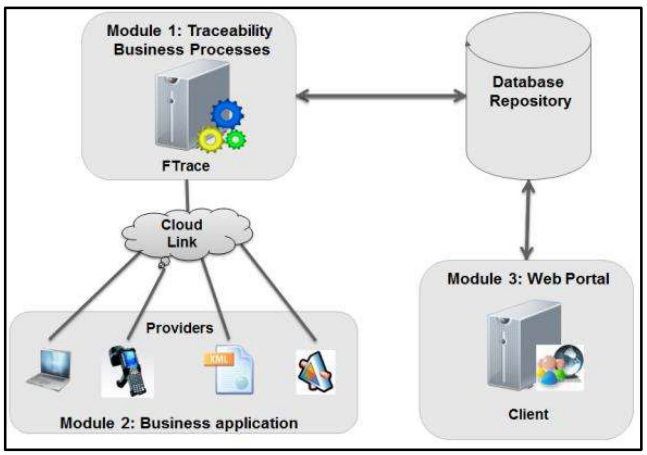


Figure 2: FTrace Information and Communication System

The "Traceability Business Processes" module includes the most important parts of the FTrace information system like the FTrace server that manage the traceability activities of the different supply chain processes. FTrace server connects with business application module through a cloud connection for recording activities and collects information from supply chain providers. Information recorded is stored in a database for finally showing traceability information needs to client in web portal. In order to allow a transparent traceability between providers, it is necessary to provide information on all internal transformations of each provider's system. FTrace allows interoperability and integration with existing provider systems. FTrace can connect with different types of ICT provider system (web service, barcode, RFID reader, XML file…). In the following section we will describe the FTrace ICT architecture components.

4.2 FTrace ICT architecture

FTrace allow interoperability between providers and information system. It can connect different types of technologies (service, RFID, XML file, etc.). Figure 3 presents in details the FTrace architecture for the proposed solution. FTrace architecture is composed of the following components:

- Application layer: this component describes the business applications used by each provider (partner). This layer communicates with other FTrace components in order to collect traceability informations. We can define two methods for collected data: real time data extraction (using BizTalk) or Batch data extraction with ETL. Indeed FTrace can connect to provider's business applications with different adapter's type (web service, barcode, RFID…) for real time information extraction, or connecting to provider's internal database for batch extraction.
- Data Extraction Layer: this layer helps the integration of each provider in FTrace architecture. FTrace offer two data integration methods, batch extraction and real time extraction:
  - ETL: Extract-Transform-Load is a process to pull data out of one source systems (files, database, etc.) and place it into another database by following data extraction logic. The role of ETL in FTrace is to extract data from internal database of each provider in supply chain into FTrace database repository.

    - Orchestration Layer: this layer orchestrates and share data between providers. Indeed this layer feeds database with traceability information collected throughout forestry supply chain process. This layer enables a flexible and generic provider addition in the forestry supply chain. Each provider in the supply chain has a dependent orchestration for extract data and feeds the FTrace database by traceability information. For adding a new provider in the existing supply chain, we need just develop a new orchestration process to integrate the new provider to the existing ICT traceability system already developed.
    - Enterprise Service Bus: allows interoperability with existing applications. Enterprise Service Bus is a flexible approach to integration without writing code. For example in this layer, to extract information from RFID tags, we use BizTalk RFID that orchestrates RFID-related end-to-end processes and share RFID data. BizTalk RFID allows discovering, communicating, managing and integrating RFID devices into different existing applications on different providers.
- Middleware Layer: the Middleware layer proposes features like baseline filtering capabilities, reader integration and coordination. We should be able to intelligently filter multiple data sets resulting from multiple reading of objects that go through several antenna fields.
    - Information Management Rules (IMR): Define the client traceability information needs (implemented via XML files). The business process was defined by the IMR to offer all required traceability information.
    - Unified Data Representation: Define attributes and structuring the database using Papinet and StanForD standard. This layer defines the data format (wood properties, measurements, etc.) that will be traded by providers.
    - Filtration and data aggregation: In order to send and display needed information.
- Database Repository: Represent the data model for the whole supply chain. After extracting traceability information from each supply chain providers, all these information will be processed and stored in the database repository.
- Web Portal: Provide a global view of traceability information (list of providers, forests, products, etc.). Offer a flexible access to client: the user need just to enter the product identification in the interface and all the tractability information will be show to the user (since the product creation until today).

This architecture offers a reliable, extensible and scalable traceability solution. It provides two major benefits that are really critical to implement in the forest sector. In one hand, it offers the ability to accept and manage any devices. On the other hand, it offers scalable system that can subsequently adding or removing a provider in forestry wood supply chain. The proposed architecture is able to track product in real time, accurately in the forest and outside at different other providers and then using this information to make business decision that help improve the flexibility and speed of their supply chain.

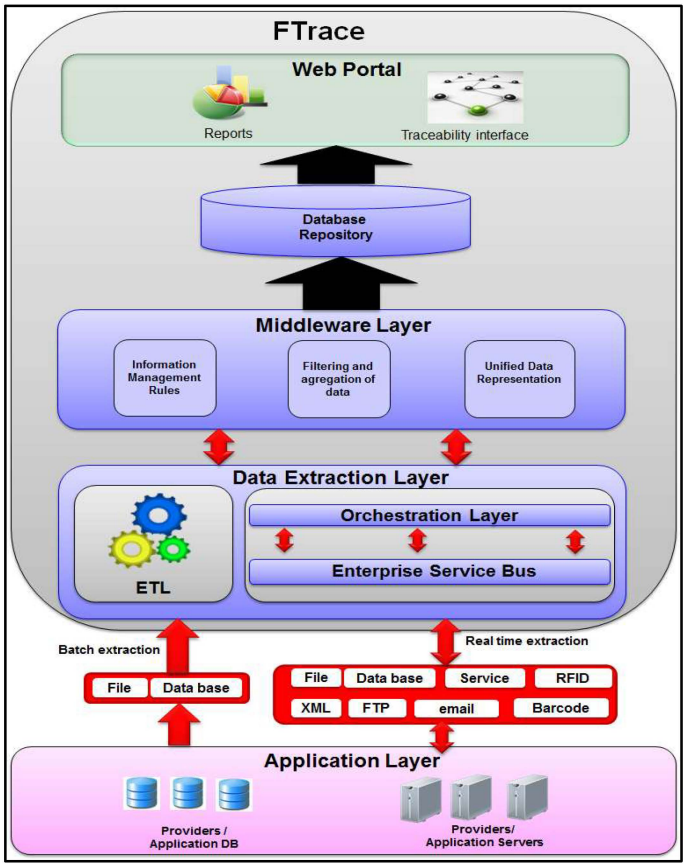


Figure 3: FTrace proposed architecture

4.3 Proof of Concept

The proposed architecture described previously was implemented and tested in a real case scenario. Figure 4 show an UML sequence diagram describing interactions done between real providers, the client and the system we propose. The client defines his traceability information needs. A set of actors types involved in the traceability business process is identified. In order to collect traceability information (for each product in inventory), providers engaged in the forestry supply chain send traceability information to FTrace system via a Cloud connection. The Web Portal displays traceability information from "FTrace" as a response to any specific request from the client.

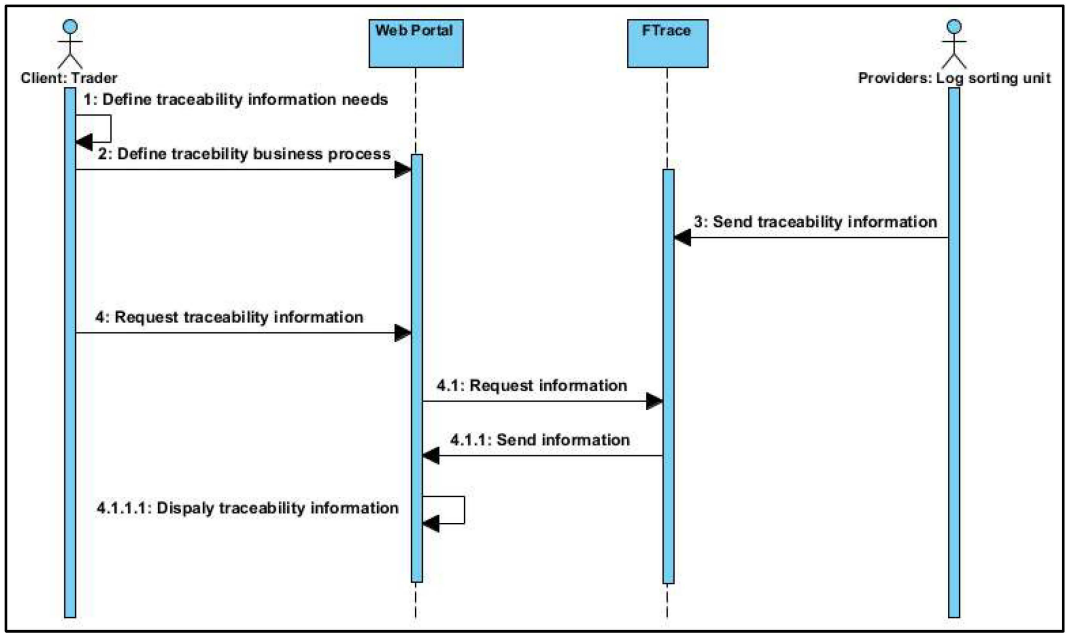


Figure 4: Traceability UML sequence diagram in the Forest Sector- Example Scenario definition

FTrace is an interoperable system; it can connect with different types of ICT provider system (web service, barcode, RFID reader, XML file…). In this prototype, we are using a provider's application developed in .Net in order to communicate with FTrace system (using XML files). These applications are implemented at different nodes of the forestry process in order to collect traceability information from providers. Figure 5 describe the log sorting provider's business application interface. By this interface, the client defines his log sorting traceability information needs. When clicking in process button, an XML file containing this information will be sent to FTrace system for processing. The processed information will be available for the client and offers the possibility to trace back some specific information from origin.

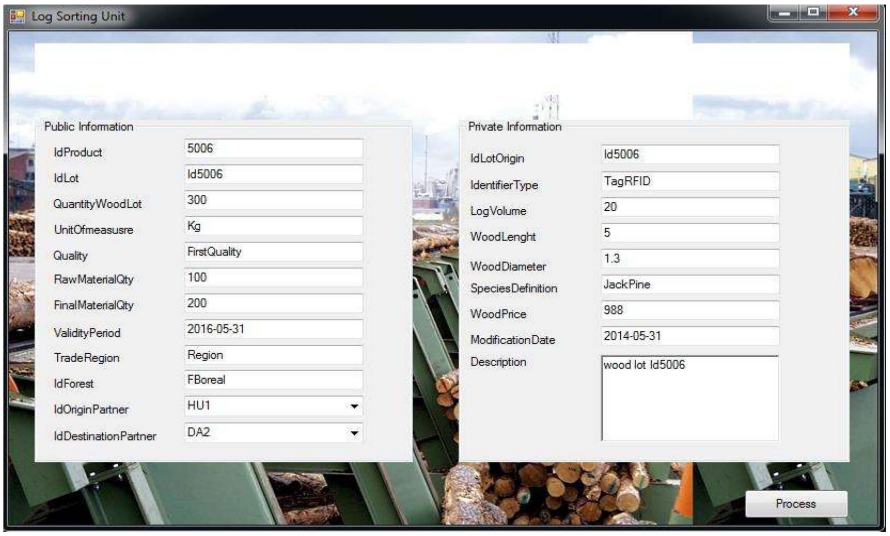


Figure 5: Providers business application

In order to exchange information between supply chain providers who are geographically distant, we propose an interoperable traceability solution equipped with internet connection. We use BizTalk as an orchestration tools to ensure the functionalities quoted previously. BizTalk provide connection between the process information and the product information. Through BizTalk usage, the system is provided automatically and in real time by reliable data. Figure 7 define an example of traceability business processes orchestration using BizTalk tools. This figure describe message exchanged between forestry supply chain provider (Log sorting provider in this case) and the FTrace system. For offering a scalable system, we can easily manage and integrate providers (adding or removing providers). For example, for adding a new provider type to the forestry wood supply chain, we must just add a new orchestration (as illustrated in figure 6) and connecting it to the existing ICT traceability system already developed.

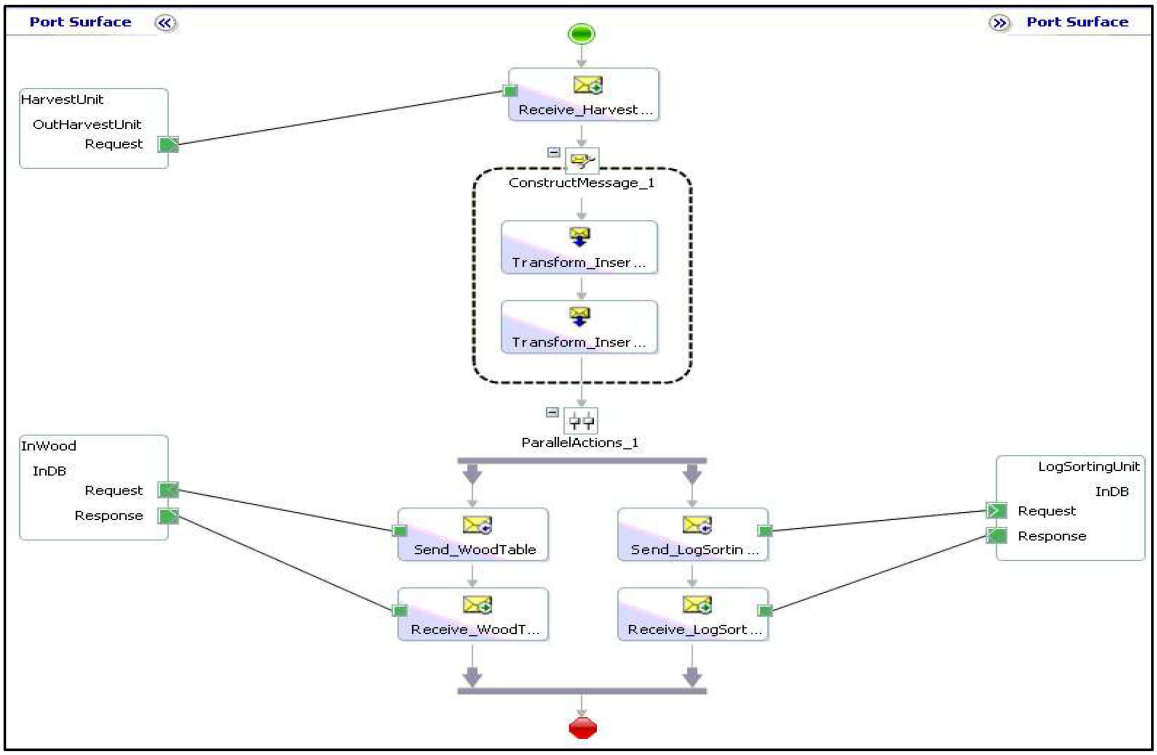
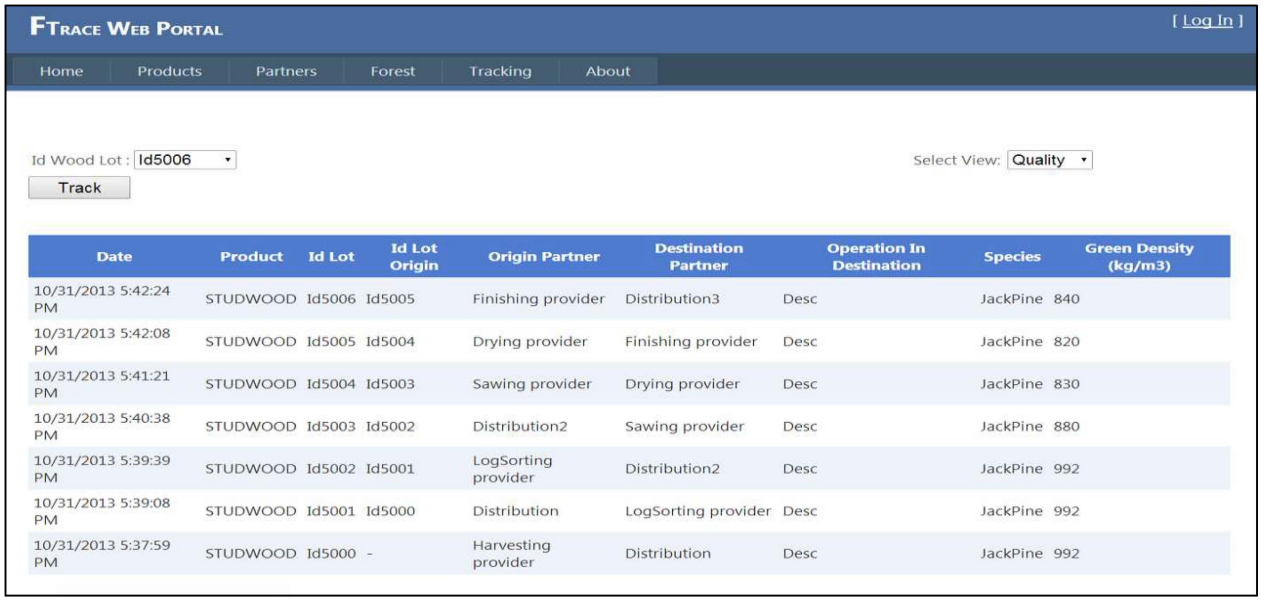


Figure 6: Traceability Business Processes – Orchestration sample

FTrace emerge Internet of Things context by: 1) using network information and 2) sharing a readable and flexible interface with end users. In order to see in a friendly manner the traceability information, the client can use a web portal. The Web portal turns requested information from FTrace system to display reliable traceability information as shown in figure 7. The Web portal is responsible to present the traceability data to the client with different views, according to the standard that has been defined in advance.



Date	Product	Id Lot	Id Lot Origin	Origin Partner	Destination Partner	Operation In Destination	Species	Green Density (kg/m3)
10/31/2013 5:42:24 PM	STUDWOOD	Id5006	Id5005	Finishing provider	Distribution3	Desc	JackPine	840
10/31/2013 5:42:08 PM	STUDWOOD	Id5005	Id5004	Drying provider	Finishing provider	Desc	JackPine	820
10/31/2013 5:41:21 PM	STUDWOOD	Id5004	Id5003	Sawing provider	Drying provider	Desc	JackPine	830
10/31/2013 5:40:38 PM	STUDWOOD	Id5003	Id5002	Distribution2	Sawing provider	Desc	JackPine	880
10/31/2013 5:39:39 PM	STUDWOOD	Id5002	Id5001	LogSorting provider	Distribution2	Desc	JackPine	992
10/31/2013 5:39:08 PM	STUDWOOD	Id5001	Id5000	Distribution	LogSorting provider	Desc	JackPine	992
10/31/2013 5:37:59 PM	STUDWOOD	Id5000	-	Harvesting provider	Distribution	Desc	JackPine	992

Figure 7: FTrace web portal

5 Conclusion

In this paper, we present a novel traceability approach based on automatic identification and data capture to trace reliable information in the forest sector. With traceability, it's possible to trace the origin of forest based products. The proposed traceability architecture will allow some companies engaging in a traceability journey to access new and traditional markets especially if customers impose the use of any kind of certification. As an example, printers are publicly committed to provide their customers with "certified paper". Thus, suppliers must provide the proof that their products are certified in the form of a chain of custody (CoC) certificate. This means that the vendor's products have been manufactured from timber sourced from "well managed forests". Another advantage from holding a traceability system is that the collected information could help companies to optimize their value chain based on better management of transportation flows of raw material and by keeping the right inventory in the best place. The proposed solution increase collaboration between the different supply chain actors through tracing the business processes execution, orchestrating different providers, integrating the different IT application used throughout the wood process and offer a scalable traceability system. In this project and regarding data extraction, we have tested two adapters to communicate with the application layer (XML file and RFID tags). As future work, we should add the other adapters such as barcode and web services. Finally, in this project, a primitive unified data representation model is proposed based on two communication standards: Papinet and StanForD. As future research, a more precise specification of data representation should be defined in order to guarantee the availability of information needed for certification purposes.

Acknowledgement

This work was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC). The authors would like to thank Jean Favreau from FPinnovations (Value Maximization/Decision support) for the support provided to this project.

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Implementing the Physical Internet real-world interface: Beyond business models, the devil is in the details

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Abstract: *The physical internet (PI) is potentially a logistics game changer that will help meet efficiency and environmental constraints associated with moving goods through complex logistical networks. The purpose of this paper is to examine "down to earth" potential roadblocks to the implementation of a PI. Many considerations are examined. In a PI, individual firms will need to deal with a wide range of principal-agent issues. In order to succeed, PI-enabled business models will have to be seamlessly integrated with enterprise information technology infrastructure and mobile devices. Social networks should also be taken in consideration as well as geographical considerations (e.g. international borders, national security requirements, etc.). It is believed that particular attention to infrastructure management and maintenance, value creation and sharing between PI participants, ease of shipping and reception, and real-time tracking will be important drivers for adoption.*

Keywords: *Physical Internet implementation, Physical Internet management, Physical Internet practice, Physical Internet and technology, Physical Internet business models.*

1 Introduction

Finding innovative and efficient ways to move goods is key to national and firm competitiveness. Yet, the transportation sector continues to face many challenges. On one hand, proprietary networks are seldom interfaced. On the other hand, environmental issues abound. For example, in 2010, the transportation sector accounted for almost a third of Canada's greenhouse gas emissions (Conference Board of Canada, 2013). A Physical Internet (PI) would help meet these challenges by solving many efficiency and environmental issues.

The implementation of a PI is bound to allow firms to reach higher levels of efficiency through – among other things – a redefinition of logistical backbones along the value chain (e.g. Montreuil, 2011). Furthermore, it is bound to radically transform business models that many take for granted. Yet, the very concept of the Physical Internet presents significant challenges for its users. Just like the digital Internet had to find its own conventions and *modus operandi*, the PI will face significant issues in its gradual rollout especially since, unlike its digital counterpart, its

traffic will consist in rival goods. This paper takes a practitioner perspective of the challenges associated to the PI's implementation, i.e. it adopts a "when-the-rubber-meets-the-road" perspective and thus is highly prescriptive.

The purpose of this paper is to outline issues for consideration when implementing large-scale PI initiatives since those entail a range of issues that proprietary solutions are not confronted to. In line with the applied nature of this research, the paper is structured as follows. In the first section, a range of considerations for firms are examined. The second section will focus on the integration of PI business models with an IT infrastructure that increasingly relies on mobile devices. The third section will take a closer look at how individuals in PI models may interact through social networks. The fourth section focuses on geographical considerations such as borders, security and the question of redundancy. This paper concludes by putting forward some design considerations and an agenda for academics and practitioners.

2 Considerations for firms

In order to strive in an increasingly competitive environment, it is paramount that firms' strategies demonstrate a high level of fit with their environment (Zott & Amit, 2008) if they want to reach high levels of performance. The PI will force firms to adapt to a new competitive reality and, should the costs of implementing PI initiatives be reasonable for firms in light of potential returns, PI initiatives are bound to become mainstream. The adoption of the PI will be dependent on resolving conflicts inherent to the PI itself. Also, the PI rests on efficient coordination between firms and individuals. These two aspects are explored below.

2.1 Sources of conflicts within the PI

The PI holds a potential for conflicts between the parties involved. Indeed, as the PI takes hold, its decentralized, open source and flexible nature will open up many principal-agent issues (e.g. Eisenhardt, 1989; Holmstrom & Milgrom, 1991). This implies that decisions made by intermediaries along the supply chain will affect the senders, the other intermediaries, and the receivers of merchandise with them having minimal or non-existent input in the process, yet in the end, they may be in a position to bear the economic cost of such decisions.

Decentralization

One source of conflict within the PI framework is attributable to decentralization. In a decentralized environment, actors are often able to make decisions for themselves that affect the way they serve – and interact with – the rest of the ecosystem. This raises potential inefficiencies in the system if some protocols and processes are not centralized. Π-containers are an important means to assist in the management of such issues. However, future steps should also involve the creation of sets of π-processes, akin to the process standardization known at UPS or FedEx.

The PI being a highly decentralized environment, information and knowledge-related asymmetries (Cimon, 2004; Papadopoulos *et al.*, 2008) will need to be carefully managed and factored in. Since many intermediaries would be firms, some may feel that others benefit more from being part of the PI ecosystem than they do. These asymmetries can be managed by setting universal information dissemination standards and by allowing transparency in the system, not unlike some routing processes on computer networks.

Another aspect of decentralization is the potential influence of regional effects. These effects may hinder the implementation of π-processes. For example, all US states and Canadian provinces do not share the same holiday calendars, nor do they all automatically have the same labour regulations. Such considerations may affect the routing and delivery windows of packages as well as costs in unforeseen manners.

Open source nature

The open source nature of the PI is another one of its important characteristics. In an open source environment, actors may freely join, adapt and share what they feel are the best solutions to the issues they are confronted with. That in turn will create the need for an open source innovation process (Chesbrough, 2007) to manage the growing pains caused by the wide adoption of PI as a dominant standard.

This is bound to enable numerous creative fixes to local and hyperlocal logistical challenges. It is not guaranteed that all fixes will be relevant. Mechanisms to ensure ecosystem-wide coherence need to be put in place. A vetting process akin to Wikipedia's for the curation of its online encyclopedia should be developed to ensure the retention of the truly best practices.

Flexibility

The IP's flexibility is another key characteristic and also a potential enabler. Its flexibility entails endless possible network connections and creative routing and processes. Yet, the networks of firms involved in PI should not stifle innovations in their partner firms (e.g. Tomas & Arias, 1995). They risk doing so by imposing rigid sets of processes that will render the PI very beneficial for them, but not for other portions of the networks they belong to. Players that do not have the necessary scale may be tempted to decide that it is best for them to subcontract their process innovation to bigger players and adopt a follower strategy, leading to a suboptimal outcome for the entire IP ecosystem.

Yet, as mentioned earlier, there is a strong rationale for players, notwithstanding their size, to promote some level of optimal trade-off between the need for flexibility while taking into

account the need for relationships to be sustainable over time (Nooteboom, 2000). Because the length of relationships with others and experience within the PI ecosystem will help players build legitimacy.

2.2 In search of efficient coordination

For individual firms to enter in relationships, a coordination mechanism – or a general contracting authority – will need to exist. Coordination mechanisms are usually of three orders. They may be tied to hierarchy, markets or networks (Werle, 2012). In the case of the PI, given its networked nature, formal hierarchy may exist within firms, but would be impractical given the level of freedom actors enjoy by design. Markets would be a useful way to set up a mechanism for PI actors (firms or individuals) to trade transportation possibilities and ancillary services along portions – or the entirety – of a shipment's journey. An auction mechanism is a possibility (Remli & Rekik, 2013). Networks would also be very useful as a mechanism as they could help optimize subsets of the PI and would provide actors the flexibility to coordinate.

Another important issue will be that of PI transparency in terms of data, not only on the actual physical management of the PI (servers, data warehouses, IT tools and apps), but also in terms of pricing. Efficient coordination necessitates high levels of information for actors to allocate resources where they are needed. However, if information about π-processes should be transparent (delays, route congestion, time for typical shipments, etc.) data about shipment contents and shipments of other owners (or agents) should not be public, but limited to the parties involved and the relevant regulatory authorities. A direct implication is for new business models to emerge and for contracting to be easy, flexible and secure.

Business models

New business models should emerge for the PI. Whether they are fee-based or partially anchored in a paradigm around free products and services, whether they are open source or are proprietary to some degree (Cimon *et al.*, 2009), the new business models created will need to be thoroughly tested (Huelsbeck *et al.*, 2011) for the PI to gain legitimacy and become an option for potential participants.

This has two consequences: 1) mechanisms to share intellectual property will have to be put in place. Service-based models adopted by many companies operating in the open-source software paradigm are a relevant blueprint. 2) This means inventing new ways to create and deliver value that comes from intangibles (Lapointe & Cimon, 2009) so that the PI is leverages an ensuing flywheel effect (Collins, 2001), where small effect combine into a wide momentum. This may mean trying to achieve a balance between the complementarity of firms and their cultural compatibility like in the construction industry (Sarkar *et al.*, 2001).

Contracting

Complex supply chains with large numbers of suppliers like in aerospace (Amesse *et al.*, 2001) require modes of contracting the will facilitate their business activities and their responsibilities to one another. Unlike end user license agreements in software that deal with intangibles, the PI ecosystem will deal with physical goods that need to be physically delivered and cared for while in transit. Furthermore, the various firms involved in PI business models will also have to agree on revenue-sharing and conflict resolution schemes. As such, insurance and risk management methods will need to be devised since traditional risk transfer mechanisms may not be sufficient. Indeed, chains of liabilities may put the network at risk through a cascading effect like the one the world witnessed between financial institutions during the financial crisis (2007-2009).

3 The integration of PI business models with IT and individuals.

PI business models will need robust and distributed IT assets. By their very nature, they are boundary spanning (Rosenkopf & Nerkar, 2001) tools that will induce firms, governments and individuals to work together as a network.

Some issues around IT and PI

For the PI network to be fully integrated and seamless, many challenges that pertain to IT in supply chains (Jharkharia & Shankar, 2005) also apply in the PI ecosystem. Connectivity should exist and data transfer should be easy and seamless between actors. Along the same lines, data management will be critical since proprietary data risks finding themselves on open source channels. One possibility resides in leveraging the opportunities afforded by the Internet of Things (IoT) (see Atzori *et al.*, 2010); not only in terms of creating a sentient pervasive distributed environment meshing people and objects, but also in examining the structuration of its governance (Weber, 2013). At the firm level, aligning IT (Rouges *et al.*, 2010) on PI elements that relate to strategy is bound to help reach performance goals.

IT, PI and individual social networks

The PI is network-based and network-enabled. As such, beyond networking firms and objects, interpersonal interactions and communication (within firms or on an informal basis) will be necessary for PI initiatives to be successful. Since interactions take hold in complex social networks of varying structure and density (Provan *et al.*, 2007), a range of best practices will be needed. For example, some attention may be directed toward an optimal number of contacts individuals can manage, such as the Dunbar number that made its way into the popular press (Bialik, 2007).

Mobility

Even though individual work is of an increasingly mobile nature (Chen & Nath, 2008), mobility and social networks go hand in hand (Musolesi & Mascolo, 2007) especially in a PI environment. Such an environment will require a range of collaborative technologies to be developed. One tool that is readily available consists in mobile devices (notebooks, tablets, smartphones, etc.). Their popularity will be an important element in solving collaboration issues within the PI. Two conditions should be met to facilitate their adoption. First, this must be done from a user-centric perspective (Cimon, 2013; Véronneau & Cimon, 2007). Second, individuals' privacy should be managed in order to bring some level of protection that will potentially breed trust (Antoniou & Batten, 2011).

4 Geographical considerations.

Apart from human and IT related issues, PI business models will highlight the importance of geography in logistics (Hesse & Rodrigue, 2004) as they are implemented. On one hand, physical border crossings may prove a challenge as border management processes are better geared to deal with proprietary logistical infrastructures rather than open source ones. On the other hand, security being a defining characteristic of the post 9-11 world, a PI infrastructure needs a novel distributed security paradigm in compliance with government requirements. In line with the rival nature of the goods transported, there will be constraints on levels of redundancy in PI models, thus finding a balance between network optimality and robustness while ensuring resilience (Hamel & Välikangas, 2003) will prove to be another challenge. Finally, culture (e.g. Hofstede, 1991) remains a major factor to contend with, whether national or organizational.

5 Conclusion and implications for future research

In conclusion, the paper outlines a range of "down to earth" considerations that will need to be taken into account when implementing PI models. First, in order to strive in a PI environment, firms will need to find innovative ways to deal with the sources of conflict within the PI that are decentralization, its open source nature, and its flexibility. Efficient coordination will be crucial to PI implementation through innovating business models and contracting mechanisms. Second, PI business models, IT and individual networks will need to be in sync. Firms' strategy should be aligned with their IT, especially in a PI environment. Networking best practices and a user-centric focus on mobility are in order. Finally, awareness of geography in culture will remain an asset in PI networks.

The future is promising for PI initiatives. Moves toward cloud manufacturing environments (Xu, 2012) make the PI an attractive way of managing logistical conundrums in an efficient and sustainable manner. In light of this paper, an important deduction is that particular attention to infrastructure management and maintenance, value creation and sharing between PI participants, ease of shipping and reception, and real-time tracking will be important drivers for adoption.

Beyond this paper, future research will need to delve into product/service delivery and integration, as well as business modeling tools and methods in order to find sources of margins as efficiency gains are made. PI business models are bound to dramatically reshape government (e.g. eGovernment initiatives) and industry (e.g. automotive, aerospace, mobile telecoms, etc.) as their impacts alter global value chains, firm strategies and more.

Acknowledgments

The author would like to thank three anonymous reviewers for the suggestions that improved the quality of this paper. The usual caveats apply.

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May 28-30, 2014 - Québec City, Canada

A PI Allocation of Shipping Contracts using Reliability-Based Auctions

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Abstract: *In the context of Physical Internet solutions and more precisely the freight distribution in π networks, we propose transportation auctions as a mechanism of allocating transportation services to carriers. Transportation procurement auctions allow carriers to bid a transportation contracts for shippers. Generally, winning carriers are determined so that transportation costs are minimized. However, other criteria than price may be considered. This paper proposes a reliability-based winner determination problem for transportation procurement auctions where the allocation of long-term contracts to carriers is decided with respect to both bid prices and carriers reliability. In the Physical Internet context, this model provides the basic tools to help shippers choose the best and reliable carriers. The proposed model compares between situations where reliability is integrated along price for selecting carriers and when it is not. Results show that the proposed reliability model may lead to lower costs.*

Keywords: *Physical Internet ; Transportation auctions ; Reliability ; Travel Time; Congested Time.*

1 Introduction

The Physical Internet (PI) is an open global logistics system – inspired by the Digital Internet - that enables an efficient, sustainable, adaptable and resilient logistics web (Ballot et al., 2012). In the context of PI solutions and more precisely the freight distribution in π networks, we propose transportation auctions as a mechanism of allocating transportation services to carriers. Transportation auctions are particular trading mechanisms used by shippers to select a set of carriers. In a transportation auction a shipper first presents its requests in terms of shipping contracts. Then, a set of carriers submit bids on the contracts they are interested in. Given the economy of scope characterizing transportation markets, carriers are generally permitted to submit bids on a package of contracts enabling thus reducing empty moves in their individual transport networks. A bid submitted on a combination of items is known as a combinatorial bid. In its bid, the carrier gives the set of shipments it offers to serve and the price asked for doing it. After receiving all carriers' bids, the shipper solves the so-called winner determination problem (WDP) to determine winning carriers.

Generally, winning carriers are determined so that transportation costs are minimized. However, several works showed the importance of considering criteria other than the price in the selection process (Patterson et al., 2007). Recently, Rekik & Mellouli (2012) proposed a reputation-based winner determination model. They introduce the concept of hidden costs to quantify the possible additional cost that could be incurred by the shipper when a set of carriers are chosen. This hidden cost takes into account the performance of the carrier for the shipments ensured in the past with regard to a number of criteria such as delays, damages and cancellations. In this paper, we propose to consider the same concept of hidden costs to model carriers reputation but with an emphasize on time criteria. Hence, we will use the term reliability rather than reputation as commonly used in the literature when a carrier time performance is evaluated. We propose a number of improvements to the reputation model of Rekik & Mellouli (2012) by taking into account a number of relevant information to adjust the carrier past performance.

2 Reliability in Transportation procurement

A reliability of a carrier *c* is determined based on the past arrangements between the shipper and carrier *c*. This must be done considering the two following aspects: First, the shipper has to weight the past arrangements with regard to the *time* when they occurred; recent arrangements should have a larger weight than past ones (Huynh et al., 2006). Second, a minimum number of past arrangements must have occurred between the shipper and the carrier so that a fair and relevant judgement of the carrier performance is possible. This minimum number is referred to as the *credibility degree* (Sabater & Sierra, 2001).

We propose to compute a carrier reliability based on two attributes: travel time and congested time.

2.1 Travel Time

The *travel time* computes the required time to deliver the goods. It represents the door-to-door transport time including loading and unloading (Beuthe and Bouffioux, 2008). The shipper has to consider delay in travel time made by carriers in order to determine their reliability. Hence, the reliability of a carrier, based on travel time, is assessed by the distance between two travel time values: 1) the observed travel time (made by the carrier), and 2) the estimated travel time (estimated by the shipper). When this distance increases, the reliability will increases and vice-versa.

Formally, let *s* be a shipment contracted in the past by the shipper to carrier *c*. Let *OT(c,s)* be the value of the travel time observed for carrier *c* for shipment *s*. Let *ET(s)* be the estimated travel time as considered by the shipper for shipment *s*. Define *R(c,s)* as the relative deviation (in percentage) between the observed and the estimated travel times. That is, the reliability *R(c,s)* of the carrier *c* of a shipment *s* is computed as follows:

$$R(c,s) = \frac{OT(c,s) - ET(c,s)}{ET(c,s)} \quad (1)$$

Obviously, the larger the value of *R(c,s)* is, the less reliable is carrier *c*.

In this paper, we propose an innovative way to compute the reliability based on travel time using the following parameters: the time factor and the credibility degree.

2.1.1 Time factor

Let *S(c)* be the set of all past shipments contracted by the shipper to carrier *c*. As already mentioned, not all the past shipments will have the same impact when computing a carrier *c*

reliability. Shippers have to weigh the past shipments with regard to the time when they occurred; recent data should be given more impact than old one (Huynh et al., 2006). Hence, if $\check{R}(c,s)$ is the value computed for shipment *s*, then this value is adjusted by a time factor $\alpha(s)$. We propose to compute this weight as in Huynh et al. (2006). The time factor associated with past shipment *s* is computed as follows:

$$\alpha(s) = e^{-\frac{\Delta t(s)}{\lambda}} \quad (2)$$

where $\Delta t(s)$ is the time difference between the current time and the time *t(s)* in which the shipment *s* was ensured by carrier *c*, and λ is a recency scaling factor depending on the time unit used (Huynh et al., 2006). Huynh et al. (2006) propose to use the exponential function for rating recency since, unlike linear functions, it helps adapt quickly to any changes in carrier performance over time.

2.1.2 Credibility degree

To have a good assessment of a carrier reliability in period *t*, the shipper should have a minimum experience with this carrier at period *t*. Let M denote the number of arrangements required so that a fair judgement of a carrier performance is possible. Let *NB(t(s))* denote the number of past arrangements made by the shipper with carrier *c* at period *t(s)*. Then, the credibility degree coefficient ξ(s) associated with shipment *s* is given by: (Sabater & Sierra, 2001)

$$\xi(s) = \begin{cases} \sin\left(\frac{\pi}{2M}|NB(t(s))|\right) if |NB(t(s))| \in [0, M] \\ 1 \ Otherwise \end{cases} \quad (3)$$

The sin function is used because its behaviour is close to the credibility degree when *NB(t(s))*, the number of past arrangements made by the shipper with carrier *c* at period *t(s)*, is less than *M* the number of required arrangements.

However, often in practice, the deviation between estimated and observed travel times is due to external factors that are not controllable by the carrier. We speak then about *congested time*.

2.2 Congested Time

In the motor carriers mode, the congestion is defined as a situation in witch carrier deliver the freight in usual or desirable manner due to traffic problems (extra distance, weather conditions, and peak hours) (Hensher et al., 2007; Masiero and Hensher, 2010). The congested time is the increase in time relative to deliveries under special conditions. It can be computed based on a set of criteria such as: the population, the weather, the public transit system capacity, the geography, the percentage of trucks in the traffic mix, the employment levels, and the off-peak travel (Langer & Winston, 2006). In our case, the congested time *CT(c,s)* associated with carrier *c* for arrangement *s* is computed based on : (1) the weather congested time $CT_w(c,s)$, and (2) the peak hours congested time $CT_p(c,s)$. The congested time *CT(c,s)* associated with carrier c for arrangement s is computed as the sum of $CT_w(c,s)$ and $CT_p(c,s)$ as follows:

$$CT(c,s) = CT_w(c,s) + CT_p(c,s) \quad (4)$$

2.2.1 *Weather congested Time*

We assume that the weather can take one of these three values: 1) good, 2) medium, and 3) bad. Based on precaution data of highways, there is a correspondence between weather conditions and truck speed (RoadSafety-Canada, 2014). Hence, in a good weather, the speed must not exceeded *(100km/h).* For a medium weather, the speed is limited to (*70km/h)*. Finally, in a bad weather, the speed is limited to *(50km/h)*. For example, if the weather value is "Medium", the carrier must reduce its speed of $30km/h = 100 - 70$ at its normal speed *(100km/h).* Hence, the weather congested time is closely related to the percentage of speed decrease ($\frac{100-70}{100}$).

Let $OD_w(c,s)$ be the observed distance travelled by the carrier *c* in the weather situation for shipment *s*. The weather congested time $CT_w(c,s)$ given to the carrier *c* for arrangement *s* is computed as follows:

$$CT_w(c,s) = \begin{cases} OD_w(c,s)\left(\frac{100-50}{100}\right) & if\ weather\ value = "Bad" \\ OD_w(c,s)\left(\frac{100-70}{100}\right) & if\ weather\ value = "Medium" \\ 0 & if\ weather\ value = "Good" \end{cases} \quad (5)$$

2.2.2 *Peak Hours congested Time*

Based on the precaution information of highways, two intervals of time are considered as peak hours: 1) from 7:30am to 9:30am, and 2) from 3:30pm to 5:30pm. In these two intervals, the speed is limited to *50km/h* instead of *100km/h* (RoadSafety-Canada, 2014).

Let $OD_p(c,s)$ be the observed distance travelled by the carrier *c* in the peak hours for shipment *s*. The peak hours congested time $CT_p(c,s)$ given to the carrier *c* for arrangement *s* is computed as follows:

$$CT_p(c,s) = \begin{cases} OD_p(c,s)\left(\frac{100-50}{100}\right) if\ peak\ hours \\ 0\ otherwise \end{cases} \quad (6)$$

Then, the relative deviation (in percentage) between the observed and the estimated travel times that is attributable to carrier *c* for shipment *s* is given by:

$$\check{R}(c,s) = \frac{\left(OT(c,s) - CT(c,s)\right) - ET(c,s)}{ET(c,s)} \quad (7)$$

Combining all these attributes, the reliability of a carrier *c* is computed as:

$$R(c) = \frac{\sum_{s \in S(c)} \xi(s)\alpha(s)\tilde{R}(c,s)}{\sum_{s \in S(c)} \xi(s)\alpha(s)} \quad (8)$$

3 Reliability-based WDP model

Let *K* be the set of new shipping contracts requested by the shipper in the current auction and *C* the set of carriers invited to participate to the auction. Each carrier $c \in C$ is assumed to submit a set of bids B_c to respond to the shipper's requests. A bid *b* in B_c is a pair (K_b;BP_b) where K_b is the

set of contracts in K that carrier c offers to serve in its bid b and BP_b is the price asked to serve all these contracts. Let x_b a binary decision variable defined for each submitted bid b such that $x_b = 1$ if bid b wins, and 0; otherwise.
Consider also a set of constant parameters δ_{bk} such that $\delta_{bk} = 1$ if bid b offers to serve contract k and $\delta_{bk} = 0$; otherwise.
The WDP can be modelled as follows:

$$(P) : Min\ Z(x) \tag{9}$$

$$\sum_{c \in C} \sum_{b \in B(c)} \delta_{bk} x_b \geq 1\ \forall\ k \in K \tag{10}$$

$$x_b \in \{0,1\}\ \forall\ c \in C, b \in B_c \tag{11}$$

Model *(P)* is a set covering formulation that minimizes a given objective function *Z(x)*. In case winning bids are determined based on carriers' ask prices only, the objective function *Z(x)* is formulated as:

$$Z(x) = \sum_{c \in C} \sum_{b \in B_c} BP_b x_b \tag{12}$$

In the reputation-based model proposed by Rekik & Mellouli (2012), the objective function has the form:

$$Z(x) = \sum_{c \in C} \sum_{b \in B_c} (BP_b + HC_{cb}) x_b \tag{13}$$

where $HC_{c,b}$ represents the unexpected hidden cost that the shipper would additionally pay if carrier c wins bid b given the carrier c reputation. In other words, unexpected hidden costs translate in monetary values the reputation of the carrier in terms of shipping performances. Constraints (10) guarantee that each contract is covered at least once by carriers' bids. Constraints (11) are integrality constraints.
In our context, hidden costs are determined based on the carrier reliability. More precisely, if D_k denotes the cost incurred by a carrier for a unit time delay in contract k, then the hidden cost that could be incurred by the shipper if contract k is assigned to a carrier c is given by:

$$HC_{c,k} = D_k \times R(c) \times ET(c,k) \tag{14}$$

ET(c,k) is the time the shipper estimates for ensuring shipment k by carrier c. Given combinatorial bidding context, it is assumed that all the contracts in a winning bid must be allocated to the carrier winning this bid. We rather then consider a hidden cost associated to a bid b submitted by a carrier c as:

$$HC_{c,b} = \sum_{k \in K_b} D_k \times R(c) \times ET(c,k) \tag{15}$$

4 Experimental Results

In order to highlight the usefulness of the integration of the reliability in the carrier selection process, two scenarios are compared. In the first scenario (scenario 1), carriers are determined

based on bid ask prices only. The second scenario (scenario 2) takes into account both ask prices and carriers reliability.

Three problem settings are generated. Each problem setting is defined by: the number of auctioned contracts $|K|$, the total number of submitted bids $|B|$, the number of participating carriers $|C|$, and the number of past arrangements $|H|$ considered to evaluate carriers reliability. 50 instances are randomly generated for each problem setting. For each instance, we compute the relative increase (in percentage) in bid ask prices yielded by scenario 2 compared to scenario 1, and the relative savings (in percentage) in hidden costs and total costs obtained for scenario 2 compared to scenario 1. Table 1 reports the average increase and the average savings (AV) over the 50 instances of each problem setting, as well as the corresponding standard deviation (SD). A percentage saving/loss for an instance *i* and a performance measure PM is computed as:

$$\frac{P^2(PM,i) - P^1(PM,i)}{P^1(PM,i)} \times 100 \quad (16)$$

where $P^1(PM, i)$ is the value of the performance measure *PM* with scenario 1 for instance *i* and $P^2(PM, i)$ its value for scenario 2. Observe that for scenario 1, the delay hidden costs is computed a posteriori once the winning bids are determined based only on ask prices. Hence, when the value in equation (16) is negative this means that scenario 2 performs better than scenario 1 for the corresponding performance measure.

Table 1: Impact of considering carriers reliability on transportation costs

Scenario Family	Bid Price		Hidden Cost		Total Cost	
(|K|; |B|; |C|; |H|)	AV	SD	AV	SD	AV	SD
(|20|; |100|; |10|; |1000|)	0.10	0.35	-4.62	6.60	-0.80	1.24
(|40|; |120|; |20|; |2000|)	0.74	0.68	-14.73	9.78	-1.48	1.09
(|60|; |180|; |30|; |3000|)	1.07	0.97	-17.78	11.75	-2.39	1.59

The results of table 1 show that the scenario 1 always generates direct costs that are lower than those obtained with scenario 2. This result is expected since scenario 1 selects carriers that minimize only the total bid ask price. The average increase in bid prices for scenario 2 ranges between 0,10% and 1,07%. The opposite behaviour is observed for total hidden cots (the lowest values are always obtained with scenario 2). This was also predictable given the objective function of the WDP considered in Scenario 2. However, it is clear from Table 1 that the saving in hidden costs is much more important in scenario 2 versus scenario 1 (up to 17,78%) against a relatively smaller increase in direct costs (no more than 1,07%) yielding a saving in total transportation costs for all the instances that reaches 2,39%.

Hence, although considering reliability may yield an increase in the direct costs, a significant saving in the total transportation costs can be achieved when the reliability of carriers is considered.

5 Conclusion

This paper proposes a reliability-based WDP to determine the winners of a transportation procurement auction. In the Physical Internet context, this model provides the basic tools for shippers in order to evaluate the bids they receive from carriers and guarantee that they are operating with the reliable ones. The results of our experimental study show that considering carriers reliability in the WDP may yield an increase in the total direct cost (bid ask-price) incurred by shippers when compared to the situation where only bid prices are considered. However, this increase is rewarded with an important saving in hidden costs and in total transportation costs. Integrating such a reliability-based system with current e-procurement operations is challenging but mandatory in the global logistics system the physical internet offers.

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Designing Business Models for Physical Internet Transit Centers

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Abstract: *The emergence of the holistic concept of the Physical Internet enables transforming the ways physical objects are designed, manufactured, and distributed. The Physical Internet provides a new open and interconnected structure to logistics networks, allowing to reconfigure business models and value creation patterns. As the Physical Internet is being further conceptualized and experimented, it becomes critical to rigorously investigate how its induced new generation of open logistics centers are to be designed and managed. The focus of this paper is to investigate a specific type of Physical Internet logistics centers, termed Transit Centers, from a business design and strategic management perspective. The emphasis is put on their potential business models, by bringing into play a business modeling canvas as a visual tool for envisioning their business operations. The proposed business models address the utility of deploying the Physical Internet to potential service providers of such nodes.*

Keywords: *Strategic Management; Canvas Business Model; Physical Internet; Transit Center; Business Model Design; Interconnected Logistics; Mobility Web*

1 Introduction

In today's modern world, logistics networks are yet deemed to be lacking in terms of both efficiency and sustainability from economic, environmental, and social aspects (Montreuil, 2011). The dominant dedication to either one user or one service provider, the emptiness of trucks and containers at departure, and the long travelling times of truck drivers, utterly result in poor asset utilization, low performance, reduced personal life for drivers, and low service levels. The Physical Internet (PI, π), as a solution to this grand challenge, is defined as a global open logistics system founded on physical, digital, and operational interconnectivity, through encapsulation, interfaces, and protocols (Montreuil et al. 2013). It enables the evolution towards interconnected logistics. Users are to exploit it through a Logistics Web, a network of open logistic networks, which can be conceptualized as having five constituents: Mobility Web, Distribution Web, Realization Web, Supply Web, and Service Web, respectively and synergistically devoted to moving, storing, realizing, supplying, and using physical objects.

This paper is to focus on the constituents responsible for good movements (i.e., the Mobility Web), and its open logistics nodes. In particular, our goal is to analyze how such nodes should be designed and managed from a strategic management point of view, in order to facilitate forthcoming Physical Internet deployment. Montreuil *et al.* (2010, 2014), Ballot *et al.* (2014) and Meller *et al.* (2014), have all addressed the physical and operational design of Physical Internet hubs and transit centers. Montreuil *et al.* (2012) have explored Physical Internet induced business model innovation.

To the best of our knowledge, there is no published study that focuses on Physical Internet logistic nodes and their management. So as to contribute toward filling this gap, we strategically study key strategic aspects such as what is to be their mission, how they are to add value, what are to be the services they are to commercialize, what are to be their revenue streams, how they are to insure service reliability and to deal with liability in cases of service disruptions, how they are to grow, and how they are to make profits and be viable in the long run.

The paper is structured as follows. We first describe the functional design of Physical-Internet Transit Centers, based on the pertinent literature. We next introduce the Business Modeling Canvas of Osterwalder and Pigneur (2010) and use it as a basis for defining the essence of business models for Physical Internet Transit Centers. Third, we address the potential growth strategies for Physical Internet Transit Centers. Finally we provide avenues for further research resulting from our exploratory research.

2 Physical Internet

The paradigm-breaking Physical Internet, conceptualized as a metaphor of the Digital Internet, enables the transmission of all products through encapsulation in world-standard, modular, re-usable, and smart π-containers, similarly as moving data through encapsulation in standard packets under TCP-IP protocols (Montreuil, 2011). This standardization allows any firm to handle any other firm's encapsulated products. The Physical Internet is to exploit a new generation of logistics facilities as π-nodes, including π-Hubs, π-Transit Centers, π-Warehouses, π-Distribution Centers, etc. These π-nodes are unique in design and managerial perspectives.

By focusing on π-Transit Centers, Figure 1 sourced from Montreuil (2011) shows significant results of exploiting these nodes, in comparison with the current approach: it allows reducing source-to-destination delivery time by 50% for a shipment from Québec City to Los Angeles, unlocking a potential for significant productivity gains for drivers, tractors and semi-trailers.

The following section will explain the process for interconnecting and operating these π-Transit Centers.

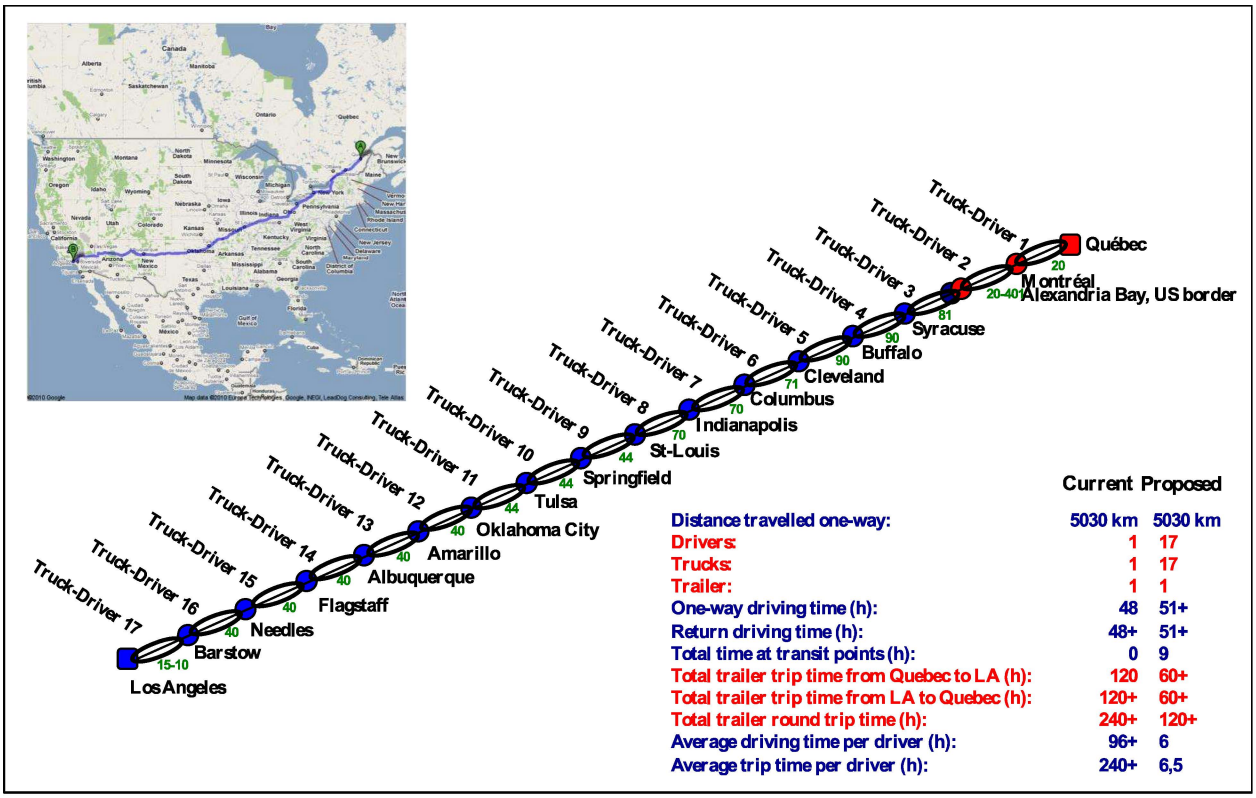


Figure 1: Illustration of an interconnected truckload transportation of trailers across a Mobility Web

2.1 Uni-Modal Physical Internet Transit Center Description

Π-transit centers are among the simplest nodes in the Physical Internet. They are used to transship trailers from one truck to another, in order to facilitate the delivery of trailers from their source to their destination. In particular, π-transit centers are to accommodate three main entities: tractors, semi-trailers, and drivers. Hereafter in this paper, we freely interchange the terms tractor and truck, semi-trailer and trailer, as well as driver and trucker. For a π-transit, a semi-trailer is treated as a single entity, indeed as a black box. It may contain a set of π-containers, but the π-transit will not deal explicitly with these. Each inbound and outbound semi-trailer has to be assigned to a tractor and a driver. All trailers must depart from their original source and reach their final destination within some specified time window. All trailer-truck-trucker (T^3) triads depart from their current location (source, final destination or π-transit) and move toward their next destination (source, final destination or π-transit) according to an agreed upon delivery time window. Truckers' daily driving hour limitations are considered as well as their choices regarding their favorable destination at the end of their work day.

Figure 2 sourced from Meller et al. (2012) shows the proposed functional design. Its unique and efficient design is readily observable.

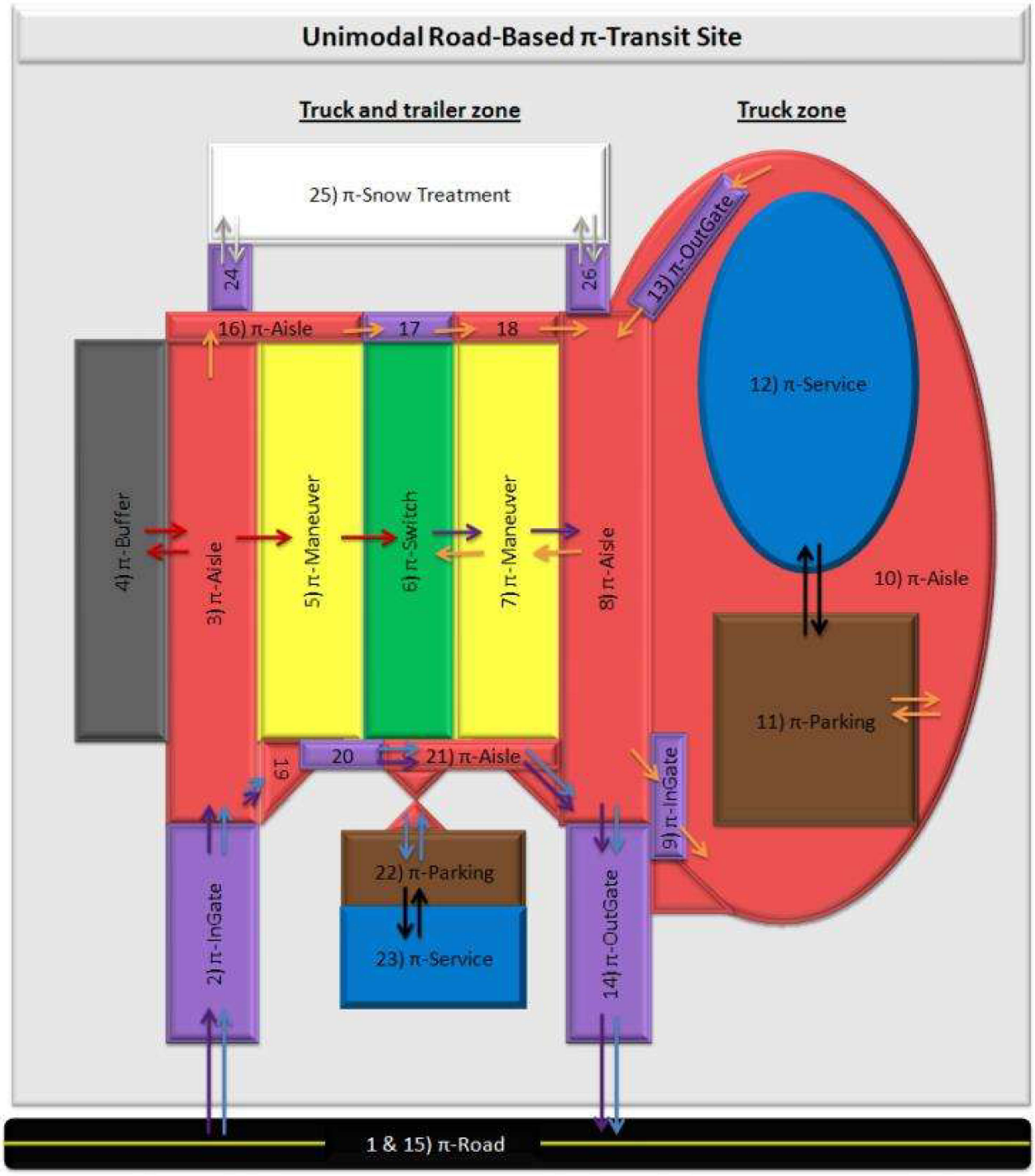


Figure 2: Block Layout for the proposed functional design

Π-transit centers are planned and managed using information from each entity involved. This information is recorded in databases, which are manageable by a negotiation protocol under what we call here the π-system. The π-system monitors movements in real time and knows the exact location and state of all trucks, trailers, and π-nodes at all times. The operational process which is guided through this π-system is as follows:

- A T^3 triad signals its intention to visit a π-Transit Center. This triad can arrive from various locations including another π-transit, trucker's home, local pick up or delivery point, or some other π-node.
- Before arrival, the π-system, through the provided information system and databases, gathers information about the capacity of the π-transit, current trailer-truck-driver triads inside the π-transit, potential T^3 triads likely to visit the facility, and their satisfactory routes. Based on this information, it finds the best match between distinct components of T^3 triads, and books a location in the π-transit for further tasks. The location for unhook-hook trailers-trucks is called π-switch.
- After arrival of the T^3 triad near the π-transit, it leaves the π-road and enters to the entrance gate of the π-transit, under the term π-InGate, for a rapid deep-security scan, entrance authorization, and getting a work order. Indeed, the π-system transfers a work order to the truck's dashboard computer. Each work order is obtained by optimizing algorithms to reduce traffic and time wasted. This work order shows every reachable area for the set of T^3 triad in the facility. After the driver acknowledges the work order and confirms its acceptance, the entrance authorization is issued and the blocking barrier is allowed to rise. The π-InGate counts the number of trailers, trucks, and drivers entering the facility. In the case that the π-transit is faced with high load of work, parking for trucks and services for drivers are considered next to the π-InGate to prevent a queue.
- After entrance of the T^3 triad in the π-transit, it moves through provided four-way roads, under the term π-Aisles, to find its booked π-switch bay as specified on its work order. Two scenarios might happen. If the π-switch is full, the set will be headed to the temporary waiting location, called a π-buffer. Otherwise, if the π-switch is free, it will go through a provided place between π-aisles and the π-switch, a space called a π-maneuver, and will enter to its booked π-switch bay. Π-maneuver in between π-aisles and the π-switch is provided to prevent potential traffics that might happen in π-aisles when a set wants to enter to the π-switch.
- After entrance to the appropriate π-switch bay, the trailer is unhooked from the truck-driver dyad. The unhooked trailer will wait for its next assigned truck-driver dyad, while the available empty truck-driver dyad will leave the π-switch, passing the π-maneuver and, based on its work order, move through π-aisles to find the next determined π-switch to hook the next planned trailer. In the case a T^3 triad enters a wrong π-switch, an alarming system on the truck's dashboard computer announces it and guides the driver to find the accurate one.
- The empty truck-driver dyad next enters a new π-switch and waits until its next trailer is hooked to it. It might take time for the π-system to find the best match between the unhooked trailer and an empty truck-driver dyad with the same intended destination. If the best match is not available, the unhooked trailer is transferred by an employee to the temporary waiting bay, π-buffer, while the empty truck-driver dyad is guided toward the truck zone which provides the π-service and the π-parking. The truck zone has a π-InGate and a π-OutGate to check the sets and count them to inform its free capacity. The π-parking provides places for keeping trucks while π-service provides washroom, restaurant, a small park containing trees, benches, picnic tables, etc., for serving drivers. The empty truck-driver enters to this zone through the π-InGate, passes π-aisle, and enters to the considered π-parking; it will wait in this truck zone until an appropriate trailer will be found by the π-system. When a match is found with a trailer the truck-

driver leaves the π-parking, enters to the π-aisle, moves toward the π-OutGate of truck zone, enters to π-aisles of truck and trailer zone, and moves toward the π-switch where the trailer is waiting.

- When a set is matched and the process is done, the new T^3 triad leaves the π-switch, passing the π-maneuver, and moves through π-aisles. Now the new T^3 triad can leave the π-transit through the π-OutGate directly or use truck zone services before leaving. In the case it wants to leave, the T^3 triad will enter to π-OutGate, a security check will be done, the authorization will be issued, the barrier will rise, and the T^3 triad will leave the π-transit. After a T^3 triad leaves the π-transit, the π-system updates its information and databases.

Figure 3 sourced from Meller et al. (2014) presents an overview of the flow of trucks and trailers in a π-transit. Explanations are related to the process inside π-switches.

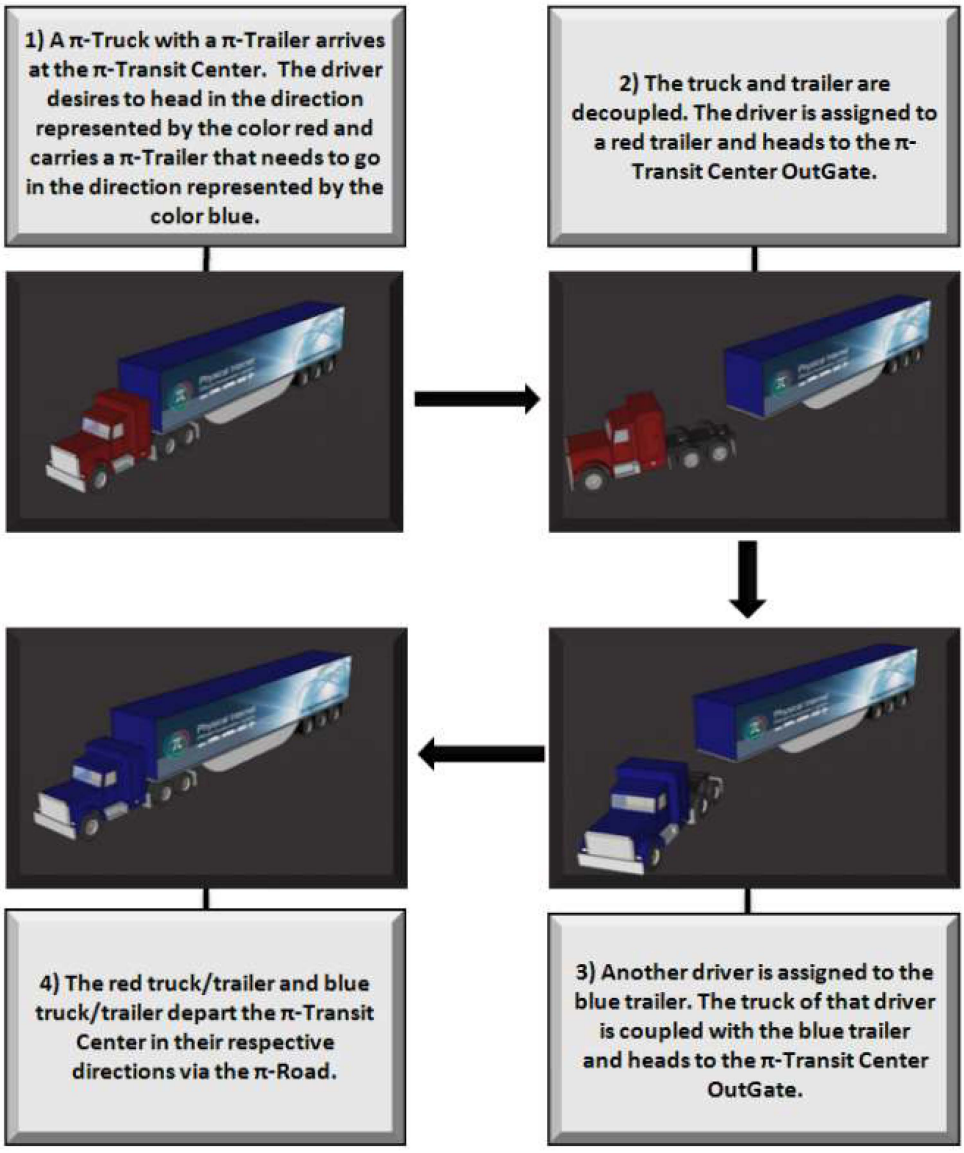


Figure 3: Overview of the flow of trucks and trailers in a Physical Internet Transit Center

Figure 4 sourced from Meller et al. (2014) shows the final 3D layout of a proposed design (front aerial view). It gives a perspective of the truck zone, the truck and trailer zone, and the π-gates, which leads to a better realization of the efficiency in the design of the π-transit.

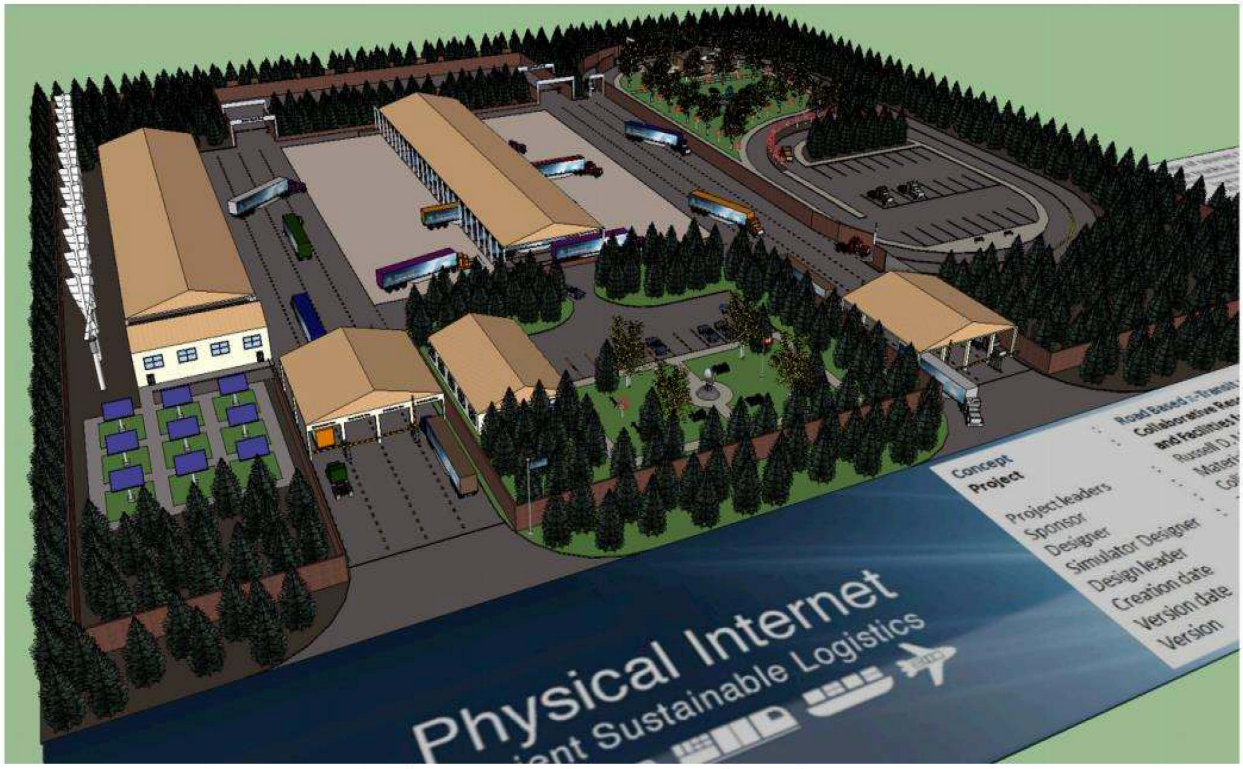


Figure 4: Final layout of a proposed design (front aerial view)

The π-transit has two key sets of stakeholders with distinct goals and expectations: its customers and its owners/operators. Customers include transportation service providers (Truck-Driver), transport service brokers (Truck-Driver), and shippers (Trailer). These customers will evaluate the performance of the π-transit based on key potential factors such as:

1) Average processing time inside the π-transit (Trailer-Truck-Driver);
2) Average percentage of departures in preferred or satisfactory direction (Truck-Driver);
3) Average percentage a π-Transit Center is able to manage rushed situations successfully (Trailer).

Π-transit owners/operators are interested in gaining competitive advantage through increasing the π-transit center capacity, attracting new customers, and keeping their current profitable customers through unique services. From a center design perspective, important factors for these stakeholders are:

1) Area of π-transit center;
2) Number of π-gates (In/Out);
3) Number of π-switches;
4) Number of π-parkings for trucks and trailers;
5) Average percentage of time the capacity of π-transit is full and Trucks/Trailers are rejected from entering (Meller *et al.*, 2012).

A better understanding of the functional design of the π-transit center raises the necessity to explore its managerial aspects and to define its innovative business model. The next sections introduce such concepts.

3 Business Modelling

A business model is a heuristic logic a firm will use to create value in a competitive environment. Osterwalder and Pigneur (2010) define business models as: "*The rationale of how an organization creates, delivers, and captures value".* Companies that have already designed their business model should also consider the dynamic environment and improve their business model, involving modifications in their value creation patterns (Montreuil et al., 2012). To help managers in defining their business model, Osterwalder and Pigneur (2010) have developed a business model canvas, a powerful visual and intuitive tool that gives a better perspective of company's businesses. The key components embedded by the authors in their canvas include customer segments, value proposition, customer relationships, channels, key resources, key partners, key activities, revenue streams, and cost structure:

- Customer Segments: Profitable customers are centers of attention of businesses and their strategies. Companies will categorize their customers and serve them through various strategies and distinct products and services. Categories of customers are based on their mutual needs, expected behavior, and other attributes. This block therefore addresses various categories of customers, especially the profitable segments a firm wants to focus on.
- Value Proposition: it is the aggregation or bundle of benefits a firm offers to its customers. Proposed value of a firm can be an innovative value, representing a disruptive offer, or the same value in the existing market with significant added attributes. Value proposition are classified into two categories including qualitative and quantitative values. Qualitative values address customer service and newness, while quantitative values address price, performance, and speed of services. Customers, based on their expectations, give various weights to these values. This block notably addresses the services or products a firm provides.
- Channels**:** they address the tools and approaches a firm uses to reach its customers and deliver its value to the market. They include sales forces, websites, networking, etc. Firms can reach their customers through their own channels, partners' channels, or a combination of both.
- Customer Relationships: they address various methods a firm uses to contact its customers. Goals out of making these relationships are customer acquisition, customer retention, and sales enhances. A firm might choose multiple types of relationships, from collaboration to automated services, for various segments.
- Revenue Streams: they address cash inflows a firm generates. It can also encompass any new, novel, undiscovered, potentially lucrative, innovative, and creative tools for income generation or a potential exploitation. Revenues can be made in transactional or recurring types. Transactional revenues address incomes from one time customer's payments, while recurring revenues correspond to incomes resulting from customer's ongoing payments.

- Cost Structure: it addresses all expenses a firm must take into account to provide a service or a product. Cost structure can be used in cost-based pricing strategies. Business models can be classified into two categories: value-driven approaches and cost-driven approaches. Cost-driven approaches focus on minimizing costs, while value-driven approaches focus on maximizing delivered values to customers. The spectrum of costs can be classified as strategic, tactical, and operational costs, while another classification can be fixed costs at one end and variable costs at the other end of the spectrum.
- Key Resources: they address any resource a firm uses to operate its business processes and make profit. They can be human resources, tangible resources (e.g., plant, machineries), intangible resources (e.g., knowledge, brand image), and financial resources. Key resources can be owned or leased from strategic partners.
- Key Partners: partnership is a successful approach to establish business operations between two or more firms, share management and profits, and access to more resources. Through partnerships, firms not only can gain access to various resources, but can also focus on their capabilities and propose unique products or services. This block is to address key partners a firm will choose to work with based on their capabilities;
- Key Activities**:** they address all the economic, environmental, and social activities a firm carries out to create value for its stakeholders. Activities are to be in line with the mission of the firm and its value proposition.

4 Π Transit Center and Business Modelling

Based on Osterwalder and Pigneur's Canvas Business Model (2010), the various business design facets of π-transits will be highlighted and classified into distinct blocks. It will therefore facilitate the analysis of various essential aspects of this type of logistics center, a necessity for superior strategic planning.

4.1 Π-Transit Center Customer Segments

A primary classification for the π-transit center customers segregates them into three key segments: transportation service providers (truck-driver providers), transport service brokers (truck-driver providers), and shippers (trailer provider). It is also applicable to categorize these three segments in a secondary classification, based on their usage of π-transit center services over a time span. Such a classification can for example exploit four distinctive segments: elite customers, strategic customers, regular customers, and transactional customers. More specifically:

- Elite customers are the most valuable segment of customers. In a determined time span, for example one month, not only their number of usages is salient, but also they use the π-transit continuously, so they are important loyal customers for the π-transit center. They are strong contributors to profit for a π-Transit Center and its owner/operator should plan for significant retention and prioritization strategies to keep them as satisfied customers;
- Strategic customers are the segment with a continuous yet lower usage frequency of the π-transit center over a time span. Their contribution to the profitability of the π-transit center is individually lower than elite customers, but they are loyal to facility and jointly they provide a sure source of profit. As a result, it is essential for the owners/operators to plan for strategies to keep them, especially as they could become future elite customers;

- Regular customers are the segment with the highest collective number of usages but with the lowest individual continuity of usage over a time span. These customers ensure a high load of work, insuring a steady inbound cash flow, so the π-transit center owners/operators should invest on attracting and retaining them;
- Transactional customers correspond to the segment with the lowest number of usages as well as the lowest continuity of usage over a time span. The owners/operators of a π-transit might hesitate to plan for strategies on attracting or keeping them for further work, since they have low share in profitability of the π-transit center; yet these customers can be potential regular, strategic, or elite customers and planning for them may be essential both for profitability and for PI openness integrity. Figure 5 illustrates this secondary classification of customers.

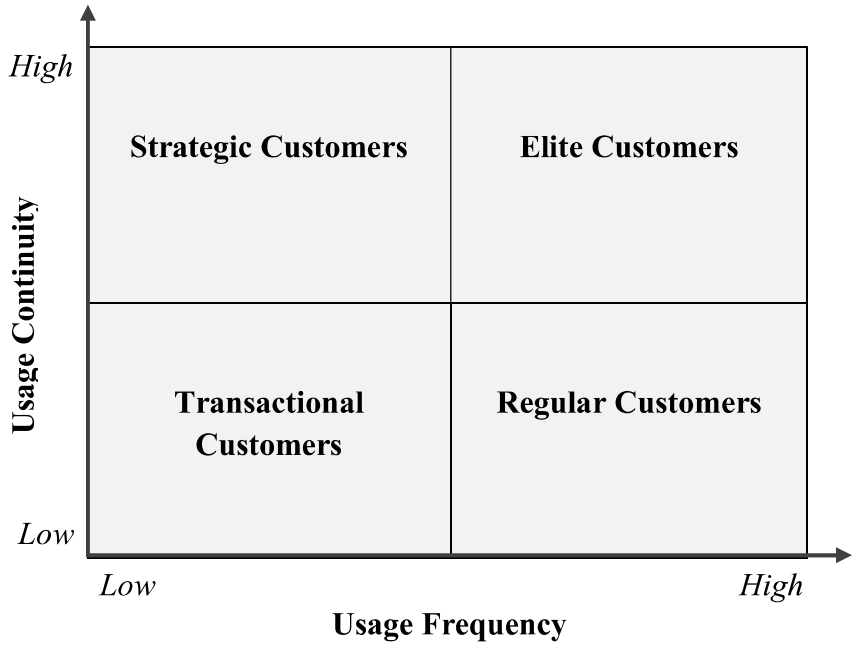


Figure 5: π-Transit Center Secondary Customer Segments

4.2 Π-Transit Center Value Proposition

The potential portfolio of services offered by a π-transit includes access services, matching services, parking services, resting services and short-term storage services.

- Access service, which is provided by the π-InGate and the π-OutGate of the truck zone and the truck and trailer zone is to address the entrance and exit security checking. It encompasses the initial entrance and final exit authorization, as well as the work order delivering for each set of trailer-truck-driver.
- Matching service is to address finding the best match for sets of trailer-truck-driver through the π-system and performing the physical matching process provided by locations, equipment, and administrative employees.
- Parking service is to address the embedded locations inside a π-Transit Center for trucks according to their needs.

- Resting service is to address embedded washroom, cafeteria/restaurant, and pleasant environment for drivers during their sojourn inside the π-transit center.
- Buffering service is to provide locations (π-buffer) inside the π-transit center, for those trailers waiting to have a well matched truck, for example for up to a few hours. In this case, the trailer would be transferred to a π-buffer by an employee and wait there.
- Storage service is to provide trailer or truck storage space for agreed upon durations, upon explicit customer request.

A π-transit can gain from insuring the quality and reliability of its services, notably through a service guarantee engagement.

4.3 Π-Transit Center Channels

A π-transit can reach its customers based on two main channels: indirect services via platforms and direct services via personalized contacts. On one hand, all essential information is provided through a platform and customers from every segment can exploit it. On the other hand, the π-transit might serve more profitable customers through personalized direct contacts, like elite customers who are power poles for the firm or strategic customers who are loyal and provide a stable profit.

In some cases, we can imagine a customer service manager sent to these customers to propose or validate some services. Customers might also not be interested in more formal relationships. However, depending upon on the management philosophy of a specific π-transit center, all four customer segments can be served by both channels.

4.4 Π-Transit Center Customer Relationships

A π-transit can exploit various strategies for its relationships with customers. Based on the importance of customer segments, distinct approaches may be used.

For example, elite customers and strategic customers can be served through collaborative relationships. Collaboration in the π-transit center is conceptualized as direct, person-to-person tight relationships, leading to a well-established mutual recognition, more information exchange, and more coherency between proposed services and their needs. It may result in customized services proposition, higher service level, more loyalty, customer satisfaction, and customer retention in the long-term.

Transactional customers and regular customers could be served through cooperative relationships. Cooperation in the π-transit is defined as one discrete relationship with customers, the latter being served through a platform or via direct relationships on request. It means that the π-transit operator serves these customers through its current superior services, made public on the PI Mobility Web platform, without customizing services for them. Also these segments might not be interested to have more relationships with the π-transit center.

Figure 6 shows the summary of potential customer relationships based on channels and customer segments.

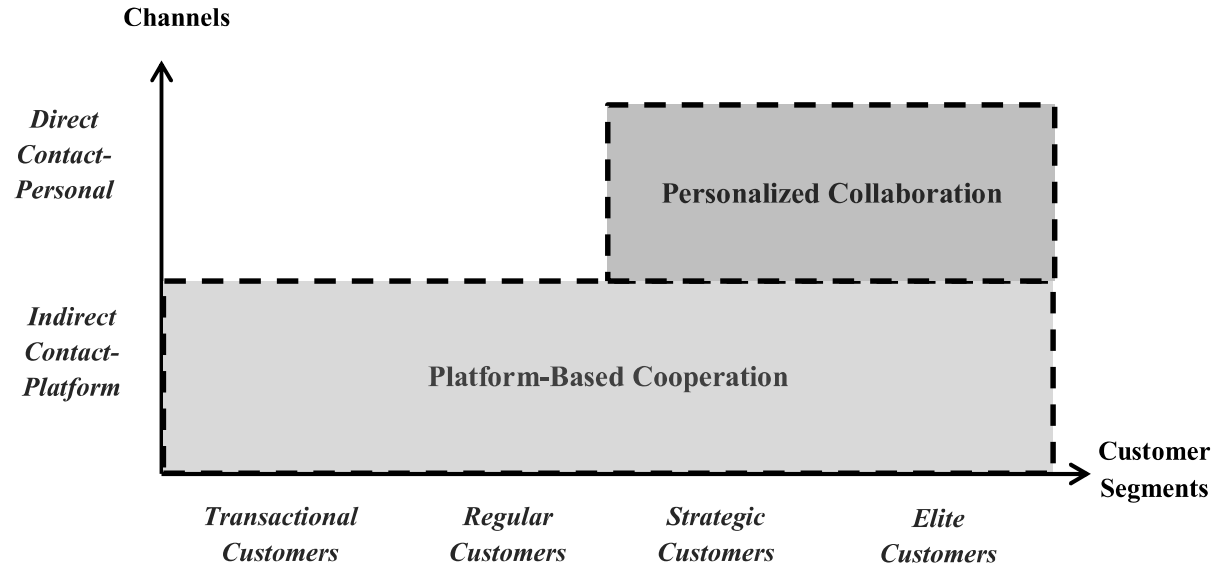


Figure 6: π-Transit Center Customer Relationships based on Channels and Customer Segments

4.5 Π-Transit Center Revenue Streams

The main revenue streams for a π-transit are through its provided services including access services, matching services, parking services, resting services and buffering services; while subsidiary revenue streams are renting extra capacity and proposing storage services.

The π-transit, based on its goals, objectives, and mission, might exploit various strategies for its services, including pricing strategies. For now, Physical Internet Webs are new and may provide unique non-competitive services, as they are at the first stage of the business life cycle. Nevertheless, when competitors will have their own π-transit, various pricing strategies based on differentiation or cost leadership strategies will become necessary. Table 1 positions strategic goals versus these potential pricing strategies. Complementarily, Table 2 clarifies concepts of various potential strategic goals and pricing strategies.

Table 1: Matching Potential Goals and Pricing Strategies for a π-Transit Center

Potential Objective	**Potential Strategies**									
	Multiple Pricing	Service Line Pricing	Skimming Pricing	Good, Better, Best Pricing	Optional Service Pricing	Penetration Pricing	Premium Pricing	Service Bundle Pricing	Loss Leader Pricing	Competitive Pricing
Profit Maximization	✓	✓	✓							
Revenue Maximization			✓	✓	✓	✓		✓		
Quantity Maximization	✓			✓		✓		✓	✓	
Profit-Margin Maximization			✓				✓			
Quality Leadership		✓			✓		✓	✓		
Partial Cost Recovery								✓	✓	

Survival	✓	✓	✓
Status Que			✓

Table 2: Concepts Underlying Potential Goals and Pricing Strategies for a π-Transit Center

Goal	Concept	Strategy	Concept
Profit Maximization	Maximize facility's returns	**Competitive Pricing**	Pricing in the line with competitors for same services
Revenue Maximization	Maximizing revenue from the sale of services	**Good/Better/Best Pricing**	Offering same services with various price levels
Quantity Maximization	Maximizing the number of sold services to follow economies of scale	**Loss Leadership**	Providing one service with low prices Attracting customers for other services and future purchases
Profit Margin Maximization	Maximizing the per unit profit margin of selling a service	**Multiple Pricing**	Pricing per service-usage in the line with prices for more serving Motivating customers to use for greater number
Quality Leadership	Signaling the high quality of service, by a high price	**Optional Service Pricing**	Charging low extra money for optional services
Partial Cost Recovery	Selling services through the lowest cost Exploiting other sources of income for compensating costs	**Penetration Pricing**	Proposing the lowest price for services Attracting/Growing the market share while gaining minimal profit
Survival	Pricing just to stay in business and recover essential costs	**Premium Pricing**	Selling unique/high quality services for buyers less sensitive to prices
Status Quo	Pricing in the line with competitors Maintaining stable levels of profit	**Product/Service Bundle pricing**	Proposing a group of services at a discounted price
-	-	**Product/Service Line pricing**	Selling a range of complementary services together
-	-	**Skimming Pricing**	Setting highest price the same as premium pricing Setting lowest price when competitors enter Setting highest price when no competitor available Increasing prices when demand enhanced Reducing prices

when demand decrease

4.6 Π-Transit Center Cost Structure

The cost spectrum of π-transits encompasses three main types of expenses as synthesized in Figure 7. The top of the spectrum concerns the strategic costs which address initial and less iterative expenses such as initial investments, land costs, sites costs, fixed employee salary costs, fixed management costs, services costs, etc. At the bottom of the spectrum, we can find the operational costs which address highly iterative day-by-day costs, such as throughput costs and resource utilization costs. In the middle of the spectrum lie tactical costs. They correspond to expenses dependent on π-transit workload such as extra employee hiring costs, extra services costs, extra administrative cost, and extra management costs. In seasons with high workload, a higher number of operators and managers are needed.

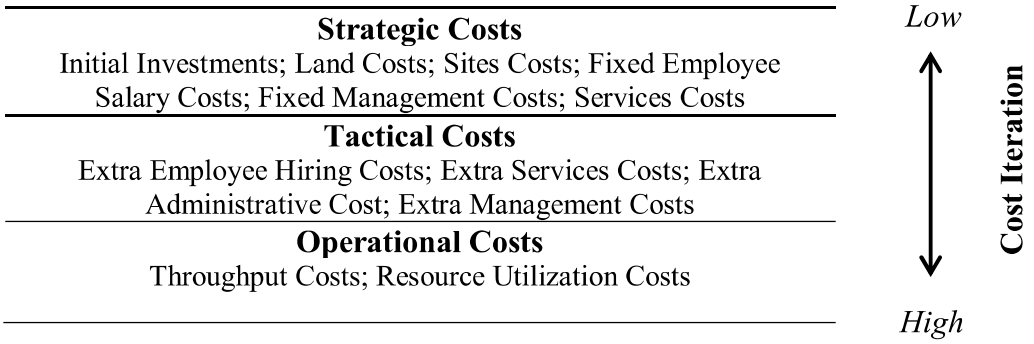


Figure 7: π-Transit Center Cost Spectrum

4.7 Π-Transit Center Key Resources

In order to exploit a π-transit, a wide range of resources are essential including physical, technological, and technical assets as well as human and financial resources, as was outlines in section 2. A π-transit can thus use various strategies for managing these resources such as partnerships in which companies provide these resources as their exclusive services.

4.8 Π-Transit Center Key Partners

The potential partners of a π-Transit Center can notably be technology providers for supplying technological needs; routing service providers for supplying trailers, trucks and drivers; governments for supporting various facilities or investments; other π-nodes for supplying extra capacity in season with high workload; or other problem solving supports inside Webs. Key customers such as transport service providers and transport service brokers can also be considered as partners as previously explained.

4.9 Π-Transit Center Key Activities

The π-transit center is involved with various tasks necessary for providing expected services, with the core activities described in section 2. In particular, based on π-transit center design and goals, these tasks involve accessing services of the π-InGate and the π-OutGate of truck and truck-trailer zones; providing matching services including administrative and managerial tasks;

providing parking, resting services, and short-term storage including administrative tasks; monitoring, controlling, and evaluating the π-transit center profitability through cost and performance assessment; and finally motivating human resources toward better performance.

4.10 Π-Transit Center Business Model Canvas Overview

Figure 8 shows an overview of key components of the business model canvas of π-transit centers.

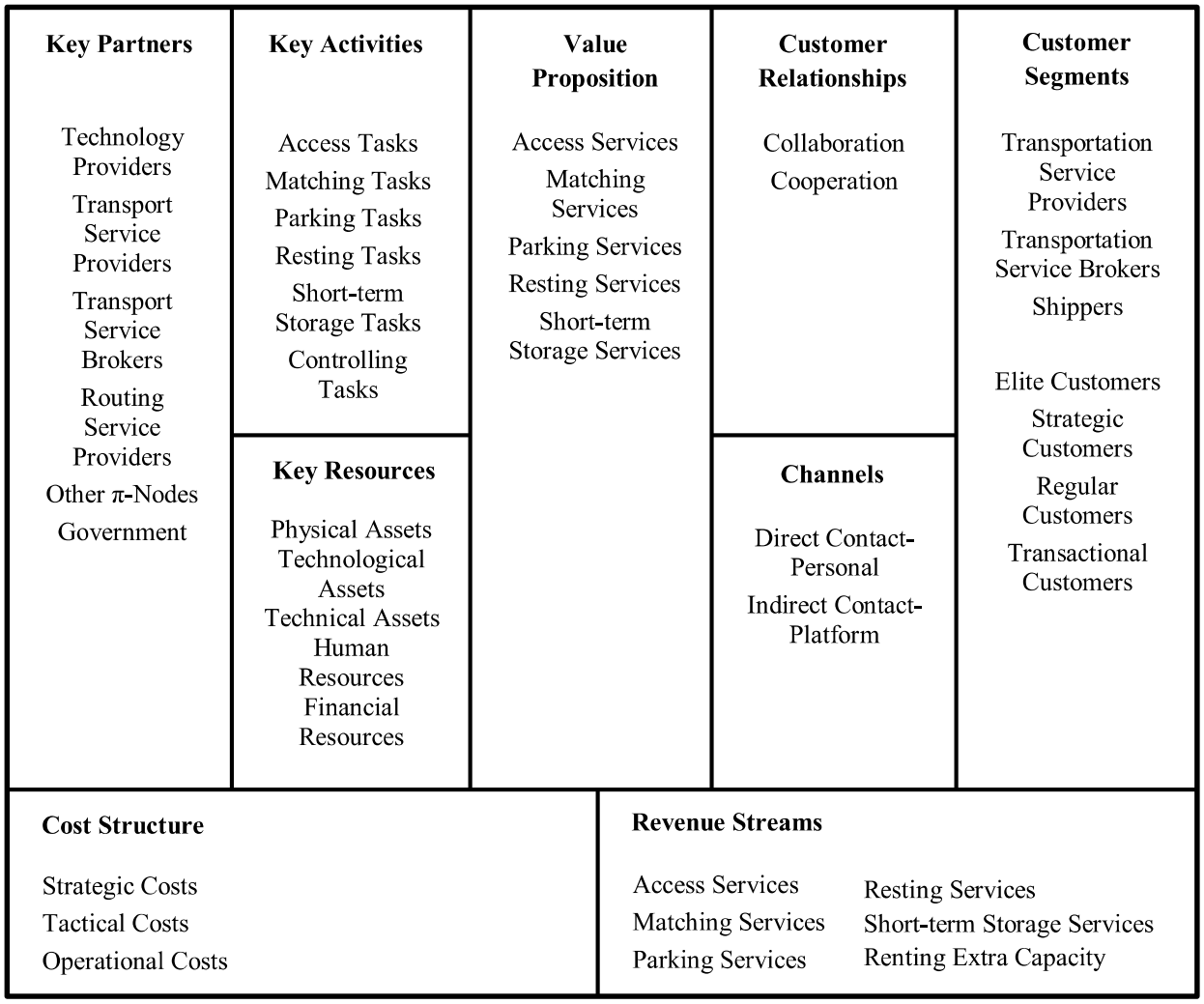


Figure 8: π-Transit Center Business Model Canvas

5 Π-Transit Center Growth Strategy

It is essential for π-transit owners/operators to think about growth strategies, whether for a new startup business or an established one, to ensure continuous efficiency and profitability in the long-term.

In general, companies should exploit their opportunities, alleviate their threats, empowering their strength, and obviate their weaknesses. There are various growth strategies available, including market penetration, service development, market development and diversification (e.g. Ansoff,

1965). Market penetration strategy aims to push existing services to their current market segments while market development strategy tries to develop new markets for the current services. Service development strategy aims to develop new products for existing markets while with diversification strategy, new services are developed for new markets.

As mentioned previously, the Physical Internet paradigm is a unique and creative concept. So in the early phases of PI implementation, the exploitation of π-transits may be non-competitive in local markets. Nevertheless, in the long run, as PI implementation builds momentum, they will have to face competitors with similar services. Consequently, in order to keep or grow their market share, they will have to exploit distinct growth strategies. A π-transit center could thus exploit growth strategies as highlighted above.

For example, new services such as π-crossdocking services, π-warehousing services, and π-distribution center services, could be provided, resulting in the attraction of new customers in the current geographical markets. The π-transit center could also enlarge its network or increase its capacity to cover larger geographical markets. Through innovative ideas, up-to-date technologies, greater synchronization with more π-nodes, strategic partnerships and intensive knowledge transfer, π-transit centers could finally ensure their sustainability in the long term.

6 Conclusion

As stated at the outset, this paper has aimed to design a comprehensive business model framework for Physical-Internet enabled transit centers. The goal of such a business modeling framework is to address how π-transits should be managed from a service provider's perspective to facilitate their further exploitation.

Using the Business Model Canvas of Osterwalder and Pigneur (2010), various dimensions of these logistics centers have been conceptualized, including their mission, services, customer segments, channels, customer relationships, revenue streams, costs, key resources, key partners, and key activities.

While these π-transit centers are not commercialized yet, their growth strategies have also been investigated since they are another concerning issue. The significant point is that based on the dynamic nature of business environment, these business models should be continuously assessed and modified to bring more value added to their networks.

Limitations of this research are as follows. First, the proposed business model canvas is limited to π-transit centers and their services, while a π-transit center might provide other services to other π-nodes such as π-crossdocking services and π-warehousing services. Second, the π-transit centers can have various business models based on their location. The nature of their locations will lead to demand differentiation, distinct missions, different customer segments, different costs, different resources, different partners, and different revenue streams which affect their competitive advantages and strategies.

Further research is needed to investigate the intricate relationship between the potential business model and the location of a π-transit center. There is also a need for assess the efficiency of business model variants in dynamic competitive environments through a simulation based assessment. Finally, this research has explored business modeling for one of the simplest types of Physical Internet logistics centers, a π-transit, opening the way for the investigation of more complex centers such as Physical Internet crossdocking hubs and open distribution centers.

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Impact of Shipper Collaboration on Carriers Selection in Reputation-Based Transportation Auctions

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Abstract: *This paper proposes combinatorial transportation auction mechanisms to allocate transportation services to in Physical Internet (PI-π) context. We propose a centralized procurement auction in which a π-auctioneer runs a unique combinatorial auction of all shippers sending their freights through the π -network. The mechanism of reputation-based combinatorial auction for trucking services procurement is proposed to the Physical Internet paradigm in which goods travel in modular containers for the sake of interconnection in open networks. We address the problem of determining winning carriers (known as the Winner Determination Problem) based not only on bid prices but also on carriers service quality performances.*

The carrier reputation is translated to an unexpected hidden cost that represents the possible additional cost that the shippers may incur if some problems occur. The objective of this study is to decide on the winning bids knowing that: (1) a same contract may include shipping containers belonging to different shippers and (2) a carrier reputation may differ from one shipper to another. Different approaches are proposed to determine hidden costs. These approaches differ on the importance given to the shippers in evaluating the carriers and their bids. Such a centralized reputation-based transportation auction is beneficial on two levels. First, it exploits the synergy between the shipping contracts yielding possibly to lower bid prices. Second, it enables information sharing between shippers on the service quality performances of the participating carriers to help them have a more accurate judgment on carriers' reputation.

Keywords: *Physical Internet, Transportation Auction, Carrier Selection, Reputation.*

1 Introduction

Montreuil et al. (2012) assert that the way physical objects are moved, handled, stored, realized, supplied, and used throughout the world is not sustainable economically, environmentally, or socially. They report that inefficiency in distribution operations has a huge impact on the environment and on the profitability of both manufacturer and carrier. In order to address these issues, (Montreuil, 2011) propose a "new paradigm-breaking vision" The Physical Internet inspired by the Digital Internet, that enables an efficient, sustainable, adaptable and resilient logistics web. It is composed of five constituent webs respectively focused on enhancing the efficiency and sustainability of moving, storing, realizing, supplying and using physical objects: a Mobility Web, a Distribution Web, a Realization Web, a Supply Web and a Service Web (Montreuil et al., 2009; 2012b). The Mobility Web deals with moving physical objects within an

interconnected set of unimodal and multimodal hubs, transits, ports, roads and ways (Hakimi et al., 2012).

One of the main ideas of Physical Internet is an open collaboration between different π -actors of the transportation network. In this trend and in the context of mobility web, we propose centralized transportation auctions as a mechanism of allocating transportation services to carriers in PI networks. Transportation auctions are particular procurement auctions where the items to be auctioned are shipments, shippers (typically large manufacturing companies, retailers, distributors or large carrier organizations as sub-contracts) are the owners of loads that need to be transported from origins to destinations, and carriers (which generally refer to transportation companies that own transportation means, such as truck lines) are are the service provider.

This paper proposes a centralized procurement auction for Physical Internet context in which shippers post their freights to the Physical Internet interface; a π-auctioneer runs a unique combinatorial auction to procure transportation services of all shippers' freights; and carriers compete to win these services by bidding.

In this paper, we consider the particular context of transportation procurement markets in the context of Physical Internet paradigm and address the problem of determining winning carriers (known as the Winner Determination Problem, WDP) based not only on bid prices but also on carriers reputation. Indeed, several studies show the importance of considering attributes other than the price to select carriers. In the literature, a few studies however considered service quality aspects in the allocation phase.

Recently, Rekik and Mellouli (2012) proposed a reputation-based WDP model for one-sided auctions including only one shipper. They propose to translate carriers reputation into unexpected hidden costs that represent the possible additional costs that the shipper may incur when dealing with the winning carriers.

The problem we address here is inspired by the work of Rekik and Mellouli (2012) but considers the case a π -auctioneer runs a unique combinatorial auction to procure transportation services of all shippers' freights. The main difference is that one should decide on the winning bids knowing that: (1) a same bid may include shipping contracts requested by different shippers and (2) a carrier reputation may differ from one shipper to another. Taken differently and assuming a total collaboration between shippers, such a centralized reputation-based transportation auction is beneficial on two levels. First, it exploits the synergy between the shipping contracts yielding possibly to lower bid prices. Second, it enables information sharing between shippers on the service quality performances of the participating carriers to help them have a more accurate judgment on carriers' reputation.

The article is structured as follows. Section two provides a literature review presenting the Physical Internet, Logistics Web and Mobility Web concepts and providing transportation combinatorial auction mechanism as will be proposed to the Physical Internet. Section three presents the reputation-based decentralized winner determination problem. Section four introduces the reputation-based centralized winner determination problem for the Physical Internet and the different methods of weighting the importance of shippers when giving their valuations of carriers reputations. The article ends with a conclusion summarizing the contribution of this research.

2 Literature Review

This section presents Physical Internet and the notions of open logistics web, open supply web and open mobility web. Then, it discusses the pertinence of the transportation combinatorial auction mechanism in realizing mobility environments such as this enabled by Physical Internet.

2.1 Physical Internet

"Physical Internet is a novel concept aiming to render the way physical objects are transported, handled, stored, realized, supplied and used throughout the world more economically, environmentally and socially efficient and sustainable. Physical Internet enables a Logistics Web consisting of Mobility, Supply, Realization, and Distribution Webs" (Hakimi et al., 2012).

The Physical Internet exploits the concept of universal interconnectivity of logistics networks and services. It proposes to encapsulate merchandises and products in world-standardized, green, modular, networked, and smart containers that can be flowed and distributed across fast, reliable, and eco-friendly multimodal transportation systems and logistics facilities (Montreuil, 2011).

The Logistic Web is defined as the global set of physical, digital, human, organizational, and social actors and networks serving the worldwide dynamic and evolving logistics needs the Logistics Web can be conceived as embedding four interlaced webs: the Mobility Web, the Distribution Web, the Realization Web, and the Supply Web (Montreuil 2009). The Mobility Web deals with moving physical objects within the global interconnected set of open unimodal and multimodal hubs, transits, ports, roads and ways (Hakimi et al., 2012).

The mobility web includes a set of π-hubs and π-routes. Products are packed in π-containers of modular sizes. These π-containers are the only unit loads allowed to be shipped on the simulated open mobility webs. The π-containers, in their way to a final destination, can transit through π-hub where they can be transferred between transportation means and/or modes. Transportation means are not anymore dedicated. They can carry π-containers of different actors. Since direct travels are not the rule in the open mobility webs, routing agents are responsible for determining the set of route segments and transportation means that containers will be affected to in order to reach final destinations. Road-based route segments can be restricted to be less than a few hours to allow most drivers to go back home in the same day.

Hakimi et al. (2012) have designed an agent-based mobility web simulation platform. The proposed model of web mobility contains three main agents responsible for decision-making within the virtually simulated logistics web: supply chain managers, transportation agents and routing agents. We present in the following the roles of these agents (Hakimi et al., 2012):

The supply chain manager (SCM): The main function of the supply chain manager (SCM) agent is to deal with order shipment decisions.

Transportation agents are responsible for managing travel of transportation means belonging to their company.

Routing agents need to be activated in the π-enabled scenarios. Such agents are responsible for determining the path segments, π-hubs, and, depending on scenarios, transportation means, that containers will contract to iteratively reach the final destinations.

2.2 Combinatorial transportation auction

The increasing cost of energy and the rising competition in transportation markets require new strategies of logistics management and force shippers and carriers to optimize their transportation services. Also, modern logistic management gives great importance to environmental concerns and sustainability. Hence, freight transportation face two interrelated challenges, the first is

economic and the second is environmental. On one hand, delivery costs have to be reduced and on the other hand inefficiency in freight operations tend to generate more greenhouse gas (GHG) emissions which have to be controlled and reduced (Quariguasi et al., 2008). One promising solution often used in this context is to avoid useless movement of traffic by optimizing transportation operations in existing transportation networks. The optimization approach is to use combinatorial auctions in transportation markets as trading mechanisms that allows carriers to bid on bundles (also called packages) of lanes (ie, origin-destination pairs). Thus, carriers are able to express their valuations for any collection of lanes they want to acquire. In general, package bidding is beneficial for situations in which complementarity/substitutability effects exists between traded items. Items under auction are referred to complementary items when the value for a combination of items is greater than the sum of the values for these items taken independently. In transportation market, freight lanes are complementary creating greater economies of scope. In fact, a significant proportion of costs in trucking operations is due to the repositioning of empty vehicles from the destination of one load to the origin of a subsequent load (Song and Regan, 2005). For this, carriers seek a set of lanes that are synergistic with respect to repositioning costs (Lee et al., 2007) and aim to acquire adjacent lanes and/or lanes that form a closed loop in order to minimize empty back-hauls and raise vehicle utilization (Song and Regan, 2005; Lee et al., 2007).

In recent years, combinatorial auctions have been used in several transportation procurement markets where shippers and third-party-logistics (3PL) providers (the services askers) and carriers (the services providers) trade shipping contracts (Elmaghraby and Keskinocak, 2004; Ledyard et al., 2002). The objective is to reduce their transportation costs during procurement. Elmaghraby et al., (2002) reported the successful results yielded by the one-shot sealed-bid combinatorial auction conducted by Home Depot Inc.

Additional applications are reported by Logistics.com and include Wall Mart Stores, Compaq Computer Co, Staples Inc., The limited Inc. and Kmart Corporation. Caplice and Sheffi (2006) provided summary information on several combinatorial transportation auctions designed between 1997 and 2003. Their synthesis reveals an average saving of 13% in transportation costs.

3 Mechanism of π-auction

A combinatorial transportation auction for the Physical Internet consists of three steps:

3.1 Bid preparation:

Shippers submit their shipments (orders) to the Physical Internet interface. Data are adapted. For example, weekly shipments are transformed to daily by repartitioning the weekly shipments over the week-days.

Besides, the SCM agent affects the order lines to π-containers while observing the weight and volume conditions of the corresponding π-containers. In this case, lines of a given order can be dispatched over many π-containers. Nevertheless the SCM agent must be able to decide to group the lines of orders having the same destination in common containers whenever possible. When a container is ready for shipment, the agent transfers a notification to the routing agent, rather than to the transportation agent (Hakimi et al., 2012).

After that, the loads of π-vehicles and π-carriers are determined by routing agents instead of SCM agents. Therefore, the notification about the availability of π-containers to transport is coming from routing agents.

Finally, a routing agent continuously handles requests for routing π-containers that are sent by SCM agents. For each request, the agent determines, segment-by-segment, the entire travel of a

π-container (Hakimi et al., 2012). From these segments, routing agent determines potential segments and transmits them to auction. Hereafter we call these segments contracts(Hakimi et al., 2012).

3.2 Bid execution:

The transportation agent ensures the loading of π-containers in transportation means and the unloading at the π-hubs across the mobility web. Upon vehicle departure from a site, the transportation agent has to notify the appropriate routing agents if there was a schedule change. Upon vehicle arrival at a site, it has to notify the SCM agent about the delivery. Furthermore, the transportation agent is responsible for managing the travel schedules of the transportation means and for publishing these schedules so that the routing agents can exploit them when establishing travel paths of π-containers (Hakimi et al., 2012).

Transportation agents are the bidders of the π-auction. Transportation agents are invited to participate in the auction by submitting their bids. Transportation agents may have existent commitments or not and aim to optimize their networks and minimize empty movements by including profitable contracts

The way Transportation agents combine contracts and determine ask prices is known as the carrier bid construction problem (BCP). Transportation agents bids may include contracts (segment of shipments) belonging to different shippers.

3.3 Bid analysis and assignment

After receiving all Transportation agents' bids, the shipper analyses bids and determines winning bids by solving the well-known Winner Determination Problem (WDP) based not only on submitted bids prices but also on the reputation of Transportation agents. The objective of the reputation WDP is to minimize the shipper transportation costs and maintain a good service quality.

Physical Internet enables a centralized procurement auction in which (1) each shipper gives his orders (shipments) to his supply chain manager which dispatches, the lines of a these orders over many π-containers and groups the lines of the orders having the same destination in common containers. When a container is ready for shipment, the supply chain manager transfers a notification to the routing agent, (2) the routing agent splittes these shipments into segments and determines from these segments, potential segments (called in our context contracts) and transmits them to auction, (3) a π-auctioneer runs a centralized auction of all these contracts (4) transportation agents of each transportation company solves a Bid Construction Problem in order to determine the contracts to submit in the same package and the package bids prices; (5) π-auctioneer solves the winner determination problem taking into account the reputation of carriers and obtain the winning bids and finally (6) the π-auctioneer solves the Cost Allocation Problem to decide the amount that each shipper will pay to each transportation company.

Crainic et al. (2009) have already considered a centralized context for general procurement markets. They report that putting together in the same auction a larger variety of items coming from different buyers would yield an important saving in the total cost to be paid by all buyers, especially when a high level of synergy exists between the traded items. Crainic et al. (2009) emphasize on the cost allocation problem. That is, how to decide on the cost to be allocated to each shipper once the auction ends.

For the remainder of the paper, we address the Winner Determination Problem of combinatorial auction. Firstly, we present the decentralized reputation-based WDP such as modeled to one shipper in a traditional context and then we present the centralized reputation-based WDP such as designed for the Physical Internet

4 Decentralized Reputation-based WDP

Let E, respectively A, be the set of shippers, respectively, carriers, participating in the auction. Let also $K_{(e)}$ denote the set of shipping contracts requested by shipper e and $K = \cup_{e \in E} K(e)$ the set of all contracts to be auctioned. Each carrier $a \in A$ submits a set of combinatorial bids $B_{(a)}$. A bid $b \in B(a)$ is defined by a pair $(K(b); BP_b)$, where $K(b)$ denotes the set of contracts carrier a bid on and BP_b is the price asked for serving all these contracts.

Recall that $K_{(b)}$ may include contracts of different shippers. To model the problem, we define a binary decision variable x_b for each submitted bid b; $x_b = 1$ if bid b wins, and $x_b = 0$, otherwise. We define constant binary parameters δ_{bk} such that $\delta_{bk} = 1$ if contract k is covered by bid b and $\delta_{bk} = 0$; otherwise. Finally, as suggested in Rekik and Mellouli (2012), we translate carriers reputation in terms of additional hidden costs, denote HC(.), that could be incurred by all the shippers when a vector x of winning bids is chosen.

The WDP is formulated as follows:

(P1):

$$\min \sum_{a \in A} \sum_{b \in B(a)} BP_b x_b + HC(b) x_b \qquad (1)$$

$$\text{s.t.} \quad \sum_{a \in A} \sum_{b \in B(a)} \delta_{bk} x_b \geq 1 \qquad \forall k \in K, \qquad (2)$$

$$x_b \in \{0,1\} \qquad \forall a \in A, b \in B(a). \qquad (3)$$

The objective function (1) minimizes the total bid price (the direct cost) and the total hidden cost. Constraints (2) ensure that each contract is served. Constraints (3) define the binary nature of decision variables.

Rekik and Mellouli (2012) report that a carrier reputation is determined based on a set of service attributes, denoted Ω. To evaluate the reputation of a carrier a with respect to an attribute ω Ω, a shipper will rely on the arrangements it has done in the past with carrier a (its historical performance).

In the following, the reputation of a carrier a provided by a shipper with respect to the attribute $\omega \in \Omega$ is denoted $\Gamma_{a,\omega}$. For example, if the on-time delivery criteria is considered, then $\Gamma_{a,\omega}$ could be seen as the average relative delay recorded for carrier a for the past shipments it ensured for the shipper.

Each shipper is assumed to have an estimation on the cost to be incurred when a unit deviation with respect to criteria ω occurred for contract $k \in k(e)$. This cost is denoted $C_{k,\omega}$. For the on-time delivery criteria, for example, $C_{k,\omega}$ could represent the additional cost caused by a one-unit time delay in contract k.

The hidden cost, $HC_{(b)}$ associated with bid b is calculated as follows:

$$HC(b) = \sum_{k \in K(b)} HC_{a(b),k}, \text{ and } a(b) \text{ is the carrier submitting bid } b.$$

Based on this, the hidden cost, $HC_{(a;k)}$ associated with contract k when served by carrier a is computed as:

$$HC_{a,k} = \sum_{\omega \in \Omega} C_{k,\omega} * \Gamma_{a,\omega}$$

$\Gamma_{a,\omega}$ is calculated as follows:

$$\Gamma_{a,\omega} = \frac{\sum_{t \in T_a} (\bar{\gamma}_{a,\omega,t} + z_\omega * \sigma_{a,\omega,t})}{|T_a|},$$

Where

$\gamma_{a,\omega,t,s}$: Value taken by attribute ω in the shipment s ensured by carrier a in period t.

$\bar{\gamma}_{a,\omega,t,s}$, respectively, $\sigma_{a,\omega,t,s}$ are the mean value, respectively, standard deviation, of attribute ω in period t for carrier a.

$$\bar{\gamma}_{a,\omega,t} = (\sum_{s \in PS_{a,t}} \gamma_{a,\omega,t,s}) / |PS_{a,t}|.$$

$PS_{a,t}$: The subset of shipments in PS_a that correspond to period $t \in T_a$.
PS_a The set of shipments considered by the shipper to evaluate the reputation of carrier a;
z_w : Risk aversion behaviour of the shipper with regard to attribute ω.

5 Centralized Reputation-based WDP for Physical Internet

In we adopt the same approach for the evaluation of carrier reputation as in Rekik and Mellouli (2012) as well as same notation. Thus, the reputation of carrier a provided by shipper e with respect to the attribute $\omega \in \Omega$ is named $\Gamma a,\omega,e$.

When combinatorial bidding is permitted, a same bid submitted by a carrier a may include contracts belonging to different shippers, say *e1* and *e2*, because there is a synergy between these contracts given carrier a existing network. Such a synergy is due to a reduction in empty moves, for example, and generally yield interesting bid ask prices for both shippers. However, carrier a could be viewed as a reliable carrier by *e1* and an unreliable one by shipper *e2*. In a π-context, products of various orders are packed in π-containers which are assigned to one or many transportation means that will transport them to intermediary nodes of the mobility web toward the final destination (Hakimi et al., 2012). Consequently, a contract may include π-containers from different shippers say e1 and e2 and the evaluations of these shippers may be different. For example, carrier a could be viewed as a reliable carrier by *e1* and an unreliable one by shipper *e2*. For this, the objective of this paper is to address these issues and propose different ways of computing carriers reputation depending on the shipper importance (weight) in the auction. Three methods of reputation computation are given and the objective is to find a unique valuation of carrier reputation based on different valuations of shippers having π-containers in the same contract. We assume, also, that a consensus between collaborating shippers on the service quality (reputation) attributes is established. In this study, we consider the same attributes as in Rekik and Mellouli (2012) which are delay, damage and cancel.
Each shipper posting his loads in the π-network communicates his evaluations of the carriers towards the attributes the π-auctioneer.
In the rest of the paper, the reputation of a carrier a provided by shipper e with respect to the attribute ω is denoted $\Gamma a,\omega,e$. This reputation is computed based on the formula proposed by Rekik and Mellouli (2012) for the decentralized case. Each shipper e is also assumed to have an estimation on the cost to be incurred when a unit deviation with respect to an attribute ω occurred for contract $k \in K(e,b)$. This cost is denoted $C_{k,\omega}$ as for the decentralized WDP.

Consider a bid *b* submitted by a carrier $a \in A$ such as $b \in B(a)$ and $b = (K(b);BP(b))$.
The generalized mathematical model of the centralized WDP can thus be formulated as model (P1). $HC_{(b)}$ *and* $HC_{(a;\ k)}$ are computed as in decentralized WDP. However, the valuation of the reputation of carrier *a* (provided by all shippers having π-containers in the contract k) with respect to the attribute $\omega \in \Omega$ named $\Gamma a,\omega$, *is computed based on different valuations of* the reputation of carrier *a by the different shippers* having π-containers in the contract k $\Gamma a,\omega,e$. Let $E(k)$ be the set of shippers having π-containers in the contract k.

$$\Gamma_{a,\omega} = \sum_{e \in E(k)} w_{e,k} \Gamma_{a,\omega,e}$$

To ensure fairness between different shippers we propose weighting the different valuations of shippers $\Gamma a,\omega,e$. $w_{e,k}$ is the weight associated with the *valuations of shippers* $\Gamma a,\omega,e$.
In the following, we propose three methods of determining weights $w_{e,k}$ depending on the global, local and historical importance of the shipper.
Global importance: in this case we favour the shipper $e \in E(k)$ that has the larger percentage of requested contracts (in the whole auction) when compared to other shippers having contracts in the auction.

$$w_{e,k} = \frac{|K(e)|}{\sum_{e \in E(k)} |K(e)|}$$

Local importance: Here, we favour the shipper that has the larger number of π-containers in the contract.

$$w_{e,k} = \frac{|K(c)|}{\sum_{e \in E(k)} |K(c)|}$$

Historical importance: in this case, we favour the shipper that has the higher level of knowledge of carrier a submitting bid b with regard to the other shippers having contracts in b. This level of knowledge is through the number of shipments contracted in the past with the carrier. Formally, let $|S_{(e,\ a)}|$ denote the number of shipments of shipper *e* ensured in the past by carrier *a*. Then, the weight $w_{e,k}$ is computed as:

$$w_{e,k} = \frac{|S(e,a)|}{\sum_{e \in E(k)} |S_{e,a}|}$$

6 Conclusion

Physical Internet is a novel concept aiming to render the way physical objects are transported, handled, stored, realized, supplied and used throughout the world more economically, environmentally and socially efficient and sustainable. Physical Internet enables a Logistics Web consisting of Mobility, Supply, Realization, and Distribution Webs.
This paper proposes centralized transportation auctions as a mechanism of allocating transportation services to carriers in π-networks. The mechanism of the transportation combinatorial auction is adapted to the context of Physical Internet and the π--auction is proposed. We deal specifically with the WDP when the selection of transportation agents take into account the reputation of these transportation agents and when π-auctioneer weight the different shippers valuations of the same transportation agent. Three method of weighting these different valuations are proposed.

Next researches will measure the usefulness of the auction mechanism in the Physical Internet context and measure the importance of considering reputation in the Winner Determination Problem.

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From Integrated to Interconnected B2C E-Commerce Distribution: An agent-based simulation Assessment

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Abstract: *Current e-commerce logistics systems are based on the integration of the closed and private distribution systems of different stakeholders including manufacturers, distributors and Third Party Logistics (3PLs). The integrated e-commerce distribution systems suffer from conventional distribution inefficiency and unsustainability symptoms such as underuse of distribution center capacities and important physical flows resulting in important greenhouse gas emissions and fuel consumption as well as operating underused capacity vehicles. In order to overcome B2C e-commerce inefficiencies, Physical Internet (PI) enabled interconnected distribution is a potent alternative to conventional logistics through its use of an open Distribution Web supported by the exploitation of an open Mobility Web.*

We present in this paper a multi-agent simulation based analysis of the implication of PI enabled interconnected e-commerce distribution, where operational strategies are implemented through the behavior of autonomous software agents, like optimization based dynamic inventory balancing deployment planning. We report improvements in economic, social and environmental performances of interconnected B2C distribution scenarios in comparison with performances of integrated B2C distribution scenarios. We quantify the performances of a leading furniture manufacturer through key performance indicators of simulated scenarios across different distribution stages from the manufacturer factories until reaching the final E-Consumer.

Keywords: *E-Commerce, Physical Internet, Interconnected Distribution, Performance, Sustainability, Agent-Based Simulation.*

1 Introduction

Business-to-Consumers (B2C) e-commerce distribution systems of leading players such as Amazon.com and NewEgg.ca are currently typically operated through the integration of their suppliers' private distribution networks and the parcel delivery system of their preferred contracted third party logistics (3PL) service provider (e.g. DHL, FedEx and UPS). The online order placement and delivery can be summarized through the six following steps. (1) An e-consumer orders online a product from the e-retailer website. (2) The online order information is then transmitted from the e-retailer to the supplier's information system. On its side, and

depending on its consolidation strategy, (3) the supplier consolidates its consumer orders and ships them to a dropping location of the e-retailer's preferred 3PL, from where the 3PL (4) collects the orders of concern and (5) ships them through its hub-and-spoke network until (6) the final leg when it is locally dispatched for delivery at the consumer home or an agreed upon pick-up location, such as a click-and-collect drive. Figure 1 illustrates this six-step process from the perspective of a supplier having to deal with multiple e-retailers and third-party logistics providers, as is the focus of this paper.

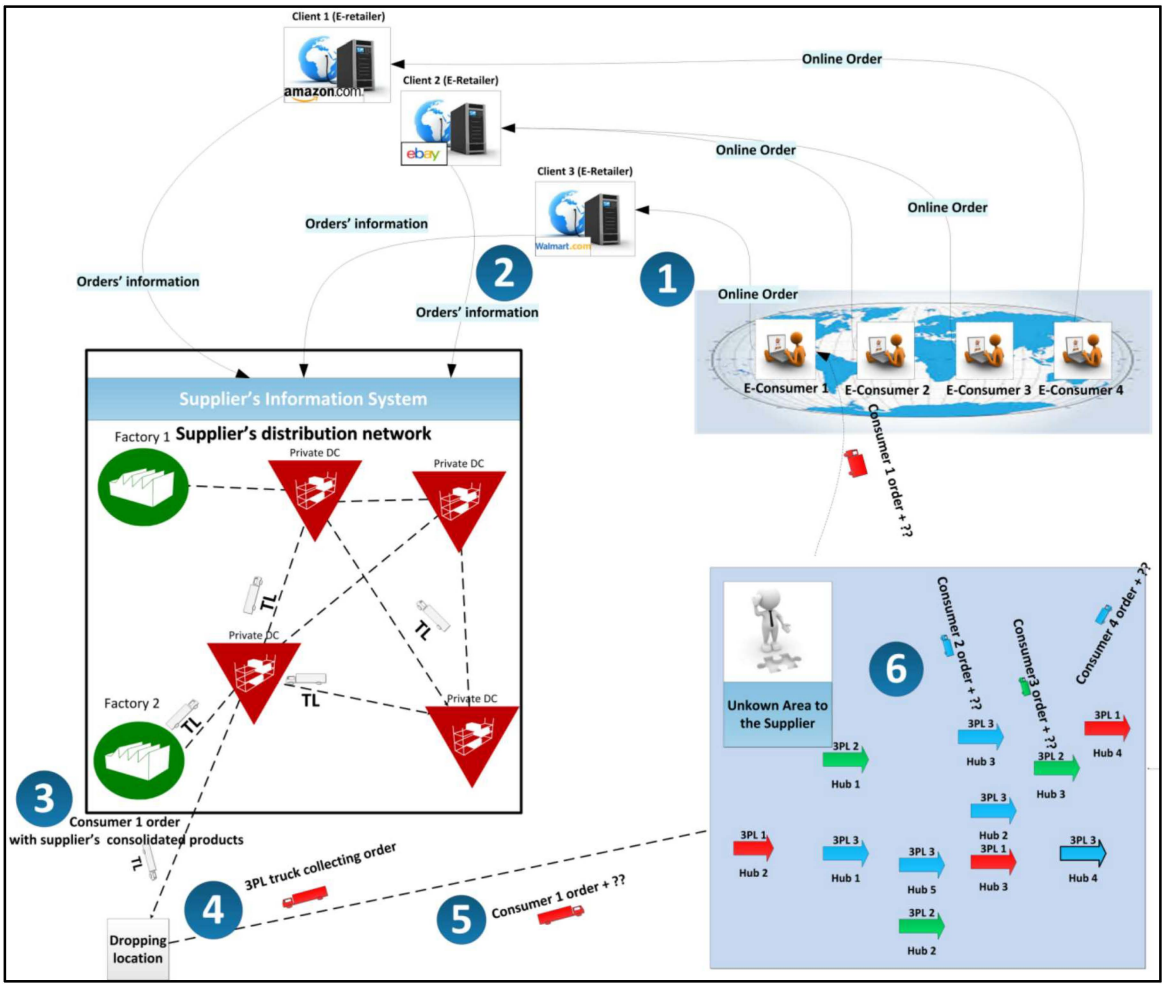


Figure 1: The overall B2C Distribution process from the supplier's perspective

The backbone of current multi-actor complex integrated B2C distribution systems lays on classic logistics systems that suffer from inefficiency symptoms such as the underuse of distribution center capacities or important physical flows resulting in important greenhouse gas emissions as well as operating underused capacity vehicles. Through the operation of interconnected distribution webs, the Physical Internet (PI) Initiative (Montreuil, 2011, 2013) targets overcoming inefficiency symptoms through the operation of open distribution centers, while deploying and delivering products through the web of mobility. PI enabled interconnected distribution systems are potent alternative candidates to current integrated distribution systems in the context of B2C E-Commerce distribution.

The aim of this paper is to validate the assertion that the exploitation of interconnected distribution by an e-supplier improves the distribution system efficiency and sustainability from economic, social and environmental perspectives. To this end, we adopt a multi-agent based simulation approach which is suitable to model and mimic complex system dynamics such as B2C distribution systems.

First, in section 2, we present a review actual integrated B2C E-Commerce distribution systems, contrasting them with the arguments defending the PI interconnected distribution as a solution for solving inefficiency and sustainability issues of these systems. In section 3, we present the agent-based simulation models we developed to enable empirical comparative analysis of integrated B2C distributions versus interconnected B2C distribution systems. Section 4 details the simulation scenarios we used to investigate actual and alternative integrated B2C distribution system as well as an alternative interconnected B2C distribution system of a leading e-commerce furniture manufacturer that currently operating three distribution centers located nearby its factories located near Québec City (Canada) and the city of Juarez (Mexico). Section 4 also reports on the simulation results. Finally, we conclude in section 5 by highlighting the main findings from our current research and presenting future research avenues for further investigating interconnected B2C distribution systems.

2 Literature Review

The backbone of e-commerce logistics is notably based on the participation of suppliers and parcel delivery service providers (Vergnion and Montreuil, 2001; Lim, H. and Shio, 2011). Suppliers deploy physical goods and fulfill online demand while parcel delivery service providers are responsible for delivering physical goods from the suppliers' distribution centers to drop points close to final consumer location (Yu and Xiu-yan, 2010). The overall resulting distribution systems, from suppliers to the end consumers of their products, suffer from inefficiency and unsustainability symptoms as underuse of distribution center capacities (Kämäräinen and Punakivi, 2002) or important physical flows resulting in important greenhouse gas emissions and fuel consumption as well as operating lowly filled vehicles (Taniguchi and Kakimoto, 2003). In B2C e-commerce logistics, economies of scale are hard to achieve and distribution costs may increase because of instable consumer demand (Lv and Zhang, 2010). Distribution cost evolution depends not only on consumer demand profiles, but also on the distribution sector (Zhu and Kraemer, 2002).

In order to overcome B2C e-commerce inefficiency aspects, PI enabled interconnected distribution systems are an interesting alternative candidate to current integrated distribution systems (Montreuil, 2011). With the Physical Internet, a Distribution Web is responsible for storing physical objects encapsulated in modular containers while a Mobility Web is responsible for moving these containers from source to destination in relay mode through open hubs (Hakimi et al., 2012). The Distribution Web exploits the use of open distribution centers offering storage spaces to heterogeneous suppliers, according to their storage capacity needs, without engaging these suppliers in leasing or possessing distribution centers (Montreuil et al., 2012). The number and location of open distribution centers in which a supplier stores its container-encapsulated products are set so they are close to both suppliers and consumers. The "on-demand" storage space in open distribution centers and their geographic location is an interesting solution to the

distribution center capacity underuse issue in e-commerce. Furthermore, the efficiency of the Mobility Web can improve not only transportation costs incurred to the e-suppliers, but also overall vehicle fuel consumption and induced greenhouse gas emission.

The conventional integrated B2C distribution and the alternative interconnected distribution consist in complex systems where several processes from various actors interact in order to run the operations of the deployment and delivery of online ordered products. Then there is a need for a decision support tool in order to analyze and compute performances from both distribution systems. Simulations are widely used in supply chain management as decision support tools (Cimino et al. 2010). In particular, multi-agent simulation platforms are suitable to model and mimic complex system dynamics (Jennings, 2000; Govindu and Chinnam, 2007). Thus we choose to adopt a multi-agent simulation based analysis approach in order to contrast between actual and alternative E-Commerce distribution systems.

3 The open distribution web simulation model

We propose two simulation models for modeling and analyzing integrated and interconnected B2C e-commerce distribution systems. The first model considers the specificities of integrated distribution where supplier private distribution systems interact with 3PL hub-and-spoke networks to analyze resulting supplier performances in current e-commerce distribution scenarios. The second model takes into consideration the exploitation of an open Logistics Web with its Distribution and Mobility Web constituents (Montreuil et al. 2013) as enablers for an interconnected B2C distribution, in order to analyze supplier's resulting performances from scenarios of PI-enabled distribution as a logistics alternative in the context of B2C e-commerce.

3.1 Integrated B2C e-commerce distribution simulation model

In order to contrast actual e-commerce distribution performances with potential performances resulting from interconnected distribution scenarios, we use the agent-based simulation model we proposed in Naccache et al. (2014). In our previous work, we presented the main components from a B2C integrated distribution network simulation model, i.e., the agents, the agent behaviors and the simulation parameters. The agents are the autonomous software components that are responsible for reproducing a given distribution process, i.e. Shipment, Inventory, Production, Product deployment and Consumer orders. *Shipment agent* is responsible for executing product deployment orders communicated by the *Distribution agent*. Also, *Shipment agent* is responsible for consumer order routing and shipments. It is associated with the factories, distribution centers (DCs) and 3PL hubs. *Inventory agent* adjusts inventory levels according to received and shipped products and is associated to (DCs). *Production agent* plans and executes production calendars in factory nodes. *Distribution agent* is responsible for product deployment decisions which are executed by the factory and DC *Shipment agents*. Finally, *Consumer agents* order products from their respective locations.

Each agent implements a set of behaviors according to its responsibility and to the simulated distribution scenario. An agent behavior object may notably reproduce the historic behavior of a process (based on an operational log) or an operational logic. In addition to agent behavior, a simulation scenario is set up through simulation parameter values. Simulation parameters that are shared among all simulation scenarios can be assigned to one of four categories concerning,

distribution network structure (supplier's side and 3PL side), agent behavior class for each simulation agent, transport parameters and deployment plan parameters (Table 1).

Table 1: Simulation parameters

Parameter Category	Parameter	Description
Distribution network structure	NMv	Supplier v's distribution network: refers to a set of a supplier's factory and distribution center nodes in addition to their links.
	NTt	3PL t's transportation network: refers to a set of node for a given 3PL (hubs, terminals) in addition to their links.
Agent Behavior	CBv	v's consumer agent behavior identifier.
	PBv	v's production agent behavior identifier.
	SBv	v's stock agent behavior identifier.
	DBv	v's distribution agent behavior identifier.
	ShBv	v's shipment agent behavior identifier.
	TSB	Transportation schedule for 3PLs: the daily frequency of consolidations made by the 3PL shipment agents
	TST	Time of the first daily consolidation of 3PLs
Transport Parameters	TWH	Trucker maximum working hours per day.
	TRH	Trucker resting hours per day.
	DSr	Driving speed on a route from type r.
	AFPab	Average 3PL truck filling percentage of vehicle traveling from node of type a to node of type b.
	FPDab	3PL truck filling standard deviation of vehicle traveling from node of type a to node of type b.
	MWCab	Maximum weight capacity of vehicle traveling from node of type a to node of type b.
	MVCab	Maximum volume capacity of vehicle traveling from node of type a to node of type b.
Deployment Plan Parameters	α	Smoothing factor for demand forecast
	covDaysNb	Number of target days of coverage
	Xmin	Lower bound of deviation of product shortage in a DC from its actual coverage, to define first priority shortages to be fulfilled when a deployment plan is executed.
	Ymax	Upper bound of the number of actual days of coverage over the target number of days of coverage of a product in a DC, to define first priority shortages to be fulfilled when a deployment plan is executed.

The resulting integrated distribution simulation models current B2C e-commerce logistics scenarios and can be adapted to model as well alternative B2C distribution scenarios. In order to assess the potential of adopting PI enabled interconnected distribution in the B2C distribution contexts, we extended the previous model to take into account the special characteristics of the interconnected distribution to obtain the PI-Enabled interconnected distribution simulation model.

3.2 PI-Enabled interconnected distribution simulation model

In order to highlight the e-supplier performance improvements when adopting an interconnected distribution system in B2C versus a conventional integrated distribution, we developed a simulation model inspired from the one presented in section 3.1. This second simulation model takes into consideration the special features of interconnected distribution, namely the open Distribution and Mobility Webs.

A supplier's preferred interconnected distribution network is a set of open DCs selected from the set of all available open DC operating the interconnected distribution system. During strategic planning, the preferred open DCs of a supplier are located so as to minimize the total logistics cost including DC exploitation cost, inventory holding and transportation costs, as well as business-specific environmental and social goals. In comparison with an integrated e-commerce distribution system, the number of open DCs in the resulting preferred interconnected network exceeds DCs within a supplier's private distribution network. Meanwhile, no leasing or acquisition cost is incurred to suppliers while "virtually implementing" their preferred interconnected distribution network. The preferred open DC network is generated previously to simulation scenario instantiation thanks to a network design heuristic or exact optimization model. The resulting preferred DC network is set as a simulation parameter input. Furthermore, assuming the use of the Mobility Web, the *Distribution agent behavior* and the *Shipment agent behavior* in an interconnected simulation model, differ from their equivalent in the integrated distribution simulation model. We provide more details about the differences between these agent behaviors in section 3.3.

In order to model the integration of the Mobility Web into the interconnected distribution simulation model, we do no longer take into account the explicit participation of each 3PL in the distribution system, rather assuming that all transportation services are provided by the Mobility Web in which numerous 3PLs are to contribute. In the integrated distribution system, products are usually transported in a truckload (TL) mode between private supplier DCs (*Deployment* stage), where vehicles only contain this e-supplier's products. In addition, consumer orders shipped to their final consumers from their e-supplier's closest private DCs (*Order Delivery* stage) are transported by the parcel delivery service providers in a Less-Than-Truckload (LTL) mode, where vehicles contain the consumer orders of the e-supplier mixed in with parcels from other heterogeneous sources.

Assuming the use of a fully functional Mobility Web, product transportation across an interconnected distribution system is made in a LTL-like service in both *Deployment* and *Order Delivery* stages, where vehicles transporting an e-supplier's products also contain products from other sources. The transportation cost of a vehicle in a Mobility Web is modeled as being proportional to the distance traveled and to the total weight of transported products over the total weight load capacity of the truck. In the *Deployment stage*, the e-supplier's product deployment

transportation cost is modeled as being proportional to the total weight of supplier's products over the total weight load of the vehicle (E-Supplier contribution to the vehicle cost), where we assume that a vehicle in this stage is in average fully loaded at a predetermined level (such as 90% in this study). In the *Order Delivery* stage, the e-supplier's consumer order transportation cost is composed from the contribution of the e-supplier to the vehicle cost plus a handling cost proportional to the weight of each consumer order. At the *Order Delivery* stage, we assume that a vehicle is in average fully loaded at an average predetermined level (here 50%).

Finally, the simulation parameters in this simulation model are kept the same as presented in Table 1, while discarding the ones attached to a specific 3PL's activities (i.e: *TSB,* TST, AFP_{ab} and FPD_{ab}).

3.3 Agent behaviors

Each software agent in our simulation models is responsible for one distribution process, while their associated behaviors can be changed to model different distribution scenarios, i.e. integrated and interconnected distribution scenarios. For the extent of the current research, we used the same *Consumer*, *Production* and *Inventory agent behaviors* in both the integrated and interconnected distribution simulation models, while we developed for each simulation model a specific *Distribution agent behavior* and a *Shipment agent behavior*.

Shared agent behaviors

The Consumer agent behavior is implemented by the *Consumer* agent. It consists of a historic behavior reproducing the log of consumer orders from our industrial partner, saved in the *HistoricConsumerOrder* database table. *The Production agent behavior* is implemented by the *Production* agent. It consists of a historic behavior playing back E-Supplier's production orders calendar saved in the *HistoricProduction* database Table. The *Inventory agent behavior* is implemented by the *Inventory* agent. It adjusts the on hand inventory level of products at each DC according to received and shipped products.

The Shipment agent behavior

The *Shipment agent behavior* that is implemented by the *Shipment* agent consists in shipping product quantities between DCs, as ordered by the *Distribution* agent, at the *Deployment stage*. At the *Order Delivery* stage, the *Shipment agent behavior* routes consumer orders from their closest DC having the ordered product in inventory and located within a maximum distance distance (*MaxDistance*) that allows it to fulfill the consumer order within the promised delay. *MaxDistance* parameter is specific to the *Shipment agent* behaviors we developed within the scope of this paper. In the integrated distribution simulation model the *Shipment agent behavior* routes the consumer orders from their respective private DCs to their final consumer locations, across the hubs of their client assigned 3PL, using a shortest path algorithm. In the interconnected distribution simulation model, the *Shipment agent behavior* directly ships orders from their respective open DCs directly to their final consumer locations, assuming the existence of PI-hubs from the Mobility Web.

The Distribution agent behavior

The *Distribution agent behavior* implemented by the *Distribution* agent aims at dynamically deploying product excesses in DCs to balance inventory levels all over the distribution network in order to respond smartly to forecasted demand, according to the needs of each DC for each product. At each simulation day, the main agent behavior routine proceeds in a sequence of four main subroutines SR1, SR2, SR3 and SR4, as illustrated in Figure 2. Two *Distribution* agent behaviors are inherited from the basic *Distribution agent behavior*, namely the *Integrated Distribution agent behavior* and the *Interconnected Distribution agent behavior* implemented respectively in integrated and interconnected distribution simulation model.

The first Subroutine SR1 assigns each consumer order to its closest DC having inventory for the ordered product, and which is located within a maximum distance equal to *MaxDistance* parameter. In SR2, inventory excesses and shortages are computed as following: first a target coverage stock level is computed. This security stock of a product p at a given DC x is computed through the estimation of the target inventory coverage to be held expressed in equation (1), where $\hat{d}(p,x)$ is the daily demand forecast of p at x (computed through the exponential smoothing with a factor α=0.03) and covDaysNb(e) is the target number of coverage days of x's echelon e.

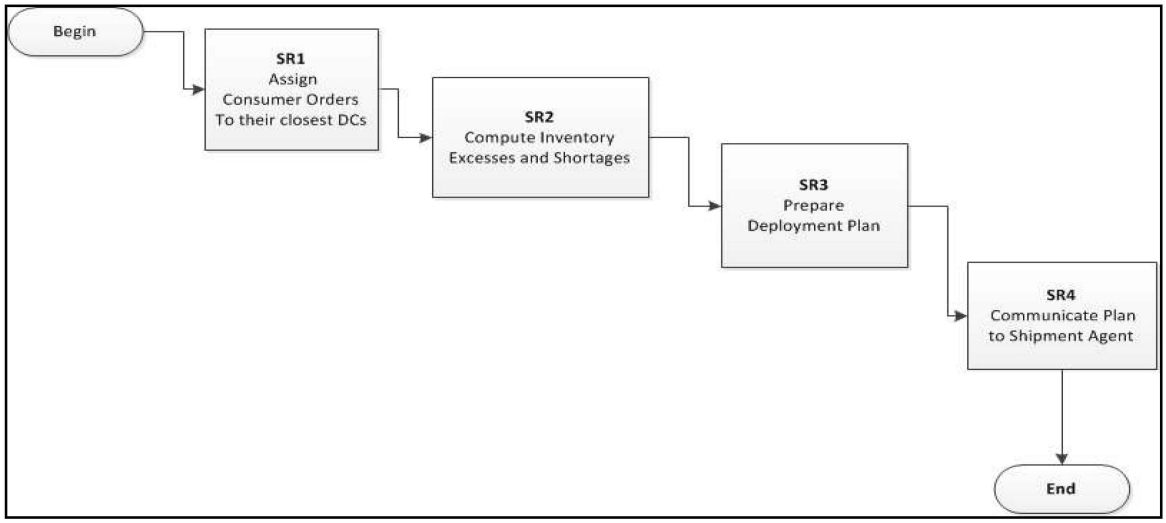


Figure 2: Distribution agent behavior subroutines

Then SR2 computes the set of gaps as expressed through equation (2) where $NetInventory(p,x)$ is composed from quantities of product p in stock at node x summed to quantities of in-transit product p being shipped to x, from which assigned consumer order quantities are deduced. Estimated inventory excesses and shortages correspond respectively to positive and negative gaps ($gap(p,x)$).

$$TargetCoverage(p,x) = \hat{d}(p,x)covDaysNb(e) \quad (1)$$

$$gap(p,x) = NetInventory(p,x) - TargetCoverage(p,x) \quad (2)$$

SR 3 is divided into four steps (Figure 3), namely SR3.1, SR3.2, SR3.3 and SR3.4, where SR3.3 is implemented differently according to the desired simulation model (integrated and

interconnected). SR3.1 sorts shortages according to their priority of fulfillment, the most urgent shortage being the one with the greatest value of the estimated deviation of product shortage in the DC of concern from its actual coverage and with the lowest number of actual days of coverage over the target number of days of coverage of a product in the DC of concern. Then, SR3.1 detects emergency shortages to be fulfilled based on X_{min} and Y_{max} parameters presented in Table 1.

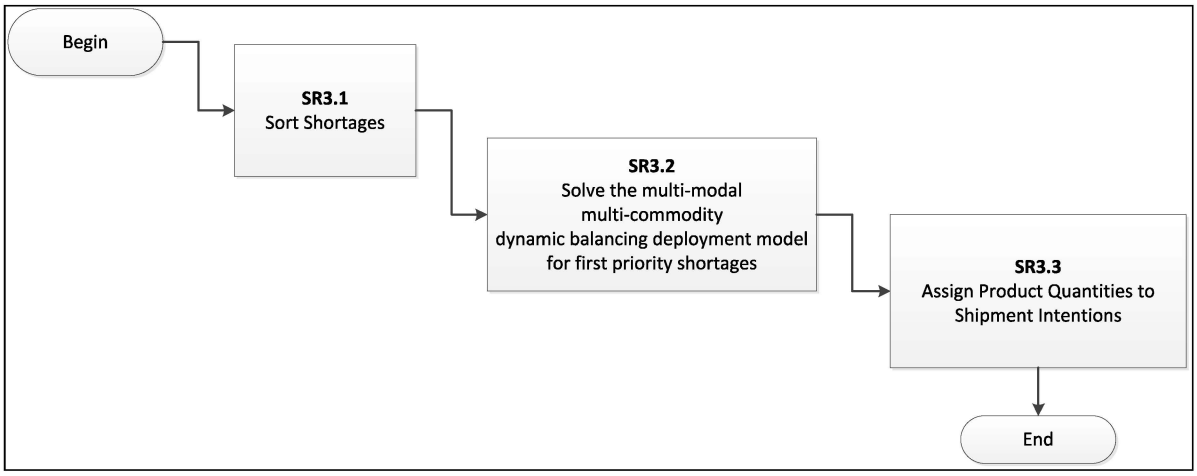


Figure 3: Subroutine SR3 details

Based on available product excesses and emergency shortages, SR3.2 finds a near optimal solution of the *Multimodal multi-commodity dynamic balancing deployment model* to deploy the emergency shortages (equations (3) - (8)). This linear program aims at minimizing shipment costs to cover inventory redeployment targets (reducing and increasing inventories of specific products at specific DCs), with respect to used vehicle capacities.

$$Minimize\ Z = \sum_i \sum_j C_{mij} S_{mij} \tag{3}$$

Subject To

$$\sum_{j,m} X_{mpij} \leq a_{pi}\ ; \quad \forall p, j \tag{4}$$

$$\sum_{i,m} X_{mpij} = d_{pj}\ ; \quad \forall p, i \tag{5}$$

$$\sum_p v_p X_{mpij} \leq v_m S_{mij}\ ; \quad \forall m, i, j \tag{6}$$

$$\sum_p w_p X_{mpij} \leq w_m S_{mij}\ ; \quad \forall m, i, j \tag{7}$$

$$X_{mpij} \geq 0\ ;\ S_{mij} \geq 0;\ X_{mpij} \in \mathbb{N};\ S_{mij} \in \mathbb{N} \tag{8}$$

Where

i: Source node.
j: Destination node.
p : A product to be deployed.

m : Vehicle type (Ex.: 53' truck, van).
a_{pi}: Quantity of product p available to be deployed from source node i.
d_{pj}: Quantity of product p to be fulfilled at destination node j.
w_p: Weight of product p.
v_p: Volume of product p.
w_m: Weight capacity of vehicle of type m.
v_m: Volume capacity of vehicle of type m.
C_{mij}: Cost of a vehicle of type m shipping from i to j.
X_{mpij}: Decision variable of the quantities of p to be deployed from i to j using vehicles from type m.
S_{mij}: Decision variable for the target number of vehicles of type m to be used to ship products from i to j.

Then, SR3.3 computes plans for product movements (shipment intentions) to be considered later on by the Shipment Agent in order to assign product quantities in vehicles from sources to destinations of concern. SR3.3 in the *Integrated Distribution agent behavior* is different from SR3.3 in the *Interconnected Distribution agent behavior*, through their respective consolidation logics detailed in Table 2.

Table 2: SR3.3 details in Integrated versus Interconnected Distribution agent behavior

Integrated Distribution agent behavior	Interconnected Distribution agent behavior
1. Assign X_{mpij} (emergency shortages) to shipment intention. 2. Sort remaining unassigned shortages in decreasing order of product shortage deviation from actual coverage, and increasing order of actual days of coverage over the target number of days of coverage. 3. Progressively fill resulting trucks being loaded less than the loading threshold with one day of estimated demand coverage from the first element in the sorted non-urgent shortage list, while products can be assigned and the truck filling has not reached the *AFPab* threshold parameter.	1. Assign X_{mpij} (emergency shortages) to shipment intentions.

In the integrated system, the supplier has to consolidate efficiently its products into full trucks. Filling trucks with only first priority shortages may result into partially filled trucks, which may be delayed to the next deployment planning and increase the inventory shortage of the product at the corresponding DC. Thus, the *Integrated Distribution agent behavior* has to check whether it is possible to fill trucks until reaching the filling threshold with remaining unassigned shortages. The second simulation model assumes using the Mobility Web, thus the *Interconnected Distribution agent behavior* considers only

assigning first priority shortages, having the confidence that the Web of mobility system would achieve full trucks including not only the supplier's product, but also other items of other organizations, stored in the source open DC and heading toward the same next destination.

Finally, in SR3.4, the *Distribution* agent communicates each shipment intention corresponds to truck filled beyond *AFPab* threshold parameter, as shipment orders.

4 Experiment and results

The experiments presented in this paper are based on a case study of *Southshore Industries* (*SI*), a leading North-American e-commerce furniture manufacturer serving flagship clients such as Amazon.com and Walmart.com that sell *SI*'s products all across Canada and the United States markets. *SI* currently makes its products in three plants, stores them in its DCs nearby its plants, and ships daily consumer orders in truckloads from these DCs to the closest dropping locations their e-clients' 3PLs in Champlain, NY, USA or El Paso, TX, USA. Then, the 3PL delivery service provider *T1*, *T2* or *T3* specified by the e-commerce client, collect *SI*'s drop-shipped consumer orders. These providers are responsible to move the products ordered online through their respective hub-and-spoke networks to their purchasing consumer. Figures 4 to 6 display modeled networks for these delivery service providers. *SI* is actually able to promise a delivery within an average delay of four days to e-consumers in Canada and a delivery within an average delay of five days to e-consumers in the United States.



Figure 4: T1's hub-and-spoke network (hubs in orange)



Figure 5: T2's hub-and-spoke network (hubs in orange)



Figure 6: T3's hub-and-spoke network (hubs in orange)

Based on SI's production and consumer order log, we aim to assess its performances in both integrated and interconnected B2C distribution systems with increasing consumer delivery speed requirements, shrinking *SI*'s actual delivery promise down to 3 days to both Canadian and United States' E-Consumers. To assess the economic, social and environmental performances of SI in an integrated distribution scenario, we used our simulation model presented in section 3.1,

using the network presented in Figure 7 that illustrates integrated distribution network proposed for SI under a 3-day delivery policy. Then, in order to investigate the performance improvements for SI when adopting interconnected *B2C* distribution, we modeled a 3-day-delivery interconnected distribution scenario through the simulation model presented in section 3.2, using the preferred open DC network illustrated in Figure 8.

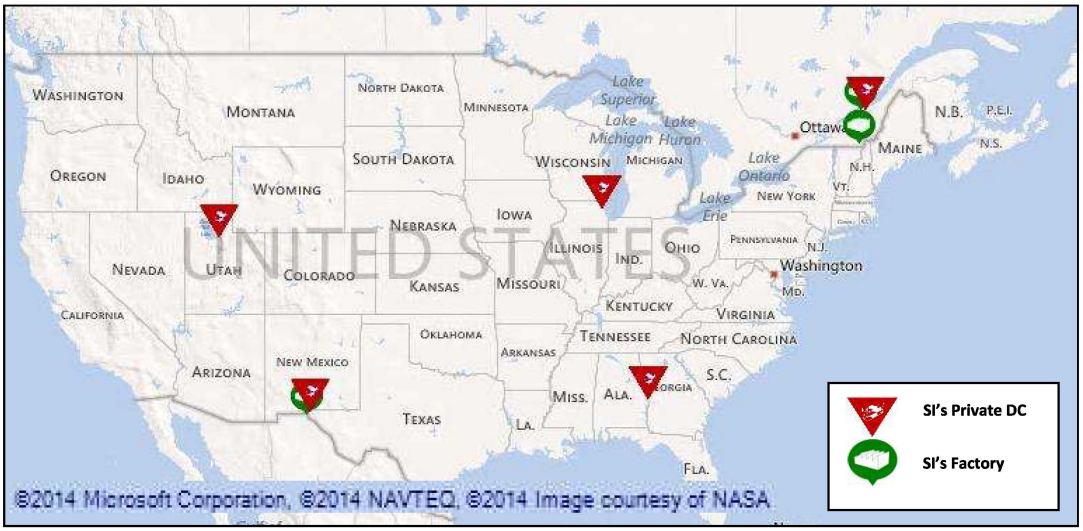


Figure 7: Private DCs in SI's 3-day delivery network under an integrated distribution scenario

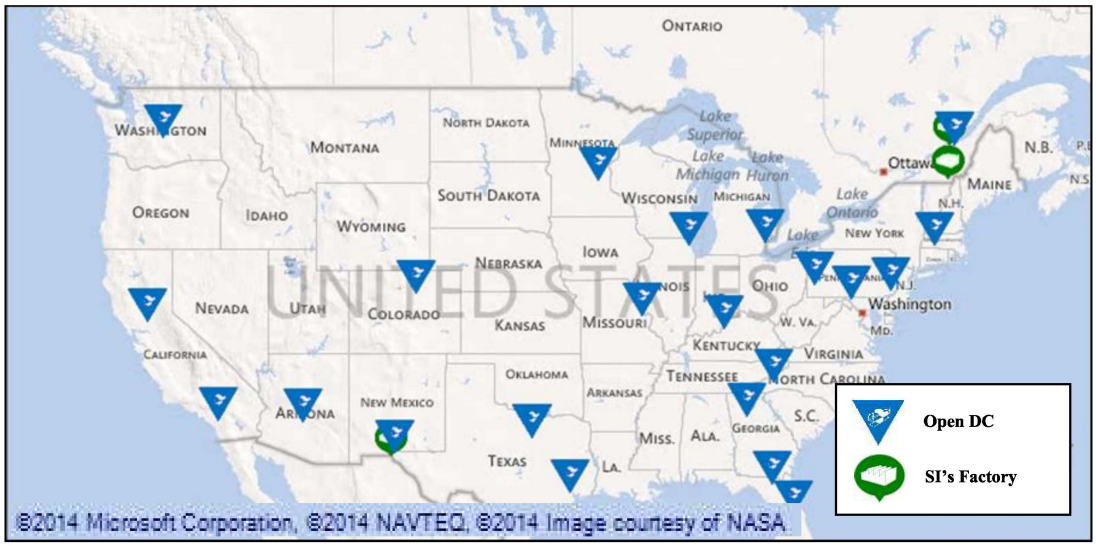


Figure 8: Preferred open DCs in SI's Network under an interconnected distribution scenario

For each simulation scenario we computed economic, social and environmental performances according to a set of Key Performance Indicators (KPI). Economic performances are quantified in Table 3, environmental performances are quantified in Table 4 and social performances are quantified in Table 5.

As illustrated in Table 3, thanks to the use of the Mobility Web, the interconnected distribution system caused a decrease of 29% in the *SI*'s transportation costs in the *Deployment* stage

acrossDCs in comparison with the integrated distribution system. Also, a decrease of 31.4% is observed in *SI*'s e-clients' costs during the *Order Delivery* stage. Both transportation costs from *SI* and its e-clients resulted in a total overall decrease of 31%. This total decrease improved the transportation part in the selling price of a product to E-Consumers, as it resulted in a decrease of 31.5%.

Table 3: Economic Performance improvements in interconnected system versus integrated system

Indicators	Performance Improvements
STC = *SI*'s Supplier Transportation Cost (*Deployment* stage)	-29%
CTC = Total Clients' Transportation Cost (*Order Delivery* stage)	-31.4%
TCT = **STC** + **CTC** = Total Transportation Cost	-31.0%
TCT/Revenues =Transportation Cost from the Consumer's Perspective	-31.5%

Table 4: SI's Environmental Performance

B2C Distribution Scenario	KPI	Integrated	Interconnected
Deployment stage	Fuel (10^3 L)	669	466
	Energy (MJ)	25 881	18 025
	CO_2 (T)	1 782	1 241
	CH_4 (T)	0.09	0.06
	N_2H (T)	0.27	0.19
Order Delivery stage	Fuel (10^3 L)	1214	617
	Energy (MJ)	46 953	23 869
	CO_2 (T)	3 233	1 643
	CH_4 (T)	0.16	0.08
	N_2H (T)	0.49	0.25
Total	Fuel (10^3 L)	1 883	1 083
	Energy (MJ)	72 834	41 893
	CO_2 (T)	5 014	2 884
	CH_4 (T)	0.25	0.14
	N_2H (T)	0.75	0.43

According to Table 4, if *SI* adopts an interconnected distribution system, the environmental performances are improved at all distribution stages, in comparison with environmental performances in the integrated system. At the *Deployment* stage, a decrease of 30% in *SI*'s contribution to vehicles' fuel consumption and gas emissions is observed. At the *Order Delivery* stage a decrease of 49% is observed in *SI*'s contribution to vehicles' fuel consumption. The overall contribution of *SI* in vehicle fuel consumption drops by 42% in the interconnected distribution system when compared with the integrated distribution system. The important decrease of fuel consumption in the delivery stage is due to the use of the openly pooled Mobility Web.

Finally, as presented in Table 5, from a social performance perspective, an increase of 9% in *SI*'s on-time order delivery is obtained through the interconnected distribution system as well as an improvement in SI's average truck load rate versus the average used truck capacity ratio, where we observed a decrease of 85% at the *Deployment* stage and a decrease of 59% at the *Order Delivery* stage. The social performance improvement does not only include *SI*'s performance, but also the driver work condition: the ratio between rest cycle count and driving cycle count is reduced from 66% to zero when shifting from integrated to interconnected distribution, due to significantly shorter driving routes.

Through the reported results, we proved through simulation, and based on real operational data from *SI,* that the PI-Enabled interconnected B2C distribution system improves economic, environmental and social performances at all stages of product distribution, compared with a conventional B2C integrated distribution system.

Table 5: Social Performance

B2C Distribution Scenario	KPI	Integrated	Interconnected
SI's Service Level	On time Delivery	85%	93%
SI's Average Truck Load Rate VS. Average Used Truck Capacity Ratio	*Deployment* stage	100%	15%
	Order Delivery stage	1%	1%
Rest Vs. Drive Cycle ratio	*Deployment* stage	69%	0%
	Order Delivery stage	66%	0%
	Total	66%	0%

5 Conclusion

The adoption of an interconnected open distribution in the context of B2C is an interesting alternative to be considered not only by suppliers, but also by e-clients. In fact, we reported

performance improvement at the different stages of the distribution, i.e. *Deployment* and *Order Delivery*.

The current study focused on distribution, assuming production decisions out of its scope. This has lead to results having the system fulfilling only 96% from total e-consumer order intentions in the tight three-day delivery policy. In further studies, this scoping constraint has to be unlocked, allowing production decisions to be dynamic, in order to help improve product deployment in face of stochastic demand.

As another research avenue, the interconnected B2C distribution system robustness has to be tested in more variable conditions, for example taking into account regional characteristics of consumers as well as demand seasonality creating huge peaks and valleys of demand.

Acknowledgements

This research was supported by *Bureau de l'efficacité et de l'innovation énergétiques (BEIE)* and by *le Ministère de l'enseignement supérieur, de la recherche, de la science et de la technologie (MESERT)* through its *Programme de soutien à la recherche (PSR), volet : initiatives internationales de recherche et d'innovation (SIIRI)* and *Southshore Industries*.

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System Dynamics Analysis for RFID-enabled Manufacturing Systems

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Abstract: *System dynamics (SD) is a modeling simulation approach to integrate all the dynamic factors involved in the overall process to achieve the statistical optimization of the operation by controlling the structure and parameters of manufacturing system. The application of those object-sensing enabling technologies such as RFID results in an intelligent physical internet for the dedicated system and process, which owns the ability of acquiring the dynamic behavior of system in a real-time and accurate way. SD can thus make the comprehensive simulation and analysis of the operation performance so as to achieve the optimal performance. This paper develops a SD model for WME – a RFID-enabled Manufacturing System. Simulation shows the comparison between WME and traditional manufacturing systems. It also evaluates the investment of achieving WME to provide a feasible approach of whether and how to implementing RFID.*

Keywords: *Manufacturing system; physical internet; internet of things; system dynamics.*

1 Introduction

The manufacturing system is an organic whole made up of human and machine generally, which converts production factors such as resource, equipment, manpower and information into product or service. The conversion is always through purchasing, manufacturing, warehousing, transportation, service and information processing (Chen and Ma, 2005). Both the factors' intrinsic characteristics and their input/output processes are subject to high dynamics such as equipment failures, the fluctuated replenishment rate and the different efficiencies of workers, which largely affect the overall production efficiency. In addition, the dynamics of individual factors will be magnified when factors have coupling relationships, and thus largely affected the performance of production systems. For example, the supply rate of materials will not only restricts the production efficiency of one procedure, but also affect the inventory levels of adjacent buffers (Xu et al, 2004; Liu et al., 2004). In order to maintain a good system performance, we need to find out the relationships between the dynamic factors and the system performances from the system point of view, and seek the best interaction strategies among factors.

System dynamics (SD) provides a feasible theory, viewpoint, method and tool for solving the problem with high complexity and dynamics (Forrester, 1961). Based on the control theory, SD gains the overall performance rule from the dynamic factors by setting up the mechanism of

information feedback and delay in each factor, and making analysis on the factors and the causal relationship through simulation. Then, it helps to improve the structure by adjusting the relationship between factors or changing the inputs. Finally, the strategy for the logistics, information flow and cash flow will be integrated and optimized by SD effectively (Zhang et al., 2010). With the knowledge of manufacturing system structure and the dynamic relationships among factors, SD has been widely applied to the modeling and simulation on the enterprise level, including enterprise management (Minegishi and Thiel, 2000), production operation (Vlachos et al., 2006), processing reengineering (Ozbayrak et al., 2007), inventory control (Angerhofer and Angelides, 2006), and bullwhip effect of supply chain/logistics (Disney and Towill, 2003). SD has played an effective role in changing the original behavior of system model, optimizing the effects of dynamic strategy and analyzing the efficiency quantitatively (Zhang and Fang, 2008).

The application of Internet of Things (IoT) technologies such as RFID to manufacturing processes results in the so called Manufacturing Internet of Things (MIOT). MIOT could be regarded as an important component unit of the physical internet, or an enterprise-wide realization of physical internet. After nearly ten years intensive research, MIOT has been used widely in the production management, automatic positioning and data acquisition. From the operation point of view, MIOT can simplify the processes of data recording and inventory accounting to make the production visualization and realizes the lean management. From the information viewpoint, it also provides the advantages as follows. (1) Improving the transfer speed and precision of the production information to ensure rapid and accurate production control (Liu et al., 2010). (2) Expanding the data collection scope and reducing the data granularity, thus improving the synergy of breadth and depth of manufacturing system (Chryssolouris et al., 2009; Curtin et al., 2007). (3) Changing/expanding the way of information communication from 'one-to-one' to the interactive network of 'N-to-N', and thus strengthening the ability of production control (Bottani et al., 2009; Doerr et al., 2006). The quality of information has also been increased. It makes the simulation of the manufacturing system more realistic and helps to verify the adaptability of the JIT production and adaptive control in the specific production environment (Brintrup et al., 2010; Chow et al., 2007). It also provides the possibility to conduct online SD simulation based on real-time data rather than the offline simulation based on statistic data.

The wide, real-time and accurate capturing of system dynamics offers the necessary condition for the application of SD. On the other hand, SD also provides the simulation-based approach as a correction strategy for evaluating and optimizing MIOT. The integration of RFID and manufacturing system has extended the simulation depth to include both the original layer of production material and the new layer of RFID-enabled physical internet. This paper discusses different operations of manufacturing system firstly. Then, we conduct SD simulation for an typical MIOT named Wireless Manufacturing Enterprise (WME), which was developed by the project team (Qu et al., 2013). Several research questions need to be answered. First, the comparative analysis of MIOT performance. By comparing the operation effectiveness and efficiencies of applying MIOT or not, how the real-time information will affect the structure and behavior of a manufacturing system will be shown; (2) Analysis of RFID investment schemes. To choose the better RFID implementation scheme, key performances of the system will be compared quantitatively.

2 Operation Analysis

The use of advanced management technology and automatic facilities has enhanced the operational level of manufacturing systems to an intelligent and automatic level. As shown in Figure 1, it's a warehouse's duty to manage the input/output of the raw material and finished product in their respective storage areas, such as the input buffer and output buffer of the process unit M. Figure 1 A stands for the traditional manufacturing system which is pushed by the production plan and realized the flow of material and information are all in a passive manner. With RFID implementation as shown in Figure 1B, the manufacturing system has realized the adaptive management. On one hand, RFID makes the object position visible and information acquisition automatic, which helps to simplify the human's involvement in inspecting, recording, counting and improve the accuracy of work-in-process (i.e. WIP) inventory information. On the other hand, the real- time information interaction among the production plan and i-flow (i.e. the information interaction between the units) enhance the ability to form a dynamic system with information feedback effectively which close their information gaps.

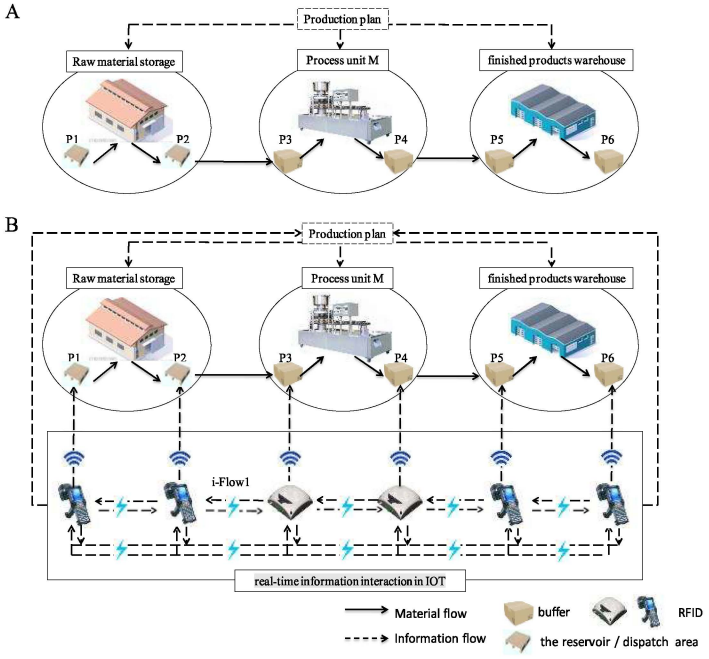


Figure 1: RFID-enabled manufacturing system

The information-based management strategy has direct influence on the operation of a manufacturing system. Let us take buffer P3 as an example to explain the relationship between distribution strategy and the inventory of P3. Figure 2A and Figure 2B shows the operation based on Figure 1A. Figure 2A is stand for the traditional manufacturing system with (Q,R) distribution strategy when the production task keeps steady, which requires that obtain the right quantity of products at the right time and achieve the production balance through coordinating the production rate. Therefore, it saves storage in warehouse and ensure the normal supply for production line. Figure 2B is the traditional manufacturing system with (Q,R) distribution strategy when the production task is fluctuant. Due to the lack of rapid information feedback from production process and the high adaptability of production plan, it's hard for a traditional manufacturing system to deal with the M's production dynamics. If the demand is beyond the original plan, Q can only complete the task in t1 (t1<T) and the production will be disrupted for the lack of materials. Otherwise, there will be redundant inventory in P3. Figure 2C shows a

RFID-enabled manufacturing system with the real-time distribution strategy. It has unified all the information about employees, procedures and processes, working time, equipment in order to control the production plan, progress tracking and risk prediction. Therefore, it will improve the speed of information transmission through compressing i-flows and thus enable the realization of real-time distribution. In this way, small batch material distribution strategy could be achieved in a JIT manner.

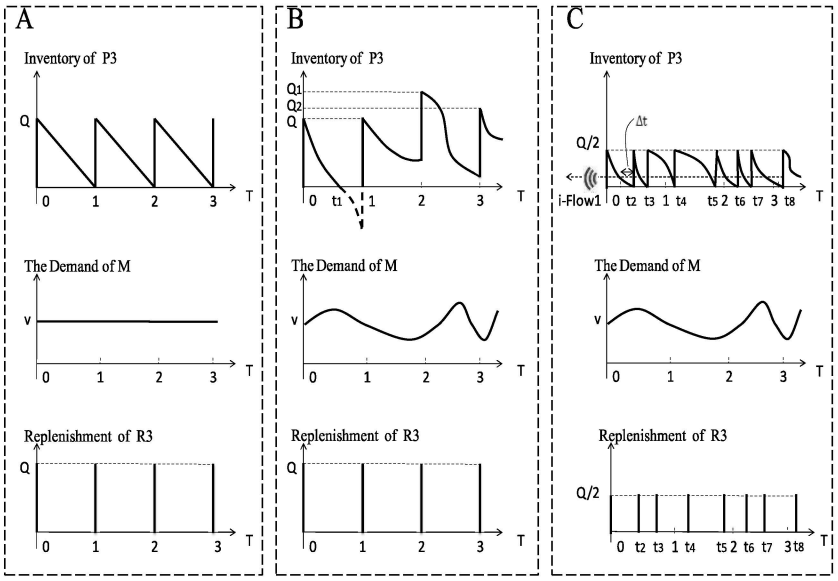


Figure 2: The inventory control of buffer P3

3 Model Structure

3.1 Causal Loop Diagram

In system dynamics, causal loop diagram is a description of complex relationship among different main phases or elements of manufacturing system. There are two distinct loops, i.e. the positive feedback loop (+) and the negative feedback loop (-). The former enhances the effect of the incentive factors to itself further, while the latter eliminates the positivity and makes the system return to equilibrium. Before dealing with the main feedback loop, one important definition of the SD model needs to be discussed, namely the relationship between the manufacturing system and RFID. The system is determined by the production process and the causal loop diagram keeps the same structure no matter RFID is used or not. Figure 3 illustrates the major feedback loops and the impacts on the final SD model. According to the production process, the causal loop diagram is divided into several units (i.e. M1, M2, M3), and each one contains positive or negative loops.

Taking process unit M1 for example. Loop 1 describes the balancing impact of different rates on inventory. As a matter of fact, the production process is driven by the production plan from raw material to semi-finished products in M1. The production rate has a positive influence on the inventory level, so does the raw materials delivery rate. But the inventory is low by the semi-finished products delivery rate.

Loop 2 is a representation of the balancing feedback between the raw material delivery and demand. The more the level of the requirements, the more raw materials need to delivery to

production line and supply the consumption in buffer. If the delivery rate goes up, the capacity planning will be changed to achieve higher production efficiency.

Loop 3 shows that the inventory has a counteractive effect on the production capacity planning. Therefore, when the actual capacity of M1 is more than the expected and its products cannot be delivered to the subsequent unit, there will be an inventory backlog in buffer. The system will increase the production speed to alleviate the inventory pressure.

Loop 4 represents the inventory among different units. There are two methods of distribution. One is delivering the semi-finished products from M1 to M2, while another is moving the rest to the warehouse. If the demand of the subsequent unit has been satisfied, the manufacturing system can restrain the inventory accumulation through enhancing the stock transfer rate.

3.2 Rate and Level Diagrams

The next stage in the modeling process is to convert the causal loop diagram to rate and level diagrams. The model constructed for the manufacturing system is shown in Figure 4. It comprises two parts, namely the traditional manufacturing system and RFID-enabled manufacturing system. In this paper, we will adopt the wireless manufacturing execution system (WME) as an demo system for the whole analysis. It shows (N+2) material flows: (1) Production logistics among N process units. As a sequence, there are a lot of WIP inventory and buffer inventory (i.e. input buffer inventory and out-Buffer inventory) in the procurement, production, distribution and other portions. (2) The raw material flow and the finished goods flow, which is accumulated by the input and output delivery in warehouse.

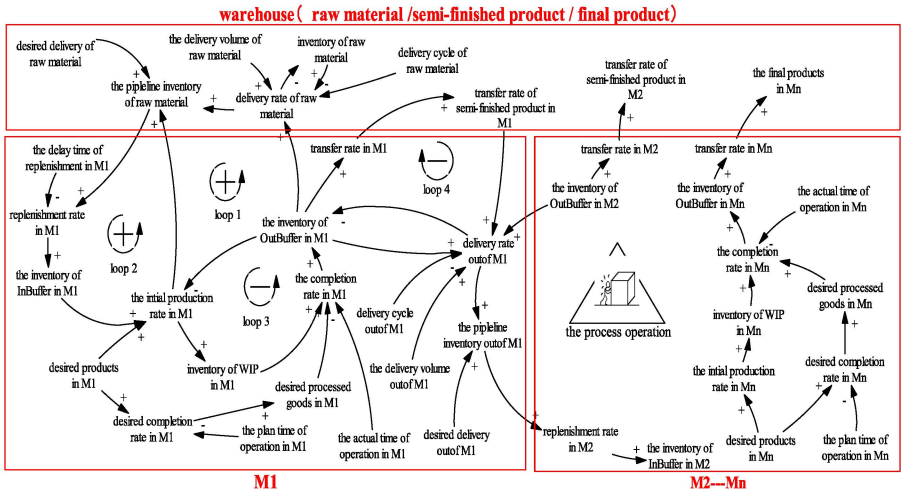


Figure 3: Manufacturing causal loop diagram

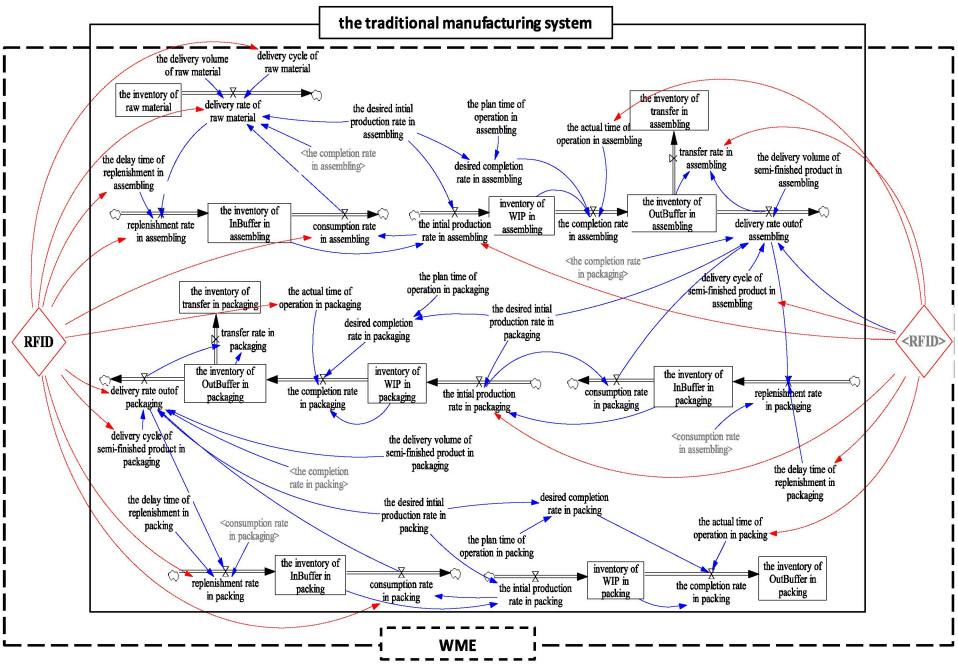


Figure 4: Manufacturing rate and level diagram

4 System Dynamics Modelling for RF ID-Enabled Manufacturing System

4.1 WME - A RFID-enabled Manufacturing System

Figure 5 represents the average behavior of the WME system. Based on the system structure, RFID could be installed in seven locations, including the warehouse and the input buffers and output buffers for three process units. We have the following assumptions: manufacturer's production capacity is unlimited and the overall output is 480 pc per day; the raw material is enough for production; there are three process units, including assembling, packaging and packing operations. The production time of different units follows a normal distribution. The system was simulated for one –working day (i.e.480 minutes) with 1-minute step. The whole simulation is by the widely known system dynamics tool named Vensim PLE.

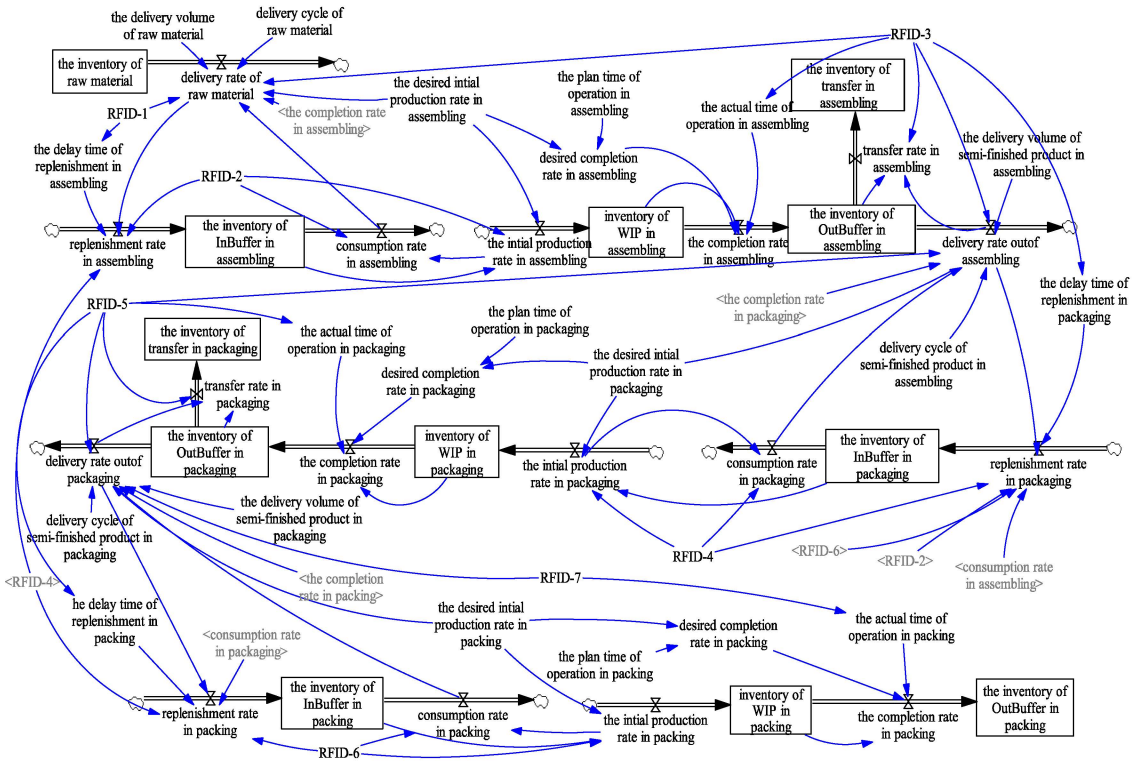


Figure 5: The SD model of WME

4.2 Equations Definition

WME and the traditional manufacturing system have the same operational logic. The stock level of a buffer is determined by the input/output rate (e.g. replenishment rate, production rate, completion rate, delivery rate) , given by equations (1) and (2). Equation (3) means that WIP is derived from the previous value of WIP plus the initial production rate minus the actual completion rate for the current dt period. In addition, the main effects of 'RFID' input variable in WME are shown next. We will compare the traditional manufacturing system with RFID-enabled WME which enables monitoring and tracking.

The information transfer time

The time of information transfer includes information acquisition and receiving, information transition, information sending and so on. The transfer time is largely related to the number of interacting node and the transmission path. The information which could be acquired within expected time span and used for decision making is defined as effective information. Delayed information results in lower efficiency. As compared with the traditional manufacturing system, WME helps to shorten the information time delay and therefore the production rate is calculated by equation (4).

The adaptive management

For a fixed distribution amount, there is negative correlation between volume m and distribution cycle time T. As compared to the traditional (Q, R) distribution strategy, WME can ensure the consistency between the delivery rate and the production rate to reduce the inventory backlog in

buffer. It relies on the accuracy and promptness of information interaction. The delivery rate variable relationship is thus computed as (5).

The adaptive control of the line-side inventory

Line-side inventory is dealt with in two ways, i.e. delivering to subsequent unit or to warehouse. The traditional manufacturing system adopts the periodical inventory management., Delivery is performed at time t if the inventory level is higher than m, otherwise to wait for the next cycle. WME can monitor the buffer inventory in a real-time manner and conduct just-in-time inventory transfer. The transfer rate variable relationship is computed as (6).

5 Simulation Results

5.1 Information interaction

Buffer is a critical control point in the production logistics. WME can get rich information from buffers, such as input/output time, quantity of the raw material inventory/ semi-finished products inventory/ final product inventory (FGI), etc. Although we could assume that each part in WME supports information transfer and feedback, it is impossible or unnecessary that any part could communicate with all other part. How to distribute information to designated nodes is important. It helps avoid the information redundancy and also accelerate the information transfer.

Ways of information interaction

We consider three types of information interaction in WME.

(1) In-Buffer to In-Buffer (I-I for simple). All parts could share all the information of In-Buffers, including the quantity of replenishment, the arrival time of replenishment and the inventory of the In-Buffer.
(2) Out-Buffer to Out-Buffer (O-O for simple). The process units can share their information about Out-Buffers, including the quantity of delivery/transfer, the arrival time of delivery/transfer and the inventory of the Out-Buffer.
(3) In-Buffer to Out-Buffer (I-O for simple). This could be regarded as the combination of the first two ways.

Design of scenarios

There are overall four simulation scenarios considered in this study.

(1) Scenario 1: the traditional manufacturing system;
(2) Scenario 2: WME with ‘I-I’ information interaction;
(3) Scenario 3: WME with ‘O-O’ information interaction;
(4) Scenario 4: WME with ‘I-O’ information interaction.

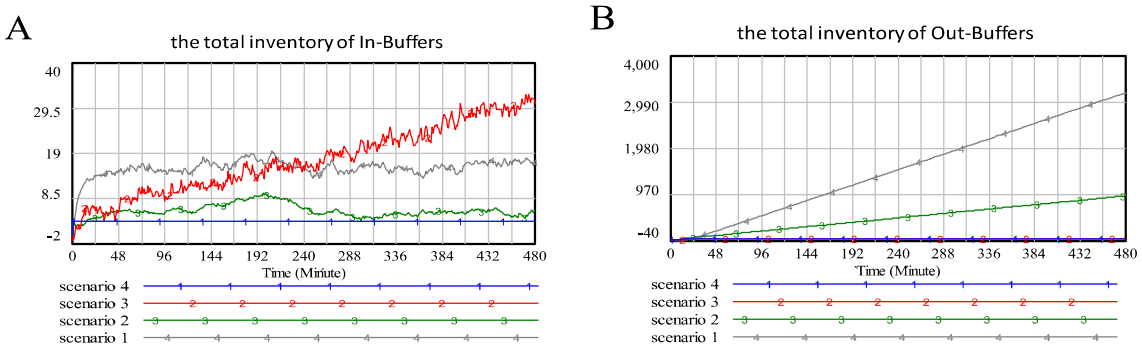
This paper will discuss the effects generated by different frequency (F) of information interaction. The three sample frequency values are set to 1, 3, 5 minute a time.

5.2 Simulation of the Traditional Manufacturing System and WME

Inventory Reduction

The system is simulated by considering the reduction in inventory under four scenarios. As Figure 6 shows, the average inventory levels of In-Buffer and Out-Buffer get increased in the traditional manufacturing system. However, the WME has different results. The inventory level

of In-Buffer is fluctuated around 0 while the Out-Buffer's is still higher in scenario 2. The results of scenario 3 are exactly the opposite of those obtained in scenario 2, in which the inventory level of Out-Buffer keeps lower and the In-Buffer's of subsequent unit needs to hold higher inventory. In scenario 4, the system wins because it always holds the lowest inventory.



(A) the total inventory of In-Buffers. (B) the total inventory of Out-Buffers.

Figure 6: Simulation of inventory

Table 1: Simulation Of Pipeline Inventory

Scenario	Non-RFID-enabled	RFID-enabled		
		F=1	F=3	F=5
Scenario 1	3302	/	/	/
Scenario 2	/	1041	1057	1079
Scenario 3	/	132	148	174
Scenario 4	/	105	120	157

Production Output Increase

The production output is mainly determined by production rate and delivery rate. As shown in table 2, the average production output of the traditional manufacturing system is lower than all scenarios of WME. From the simulation, it turned out that scenario 4 has the highest product. Also, there is a positive correlation between the quantity of product and the frequency of information interaction.

Table 2: Simulation Of Product Inventory

Scenario	non-RFID-enabled	RFID-enabled		
		F=1	F=3	F=5
Scenario 1	473	/	/	/
Scenario 2	/	478	478	477
Scenario 3	/	502	500	496
Scenario 4	/	506	502	501

Production Time Shortening

The effect of different scenarios on the time of making the same amount product is shown in table 3. The production time is out of plan in scenarios 1 and 2, and the system needs to increase the number of workers and working hours to finish the task. However, the manufacturing system can produce more products in the limited time in scenario 3 and 4. In particular, the production time has a trend of being lower slightly with the frequency rising. WME outperforms in two

aspects. Firstly, reducing the inventory is beneficial to control the holding cost of inventory and other costs. Secondly, it can create more economic benefits by producing more products or shortening the production time, for releasing extra time the staff can effectively do other kind of work.

5.3 Cash Flow Analysis

Some studies have testified that RFID technology has an impact on the profitability in enterprises. But the technology has not been widely used because of higher cost. Therefore, enterprises begin to consider two questions, including the necessity of application RFID and the profitability. To quantitatively analyze the economic benefits of RFID system, SD simulation is adopted to conduct cash flow analysis to evaluate the return on RFID investment under different RFID schemes.

RFID system cost

The implementation cost of WME includes hardware cost, software cost, system integration cost, equipment installation cost, labor cost and the cost of business process reengineering. The hardware includes reader, antenna, tag and computer equipment, while the software contains the database, middleware, etc. The UHF RFID hardware used in the WME system is composed of one reader and two antennas, and the total cost is ¥10000. This paper assumes that the RFID system has a 5-years useful life. The cost for equipment maintenance, system management and training are 15%, 12% and 10% of the RFID hardware cost respectively. So the cost of one RFID system is calculated as follows:

The average value of one RFID system is calculate as:

$$10000 / 5 = 2000 \tag{7}$$

The depreciation expense of one system at the end of the first year

$$(10000 - 2000) / \left[(5 - 1 + 1) / (1 + 2 + 3 + 4 + 5) \right] = 2667 \tag{8}$$

The annual equipment maintenance cost

$$10000 * 15\% = 1500 \tag{9}$$

The annual system management cost

$$10000 * 12\% = 1200 \tag{10}$$

The annual training cost

$$10000 * 10\% = 1000 \tag{11}$$

The annual cost of one RFID system

$$2667 + 1500 + 1200 + 1000 = 6367 \tag{12}$$

Profit analysis

Considering the simulation under the higher frequency of information interaction (i.e. F=1) is better than others in 4.1. The following assumptions are considered for cash flow analysis: there are 25 workdays and the plan of production time is 480 minutes per day; the daily storage fee is 0.02 per piece; the cost related to inventory (e.g., the utility bills, the depletion expenses of materials) equal to 10% of the inventory maintenance cost; a gross profit per product is ¥4.

Table 3: Comparing the Profit Monthly

Scenario	the inventory maintenance cost (RMB)	the cost related to inventory (RMB)	the profit of production (RMB)
(1)scenario 1 F=1	1,651.00	165.10	47,300.00
(2)Scenario 2	520.52	52.05	47,800.00
(3)Scenario 3	66.00	6.60	50,200.00
(4)Scenario 4	52.50	5.25	50,600.00
gap			
(5)=(2)-(1)	1,130.48	113.05	500.00
(6)= (3)-(1)	1,585.00	158.50	2,900.00
(7)=(4)-(1)	1,598.50	159.85	3,300.00

Calculations are performed for difference scenario of under the schemes of WME. As shown in table 5, the best investment return is achieved ofby scenario 3. and iIt is profitable within one year time frame. What's moreIn addition, it has demonstrated that installing RFID devices in a few parts may work better than installing RFID to around if one enterprise wants to bring RFID into the manufacturing the whole system.

Table 4: Simulation of Product Time

FGI	Scenario1	F=1			F=3			F=5		
		Scenario2	Scenario3	Scenario4	Scenario2	Scenario3	Scenario4	Scenario2	Scenario3	Scenario4
0	0	0	0	0	0	0	0	0	0	0
80	87	82	80	76	82	81	80	83	79	79
160	167	162	155	153	162	157	155	166	162	158
240	247	242	231	228	242	234	232	243	236	231
320	327	322	307	304	322	310	308	323	311	308
400	407	402	382	380	402	385	383	403	388	383
480	487	482	458	456	482	461	458	483	465	459

Table 5: Return on Investment under the Schemes of WME

Scenario	RFID cost (RMB/Year)	RFID profit (RMB/Year)	Five-year net profit (RMB)	Static payback time (Year)	Rate of return on investment (%)
Scenario 2	19,101.00	20,922.60	9,108.00	4.57	0.10
Scenario 3	25,468.00	55,722.00	151,270.00	0.84	1.19
Scenario 4	44,569.00	60,700.20	80,656.00	2.76	0.36

6 CONCLUSION

The application of IOT technologies such as RFID simplifies the processes of data recording and inventory accounting. It enables the production visualization and lean management, and improves the quality of production information including the accuracy, scope and speed of information transmission. It contributes to the JIT production and adaptive control effectively. In

this paper, SD is used to simulate and analyze the influence of dynamics factors in a RFID-enabled manufacturing system.

We have compared the key performance of different RFID using schemes and drawn the following conclusions: (1) A RFID system contributes to the lean management of a production system. The real-time feedback of information and adaptive distribution strategy can improve the production operations, such as reducing the information redundancy, feedback delay, logistics interruption and inventory backlog. (2) The diversified ways of information interaction brought by RFID has changed the flow and quality of information. (3) Many factors affect the effectiveness of a RFID-enabled manufacturing system, including the location of installing RFID, the way and frequency of information interaction. It also provides an economic evaluation approach to select the best scheme of implementing RFID through quantitatively calculate the investments and profits of RFID. This paper focuses the investigation on the machine level. In the future work, we will investigate the RFID values for the process and enterprise levels, and consider more dynamic factors among the system to make the research more realistic and comprehensive.

7 Acknowledgement

This paper is supported by National Natural Science Foundation of China (51105081), Guangdong Natural Science Foundation (S2012010010016), Guangzhou Pearl River New Star Fund Science and Technology Planning Project (2011J2200017), Guangdong College Talent Import Scheme (11ZK0066), National Science and technology support program (2012BAF12B10), and Industry-University-Research Cooperation Key Project of Guangdong Science and Technology Commission (2011B090400409).

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Auction based transport services allocation in Physical Internet: a simulation framework

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Abstract: *The Physical Internet concept proposes a new way to move goods towards customers across a network of interconnected logistics services. Giving to this concept the containerized goods travel form one hub to another until reaching final destination. This principle implies that each container searches the best service on its route. Accordingly the logistics service providers and hereafter the carriers offer services (transport between hubs). Therefore the allocation of a service to a provider becomes more dynamic and an efficient mechanism between offers and demands is required. We propose here a combinatorial auction mechanism based on mechanism design theory to efficiently allocate bundles of containers to transport services. The hypotheses are described and the mechanism is split into different processes called rules. The contribution of this work is based on the ability of the Physical Internet to reallocate a container to carrier at each hub if it improves the routing of the container and the utilization of the logistics network resources. An example illustrates how the proposed mechanism will work at the level of a single hub and how containers bundles are allocated to carriers.*

Keywords: *Physical Internet, Transport service allocation, Combinatorial Auction, Mechanism Design.*

1 Introduction

Physical Internet is an innovative concept in logistics and it is now becoming a new research topic in the supply chain field, see (Montreuil 2011) and (Montreuil, Meller et al. 2013). One of its major objectives is to improve efficiency of freight transport. To do so, this new approach favors interconnection of all logistics services through hubs to better use transport means by shifting loads to bigger and more efficient means and increase fill rate. In a recent work a model assess the performance of a Physical Internet network based on the case of fast moving consumer goods in France, see (Sarraj, Ballot et al. 2013) and (Sarraj 2013). An agent-based simulation model coupled with optimization was developed to simulate and optimized the route of containerized shipments across an open network between plants and retailer distribution platforms. By implementing Physical Internet concepts the simulation showed a reduction up to 40% of global cost and up to 60% of CO2 emissions from transport. Following this former work, in this paper we address the transport service allocation problem within Physical Internet.

In an open transport network as Physical Internet shipments, here containers will go through the destination by intermediate hubs in the network, namely PI-hub (PI for Physical Internet

hereafter). In each PI-hub the shipments will have the chance to be reallocated to new carrier to provide the lower price to destination. How to allocate transport requests to transport services in such a context is the research question addressed here. As the first step, this paper aims to present the problem ad-dressed in the context of a network of interconnected logistics services and a framework to allocate transport services. The third part presents the selected methodology, namely combinatorial auction inspired from Mechanism Design theory. The fourth part introduces the transport service allocation rules in PI Network based on auction mechanism and the fifth part the implementation in proxy agents. A case study illustrates the proposed framework.

2 Motivation and methodology

2.1 Transport allocation needs within the Physical Internet

The Physical Internet approach of logistics enables the interconnection of all logistics services, trans-port includes of course (Montreuil 2011). According to this concept, like in Internet, the shipments travel throughout different sub-network "seamlessly". On one hand unlike in Internet free of charge peer-to-peer agreement is not an option as each shipment implies a cost. On the other hand, the organization of transport in PI Network differs by a much more open and dynamic context from the traditional organization in that the later is based very limited search, often-static allocation of means. More precisely, in PI Network the containerized shipments will go through the network allowing them having stops in several PI-hubs where theirs route can be modified if a better solution is available. Here the role of the PI-hubs is not only loadings and transshipment points (modal shifting for example), but also a place where shipments can be reallocated to a more efficient carrier or to a better route. The decision can only be made locally in each PI-hub, considering the real-time state of the network (availability, delays…) requests and offers on the spot. It is a decentralized system but with a global view. The proposed approach will be tested here at the level of a PI-hub.

2.2 Proposed approach

In such decentralized transport network, the most important question is how to dynamically and locally match the requests and offers in each PI-hub meanwhile globally optimise the transport in the network. The Mechanism design is one of the tools to answer the question. (Narahari, Garg et al. 2009) define it as: "the theory of mechanism design is concerned with settings where a policy maker (or social planner) faces the problem of aggregating the announced preferences of multiple agents into a collective (or social) decision when the actual preferences are not publicly known… The main focus of mechanism design is to design institutions or protocols that satisfy certain desired objectives, assuming that the individual agents, interacting through the institution, will act strategically and may hold private information that is relevant to the decision at hand". According to its definition and objectives, the Mechanism Design theory is appropriate for PI Network for studying the transport service allocation problem. It is therefore adopted in our research work.

Not many papers studying Mechanism Design in freight transport can be found in the literature. In general there are two applications of mechanism design related to our work: the first approach is based on inverse optimisation aiming to provide a optimal plan allowing carriers exchanging their capacities, see (Agarwal and Ergun 2008) and (Agarwal and Ergun 2010); and the other is

based on logistics auction mechanism, see (Huang and Xu 2013) and (Xu and Huang 2013). The proposed inverse optimisation seems not applicable to our case because, in one hand it requires collecting the private and true logistics information (capacity, cost, etc.) of all carriers to compute the optimal exchange prices that make the carriers have incentive to follow the plan, and this task is very difficult to be performed in PI network. In other hand, the proposed capacity exchange prices are implemented as regulation and no carrier in the alliance can refuse it. This setting is too much of a risk in PI Network which gives a very high flexibility to carriers and shippers for offering or accepting prices. Nevertheless, the auction mechanism approach without these disadvantages is more suitable to the scope of problem. Thus it is adopted. In the next part we present the preliminaries of auction theory following by framework of application to PI network.

3 Literature review of auction theory applied to transport

This part aims to introduce the auction theory to transport service procurement. For all basic knowledge of mechanism design theory and particularly auction theory, readers can refer to (McAfee and McMillan 1987), (Andres Figliozzi, Mahmassani et al. 2003), (Day and Raghavan 2007) and (Narahari, Garg et al. 2009). Here we will go straight forward to its applications to freight transport.

The literature pays more and more attention to application of auction mechanism to transport service procurement, see (Elmaghraby and Keskinocak 2004), (Sheffi 2004), (Huang and Xu 2013) and (Xu and Huang 2013). Two main applications related to our work can be found in the literature.

The first application is the auction based transport marketplaces that match requests and transport services. A good example, presented in (Ledyard, Olson et al. 2002), is the implementation of the first freight exchange system using combinatorial auction. This real case, conducted by Sears Logistics Services (SLS) and the consulting company Joseph Swanson and Company (JSCO), shows that the system can help SLS consolidating its trucking services. Thanks to that, SLS achieves $ 3.3 mil-lion (13 percent) of total cost savings, comparing with the previous rates.

Another application is to use combinatorial auction based request-outsourcing market to help carriers improve their cost efficiency. Carriers firstly form a collaborative group and make mutual agreement on performance and price. When a carrier obtains an order, it will evaluate the compatibility between this order and his scheduled operations by optimization tools, to decide whether to auction this order to the other carriers. When this order is auctioned, the other carriers evaluate this order, and the carriers having compatible operations will bid for it. Analysis shows that such collaborative system the system is a Pareto efficient one in which no participants are harmed and many are better off, see (Regan and Song 2003), (Jin and Wu 2006) and (Schwind, Gujo et al. 2009).

In this paper both of them are considered in the auction mechanism to take advantage of the PI network. On one hand, new entrance requests will be allocated to the carriers offering lowest price after auction, i.e. auction-based marketplaces; on the other hand the PI network enables carriers exchanging their capacities via auction based real-location in the PI-hubs. The combination of the two approaches in the context of the PI network is the contribution of the paper. In addition, the particularity in PI network is that the auction mechanism should not only

play the role of allocating requests to offers, but also have the objective to globally improve transport efficiency. In the next part we discuss the construction of such auction mechanism.

4 A framework for transport ser-vices allocation in Physical Inter-net Network

This part concerns the main contribution of this paper: the construction of an auction based transport service procurement mechanism in PI network. The mechanism can be discussed in two aspects: pre-defined rules in the whole network looking for global efficiency; and auction mechanism in local PI-hub allowing optimally matching requests and offers.

4.1 Transport rules in network

In order to guarantee service and global efficiency in PI network, while making all participants in this system can benefit from the synergies therein, following rules are established.

Rule 1: Allow reallocation of requests and enable co-delivery of requests. This is the core activity and advantage of flow consolidation enabled by PI network. In each PI-hub, shipments, i.e. requests (both the requests whose origin is the hub and those passing through the hub) are put in a pool so that they could be reallocated to other carriers who can provide a lower price to fulfil the requests. Herein optimise globally the transport efficiency.

Rule 2: No half-way dropping. This rule aims to guarantee service in the network, saying the reallocation will happen if and only if the fulfilment of requests is guaranteed. To do that, the carrier bidding for a request should submit a price that covers its route to final destination, whether re-quests of allocation or reallocation. In other words, if no reallocation is possible, the carrier should fulfil the transport till the final destination (with the proposed price). The question of route determination is not concerning in this paper, and we follow pervious related works like (Sarraj 2013). We suppose that once a transport request is received, its route is determined by the A* best path optimization. And for the reason of complexity, vehicle routing is not considered here.

Rule 3: Non arbitrary carrier-shifting. If there are more than one carrier offering better/lower price for a request, it should be allocated to whom offering lowest price (and arbitrarily allocate to one of those having same price). In addition, once a price is promised to a shipper for shipping his request(s), the price cannot be increased while shifting the request(s) from one carrier to another, in order to protect the interests of shippers.

Rule 4: Incentive for reallocation. If carrier-shifting behaviour happens under the previous rules, some savings, which are in fact the price difference when reallocating requests, will be generated within the sys-tem. Here we claim that all participants, i.e. shipper and carriers, should have somehow the right to share the savings, in order to make them all have incentive to reallocate the request. This rule is proposed here but further study is still necessary. Hence it will be not considered in the auction mechanism in this paper.

All these rules, expect the fourth, are taken into account in the auction mechanism, specifically in the proxy agents presented in the next part. Not in this paper but in next step, we can further investigate the flexibility of the rules in PI network and the impact on the global efficiency of transport.

4.2 Auction type selection

The Auction mechanism adopted in this paper is the First Price Sealed Combinatorial Auction (FPSCA, or just CA for short), in which shippers and carriers are respectively the auctioneers and the bidders. In every predetermined time interval (one hour for example), one CA is carried out at each hub to allocate the requests on the spot to present carriers. In a given hub the process of each CA is as follow. At the beginning, information of all requests is collected by the auctioneer's proxy agent then communicated to the local carriers' proxy agents. And then the later agents analyze the requests and propose bids according to carriers' personalized configuration (cost function, profit margin, etc.); and they need to make decisions of on which request bundles to bid and for what price in order to maximize carriers' profit. Once the proposition of bids validated by carriers, the bids will submit to the auctioneer agent and the decision will be made by a winner determination model. Finally the decision will be sent to carriers so that on auction process is finished. In Part 6 we will use an illustrative case to discuss more details of the process. In the next section we firstly introduce the concept and the function of agents.

5 Role of agents in the auction process

In transport CAs, the carriers would encounter difficulties when making bidding decisions, due to the exponential number of possible bundles in the number of requests. In addition to the complexity of evaluating all possible bundles, the carriers need to decide which bundles to submit. Evaluating and submitting all possible bundles would be prohibitively time consuming not only for the bidders, but also the auctioneer. Here we propose the use of autonomous proxy agents to facilitate and assist the bidding-decision-making process of carriers and auctioneers. This term is wildly discussed in the literature on auction theory, see (Parkes and Ungar 2000), (Plummer 2003) and (Cramton, Shoham et al. 2006). Two agents with different function are considered in the auction system.

5.1 Proxy bidding agents

In the auction system carriers will make use of an own proxy for all bidding decisions, i.e. proxy bid-ding agents. The mission of each proxy bidding agent is to provide the best bidding strategy to his client carrier, with consideration of its client's private information (cost rate, revenue expectation, capacity, etc.). It will be conducted in two steps as follow.

Determining the feasible request bundles. In transport auction games a Request Bundle (RB) is a subset of requests in a given pool. In other worlds, the whole set of RBs represents all combinations of requests. At first step the proxy agent should find out the feasible RBs from the pool to its clients, which must satisfy two conditions: route compatibility and carrier's capacity. According to Rule 2, the route of each request is pre-determined and it should not be modified during allocation-reallocation, so that only the requests having destinations along the same route that can be jointly delivered by one truck are compatibles (recall that vehicle routing is not considered here). We put all compatible requests that can be consolidated along a common route i in the same group, namely compatible group G_i. After identifying all such compatible routes (may be overlapping), we consider the subsets of compatible group $\{G_1,\ldots,G_n\}$. Furthermore, if we should make a hypothesis that for each carrier in one hub his capacity is limited (here only considering capacity of volume), he will only consider the RBs that he can handle. The proxy agent should also take into account this private information from its client. Finally, only those RBs that satisfy at the same time the two conditions are considered as feasible RBs that are

proposed to carriers. It is denoted as subsets $RB_1,\ldots, RB_k$ of compatible groups $\{G_1,\ldots,G_n\}$, which $RB_i \neq 0$ and $RB_i \subseteq G_j$ with $i \in \{1\ldots k\}$ and $j \in \{1\ldots n\}$, and $\sum_{r \in RB_i} v_r \leq CP_t, \forall RB_i$, where v_r is the volume of one request r in RB_i and CP_t is the capacity of carrier t_i (in volume). If we define that a truck is a carrier (or decision will be made individually for each truck), the capacity of each carrier will be limited to the volume of a truck. Hereafter we maintain the hypothesis that a truck is equivalent to a carrier.

Proposing bid for each feasible request bundles. Once feasible RBs are determined, the next step is to set up a bidding price for each bundle to be submitted to the auctioneer. Firstly we define the transport cost of truck (a carrier) t_i delivering a RB as CT^{ti}_{RB} and it is calculated by Equation (1):

$$\textit{Cost: } CT_{RB}^{t_i} = c_f^{t_i} + c_d^{t_i} \cdot max\{d_r | r \in RB\} + \sum_{r \in RB} c_{dv}^{t_i} d_r v_r \quad (1)$$

$$\textit{Bidding price: } P_{RB}^{t_i} = CT_{RB}^{t_i} \cdot (1 + mr^{t_i}) \quad (2)$$

The transport cost is composed by three parts. Firstly the fixed cost rate c^{ti}_f (€/truck) for using a truck; secondly the backhaul cost presented by a variable cost rate of distance c^{ti}_d (€/km) multiplied by the longest distance among requests in the bundle (backhaul running after final destination); and thirdly the sum of the cost for each request calculated by the distance-volume-related variable cost rate c^{ti}_{dv} (€/km-volume) multiplied by each request's distance d_r and volume v_r. Due to the fixed cost in the equation, the feasible RBs of low volume will have high cost rate, thereby undesirable. Based on the cost function, the carrier t_i's bidding price for a bundle RB P^{ti}_{RB} is computed by Equation (2), where mr^{ti} is the bidding margin rate of carrier t_i representing his expecting profit margin rate. Obviously the fixed or variable cost rates as well as the profit margin rate are private information of carriers to be submitted only to their own proxy agent.

5.2 Proxy auctioning agents

The auctioneer that stands for shippers will also use an own proxy agent for running the auction, namely proxy auctioning agent. It has two main functions: allocating requests to offers by auction and determining payment for shippers.

Payment and Payment rate. First of all we discuss the payment issue. As said in 4.2, we adopt the first price auction in this paper. Once bidding price for a bundle is determined, we can further calculate the payment of each request in the bundle. We define that the payment/price for a given request r, noted as PS^{ti}_r, is proportional to the total payment/price of the bundle that it belongs to, in terms of distance-volume. Based on Equation (2), it is calculated by Equation (3). In addition, we can calculate the payment rate RS^{ti}_r by Equation (4). This payment rate can also be interpreted as the individual logistics efficiency. A low payment rate for a request implies high transport efficiency for shipping the request. Also, we can observe that all requests in the same bundle have equal payment rate, i.e. equal efficiency on transport.

$$\textit{Payment of request r in a RB: } PS_r^{t_i} = P_{RB}^{t_i} \cdot \frac{d_r \cdot v_r}{\sum_{r \in RB} d_r \cdot v_r} \;\; ; \;\; \forall i \in RB \quad (3)$$

$$\textit{Payment rate: } RS_r^{t_i} = \frac{PS_r^{t_i}}{d_r \cdot v_r} = \frac{P_{RB}^{t_i}}{\sum_{r \in RB} d_r \cdot v_r}; \;\; \forall i \in RB \quad (4)$$

The concept of payment rate is very important to the auction mechanism in PI network. In general, a request, or a requests bundle will be allocated to the carrier (the winner) who proposes the lowest payment rate, in other words highest transport efficiency. In particular, for those reallocating requests, the reallocation will happen only if lower payment rate is available. This is to guarantee that shippers will never pay more than the previously promised price while reallocating, as said in Rule 2. Refer to the model (5)-(9) for further discussion. Hence, requests as well as carriers in a given hub will be divided into two groups when bidding: local requests that start their route from the hub, and passing requests that are originally from another point and that are passing by the hub for transhipment. As defined, only the passing requests are considering for reallocating. Accordingly, a carrier is called passing carrier if he arrives at the hub while carrying passing requests, or local carrier if he starts from the hub. To determine the allocation/reallocation of requests, we need a Winner Determination Program.

Bidding language. At first place we define the bidding language which represents the bidders' preference as follow. As regulated by the rules, once a carrier won a request he should assure the fulfilment till final destination, in case that no reallocation is happened. Considering that carriers will have a limited capacity, at most one feasible RB should be allocated to each carrier, which should have the highest volume and thus lowest cost rate. It is therefore the *XOR* bidding language as defined in (Lehmann, Müller et al. 2006). For example a carrier submit a bid (RB_1, P_{RB1}) *XOR* (RB_2, P_{RB2})…*XOR* (RB_k, P_{RBk}) means that the carrier want to deliver only one of the bundles RB_1 to RB_k. In other worlds, even though he will submit a bid for each bundle in an auction, he will win at most one bundle.

WDP formulation. We adapt the Winner Determination Program (WDP) developed in (Lehmann, Müller et al. 2006) in the specific context of PI network, and it is formulated as follow. For a given hub h_o, we denote the set of all bidders (carriers) by $T_{ho}=\{t_1…t_n\}$, the set of all transport service requests by $R_{ho}=\{r_1…r_m\}$, the set of request bundle by $RB_{ho}=\{RB_1…RB_k\}$, and for a given carrier ti the set of evaluated prices by $P^{ti}_{ho}=\{P^{ti}_{RB1}…P^{ti}_{RBk}\}$ for delivering the bundles RB_{ho}. Under the conventional biding language, carrier t_i will submit bids $B^{ti}_{ho}=\{b^{ti}_{RB1}$ *XOR* b^{ti}_{RB2} … *XOR* $b^{ti}_{RBk}\}$, where b^{ti}_{RBi} is a couple of $\{RB_i , P^{ti}_{RBi}\}$ for a bundle $RB_i \in RB_{ho}$. In addition, we make a hypothesis that for each RB the bidding price submitted by carriers will be equal to the evaluated price, i.e. $b^{ti}_{RBi}=P^{ti}_{RBi}$. With particular regard to reallocation of requests, we further denote the set of passing carriers by $PT_{ho}=\{pt_1…pt_n\}$ and accordingly the set of passing requests for a given passing carrier pt_i by $PR^{pti}_{ho}=\{pr^{pti}_1… pr^{pti}_n\}$. Obviously we have $\sum_{pti} PR^{pti}_{ho}=PR_{ho}\subseteq R_{ho}$ and $PT_{ho}\subseteq T_{ho}$. As regulation, passing carrier pt_i must submit a bid/bids for all requests in PR^{pti}_{ho}, but which could be included in other requests bundles and their bids with lower payment rate (higher efficiency on transport), as shown in the illustration case. For a passing request pr_i, if we use RS'^{pti}_{pri} to denote the previous payment rate (from the passing carrier pt_i), and RS^{ti}_{pri} to denote the current payment rate (proposed by carrier t_i), so that the reallocation can happen only when $RS'^{pti}_{pri}\geq RS^{ti}_{pri}$. As it is, the WDP with *XOR* bidding language, namely the WDP_{XOR}, used for transport service allocation in PI network is defined as:

$$\text{Min}: \quad \sum_{t_i \in T_{ho}} \sum_{RB_i \subseteq RB_{ho}} b_{RB_i}^{t_i} x_{RB_i}^{t_i} \tag{5}$$

s.t.:

$$\sum_{t_i \in T_{ho}} \sum_{RB_i \subseteq RB_{ho}; RB_i \ni r_i} x_{RB_i}^{t_i} = 1; \quad \forall r_i \in R_{ho} \tag{6}$$

$$\sum_{RB_i \subseteq RB_{ho}} x_{RB_i}^{t_i} \leq 1; \quad \forall t_i \in T_{ho} \tag{7}$$

$$RS_{pr_i}^{pt_i} - \sum_{t_i \in T_{ho}} \sum_{RB_i \subseteq RB_{ho}; RB_i \ni pr_i} x_{RB_i}^{t_i} RS_{pr_i}^{t_i} \geq 0; \ \forall pr_i \in PR_{ho} \ and \ \forall pt_i \in PT_{ho} \tag{8}$$

$$x_{RB_i}^{t_i} \in \{0,1\}; \quad \forall t_i \in T_{ho}; \ \forall RB_i \in RB_{ho} \tag{9}$$

Where the x^{ti}_{RBi} is a binary decision variable binary with $x^{ti}_{RBi}=1$ if request bundle RB_i is allocated to carrier t_i and 0 otherwise. Equation (5) is the objective function to minimise the total cost for allocating all requests bundles. The constraint (6) guarantees that all requests (included in request bundles) will be allocated only one time (to only one carrier). The constraint (7) guarantees that each carrier/bidder will win at most one bundle (according to *XOR* strategy). The constraint (8) is imposed to ensure that a passing request can be reallocated only if it distributed a lower payment rate. Knowing that if without this constraint, a global optimum solution may impose a high payment rate to a passing request. Therefore this constraint is in particular important in the PI network since it guarantees that after reallocation the shippers will never pay more than the previously promised price. The proposed model WDP_{XOR} can therefore allocate all requests in the pool to carriers with minimising the total cost, while satisfying the Rules 1 to 3 defined to PI network.

In Part 5 we have presented the construction of the auction system in PI network. In the next part we will further illustrate how to apply such system basing on an illustrative case.

6 Illustrative case

In this part we make use of a numerical example to illustrate the application of the auction system. We used *Mathematica*® to simulate the case, in which all presented equations (1)-(9) are programmed. The case is based on a given hub h_0 which is one of the PI hubs within the PI network. We assume that in a given moment there are 7 requests $\{r_1 \ldots r_7\}$, and 4 carriers $\{t_1 \ldots t_4\}$. Table 1 presents the final destination, the route and the volume of each request. In particular we define that r_3 and r_4 are passing requests (considered as one request bundle) and carried by t_1 as passing carrier. Fig 1 presents the network of all requests, namely the request network, with distance of each segment. As it is, the auction is executed by several steps.

Table 1: Transport requests in a hub h_0

Requests	Destination	Route	Load (by unit)	Passing carrier
r_1	h_1	h_0-h_1	5	
r_2	h_3	h_0-h_1 h_3	5	
r_3	h_2	h_0-h_2	5	t_1
r_4	h_5	h_0-h_2 h_5	4	t_1
r_5	h_4	h_0-h_2 h_4	5	
r_6	h_5	h_0-h_2 h_5	3	
r_7	h_5	h_0-h_2 h_5	3	

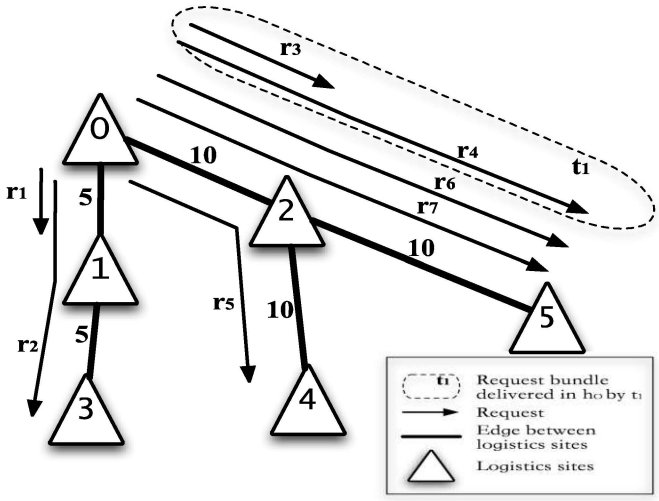


Figure 1: Network of the requests in hub h_0

Step 1. At first place all requests (local and passing) are submitted to the proxy auctioning agent; and then the information will be sent to the proxy bidding agents. At the same time, each carrier should also submit the necessary private information to their own agent, such as their capacity, profit margin rate, and cost rate etc. For simplification, we make hypothesis that the four carriers have the same capacity of 10 loading units and the same cost rate. We use different profit margin rate to differentiate carriers and we assume that $mr^{t1}<mr^{t2}<mr^{t3}<mr^{t4}$, rate so that $P^{t1}_{RBi}< P^{t2}_{RBi}< P^{t3}_{RBi}< P^{t4}_{RBi}$, for any RB_i.

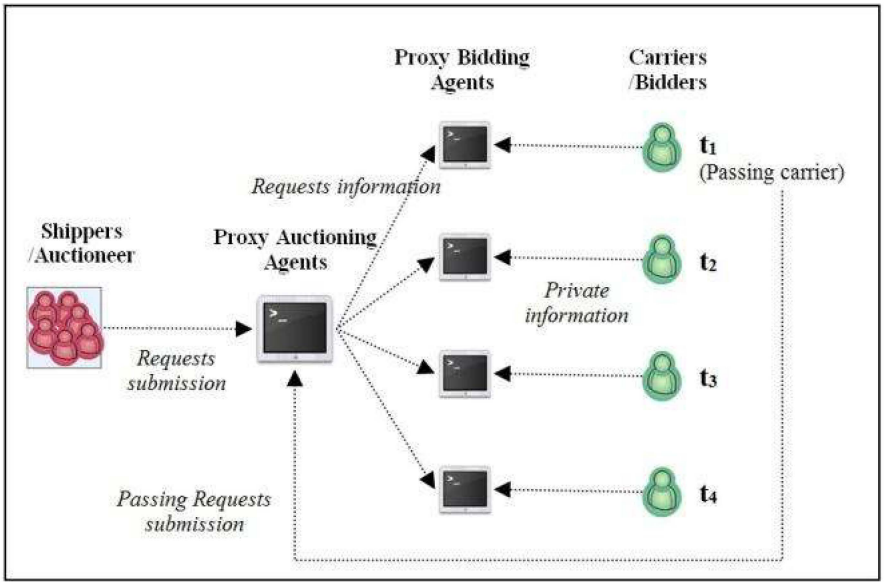


Figure 2: Collecting information of requests and carriers (Step 1)

Step 2. Once the bidding agents have received the requests' and carriers' information, they are able to compute the request bundles to be proposed to their client, as well as the cost and

bidding price by Equations (1) and (2). Fig 3 gives all compatible groups based on the input requests and the feasible request bundles RBs (recall that they are the bundles in each compatible group satisfying the constraint of capacity, specifically $\sum_{r\in RBi} v_r \leq 10$, $\forall_{RBi} \subseteq G_j$ and $G_j \subseteq \{G_1, G_2, G_3\}$). In the case we have 3 compatible groups and 16 feasible RBs. To assure that none of the RBs will be missed, the agents will compute bidding price to each RB for their own client. Thus for each carrier we have a vector of bids for all RBs; and then we have a $|T| \times |RB|$ matrix of bids in the auction, specifically 4×16 in our case, and each element is a bid b^{ti}_{RBj} (recall that $b^{ti}_{RBj} = P^{ti}_{RBj}$). Once the propositions of bidding matrix are validated by carriers, they will be submitted to the proxy auctioning agent.

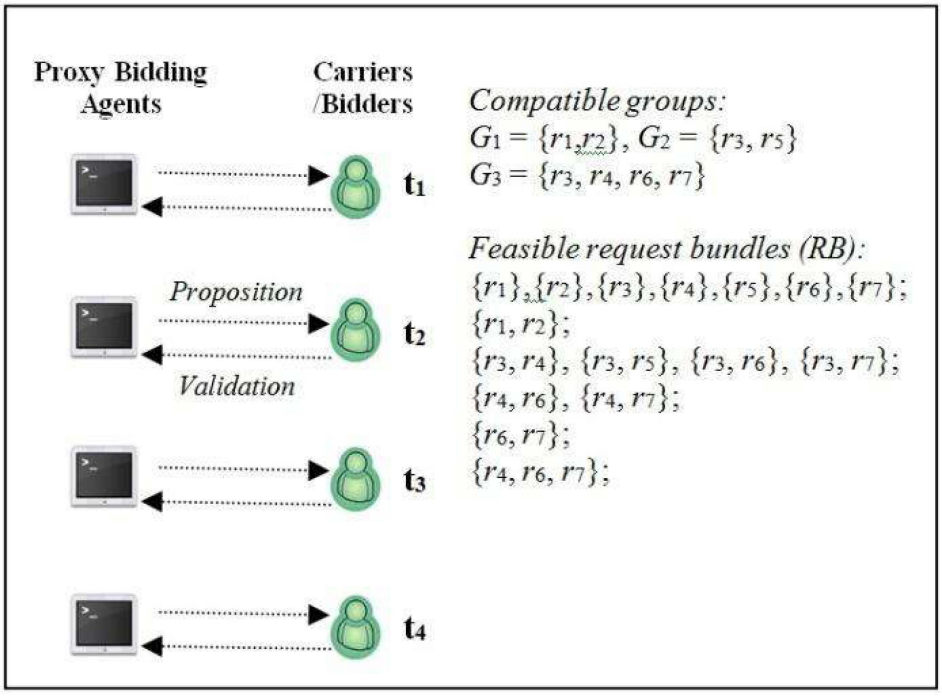


Figure 3: Feasible requests bundles proposed to carriers (Step 2)

Step 3. At the beginning of this step all bids have been submitted to the auctioneer proxy agent, where the Winner Determination Program basing on Equations (3)-(9) will be executed. As this case is simple and it contains a bids matrix in small size of 4×16, the problem is resolved by *Mathematica* in the very short time. The outcome of the case is illustrated in Table 2, showing that request bundle $RB_1=\{r_1, r_2\}$ is allocated to t_3, $RB_2=\{r_3, r_5\}$ to t_2, and $RB_3=\{r_4, r_6, r_7\}$ to t_1. Especially, the passing requests r_3 and r_4, arrived as a bundle, are reallocated to different carriers who provide lower payment rate to them (higher fill-rate and efficiency). Once the auction finished, the payment of each request in the bundles will be computed by Equation (3), and then proposed to the shippers. The process will be finished by validating the payment of shippers to carriers so that the shipments begin.

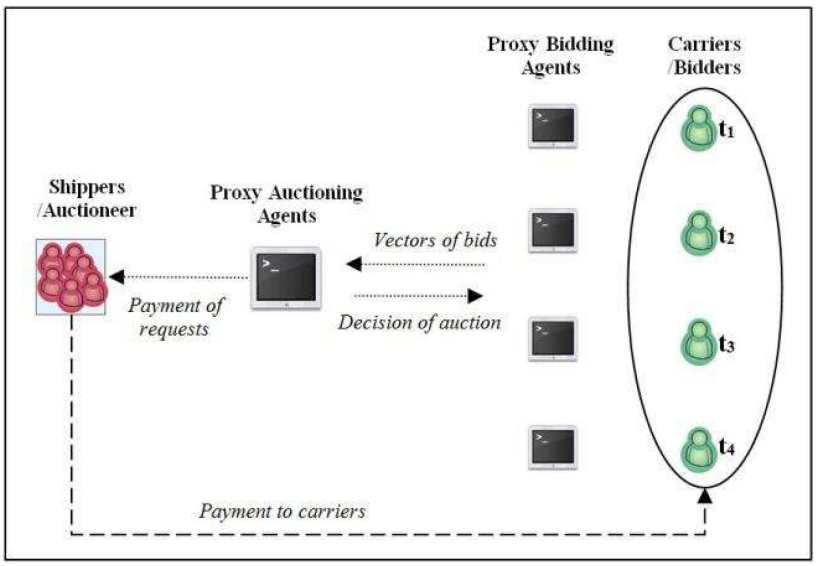


Figure 4: Determination of auction and payment (Step 3)

Table 2: Payment of requests to carriers

	r_1	r_2	r_3	r_4	r_5	r_6	r_7	Sum
t_1				4/10 P^{t1}_{RB3}		3/10 P^{t1}_{RB3}	3/10 P^{t1}_{RB3}	P^{t1}_{RB3}
t_2			1/3 P^{t2}_{RB2}		2/3 P^{t2}_{RB2}			P^{t2}_{RB2}
t_3	1/3 P^{t3}_{RB1}	2/3 P^{t3}_{RB1}						P^{t3}_{RB1}

This simple case illustrates the process of the auc-tion mechanism in a given hub with an optimal solution. Since the PI network is a decentralised system, the mechanism can be generalised to all hubs in the network.

7 Discussion and conclusion

In this paper we address the following question. How to allocate transport requests to services in Physical Internet network? A framework with rules, auction mechanism and multi-agents system is proposed for constructing a simulation model. This work is designed to take advantage of the more open and dynamic environment enabled by the Physical Internet to allocate and even reallocate a container to carrier at each hub if it improves the routing of the container and the utilization of the logistics network resources. This model is illus-trated on a simple case to give insight about the proposed approach.

To go further in this direction, more research is needed. The first step will be a demonstration based on much more data and should be carried on in order to validate the approach, its computational complexity and its performance compared to current practices. This demonstration will require a particular methodology to compare different trans-port allocation practices with limited biases.

In addition, more powerful simulation software is necessary to simulate a network with several PI-hubs and an implementation of agents in each hub. This global simulation is really interesting to check the dynamic of the systems subject to a large number of shipper's requests and carrier's offers. We propose to implement the approach in a multi agents based simulation tool for this next step with an embedded optimization tool. As is was also used in the former works related to Physical Internet simulation (Sarraj, Ballot et al. 2013), it will provide new insight about how the PI network could behave and a more accurate performance assessment.

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Towards a smart interconnected era
of efficient and sustainable
logistics, supply chains and transportation

May 28-30, 2014 - Québec City, Canada

The 3D Supply Network

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Abstract: *Traditional supply chains cannot keep pace with consumer demand and rising costs. A new distribution system is needed to deliver against the changing landscape. The vision of ES3's 3D Supply Network is to create a streamlined supply solution, much like the Physical Internet Initiative. By leveraging ES3's scale, manufacturers and retailers combined their mixing centers and distribution centers into one large facility. This supply chain innovation eliminates a warehouse touch, reduces supply chain inventory, and reduces errors and damages. This is not an enhancement to supply chain practices; it is a true transformational redesign of the grocery supply chain. The 3D supply network moves product faster at a lower cost, saving time and money.*

Keywords: *collaboration, supply chain, supply network, automation, sustainable, mixing center, distribution, logistics.*

1 The 3D Supply Network

As product moves from farm to table, its path along the current supply chain ensures it endures a multitude of stops, layovers, and touches before arriving in the consumer's home. This journey costs money and takes time, shrinking margins and making the product less fresh at the point of consumption.

The current supply chain model dates back to the 1950's when the last update was made to the system. Distribution started with a 1D model where product shipped from factory to retailer, and evolved to a 2D model in the 1950's, where product shipped from the factory to manufacturers' mixing center. This change enabled retailers to buy full truckloads and have shorter lead times. Today, manufacturers have promulgated this model, building adjacent mixing centers in large industrial parks. Every day, each manufacturer loads trucks and sends them off to the same retailers as the warehouse next door. Think of the waste as a truck leaves with a single layer of canned goods pallets that weighed out the truck, minutes after a cubed-out truck of paper towels leaves from the other side of the industrial park. A truckload with cans on the bottom and paper towels on the top could have left for half of the cost.

Imagine the benefits if just those two warehouses functioned as one: retailers could build a truckload order across all of those products. Now imagine the benefits if more than two manufacturers collaborated to send fully utilized trucks from one shared warehouse to multiple retailers. This is the 3D supply network model; manufacturers and retailers leverage shared infrastructure to deliver product more quickly, sustainably, and inexpensively to its end destination, as illustrated in Figure 1(ES3, 2014). Trucks are optimally filled due to the greater variations in product size and weight. Service is faster because scale allows products to ship daily to the retailer. Costs are lower because shared services and fewer, fuller trucks save money. Not only do manufacturers and retailers win, as service improves, but consumers benefit as costs are taken out of the supply chain, instead of being reflected in higher shelf prices.



Figure 1: The Distribution Evolution

2 Current Realities

This new distribution model becomes more appealing in light of today's realities. Macro transportation and consumer trends are increasing the cost and length of products' journey. The decrease in carrier capacity, the lack of prime warehouse real-estate, and consumers' changing dynamics have accelerated the traditional supply chain's march towards obsolescence. Demand for truck drivers is outpacing supply, as current drivers retire without younger replacements to backfill. The average age of a truck driver in the US is 50; this means that more than half of the truck driver population is at retirement age, or will retire over the next few years, significantly reducing trucking capacity. New regulations and hours-of-service rules further hinder trucking capacity, increasing time needed to transport items due to mandatory stops and restart periods. Industry pundits estimate these two factors will create a shortage of 250,000 drivers in the industry by the end of 2014 (Berman, 2013). As eCommerce grows, prime warehousing and distribution real estate near consumer and FedEx/UPS hubs is increasingly scarce, causing many

companies to locate inventory further from their customers or retrofit automation into less than ideal facilities.

Increasing demands for variety and niche products are flooding the supply chain with slow-moving SKUs, crowding already full facilities and increasing labor costs. Stores are carrying differentiated assortments, acting as curators, rather than selling every single item.

As older generations become less mobile, and want to make shopping easier, they are going online to take advantage of click-and-collect or home delivery models. Younger generations see the appeal in these models as well, and find home delivery especially relevant as they flock to urban areas. This urban migration is causing a corner store renaissance, as Millennials are living in areas where they work, play, and shop, and need easy access to fresh food and groceries.

More than ever before, convenience is driving consumers' purchasing decisions. They have grown accustomed to instant gratification enabled by the omni-presence of the internet, and expect the same ease of use when shopping. The always connected phenomenon is enabling reviews in real-time, making it more important than ever to keep consumers happy.

Yet as quickly as the consumer wants their product, they do not want to have to pay an arm and a leg to receive the product in a timely fashion. Consumer confidence and spending levels have not yet returned to pre-recession levels, making price point a thorn in the side of retailers and manufacturers alike. Branded manufacturers are feeling the impact from increased private label sales, as consumers who tried private label during the recession stick with products they now know and enjoy. Private label penetration is high, and expected to only grow as retailers invest more capital into improving store brands as a point of differentiation. Some national manufacturers are reducing prices to better compete against these store brands, creating a need to cut costs elsewhere in the supply chain to make up for the lost revenue at the store level.

With stores getting smaller and urban populations growing, the challenge and increased costs of getting product to the store will drive the evolution to a many-to-many, or 3D, supply network. This distribution infrastructure ships product directly from manufacturers' inventories on a single truck to all of the retailers in a shopping center. Product is delivered daily (or more frequently) to grocery stores, mass merchandisers, drug stores, and value stores in close proximity. This shared distribution network allows manufacturers to quickly send fresh product to the consumer, and lowers the cost of distribution. It is the Internet for consumer goods.

3 Connected and Collaborative

The 3D supply network is well-equipped to meet the demands of changing consumers and marketplace conditions. A 3D supply network must be utilized to supply product more quickly and at a lower cost, giving manufacturers and retailers more time to focus on keeping customers and consumers happy. This connected and collaborative 3D supply network is the only network that will deliver in the face of coming changes to the CPG industry, using its flexibility and

resiliency to continuously adapt and deliver superior service. Advanced technology optimizes replenishment and decreases distribution cost, speeding up order to delivery cycle times.

This increased speed is only possible with collaboration from both manufacturers and retailers, as illustrated in Figure 2 (ES3, 2013). Participation from many companies provides scale to the operation, creating benefits that would be impossible to otherwise obtain. ES3's collaborative 3D Supply Network leverages shared infrastructure to move the economic order quantity (EOQ) from a pallet to a case, reducing cost and increasing delivery speed. This network speeds up the supply chain by delivering in 24 hours or less, reduces cost through automation and consolidation, and provides high service rates from its pool of Northeast inventory across nearly 50 manufacturers.



Figure 2: ES3's 3D Supply Network

ES3 is able to deliver this service through a simple mantra: fewer touch points and fewer miles are better. The use of horizontal collaboration, or consolidating inventory into one large group to support servicing stores or consumers directly, delivers on both these goals.

The Physical Internet Initiative envisions a horizontal logistics network similar to ES3's 3D Supply Network. Designed to address the Global Logistics Sustainability Challenge[1], the Physical Internet framework connects logistics systems through shared resources, collaboratively handling, storing, and transporting goods (Meller et al., 2012). ES3's 3D Supply Network is a working example of that framework; its hub facility provides a collaborative platform that ships to and receives from multiple manufacturers and retailers. This planned collaboration gives manufacturers more flexibility, allowing for greater rail utilization, which reduces greenhouse gas emissions and fuel usage as compared to truck shipments. In the 3D supply network, as espoused in the Physical Internet Initiative, inventory is stored close to end users, shortening response times and increasing service levels. Integration of the internet is crucial to this operation, enabling real-time tracking and monitoring of product movement and location. Additionally, the 3D supply network makes good on the Physical Internet's desire to remove waste from the system. By sharing resources and making use of high-tech automation, less energy is expended, reducing waste and environmental impact. The 3D network is also designed to be highly resilient, ensuring the facility is never down, keeping product flowing smoothly when consumers need it most. Just as the Physical Internet envisioned, ES3's 3D Supply Network is economically, environmentally, and socially efficient and sustainable.

ES3 has tested many key ideas of the Physical Internet in its northeast mixing center, which can be thought of as a Physical Internet "backbone facility." ES3's interconnected logistics hub, data systems, and distribution network provide a platform for shared facility use, moving product from manufacturers to retailers. The facility sorts inbound product into three areas, depending on its velocity. Fast-movers are unloaded to a flow-through area to be cross-docked, or rapidly selected. Medium-velocity products are stored in racking, until they are ready to replenish a pick slot, and slow-movers are sent to an automated case-pick area. This system reduces touches, which in turn reduces cost, and is highly efficient, saving time. On the outbound side, the magnitude of SKUs from a multitude of manufacturers, and the high outbound volume provide enough variation that trucks can be fully optimized, reaching upwards of 42,000 case-adjusted weight (CAW). Through this framework, ES3 has been able to surpass the Physical Internet's goal of moving the EOQ from a truckload to a pallet (Meller et al., 2012), and has delivered an EOQ of a case.

Once product is shipped from ES3's collaborative facility, this product is delivered directly to its end destination, eliminating a leg of transportation and receiving/put-away that would occur at a retailer distribution center, saving significant time and money.

Consolidating a vast number of disparate SKUs provides many benefits, including increased load utilization due to the high degree of variety on each load. Safety stock is reduced due to quick replenishment cycles from the large pile of inventory. Warehousing, distribution, and transportation costs are lower due to the fact that they are shared across a larger base, reducing total cost for all parties involved.

[1] See B. Montreuil, "Toward a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge," Logistics Research.

4 Tangible Savings

Retailers and manufacturers have seen tangible savings from adopting this model. The key is to get rid of the middleman. If you put the manufacturers' mixing centers in the same facility as the retailer's distribution center magic happens. Handling, inventory, and transportation costs are dramatically reduced as the supply chain becomes more streamlined and efficient.

The removal of unnecessary touch points and miles reduces the total supply chain cost of getting product from manufacturer to retailer by 30% for both manufacturers and retailers. This translates into about $0.54 to $0.78 reduction per case based on research done by AT Kearney for ES3, as illustrated in Figure 3 (2010). These savings are dramatic in an industry where money is made in pennies on a case, and provide real value for manufacturers and retailers alike.

Manufacturers are guaranteed savings through reductions in case pick and transportation costs. Also, due to the accuracy inherent in ES3's systems and automation, ES3 assumes all responsibility for shipping errors (overs, shorts, and damages or OS&D). These are the contractual savings. Other savings that accrue to the manufacturer include:

- **Reduction in customer service costs:** The manufacturer no longer needs a customer service team to support order changes, order expediting and tracking, vendor-managed inventory (VMI), OS&D, etc.
- **Streamlining of plant operations:** Product is shipped to ES3 based on optimizing manufacturer flow, not waiting for the retail order. This allows the manufacturer to reduce product handling at plant locations and to ship via the most efficient mode of transportation, such as rail.
- **Improved product traceability:** The manufacturer usually loses visibility of product movement once it arrives at the retail distribution center. In ES3's model, the manufacturer sees when the product moves to the store.
- **No need for outside storage:** ES3's facility is vast enough to store inventory buildup for peak season, eliminating the need for outside storage as production ramps up. This saves manufacturers shuttle/transfer, storage and handling fees as the product is delivered to ES3 as soon as it is produced, and shipped directly to its end destination when ordered.

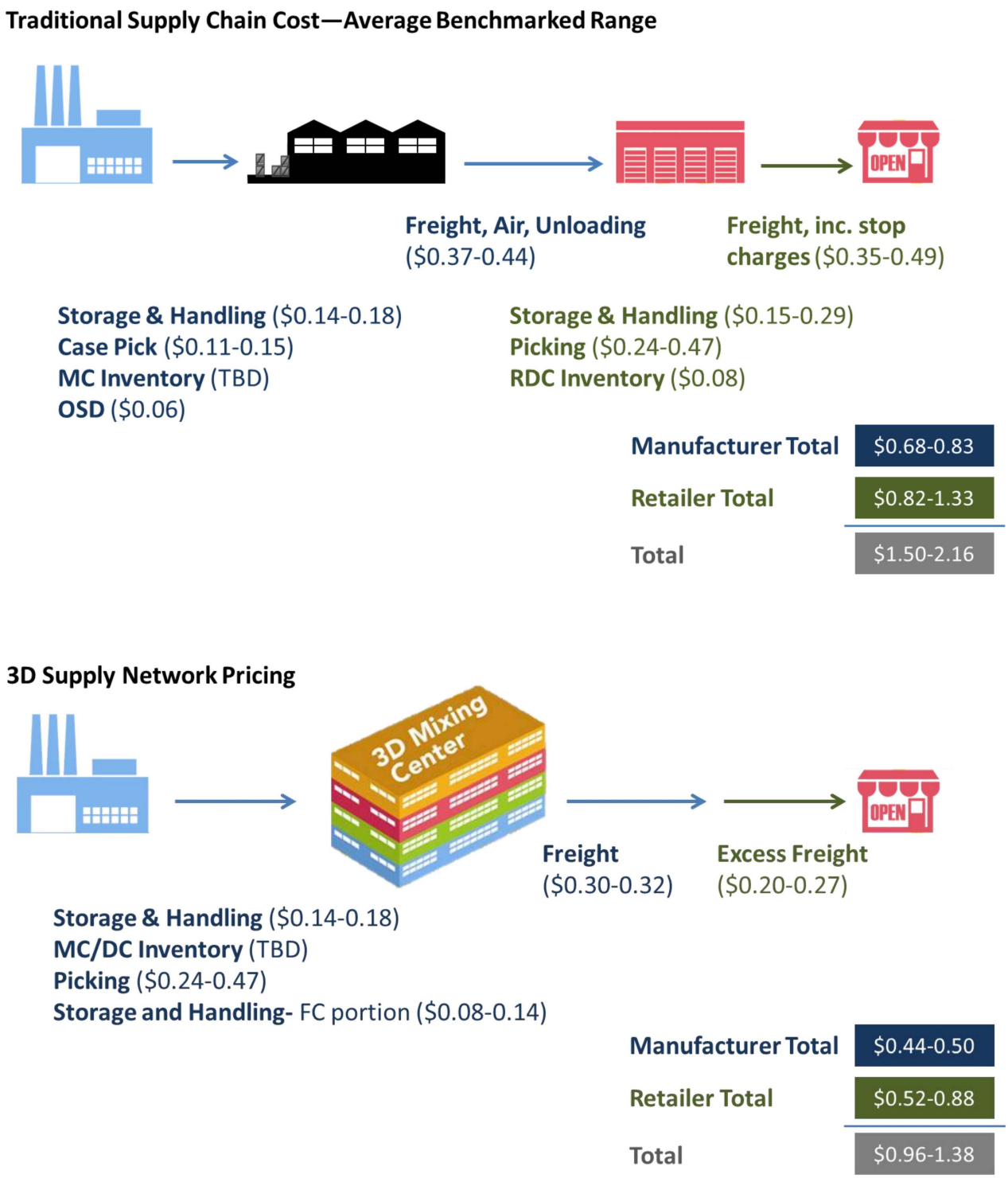


Figure 3: Savings from Utilizing ES3's 3D Supply Network

Retailers, using ES3's Direct-to-Store (D2S) program, are charged a cost per case that is lower than what they were able to achieve in their distribution center. Additionally, they have no

inventory carrying cost on manufacturer-owned inventory in ES3, as product moves directly from manufacturer inventory to the store. The transportation cost that manufacturers paid to get the product to the retailer's distribution center is now used to get the product to the store, dramatically reducing the retailer's transportation costs as they no longer have to pay to send products to stores. Retailers see lower landed shelf costs for ES3 participating manufacturers. ES3's automation can even build retailers aisle-friendly pallets, which are estimated to provide labor savings of 30 minutes per store, per day.

ES3's automation reduces touches and increases sustainability, providing additional labor and environmental savings. Conveyors, lifts, and cranes put-away, store, and retrieve pallets, while case pick automation stores and selects cases, building optimized pallets to send directly to stores. Fewer touches are required by automation, translating to a lower cost, and reducing the amount of energy expended to move the product. The relative compactness of automated buildings also provides many savings over a conventional building, using less land and 40% less energy. Automation does not need lights or heating and cooling, providing additional savings. Features like regenerative breaking on cranes or other machines harness surplus breaking energy, generating a sustainable power source. Automation is programmed to optimize product movement, ensuring that only the necessary amount of energy is expended (Worker, 2012).

The benefits of automation extend to reduced product waste. The tempered speed and programmed force of automation reduce damage during the selection process, as well as reduce the amount of shrink wrap needed. Automated palletizers pack optimized pallets, reducing the need for shrink wrap to as a stabilizer. Order accuracy typically improves with automation, and less maintenance is required, further reducing costs.

The lure of cost savings is not enough to drive participation in a shared supply chain; the model also needs to work seamlessly, providing real-time information and transmitting data. Clear rules of engagement and a neutral party to act as a data clearing house are keys to success in enabling a successful collaborative distribution model. The amount of data provided by both retailers and manufacturers to ES3 dwarfs what each retailer and manufacturer needs in return; ES3 is able to disaggregate data from invoices, order forms, and ASN's, remove sensitive data, and aggregate to share in an understandable format with manufacturers and retailers, so that each party receives the information they need.

5 Conclusion

The success of this model, in practice and in cost savings, is proof that the Physical Internet concept works. One shared, interconnected logistics platform can be utilized effectively to distribute consumer packaged goods from factory to shelf. This model reduces the economic order quantities from a pallet to a case, moves inventory closer to customers, reduces highway miles traveled, and improves truck utilization. Environmental impact is reduced due to shared efficiencies like transportation and co-location. Overall, the model provides better service at lower rates, incentivizing participants to join.

The collaborative platform also provides a forum for participants to share innovations and best practice ideas to ensure continuation of a collaborative partnership. The co-mingling and vetting of ideas in an open forum provides many opportunities for discussion and ideation, and a way to quickly share and standardize any improvements or processes. The sharing of ideas, resources, and products requires a strong framework to ensure distribution flows smoothly, implementation of new ideas or processes is easy, and any issues are quickly resolved. A 3D network meets all of these criteria, and then some, delivering best-in-class distribution at a lower cost than any other model.

As consumers' shopping habits, tastes, and preferences continue to change, a flexible, scalable distribution center is needed to compensate. Old models of the supply chain, designed pre-internet, are geared towards moving pallets and cases, not precise quantities of individual selling units. Product follows a forced flow, moving when directed, not necessarily optimized for the individual consumer's expectations. Companies had to choose between offering low-cost or white-glove services.

In order to succeed in the new era of supply chain, companies must adopt a 3D supply chain model. Integrating today's many disparate supply chains into a 3D supply network is the only way that faster service can be achieved at a reasonable cost. Companies today do not have the luxury of deciding to have a low-cost supply chain or a supply chain that flawlessly executes; they need to have both. In a 3D network product flows fluidly as needed, taking advantage of collaborative pathways to quickly reach its end destination. The shared facilities of a 3D network eliminate duplicate work, reduce redundancies throughout the network, and centralize safety stock. These three activities all reduce cost, while the centralized nature of the product improves service level and fill rate. Additionally, these facilities mitigate risk, as shared facilities can effectively provide infrastructure to stabilize the supply chain.

This 3D model will continue to evolve to meet the needs of manufacturers, retailers, and consumers raising the bar for distribution. Added scale will only serve to improve operations and reduce cost for all, including the end consumer.

About the Authors

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Brenda Hambleton is the Chief Marketing & Strategy Officer for ES3. She is responsible for developing new products and services, analyzing strategic opportunity, and managing all marketing and communications activities. Additionally, she helps to develop the long-term strategy for the company. Brenda's extensive speaking experience includes the Annual Global CSCMP Conference, where ES3 won the 2011 Supply Chain Innovation

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Before joining ES3, Brenda held the position of EVP, Client Solutions for Scribe Software, Inc. Brenda managed Scribe's consulting practice and the Customer Care and Customer Education Programs.
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About ES3

ES3 is an experienced team of third-party logistics experts, saving CPG manufacturers and retailers significant time and money every day. A pioneer of the 3D Supply Network model, ES3 eliminates days and reduces the cost of the supply chain for manufacturers and retailers. ES3 does this by combining warehousing, mixing, and distribution services under one roof in a collaborative multi-manufacturer and retailer model optimized by advanced technology. ES3 provides solutions across all channels, providing superior on-shelf-availability rates, maximizing its supply network to expedite replenishment. To learn more, please visit www.ES3.com.

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Towards Physical Internet Enabled Interconnected Humanitarian Logistics

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Abstract: *Based on core pillars of the Physical Internet (PI), this paper proposes a global interconnected humanitarian logistics system. By removing physical boundaries between the various actors, it aims to enable efficient interconnectivity of individuals, donors, contractors, suppliers, NGOs, international institutions, governments and beneficiaries. Moreover, it suggests a global humanitarian logistics web that is materialized in the evolution from the current private and limited logistics networks toward a more economically, socially, and environmentally sustainable and efficient global logistics system composed of multiple interconnected and open supply chains. As a result, access to global logistics networks becomes open to all actors in the humanitarian sector while allowing an endless variety of collaboration forms.*

The paper starts by an introductory perspective that explains the idea of completely revolutionizing humanitarian logistics. It then presents a broad literature review on the concept of PI and its core principles. It summarizes the current main humanitarian logistics practices and challenges, and repositions them through a PI conceptual framework. Expected results are underlined with a proposition of creating an interconnected humanitarian logistics system based on a PI conceptualization, suggesting the key components for its operationalization, including protocols, humanitarian informational platforms, and monitoring approaches while exposing scenarios of operating such humanitarian global logistics network.

Keywords: *Humanitarian logistics, Physical Internet, supply chain, disaster, crisis management, earthquake, NGO, relief network, green logistics, interconnected systems, Sustainability.*

1 Introduction

In regard to the challenging context of humanitarian crises, this paper explores the idea of using the Physical Internet (PI) to radically change the way humanitarian operations are conducted at the global level. PI stems from the general assertion that the way physical objects are currently transported, handled, stored, realized, supplied and used throughout the world is unsustainable

both economically, environmentally and socially (Montreuil, 2011). PI's premise applies both to private, public, for-profit and not-for-profit businesses.

This paper explores the perspective of PI in the context of the humanitarian relief, particularly with the goal of harmoniously and efficiently interconnecting all actors, already involved or potential, in addressing humanitarian needs, and notably crisis emergencies, at the global level. Accordingly, referring to the fundamental assertion underlying the need for PI, the current research adopts the following statement: The way the coordination of activities to design, produce, handle, transport, store, supply and use physical objects in the humanitarian field is neither efficient nor sustainable both economically, socially, and environmentally.

In the current humanitarian context, actors are mainly comprised of not-for-profit organizations, namely NGOs and international institutions (De Torrenté, 2013; Yao-Jen et al., 2010), such as the United Nations and its sub-entities, which are not fully taking advantage of all opportunities to collaborate with actors in the private sector for various reasons ranging from a lack of openness in the system to issues of ethics and conflicts of interest.

This paper explores the perspective of using Physical Internet as a means to achieve globally more efficient humanitarian logistics while ensuring sustainability. Thus, it aims at making more efficient and sustainable the conception, design, production, movement, storage, supply, construction, and use of physical objects in the humanitarian sector by proposing a global Humanitarian Logistics Web based on PI's dynamic framework. It presents a proposition of using the PI framework as a way out for the humanitarian sector's recurrent challenges and inefficiencies.

How this work began lies deeply to a scientific desire and curiosity to discover the various potentials of the Physical Internet vision to transform the way business activities are being conducted. In fact, from the start, this idea of exploring the humanitarian sector based on a PI approach was suggested by Professor Benoit Montreuil who came out with a project during the course "GSO-8008, Paradigms of Value Creation Network Management" in the winter semester of 2011. Accordingly, the work stared in January 2011 and continued though the year and until now with the main results being exposed through the current paper. The project required weekly meetings of nine researchers that were discussing every dimension of, on one hand, the humanitarian sector and the way it operates and, on the other hand, the concept of Physical Internet and how it could be translated into an operational tool for better coordinated and effective humanitarian assistance, rescuing or relief operations on a global and systemic perspective. So, after several meetings during which broad and deep discussions on the two key parts of the project's idea, namely the humanitarian and PI, in-depth literature reviews where conducted to better understand the current practices in the humanitarian sectors by identifying its strengths, weaknesses and challenges ahead while paying attention to the potential zone where a PI approach may bring radical improvements. The main objective is to transpose the generic model of Physical Internet to the field of humanitarian logistics.

The paper is divided into four parts. The first section starts by an introductory perspective that explains the idea of completely revolutionizing the humanitarian logistics. The second section presents a broad literature review on the concept of PI and its core principles. The third section then summarizes the current main humanitarian logistics practices and challenges and finally repositions them through a PI conceptual framework. Fourth is introduced the proposition of

creating an interconnected humanitarian logistics system based on a PI conceptualization while suggesting the key components for its operationalization, including protocols, humanitarian informational platforms, and monitoring approaches, and then exposing the scenarios of operating such humanitarian global logistics network. Fifth are synthesized conclusive remarks and avenues for further research.

2 Physical Internet

Montreuil et al. (2013) defined the Physical Internet (PI, π) as an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols. The Physical Internet aims to enable the global efficiency and sustainability of physical object mobility (transportation, handling), storage, realization (production, assembly, finishing, refurbishing and recycling), supply and usage (Montreuil, 2011). Economically, the Physical Internet aims to unlock highly significant gains in global logistics, production, transportation and business productivity. Environmentally, it is to create a more sustainable global environment with significant reduction in energy and pollution induced by logistics, production and transportation. Along the societal dimension, it aims to significantly lead towards the improvement of the quality of life of the logistic, production and transportation actors, and of the overall population by increasing the accessibility to objects and their functionality across the world. Accordingly, the vision of this new paradigm shift is to evolve, through a metaphor of Digital Internet, towards a PI momentum to address the grand challenge towards global logistics sustainability that the world is currently facing. These underlined core principles and potentials of PI can be transposed into various economic and social sectors such as the humanitarian domain.

Three key types of physical elements enabling the Physical Internet are the containers, the nodes and the movers (which are respectively named π-containers, π-nodes and π-movers to emphasize that they are designed for the Physical Internet), as described in Figure 1 sourced from Montreuil et al. (2010).

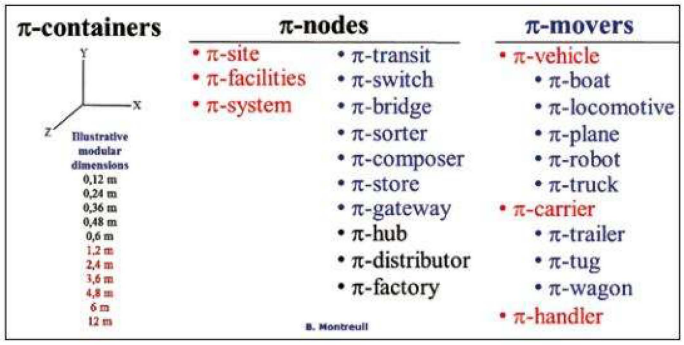


Figure 1: Key types of Physical Internet elements,
by Montreuil et al. (2012)

Containers are the fundamental unit loads that are moved, handled and stored in the Physical Internet. Physical Internet Containers come in modular dimensions. The nodes correspond to the sites, facilities, and physical systems of the Physical Internet. The movers transport convey or

handle containers within and between nodes of the Physical Internet. They also come in a variety of types, as highlighted in the figure above.

Based on its interconnectivity principle, the Physical Internet, as suggested by Montreuil et al. (2013), encapsulates physical objects in physical packets or containers named π-containers so as to differentiate them from current containers. In the context of humanitarian logistics, containers are hereafter fully named as humanitarian π-containers and nicknamed as *blue containers*. They are world-standard, smart, green and modular containers which in the perspective of this paper are seen as smart containers that are modularized and standardized worldwide in terms of dimensions, functions and fixtures and adapted to all humanitarian purposes such as being easily transformed and used as tents, dormitories or beds. In fact, currently the idea of smart containers is completely absent in humanitarian logistics.

Based on the core vision of the Physical Internet, this new humanitarian perspective states the need for fundamental changes towards better humanitarian logistics amongst which the encapsulation of donations in world-standard humanitarian smart green modular π-containers. Thus, the humanitarian Physical Internet (called hereafter HPI) perspective underlines the necessity to adapt key functional characteristics of blue containers by unitizing humanitarian donations as their content so that this content is not dealt with explicitly by the Physical Internet. Also, blue containers have to be designed in various modular sizes, from the cargo container sizes down to tiny sizes while ensuring the easiness to flow through various humanitarian transport, handling and storage modes and means.

Table 1: Key enabling changes towards Interconnected Humanitarian Logistics

Interconnected Humanitarian Logistics **Key enabling changes aligned with the Physical Internet**
Pursuing universal humanitarian interconnectivity
Embracing a unified humanitarian multi-tier conceptual framework
Activating and exploit an open global Humanitarian Logistics Web
Exploiting smart networked humanitarian containers embedding smart objects
Designing products fitting humanitarian containers with minimal space waste
Evolving from material to humanitarian π-container handling and storage systems
Evolving from point-to-point hub-and-spoke transport to distributed humanitarian multi-segment intermodal transport
Minimizing physical moves and storages by digitally transmitting knowledge and materializing objects as locally as possible
Deploying open performance monitoring and capability humanitarian certifications
Prioritizing webbed reliability and resilience of networks in humanitarian operations
Stimulating humanitarian business model innovation
Enabling open infrastructural innovation in the humanitarian sector

Moreover, the proposed humanitarian, smart, green and modular π-containers will be easy to handle, store, transport, seal, clench, interlock, load, unload, construct, dismantle, panel, compose and decompose and are tag-enabled with sensors to allow their proper humanitarian identification, routing and maintaining. This proposition considers that the blue containers be made of environmentally friendly materials, with minimal off-service footprint by minimizing packaging materials requirements through the enabling of fixture-based protection and stabilization of their embedded humanitarian products. Containers may also come in various usage-adapted structural grades with safe conditioning capabilities and in sealable structures for safety purposes.

Beside all these technical changes, to enable interconnected humanitarian logistics, there are several crucial innovations needed and which are essential for establishing PI-inspired interconnected humanitarian logistics. The most important are presented in Table 1. Section 4 is to elaborate on multiple facets of the evolution towards the interconnected humanitarian vision.

Now that the key components and premises of Physical Internet have been exposed, the next section presents current challenges of the humanitarian sector in line with its potentials towards enabled interconnected humanitarian logistics.

3 Humanitarian Logistics Challenges

The humanitarian sector encounters several challenges among which the lack of coordination among stakeholders (Stephenson, 2005), the difficulty of access for new players (Macalister-Smith, 1991), the lack of strategic location and the under-utilization of potential storage (Duran et al., 2011), the inefficient transport of products to crisis areas (Saetti and Cauët, 2008), the limited supply network (Balcik et al., 2010), the inadequate identification, management and delivery of donations to beneficiaries (Stapleton et al. 2010), and finally the neglect of environmental impact in humanitarian actions (Eng-Larsson and Vega, 2010).

All these challenges make humanitarian operations often inefficient in terms of response time and resource consumption, thus resulting in fundamental logistics problems when addressing humanitarian crises. This paper is based on the fact that currently, the way that the design, production, handling, transportation, storage, supply and use of physical objects in the humanitarian field is neither efficient nor socially, economically, and environmentally sustainable. Many humanitarian areas need improvement as well as a rethought approach to tackle major challenges.

3.1 Inefficient Transportation and Delivery of Products to Crisis Areas

Amongst the various humanitarian transportation problems, many appear to be very common in emergency operations, such as impracticable roads. In fact, regarding humanitarian logistical planning, organizations such as the United Nations stated, at the time of the Haiti earthquake crisis for instance, that a major issue to be immediately solved would certainly be transportation and roads. Indeed, most of the problems that existed before and after the earthquake are largely due to poor roads and ineffective transportation as illustrated by the image of Figure 2.



Figure 2: Haitian road after the earthquake
Source: http://interactive.wxxi.org/files/images/highlights/nou_bouke.jpg

In fact, often, crisis areas are not accessible and vehicles have difficulty to access rural areas during humanitarian emergencies. Thus, it is a good idea to create customized transport systems and vehicles dedicated to humanitarian aid in delicate areas. Moreover, the state of receiving zones is critical in emergency operations. It is necessary to perform a quick check of sites where the goods are received to identify all scenarios that may affect their arrival and receiving.

For example, in Indonesia, to manage the December 26, 2004 tsunami around Banda Aceh, some NGOs used satellite images to administer first aid logistics, which helped to better assess the state of accessibility of different areas (Saetti and Cau ët, 2008). An illustration of such cases is clearly visible in the map of Figure 3 that shows the damaged areas in and around Port-au-Prince after the Haitian earthquake disaster. Such problems could compromise any logistical humanitarian aid effort. For instance, in the case of the 2010 Haiti earthquake, aircrafts could not land at the airport in Port-au-Prince due to damaged airstrip. The map of Figure 3 says it all, through its high number of red points symbolizing difficult or even inaccessible crisis areas at the time.

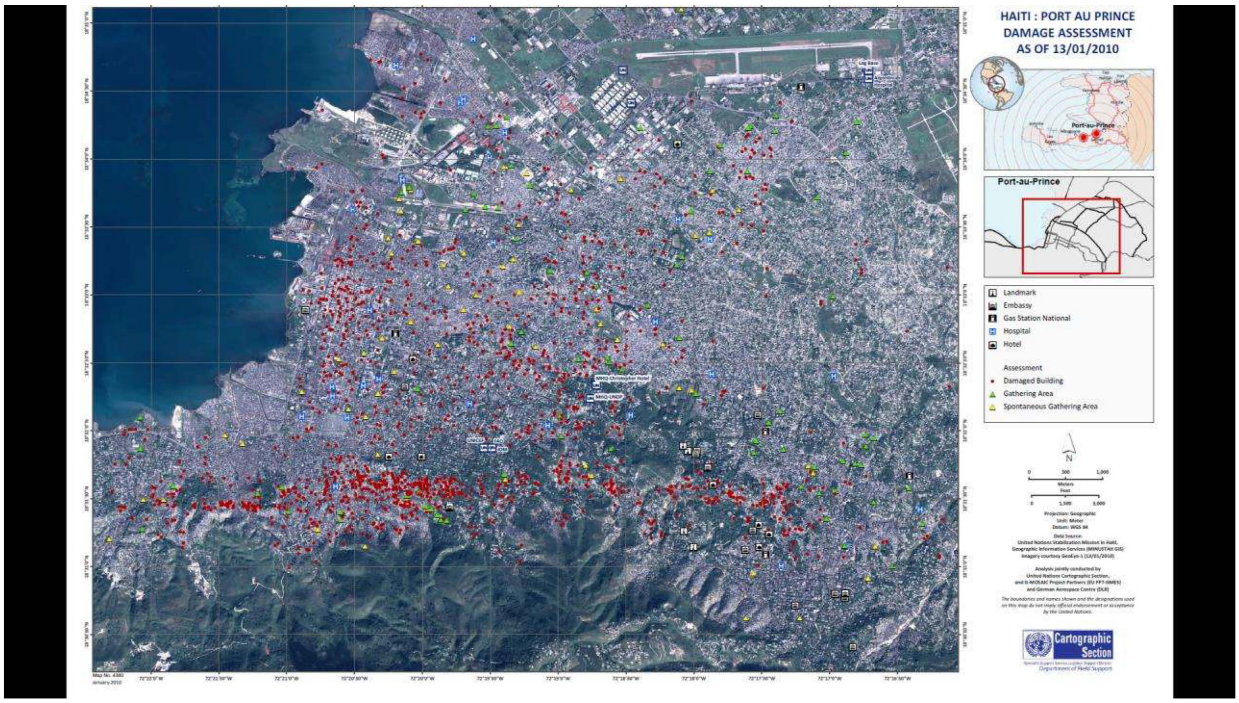


Figure 3: View of Port-au-Prince after the earthquake disaster
Source: UN Department of Field Support, Cartographic Section, 2010

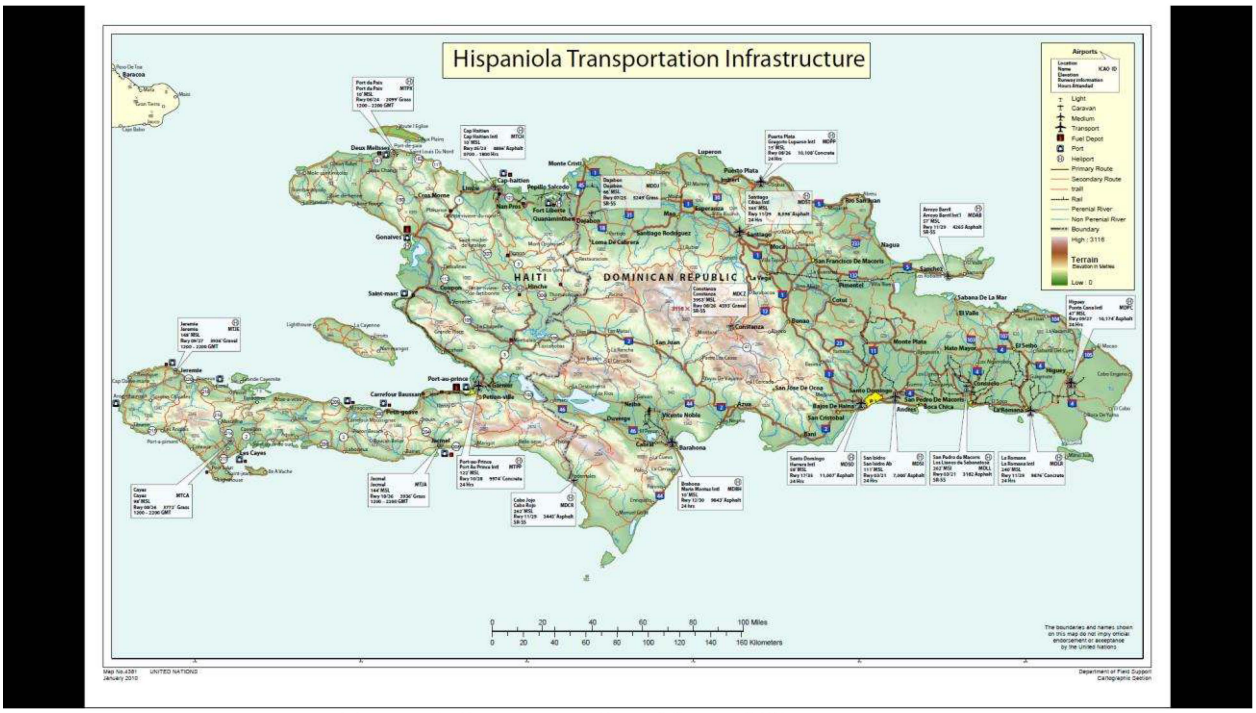


Figure 4: Dominican Republic and Haitian maps
Source: UN Department of Field Support, Cartographic Section, 2010

Other significant challenges include the unavailability of transportation while large quantity of products needs to be transported. Also, according to Thomas and William (2002), disaster response time is crucial for the arrival of donations on site. Thus, it has to be extremely quick in order to send humanitarian goods on time by identifying the most convenient roads. Finally, the choice of route and mode of transport is crucial for effective humanitarian operations. Indeed, the choice of mode of transport (air, water, rail or road) depends on a number of parameters such as needs and opportunities. For instance, in the case of the Haiti earthquake, the first days after the disaster, large aircrafts could not land on the runway. It was therefore necessary that their content be transferred to smaller aircrafts from the Dominican Republic airport to the Haitian airport (see the map of Figure 4). In fact, during the following weeks, the saturation of the airport caused subsequent major problems leading the European Commission Unit of Civil Protection to state that, on January 25, there were 7-day delay for arriving flights and 1,000 aircraft awaiting.

Amongst many other challenges, there is the recurrent weakness related to an incorrect estimation of transportation when sending humanitarian products, caused by poor demand estimation of humanitarian goods in crisis areas. Besides, there is the problem of mismanagement during the transport of humanitarian goods because even if means of transport are widely available, humanitarian goods fail to reach crisis areas on time. Also, the high cost of transportation and resource management a big issue due to the non-optimality of moved products via roads. Finally, the distribution of humanitarian goods is neither egalitarian nor controlled, thus creating the need to ensure that humanitarian donations are in good hands. In fact, humanitarian products are always expected to end up meeting the needs of affected zones and their people. The image of Figure 5 shows an operation of humanitarian donations distribution in a Haitian crisis area.



Figure 5: Residents at a Haiti camp for displaced persons getting bleach and water purification tablets from a helicopter
Source: UN MINUSTAH, Logan Abassi, 2010

Challenges of transporting humanitarian aid also lie in deciding the right modes of transportation and in optimizing routes based on the existing infrastructure and the state of the crisis areas. So, in order to ensure a better coordinated humanitarian logistical system, many improvements are needed in the transportation of products, gifts and services to areas of humanitarian crises in order to meet as quickly as possible the needs of victims. Also, innovation in transportation and delivery of humanitarian supplies to crisis areas has to be rethought. Finally, innovation in blue containers used to store humanitarian goods needs equally to be greatly improved by drawing on industrial logistics (refer to section 2), and in this sense, the use of Less-Than-Truckload transport systems could be effective.

3.2 Inadequate Product Deployment and Under-Utilization of Potential Storage Centers

Many challenges related to humanitarian logistics are related to the lack of strategic locations and the under-utilization of potential warehouses, preventing the rapid deployment of humanitarian aid (Duran et al., 2011).

In situations of humanitarian crises, the main issue is the urgency to save victims of natural, technological/industrial disaster or armed conflict or other natural/anthropogenic events that affect a given population. Often, victims live in poverty and have various urgent basic needs including water, food, clothing, health care, pharmaceuticals, blankets, tents, and lighting. Under these circumstances of extreme urgency, humanitarian organizations and non-governmental organizations use all necessary means to assist affected populations through structured logistics (procurement, transport, storage, and distribution of products/goods). Besides, warehouse inventories are additional key elements. There is an insufficiency of warehouse diversity with regards to humanitarian needs, yet addressing it is weakened by the under-utilization of warehouses (Natsios, 1995). There is a need of more suitable warehouses in order to protect humanitarian products until their distribution. In the current state of humanitarian logistics, there are three categories of warehouses that are often grouped into a single warehouse often due to a lack of space.

- General shipping warehouses: Goods are stored for an indefinite period of time, or awaiting to be sent to the field or in a secondary warehouse. These warehouses are usually located in the capitals or central points called centroids;
- Slow-rotation warehouses: Occasionally used; where non-urgent items such as spare parts, equipment or tools are stored;
- Fast-turnover warehouses: shipping warehouses where daily or frequent shipping of products are stored.

Though little choices are available to NGOs about the storage places during emergencies, the following factors should also be considered:

- Type of stored products: it takes, for example, fresh, dry and ventilated warehouses for drugs and foods, while taking into consideration that some types of products cannot be mixed;
- Convenience of location: while ensuring sufficient space for storage, warehouses have to be easily accessible for transport;
- Adequate safety rules: the right security of the warehouse has to be considered while insuring its good functional condition and its standards of external security. The natural

and social environments (opportunities, floods, landslides, armed militias based nearby, etc.) should also be considered.

Furthermore, the time constraint is an important factor in storing the products as it could be a major obstacle for NGOs. Furthermore, given the urgency of victims' needs and the pressure of public opinion, vigilance about the expiry date of the products is crucial to avoid waste. Additionally, improper storage, too many gauges or inadequate transportation could degrade humanitarian products (Saetti and Cauët, 2008).

Thus, the main challenge remains to adequately meet the needs induced by various humanitarian crises. Accordingly, advantages in using the warehouses of private companies around the world are real. The Physical Internet perspective of interconnected humanitarian logistics takes into account the location of any warehouse that may contribute to the rapid deployment of humanitarian aid. A decentralized and fluid humanitarian supply chain is fundamental for the effective and timely delivery of products (Gatignon et al., 2010). Also, in case of insufficient structures, the possibility to create temporary warehouses for rapid deployment of humanitarian aid is appropriate and should be considered.

3.3 Limited Supply Networks for Humanitarian Products

Van and Martinez (2012) showed that by using operational research to adapt supply chain best practices to humanitarian logistics, significant improvements can be achieved in addressing crises.

The main issue is that humanitarian products fail to reach destinations in a timely manner, while available products nearby are not taken as an advantage to quickly and efficiently reach the victim's needs (Balcik et al., 2010). In the current context, the international humanitarian system is based on the idea of providing goods and services to people and communities affected by disasters and conflicts across all sectors of humanitarian assistance, including health, water and sanitation, shelter and camp management, food and nutrition, agriculture, logistics, and telecommunications.

Various products have been introduced to improve humanitarian responses in situation of disaster-affected populations. For instance, in the 80s the "famine biscuit" was developed by Oxfam in collaboration with a candy company. As challenges are diverse, if the organization decides to purchase, it can create local constraints as quality and quantity are not always guaranteed. This can create a competition between organizations for the purchase of a product, making sure that the products are not available in the local market. This can cause price inflation, which can further impoverish local communities. Also the purchase of products by local NGOs can lead to a lack of supply of the normal local market. Conversely, if NGOs decide to import the product, it may cause an increase in delivery times and transportation costs, and demonstrates a lack of support for the local economy. In addition, foreign products may not be adapted to local needs.

Companies do not always have to think of physical assets when looking for ways to provide assistance during humanitarian relief efforts. There are a range of trade logistics processes and products that can be used to make a significant difference on the ground often, by simply adapting existing tools. For instance, UPS has developed its profit track pad technology, a

system commonly used to track packages in offices, to contribute to organizational relief efforts during Hurricane Katrina, the Haiti earthquake, and the oil spill in the Gulf. In Haiti, the technology has been used to manage the distribution of food to families in need. Replacing paper forms used by the Army by hi-tech barcodes to confirm what each family has received, the number of families, their location in the camp and their needs. This system has helped to ensure that all families receive supplies at the right time, and to reduce theft and fraud, while freeing up volunteers for other tasks.

Product innovations derived directly from the R & D specialist sectors allow aid workers access to new approaches which then influences the way work is undertaken. However, there may be a tendency to focus on basic product innovation, which in some cases may be harmful. In the area of management of camps, NGOs have a multitude of tent styles. Many of them are based on the idea that a single product can operate in all environments. Aid agencies have tended to focus on the delivery of tents with incremental innovations. This product-based view can lead to inappropriate innovations. A different approach to innovation can be a part of the answer to address the problems of supply. Bringing local knowledge in selecting products for a crisis may be crucial in contextualizing the delivery of aid.

Following the development context of the problem of supply and services in humanitarian crisis networks, these key issues are therefore identified: the existence of a range of trade logistics processes and products that can be used to make a significant difference on the ground; the necessity not to focus only on basic incremental innovations; and the urgency to leverage local knowledge and networks in the products choice and supply.

3.4 Inadequate Identification, Management and Delivery of Donations

Humanitarian product management is a bottleneck that can have serious impact on the effectiveness of aid delivery. To illustrate the negative impact of inappropriate donations, consider the case of the World Food Programme (WFP) in response to the food crisis in Eastern Africa in 2002. This case illustrates the complexities in humanitarian supply chain that can be caused by donations. When donations reached the area in response to food shortages, corns delivered in Zambia had traces of genetically modified organisms (GMOs). The Zambian government immediately denied the corn. Thus, WFP had to purchase local corn. This example demonstrates the cost, time and resources that can be mobilized in the event of mismanagement of donations.

Although essential, donations are often poorly managed and can impede the proper functioning of a humanitarian intervention. For example, donations occur frequently without request, and often do not meet the needs. If they are under-used or not used at all, it translates into waste of time and resources. In addition, from an ethical point of view and the image of the organization, the donations are often difficult to refuse. Finally, the response of individuals and businesses during a crisis with respect to donations cannot be guaranteed. In 2005, donations to the tsunami were funded at 475 % while the crisis in Djibouti was funded at only 39% (International Federation of Red Cross, 2006).

Partnerships, volunteerism, product, and cash are the four major categories of donations identified:

1. Donations in nature may meet the specific requirements provided by humanitarian organizations through public calls. Donors should consider the costs associated with shipping and handling. To ensure the highest level of effectiveness, donors should ensure that the goods are delivered to the recipient in a timely manner and in the right place so they can be easily used as intended by humanitarian agencies. During the 2004 tsunami, given the large amount of donations in nature from the private sector, NGOs were overwhelmed and were unable to take advantage of non-monetary gifts because they do not have the appropriate staff.
2. Donations in cash: Here the presence or absence of media determines humanitarian organizations' ability to raise funds for the less publicized disasters.
3. Resources in the form of volunteering are also possible forms of corporate contributions for disaster relief operations. They can provide technical assistance to support local knowledge. However, unless well managed, they can be detrimental to the operation.
4. Partnerships, as a donation, require a long-term commitment of both parties. Considering all the work needed to create partnerships, it is necessary to do it before the disaster arises. According to a report from the United Nations (2005), humanitarian partnership takes 12 to 18 months in general to be achieved.

3.5 Lack of Coordination among Humanitarian Stakeholders

Coordination appears to be the biggest issue slowing down the effectiveness of humanitarian actions (Stephenson, 2005). Coordination refers to the sum of various relationships and interactions between different actors operating in the framework of a joint action (Balcik et al., 2010). Here, coordination takes place in humanitarian activities. The literature in the humanitarian field uses the idea of horizontal and vertical coordination to define the concept of coordination, which is perceived to be interchangeable with the notion of collaboration (Russell, 2005). On one hand, vertical coordination is reflected in the sum of relationships and interactions between, for example, traditional NGOs and a transportation company. On the other hand, the same amount of interactions between various NGOs involved in the same humanitarian crisis is seen as a horizontal coordination.

Three levels of commitment in humanitarian actions can be specified: (a) strategic or long-term commitment, (b) tactical or medium term commitment and (c) operational or short term commitment. Here, coordination is considered as the sum of interactions at all levels of commitment. According to a finding from Stephenson (2005), humanitarian actors operate in an environment that does not globally emphasize coordination. Several factors were identified as determinant of successful planning and coordination. Table 2 highlights key influential dimensions.

Moreover, the nature of donations, expectations of donors and the availability of information are additional factors that may increase difficulties in the coordination of humanitarian actions. Above all, there is no regulation in the coordination of activities between various actors in the sector of humanitarian aid. This major weakness results in undefined specific roles of actors leading to uncoordinated actions that are causing serious problems such as resources waste or misuse, delays in the humanitarian chain, inefficient and ineffective actions when addressing humanitarian crises.

Table 2: Factors affecting the success of planning and coordination in humanitarian logistics

Number and diversity of actors	*The high number of players and diversity in cultural, geographical and procedural terms tend to create additional barriers in terms of communication. Furthermore, the operational environment of a humanitarian crisis does not have a strict regulation which ensures that roles of each stakeholder are clearly defined (Seaman, 1999);*
Competition for money and the effects of media	*The competition for money is at the highest level in the first two phases of the humanitarian crisis where the donations given to players as well as the attention of the global media are at their peak. This leads participants not to share strategic competitive information thus creating problems in terms of coordination (Stephenson, 2005);*
Use of different methods of coordination due to iterative phases of operation	*The way preparation, immediate response and rehabilitation activities are coordinated in deploying humanitarian aid is different at each step. Amongst others, the problem lies in the lock during the preparation phase which leads to a subsequent lock through all the logistic chain (Seaman, 1999). This is why the vision of coordination in delivering humanitarian aid needs to be configured in a unique, systemic, efficient, and sustainable design;*
Volatile shortages and surpluses of resources	*Scarcity and surplus of resources can consume efforts and various logistical resources that affect coordination (Gatignon et al., 2010). The case of the 2004 Tsunami where a third of the containers remained blocked at customs airports five months after the event was illustrative;*
Costs of coordination	*Coordination activity involves costs such as staff salaries, mission fees, and travel expenses. For smaller players in humanitarian aid, reduced financial capacity does not allow them to neither allocate sufficient working force nor undertake effective actions during the deployment of humanitarian aid (McCoy and Brandeau, 2011);*
Unpredictability of humanitarian crises and scenarios	*Usually, neither humanitarian crises nor their intensity, location or time are known in advance. Moreover, forecasting the state of infrastructure regarding transport or communications in a potential humanitarian area is challenging (Charles and Lauras, 2011). This makes coordination mechanisms difficult to determine in advance thus affecting the efficiency of humanitarian actions;*
Lack of standardization of products and supply chains	*The characteristics of supply chains are always associated with the type of humanitarian crisis and the actors involved (Heigh and Jahre, 2010). Accordingly, organizational and situational differences from the preparation phase to the rehabilitation phase make coordination difficult particularly regarding the supply chain especially when the concept differs from one organization to another;*

Taking the example of Haiti where the government has been overwhelmed by the scale of the humanitarian crisis and where the role of coordination was assigned to the United Nations, a major challenge resulted in the presence of several operating modes that were overlapping during the deployment of the humanitarian aid both at international and national levels.

This humanitarian cacophony causes coordination difficulties as each organization considers its own mode of operation as the best (Balcik et al., 2010) and thus tries to impose it. Also, the specific characteristics of each humanitarian crisis increase the difficulty of coordination due to operating conditions and scenarios' unpredictability. The adaptability of the response to each specific humanitarian crisis remains a challenge for all organizations.

3.6 Difficult Integration of new Players in the Humanitarian System

An analysis of NGOs' activities and structures shows limited access to the humanitarian sector for several actors. Among entry barriers is the problem of obtaining NGO status recognition both at national and international levels. These barriers revolve around bureaucratic constraints and practices amongst countries, international institutions, and beyond.

According to the international guidelines for humanitarian assistance operations (Macalister-Smith, 1991), acting effectively in the humanitarian field requires a status allowing players to practice globally in line with the assertion that the successful provision of humanitarian assistance depends on a speedy, efficient, and coordinated response based in turn on suitable legal and administrative foundations, provided that humanitarian actions are needed.

Another barrier lies in the access to government subsidies because some countries, especially African, are reluctant to massive recognition of new humanitarian organizations because such a move implies significant government expenditures.

The heavy process of decision making amongst humanitarian giants including the United Nations and its sub-entities is another issue. Due to the small number of actors in the humanitarian field, decision-making power is often detained by big organizations and NGOs that decide who should be allowed to join the network and who should be dismissed without giving sufficient objective reasons for the exclusion (Peltonen, 2010).

These types of disqualification prevent universal access to actors during humanitarian operations and reduce diversity of players while underexploiting potentials for open partnerships. Amongst key entry barriers in the humanitarian workflow, there is also the limited capacity of some NGOs vis-à-vis local conditions and specific characteristics of the humanitarian crisis such as the accessibility of the site making many NGOs with small capacities and limited resources completely disqualified and needless.

All of these barriers result in a monopoly of the NGOs cluster over the humanitarian sector where actions are not necessarily coordinated (Dworken, 1995) and at the same time compromising the ability to use additional external partners, thus weakening the potential for globally well-coordinated actions during humanitarian emergencies.

3.7 Neglect of Environmental Impact in Humanitarian Actions

How humanitarian products and services are provided is not environmentally sustainable and this is characterized by the fact that at various stages (preparedness, response, rehabilitation), humanitarian aid appears to have short-term goals (Eng-Larsson and Vega, 2011). In fact, the objectives of a humanitarian deployment are expected to be achieved in a very short time in respect with the organizations' missions. During the response phase, the long-term considerations are often ignored.

At the very first moment of the disaster, the procedures seem to prioritize immediate action thus, often making humanitarian operations following the disaster cause more environmental damage than the catastrophe itself (Eng-Larsson and Vega, 2011).

Indeed, it is rare that a product or service, in the case of humanitarian aid is designed in a sustainable manner. The emergency response and loss of human lives are often at the basis of plans prioritizing immediate action that marginalizes environmental and long-term considerations.

The approach to green logistics is quite the opposite. In a context where every action is studied in order to understand its environmental significance and sustainability, long-term considerations are paramount. So it seems that "green" temporary activity, as in the case of humanitarian logistics, is a paradox. The question to ask is: How green logistics can be integrated into organizations' temporary measures without compromising the achievement of short-term goals?

Humanitarian operations generate significant movement of materials and information. Studies exploring the management of these movements through the supply are limited, especially regarding environmental impact. However, there is an increasing awareness in the literature on this problem and its current state. Indeed, actions frequently updated and denounced show all the weaknesses while questioning the practices of various humanitarian actors.

The mismatch between institutional donations sent and actual demand can cause greenhouse gas emissions resulting from unnecessary energy waste. For instance, Bosnia and Herzegovina received more than 17,000 tons of expired drugs in humanitarian aid. This required the construction of an incinerator, mobilizing unnecessary monetary resources for transportation and storage.

Indeed, in the context of humanitarian logistics, all decisions and activities during the phases of preparedness, response and rehabilitation will impact the amount of transport used to meet needs. In addition, the distribution of products and services involves the consumption of large amounts of fossil fuels, often gaseous emissions, waste oils, and fuels. For example, in order to perform their daily tasks and their humanitarian work, members of the Fleet Forum, which includes the International Federation of Red Cross and World Food Programme, had to mobilize nearly 80,000 vehicles. Meanwhile, the organization of the United Nations peacekeeping had nearly 17,000 vehicles, most of which were trucks, SUVs and armored vehicles to meet the needs in its operations. In addition to the number of vehicles involved, the lack of communication between the different actors and their poor coordination often lead to duplication and redundancy, creating unjustified overuse of resources.

In addition, inventory management is often another problem cited in the literature as the source of large amounts of greenhouse gas emissions. Although many organizations try to preposition their inventories in strategic locations in order to minimize response time following a natural disaster, they still have to travel long distances before reaching their destination, thus generating more greenhouse gas emissions.

Therefore, in the local and global supply storage system, there is place to reduce energy waste. Finally, the exploitation of natural resources is also criticized in the literature. For example,

between 1994 and 1996, 36 million trees of Virunga National Park, in The Democratic Republic of Congo, have been used for heating and construction to meet the needs of Rwandan refugees.

Following the problems of neglecting environmental impact during humanitarian crises, key issues include the need to improve coordination to optimize transport, the use of biofuels, "green procurement" and the modification of materials used in humanitarian products to make them more environmentally sustainable. There are a variety of methods of environmental management, such as life cycle analysis that can be used in order to make a significant difference on the ground. Another challenge is the need to improve innovation in the management and recycling of waste in order to benefit from the processing and reuse. Moreover, the issue of limited access to green technologies due to high cost and low availability needs to be addressed through, for example, more electric vehicles, biofuels or biodegradable plastic products.

Finally, organizations should moderate their tendency to focus on the urgency of the response without evaluating the environmental consequences vis-à-vis their actions.

The potential solutions that the Physical Internet could bring address the sum of problems described above. Every solution identified thanks to a potential implementation of the Physical Internet covers sometimes two or several problems in different domains. It leads us to the conclusion centered on a unique vision and integrated by this idea of enabled interconnected humanitarian logistics which intend to make the deployment of the humanitarian aid efficient and sustainable.

Without claiming completeness, section 4 is hereafter describing the elaboration of an interconnected humanitarian logistics system. It also presents scenarios stemming from proposed solutions which are described in a top–down logic through the vision of the concept of the Physical Internet in all its dimensions and with particular emphasis on transport, distribution, and supply.

4 Building a Humanitarian Interconnected Logistics System Introduction

The proposed humanitarian interconnected logistics system targets the objectives of (1) creating a Humanitarian Logistics Web enabling interconnected humanitarian (a) transport, (b) distribution, and (c) supply; and (2) offering the key components for operating a humanitarian PI through (a) standardized, modular and smart humanitarian π-containers from box and case sizes to cargo container sizes, (b) adapted and appropriate humanitarian means of transport, handling, and storage and logistics facilities, and finally (c) humanitarian protocols and informational platforms.

4.1 Towards Interconnected Humanitarian Logistics

Global interconnectivity of the humanitarian logistics is to allow breaking the isolation induced by the physical borders between the various actors by enabling the interconnectivity of individuals, donors, companies, suppliers, NGOs, international institutions, governments and beneficiaries. The global Humanitarian Logistic Web is to evolve from a private logistic network or from a limited partnership towards a global logistic network of interconnected humanitarian

supply networks. The access to the global web thus becomes open by allowing the implication of all the actors of the humanitarian aid under any form of collaboration.

Interconnected humanitarian transport, as one of three key elements of interconnected humanitarian logistics, must evolve towards distributed multi-segment and multimodal transportation by using open hubs and warehouses across the world and the certified blue containers in order to exploit carriers' global networks. Interconnected humanitarian distribution means to network and to enable access to all warehouses and distribution centers of NGOs and other organizations and businesses, airports, ports, etc., allowing a better, openly pooled, storage of products before a crisis as well as a better response to crises, notably through a further distribution of the help to a disaster. Finally, interconnected humanitarian supply must evolve towards a global web of suppliers and donators, displaying in a dynamic way products and services needed and available, while involving the global certified PI networks. This mode assures an efficient adaptability to a variable demand.

As a key constituent of a humanitarian Physical Internet, the modular, intelligent and standardized humanitarian π-containers are to allow efficient transport, handling and storage of products towards disaster areas, but also to be used in other purposes on the ground such as a blue container which can become a mobile tent, etc. Adapted humanitarian means of transportation, handling and storage are indispensable to incite innovation in the conception of logistics means adapted to humanitarian crises, thus allowing the access to difficult grounds while taking into account eco-design. Finally, humanitarian protocols and informational platforms are important to building an open distributed networked infrastructure that will connect all actors in humanitarian logistics.

Scenarios that take into account the complexity of the deployment of humanitarian assistance associated with the involvement of several actors are presented subsequently in section 5, in a design that applies the principles of Physical Internet while considering the very specific nature of humanitarian intervention challenges at the global level.

Before exposing the scenarios, we hereafter present the operational characteristics and the structure of the traditional relief chain which depend of the type of disaster and the types of relief actors involved and some issues in terms of supply acquisition/procurement, pre-positioning /warehousing, transportation and coordination mechanisms. The typical flow of supplies (Blacik et al., 2010) is illustrated in Figure 6.

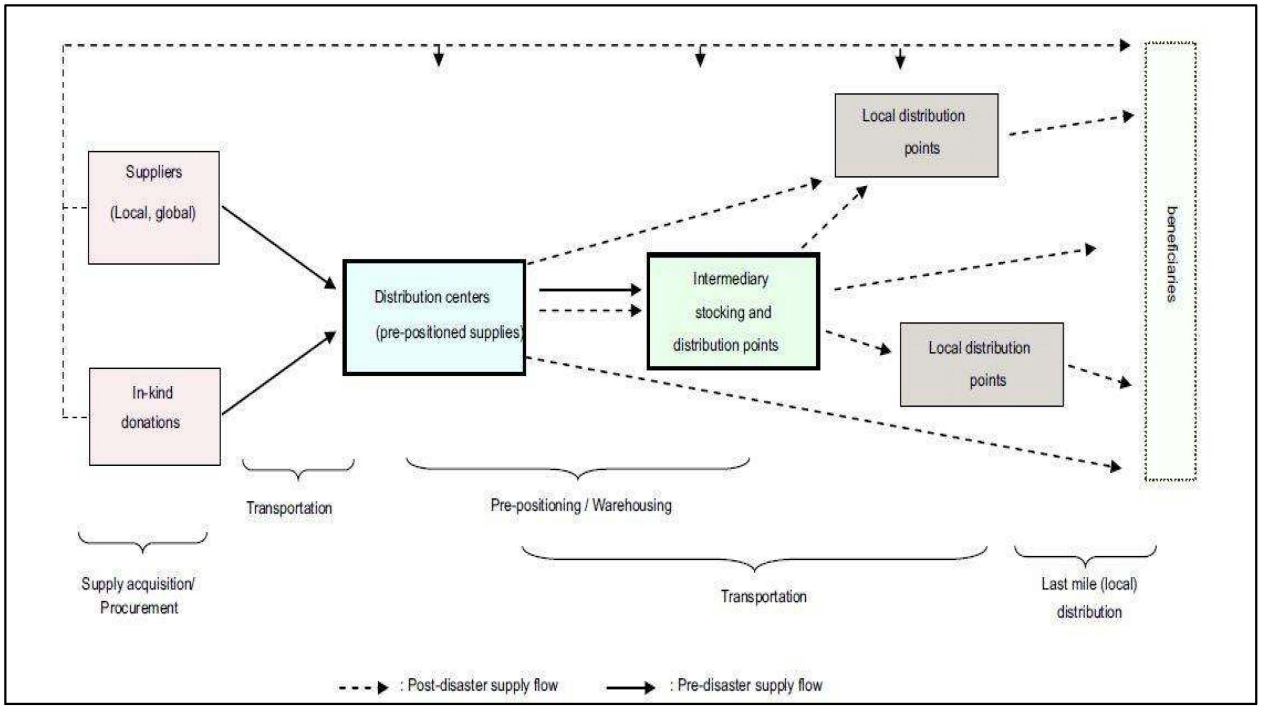


Figure 6: Relief chain structure
Adapted from Blacik et al. (2010)

In terms of supply acquisition and procurement, the NGOs, for example, can procure supplies locally and/or globally. Each of these options has advantages and disadvantages which are concentrated around the costs, the lead-times and the availability of products and/or services. If we analyse for example the costs of logistics, there is generally an important difference between the local supply versus the global one with an important cost advantage on the first one (Balcik and Beamon, 2008). It is aimed that interconnected humanitarian distribution and interconnected humanitarian supply can mitigate the risks in regard to product availability. It also could bring economies of scale and a better cost distribution in the humanitarian logistic ecosystem.

At the level of pre-positioning and warehousing, in the traditional logistic chain as shown in the Figure 6, the NGOs may hold pre-positioned stock at multiple levels (global, regional, in-country) to make sure of the availability of products. It may also hold storage facilities at airports and seaports for the same purpose. According to the proposed approach in this paper, translated in the scenarios of forthcoming section 5, the presence of a unique counter (single window) which gives the possibility to all humanitarian actors to analyze correctly the offers and demands and to take the best decisions, brings potentially important savings in terms of logistic costs, a better distribution of products and services and better resources management.

Transportation is also a key problem in the traditional humanitarian supply chain. The lack of global connectivity between carriers, the low adaptability of transport, the limiting and often (partially) destroyed infrastructure, as well as the lack of coordination are among the elements that now characterize transport in humanitarian aid. As shown in the key physical constituents of Humanitarian PI, modular, intelligent and standardized humanitarian π-containers and innovation in the design of transportation means could bring added value to the efforts of humanitarian actors to attenuate and eventually eliminate these problems.

Coordination has an extremely important and sometimes expensive role relative to participating organizations. Each actor in humanitarian aid has its specificity, resulting in coordination mechanisms becoming very heavy as multiple types of organizations are allowed to participate in humanitarian actions without standardization. The proposed approach, based on single entry point or a single window, ensures that stakeholders are brought together in a single coordination mode with added value for all stakeholders. The openly protocoled Physical Internet (PI) coordination could move humanitarian actors toward a seamless horizontal coordination.

4.2 Towards Interconnected Humanitarian Logistics

The *Humanitarian Physical Internet* (*HPI*) corresponds to the application of the Physical Internet principles to the humanitarian field in order to relieve the problems and inefficiencies of the field. It enables a global Humanitarian Logistics Web based on PI's dynamic framework and aims at making the conception, design, production, movement, storage, supply, construction, and use of physical objects in the humanitarian sector more efficient and sustainable. Operationalization of *HPI* is divided into the following three phases.

4.2.1 Upstream Phase

a) Digital Platform

The *HPI* platform digitally supports the interconnection of all stakeholders (individuals, donors, companies, suppliers, NGO, international institutions, governments and beneficiaries) and has to ensure the connection of these stakeholders with actors in the crisis zone. This platform presents the interface between the *HPI system* and each stakeholder. The latter may connect with his account, see the latest news about humanitarian crises, some statistics on the performance of the system, some forecasts of what will happen in the near future related to humanitarian crisis, information about partners (donors who want to be published, etc.), progress in operations in crisis situations, and so on. Each stakeholder has his own interface. For example, a donator has interface for funds transfer, a supplier has an interface for registering his/her products to be supplied, beneficiaries have interfaces for registering their needs, etc.

The HPI platform is to evolve with technological innovations. For example, videoconferencing with crisis zones is an application that can elevate the degree of live interconnectivity. At the present time, in such a context, it may be difficult to ensure a connection with personal computer whereas, it may be easier to connect with a smart phone. The HPI platform is to ease seamless high-performance interconnectivity.

b) Donations

Donations can be in different forms: money (cash or price reduction), services, goods, food, medicines, equipment (transport, handling, etc.), space (volume and weight) in transport means or in warehouses, back-haul movement, innovative ideas for equipment, etc.

Donations are to be received through the digital platform. As soon as there is a donation anywhere in the world, it is registered on the digital platform. Then, donations are properly labeled and the donor can give utilization tags. In fact, donors can state their restrictions and preferences in the nature of use of their donations. For example, a donor can require that his/her

donations be used for crises in Africa or only for humanitarian organizations such as the Red Cross, or yet any natural disaster except those that are war induced. This is the donor's choice. The donations are registered as humanitarian assets and are prepared and deployed in preparation and/or in response to the occurrence of a humanitarian crisis. Finally, when necessary, donated goods must be stored and moved as needed, given the scope of potential use as bounded by restrictions form donors and according to the preferences of their donors.

c) Monitoring of Worldwide Requirements

It is proposed that *HPI* embeds extensive monitoring and dashboard capabilities. In fact, good learning from, and good preparation to humanitarian crises can improve the quality of the reaction and response times to humanitarian crises. The HPI dashboard can:

(1) Examine the current situation on the world based on multiple sources of information such as satellites, news, actors in crises zones, etc.;
(2) Learn about actual situation in the world: people, demographic changes, climate changes, conflict inert-countries, people's revolutions, geographical phenomena\transformation, etc.;
(3) Learn also about occurred crises: have a history of crises, indicators of crises, the evolution of crisis, triggers of crisis as floods, wars, problems and challenges of each type of humanitarian crisis causes inefficiency in logistics operations, intervention strategies, intervention steps, key success;
(4) Forecast future humanitarian crises, assess the needs of potential crisis areas depending on the type of crisis and the crisis area expected requirements (electricity, clothing, tents, food, water, helicopter, etc.), estimate the gap between what these crisis zones need and what is available from donations;
(5) Establish tactical deployment of humanitarian assets before crisis occurrence.

d) Tactical Deployment before Crisis Occurrence

After predicting the crisis and the estimated needs of these crisis areas, *HPI* system should ensure that assets to satisfy these needs be located near predicted areas of crisis.

For this, the location of warehouses and transportation means according to available quantities is established as in the generic PI system. It is paramount that the HPI system exploits and benefits from PI-transportation means, PI-Hubs as well as PI-containers which are already in service for all kinds of other sectors.

In fact, Montreuil et al. (2013) report that trucks and containers are often half empty at departure, with a large chunk of the non-emptiness being filled by packaging. Indeed, 56.8% of containers and trucks are full but not empty, and the average of utilization of trucks and containers is 42.6%. Also, vehicles and containers often return empty, or travel extra routes to find return shipments (25% of travel) and loaded vehicles get emptier and emptier as their route unfolds from delivery point to delivery point. In this context, HPI is to exploit the empty movements and the empty volume in trucks and containers to package and transport humanitarian goods, as often as possible at humanitarian discounts or even better as donations.

To achieve these goals, *HPI* should (1) contact the related stakeholders and call for help and awareness among the different actors (suppliers, drivers, warehouses owners, donators,

volunteers, etc.) on a continuous year-round basis; (2) solve optimization problems for locating and selecting warehouses, for planning transport and for dynamic asset distribution; and after that (3) determine intervention strategies and establish an interim plan in order to be efficient when a humanitarian crisis occurs.

4.2.2 Operationalization of Interconnected Humanitarian Logistics

4.2.2.1 Containerization of Humanitarian Food, Goods and Equipment

For efficient and secure humanitarian goods transportation, handling and storage, it is proposed that blue containers be used. These are π-containers designed for humanitarian logistics. They are modular, standardized and intelligent π-containers. As blue containers, they are also designed for taking various roles, to be used for purposes besides packaging humanitarian goods. In fact, it is suggested that blue containers be transformable for reuse as tents, tables, medical offices, kitchens, etc. It should also be possible to integrate cameras in these *HPI-containers* in order to film situations in crisis areas, interventions of actors implicated there for help, people reactions, etc., and ideally to be able to transmit the movies live to humanitarian stakeholders. These films would serve to collect as much information as possible and situations about each type of humanitarian crises. On one hand, it can fulfill some function of the press, and act as a feed, if it is not possible for press members to join the crisis emplacement, and, on the other hand, it can be a knowledge base that should be analyzed later in order to draw conclusions from the past operations and plan efficiently for future interventions.

4.2.2.2 Humanitarian Interconnected Transport

As displayed in Figure 1 for the generic PI, beyond the blue containers, the other two key types of humanitarian physical elements enabling the HPI are the *HPI-nodes* and the *HPI-movers*. The HPI-nodes correspond to the sites, facilities, and physical systems of the Humanitarian Physical Internet. The HPI-movers transport, convey or handle containers within and between nodes of the Humanitarian Physical Internet.

a) Humanitarian Interconnected Transport (HPI Transport)

When a humanitarian crisis occurs, HPI system will connect to its databases, to find and repair empty volumes placed at the disposal for HPI. Volumes on containers, warehouses and means of transport owned by donators can be used to ensure efficiency of humanitarian aid interventions.

b) Humanitarian Hubs (HPI Hubs)

Humanitarian PI-hubs are a subset of π-Hubs. In fact, when a humanitarian crisis occurs, and based on location of the crisis area, a decisional problem of locating HPI-hubs should be solved. The objective is to place them near intersections with other π-hubs in a way that it contributes to the global objective which is an efficient and sustainable humanitarian PI.

c) Humanitarian Warehouses (HPI Warehouses)

Humanitarian PI-Warehouses are warehouses certified for the Physical Internet and for interconnected humanitarian purposes. There exist two basic types of actions relative to humanitarian warehouses: (1) Exploit empty space of a π-warehouse dedicated to blue containers as a donation (free or discount), (2) Create humanitarian π-warehouses, devoted for warehousing

equipment and goods for humanitarian aid, these π-warehouses can be stationary, transient or even mobile.

d) Humanitarian Supply Network

The HPI system should ensure the interconnection of service/goods providers and beneficiaries. It should integrate suppliers, the type of service they offer to the humanitarian aid and then contact them when necessary.

In the HPI conception, it is proposed that donations can take the form of a promise. For example, suppliers can donate information about the volume, the quantities, and the types of goods that they may offer in case of humanitarian crisis. In such a case, the physical goods are transferred to HPI warehouses only when a real humanitarian crisis occurs. Also, suppliers can offer discounts on goods and these goods are transferred to HPI warehouses only when a real humanitarian crisis occurs.

4.2.3 Downstream Phase

Once the crisis has ended, the HPI system should retrieve all recovered material, obsolete equipment, waste, remains, etc., that is not needed anymore in the zone. In fact, from an economic perspective, all the equipment or remaining goods can be reused in other humanitarian crises. The way that they are recovered and transported to HPI-warehouses is the same as before or in the case of humanitarian crises. Empty movements, empty means of transport and empty warehouses can be used also for delivering them to other HPI warehouses for serving other possible humanitarian crises.

From an environmental aspect, the affected areas need to be fixed and garbage that are not recycled there may be harmful. Thus, expired products must be transported to storage locations in order to be recycled afterward.

The next section proposes realistic scenarios that take into account the complexity of the deployment of humanitarian assistance coupled with the involvement of several actors, all presented in a design that applies the principles of the Physical Internet while globally considering the very specific nature of humanitarian intervention challenges.

5 Scenarios

Indeed, following the presentation of the key elements for humanitarian Physical Internet and its operationalization, all the issues raised previously conduct, this time in humanitarian logistics, towards the same conclusion as that of Montreuil (2011, 2013): the way physical objects are moved, handled, stored, realised, supplied and used through the world is not sustainable economically, environmentally et socially. Thus, concrete solutions are to be set up to building an interconnected humanitarian logistics system which will assure the global sustainability.

In this section, some scenarios are generated to present some of the possibilities provided by humanitarian Physical Internet to three types of participants in humanitarian logistics: NGO, the company and the individual. The first three scenarios concern essentially the use of the single entry point by the users, the categorization of the donations and the possible avenues of decisions

for the stakeholders. The final fourth one creates a hypothetical crisis and focuses on the value added by PI-enabled interconnected humanitarian logistics.

Scenario 1 uses a single entry point to mitigate problems presented in the section about typical relief chain structure. The scenario is triggered by a request coming from an NGO concerning goods and/or services. Figure 7 highlights the options associated with the NGO request. Table 3 presents the step-by-step process associated with this scenario.

As highlighted in Figure 8, scenario 2 is in the same context yet focuses on an offer from an individual person about donating funds, goods or services. Figure 9 highlights scenario 3 that focuses on an offer form a company. Tables 4 and 5 present the step-by-step processes associated with these scenarios.

Finally, the scenario 4 represents the case of an emergency that may arise, as happened in Haiti. Following consultation between the various humanitarian actors that form the cluster taking decisions on intervention in coordination with the government, Figure 10 presents the sequence of decisions that an NGO can take in an emergency using the Humanitarian Physical Internet. The associated step-by-step process is synthesized in Table 6.

These are four scenarios which demonstrate the added value of a humanitarian interconnected logistics system based on Physical Internet. Other scenarios must be analysed and tested in order to transpose all the PI characteristics as described by Montreuil (2011, 2013) and Montreuil et al. (2013) and sketched in Table 1.

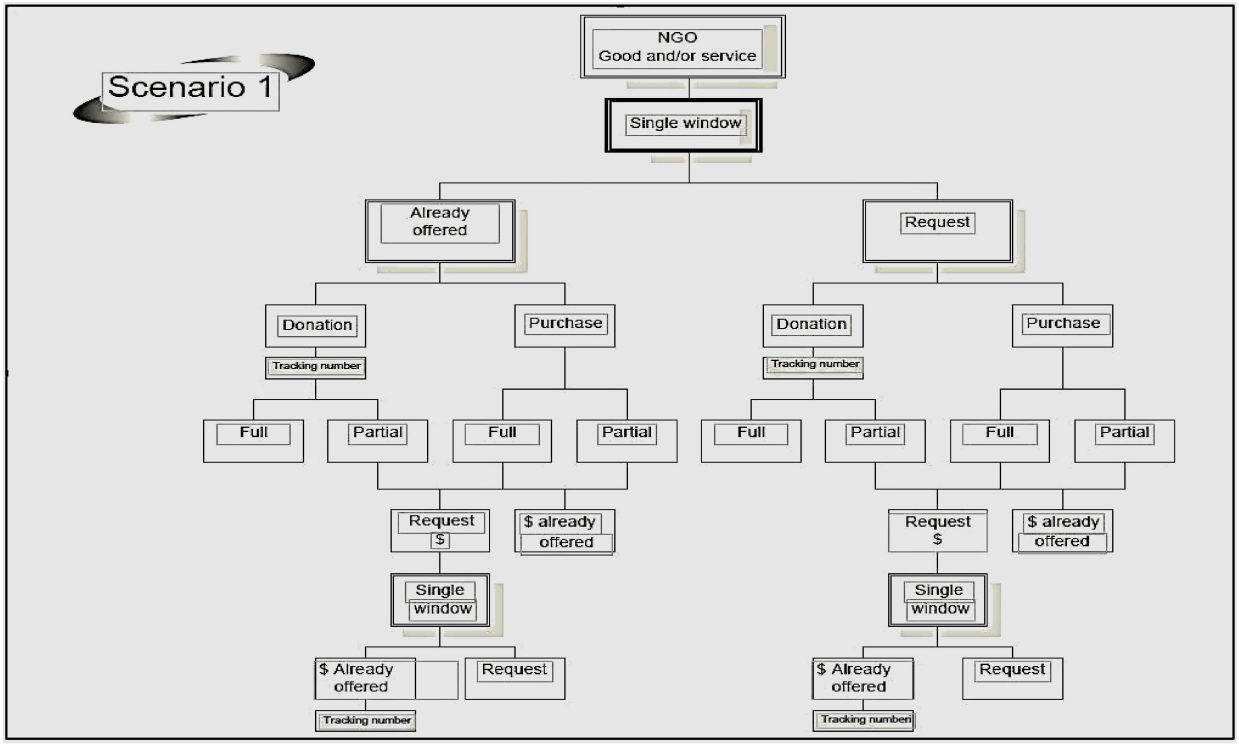


Figure 7: Scenario 1 - Request coming from an NGO

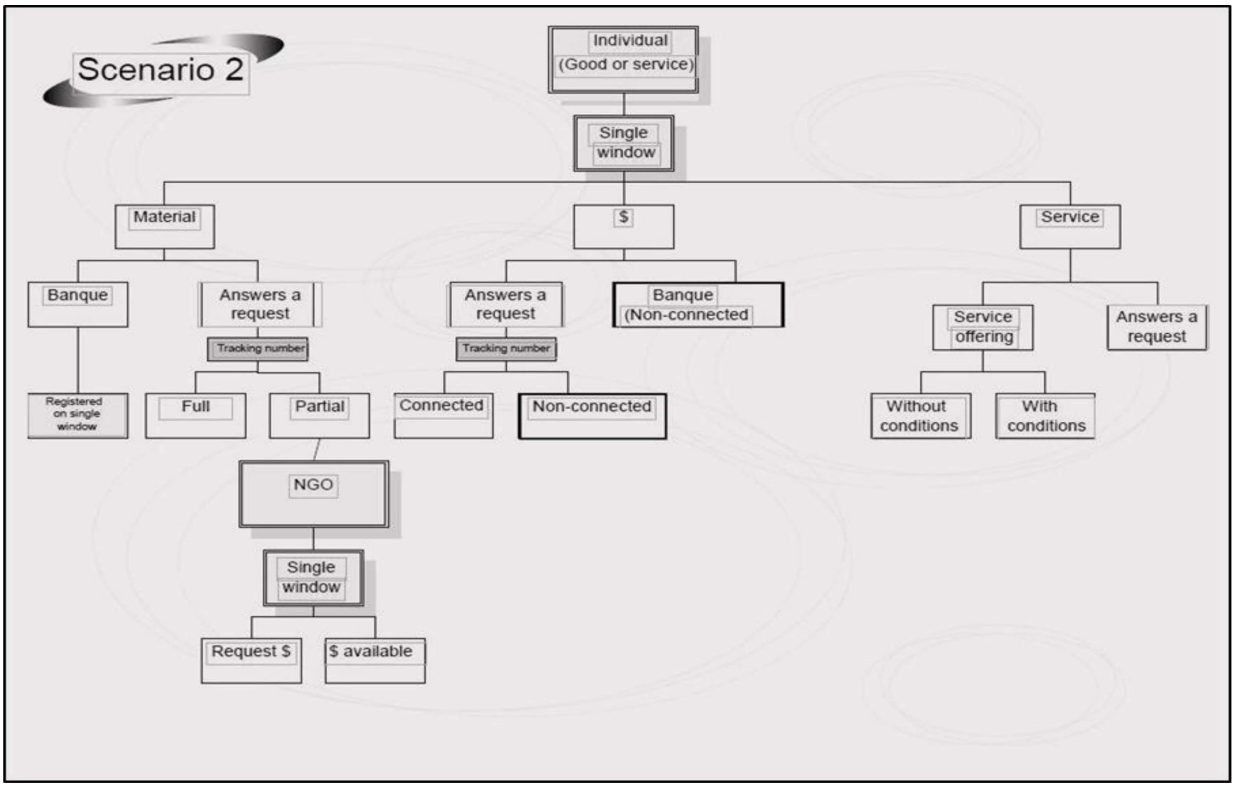


Figure 8: Scenario 2 – Donation offer from an individual

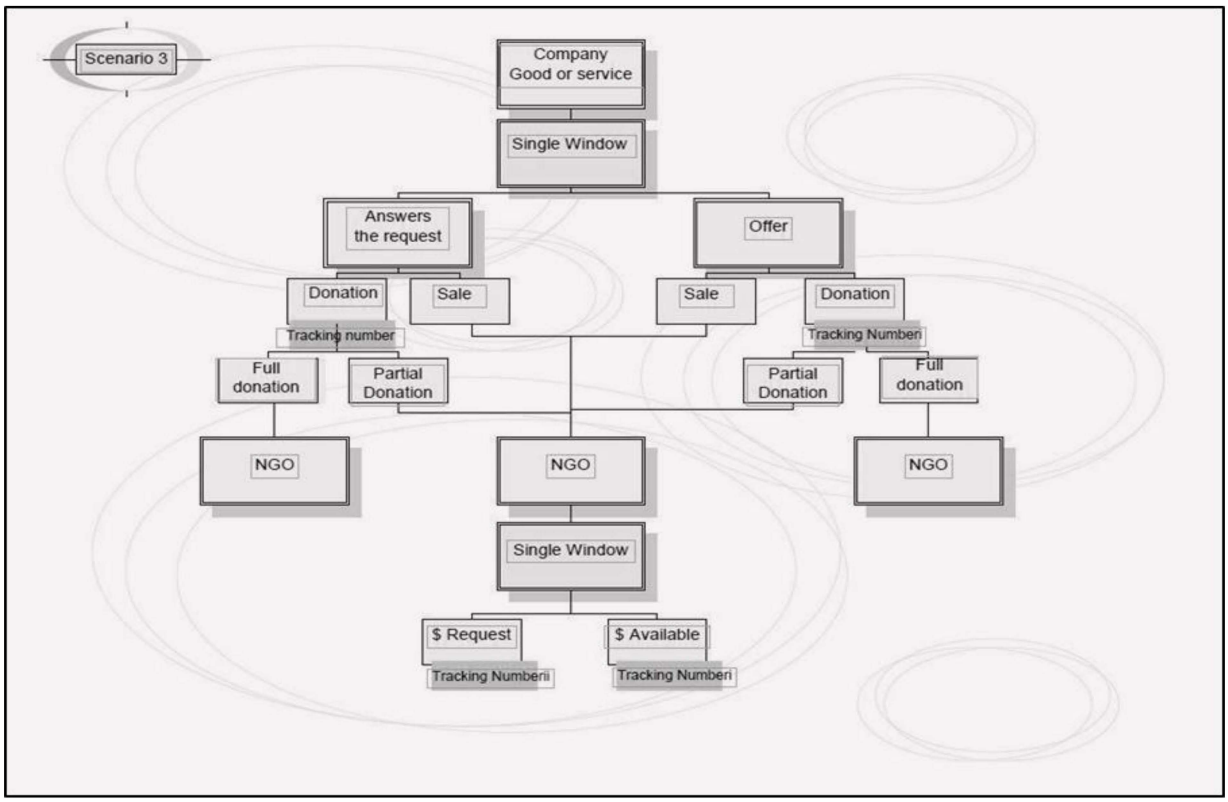


Figure 9: Scenario 3 – Offer coming from a company

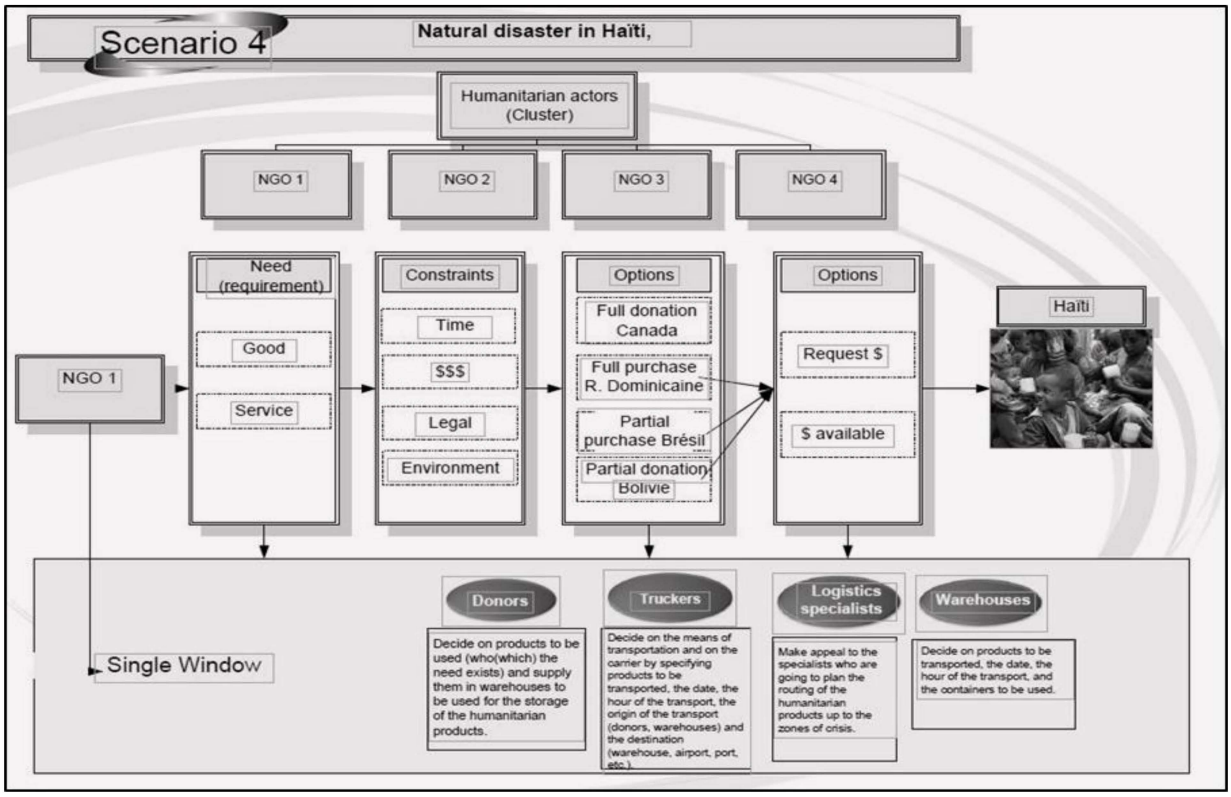


Figure 10: Scenario 4 - The sequence of decisions that an NGO can take in an emergency using the humanitarian Physical Internet

Table 3: Scenario 1 – Step-by-step process for a request coming from an NGO

Step-by-step	Action
1	Having estimated its need, the NGO consults the single window to fill it.
2	From the single window, the NGO can fill its need, by considering the already registered offers or it can create a specific request.
3	In the case of an offer already registered on the single window: a. If it is about a complete donation, a tracking number is sent to the donor. The good and/or the service is dispatched in the requested zone at the expense of the donor; b. If a partial donation occurs, the NGO can support non-covered expenses by its financial resources. If the NGO does not possess the necessary financial resources, she can consult again the single window to consider the monetary offers already registered on the single window or make a request. Once again, when a donation is incurred, a tracking number is sent to the concerned actor. c. If it is about a partial or complete purchase, the procedure of the point *b* applies.
4	In the case of a request on behalf of the NGO on the single window, the procedures illustrated to stage 3 are the same. Actually, when an actor answers at the request of the NGO, the same processes can apply.

Table 4: Scenario 2 – Step-by-step process for a donation offer coming from an individual

Step-by-step	Action
1	The individual reaches the single window to propose a material donation, a monetary donation or a service.
2	In case the individual proposes a material donation: a. If there is no request registered in the single window for the proposed item, the offer is registered in the system for future use; b. If the individual proposes a material donation to answer a request already made in the single window, two avenues are possible: b1. If it is about a complete donation, a tracking number is sent to the individual. The good or service is dispatched in the request zone at the expense of this one; b2. If it is about a partial donation, the NGO can cover non-covered expenses by its financial resources. If the NGO does not possess the necessary financial resources, she can consult again the single window to consider the monetary offers already registered on the single window or make a request. Once again, when a donation is incurred, a tracking number is sent to the concerned actor.
3	In case the individual proposes a monetary donation: a. If there is no request registered in the single window for the proposed sum, the offer is registered in the system for future use and a tracking number is sent to the individual when used; b. If the individual proposes a sum to answer a request already made in the single window, two avenues are possible: b1. The sum can be precisely connected to a specific group. For example, the request is for the humanitarian aid in Japan, but the individual can wish that the sum which he gives is for health care. A tracking number is sent; b2. The sum can be non-connected and be used according to the will of the applicant. A tracking number is sent.
4	In case the individual proposes a service: a. If there is no request registered recorded in the single window for the proposed service, the offer is registered in the system. The offer can be with or without conditions; b. If the individual proposes a service to answer a request already made in the single window, the conditions of the request will apply.

Table 5: Scenario 3 – Step-by-step process for an offer coming from a company

Step-by-step	Action
1	The company reaches the single window to provide a good or service.
2	In the case of an offer which meets a request as a donation: a. If it is a complete gift, a tracking number is sent to the donor. The good or service is supplied to the zone request on the donor's expenses. The NGO provide management in the case of a service; b. If it is a partial donation, NGO can pay the costs not covered by using its financial resources. If the NGO does not have the necessary financial resources, it can consult again the single window to consider monetary offers already recorded on the single window or make a request. Again, when a donation is incurred, a tracking number is sent to the concerned actor; c. If it is a sale, the procedure of paragraph *b* applies.
3	In the case of an offer for which there is no request registered, the procedures in sections 2 apply when the company offer is accepted.

Table 6: Scenario 4 – Step-by-step process for an NGO in an emergency using the humanitarian Physical Internet

Step-by-step	Action
1	NGO accesses the single window to find a good or service.
2	NGO analyses its needs to face constraints they may have. These constraints can be : a. Time: Does the NGO need the products or services immediately or can it wait? a. Money: Is the money available immediately? c. Legal: Are there legal constraints facing products or services? (Ex: products manufactured in the United States supplied to Cuba, etc.); d. Environment: What are the environmental constraints faced by NGOs? (Ex: chemical or biological emergencies, etc.).
3	NGO analyzes its options via the single window. For example, in our scenario we have a complete gift from Canada, a partial donation from Bolivia, a full purchase from the Dominican Republic and a partial purchase from Brazil. Comparing the constraints options, the NGO can make the best choice and make the best decision in a mix.
4.	Depending on its decisions, NGO can make a request on the single window to fund her project.

6 Conclusion

This paper has contributed towards establishing a foundation for Physical Internet enabled interconnected humanitarian logistics. Its major contributions lie on the systemic approach based on the Physical Internet perspective to bring fundamental changes to the way humanitarian logistics is currently being thought and run. Overall, the paper concludes that the Humanitarian Physical Internet has emerged as a natural and credible, effective and sustainable solution to many problems plaguing the emergency humanitarian supply chain and its management. It is part of a promising perspective and foresight to explore through scientific research by taking HPI's key components, tools, and scenarios exposed hereby to the crucial stage of full implementation.

Research avenues include the exploration of more coordinated humanitarian actions that consider the potential of the Physical Internet concept. In fact, the humanitarian emergency aid presents many challenges for organizations attempting to manage data, information and knowledge on various situations or events. Humanitarian organizations must be able to identify the critical information they need, where to find it, and the best way to share, present and disseminate it. These challenges can be addressed in part by using humanitarian PI through knowledge management to deal with its determinants and the mechanisms to be put in place to ensure sustainability.

In any humanitarian intervention, success is often determined by reference to the cost, time and quality of the intervention. Budgetary constraints are often too large and some missions are underfunded while others are over-funded. In this regard, humanitarian PI is a way to promote better financial distribution and optimization. Also, during humanitarian intervention, the lack of regulation in the humanitarian field makes stakeholders' roles not clearly defined. Given that and under current conditions, the State acting as a main coordinating actor, the following research question has to be explored: To what extent the transition to the Physical Internet will influence the role of the State and other stakeholders in terms of coordination and regulation at the level of participants, especially in the situation where the State does not have the capacity to carry out this coordination activity, as was the case of Haiti?

The proposed interconnected humanitarian framework offers one single Internet window sharing centralized and comprehensive information. Lots of information and opportunities provided by the system should allow humanitarian actors to make decisions economically, environmentally and socially optimal with a broad portfolio of solution options. In practice, the amount of information to be processed by the optimization tools is often the source of long periods of resolution. Therefore the following question has to be answered: What will be the impact of the integration of the Physical Internet to decision support tools of NGOs?

The humanitarian sector is now made into a kind of oligopoly whose main actors are the NGOs. This structure of the humanitarian field does not deal with external actors, reducing the opportunities for greater involvement of actors with the potential to contribute to the strength of humanitarian interventions. It is suggested to explore the facilitation of the entry of new actors in the humanitarian field to improve synergies between all stakeholders towards more collaborative and coordinated humanitarian actions. Accordingly, an avenue of research could be: How to facilitate the access and integration of new actors in the humanitarian field for an operationalization of the HPI?

Innovative means of transport adapted to humanitarian aid would be very useful to reach difficult places and to improve the speed of transport of humanitarian goods. For example, this could involve small land based or aerial drone based vehicles for transporting smart containers to remote villages. Thus, another avenue is to look at the potential contribution of the Physical Internet in innovating new ways to get to inaccessible areas.

In humanitarian crises, time management is fundamental to save lives. Thus, the time constraint plays a lot in storing donations. Indeed, it is a major challenge for NGOs. Given the urgency and the pressure of public opinion, they must be vigilant about the expiry date of the products to avoid waste. In addition, improper storage and inadequate transportation can degrade the products. It is therefore important to investigate further how HPI can enable to better manage the physical storage time, the storage and distribution of humanitarian aid to beneficiaries. The HPI, if globally implemented, may contribute to overcome the constraints of storage time towards a better time management.

Acknowledgements

We would like to thank the following Ph.D. students from Université Laval for their significant contributions during the early stage of this research: Alain Daou, Marie-Philippe Naud, Chaker Alayet, Gerardo Alexis Rojas Ocampo, and Coffi Dieudonné Assouvi.

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Towards Creating Sustainable Urban Areas: A Shared Passengers and Goods On-Demand Rapid Transit Proposal

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Abstract: *Nowadays, it is crucial to consider the global shifts around the world and the rapidly growing urbanization rate observed in large cities. It is also fundamental to be conscious about the impact of these changes on the way passengers moves and goods are moved through dense urban areas. This paper attempts first to present these changes and study their impacts on the different urban transportation systems. Then, in response to current transportation systems that are generally disconnected, this paper depicts a global and interconnected view of how they should be in the future. It proposes a global view of a combined and connected transit system for high dense urban center completed by a Personal and Freight Rapid Transit (PRT/FRT) system. Next, through an illustrative example, it focuses on assessing the benefits of operating a PRT/FRT system in an urban context. A heuristic solution approach is proposed to minimize its empty moves and the total energy consumption of this novel system. Preliminary experimental tests are provided to underline the promising results obtained with the integration of the PRT/FRT system in urban areas.*

Keywords: *Shared urban transportation, Personal Rapid Transit, Freight Rapid Transit, vehicle routing, simulated annealing*

1 Introduction

World urbanization trends have seen a huge increase in the recent years. Nowadays, cities' population is becoming bigger than ever and is contributing to many irreversible changes to persons and goods mobility around the world. A key fact is that more than 50% of the worldwide population is living in cities[1]. This rapid urban growth results nowadays on a number of interesting mobility and transportation challenges.

Generally, urbanization results significantly on the increase of urban moves for both goods and persons in urban and peri-urban areas. More precisely as the cities expand their size, distributing goods in city centers become more complex and hard to manage as the urban infrastructures

[1]Source: UN World Urbanization Prospects, World Business Council for Sustainable Development

have a limited capacity. Moreover, with the growth of the e-commerce proportion in distribution channels, urban goods 'demand tends to become smaller than ever with many small packages that need to be delivered to customers home in a shorter time. Accordingly, the last mile delivery problem for urban area could represent a huge challenge in the near future and deserve a more focus from transportation and logistics managers (Crainic, 2008).

From a logistics system perspective, the huge increase in urbanization rate and the change on the people 'demand for goods in urban areas, results on many distinctive challenges that urge the community to react in order to satisfy adequately current and future urban transportation 'needs. These challenges are depicted in *Figure 1*. Different research initiatives and innovative projects have been conducted in the recent years to deal with the sustainability of urban mobility, among them one could cite the physical internet manifesto (Montreuil, 2011; Ballot et al., 2012). Generally, there is two ways to deal with all the issues related to urban transportation tools: develop and enhance the service quality of the already existent transportation modes or build an innovative transportation system that offers an ecological option for urban area shareholders.



Figure 1: City Logistics Challenges (Adapted from Ehmke (2012))

In this work, we focus on the second option as we propose a conceptual approach for an interconnected passengers and goods transportation system based on the integration of Personal Rapid Transit (PRT) and Freight Rapid Transit (FRT) in urban areas. PRT and FRT are part of the automated guideway transit systems that was under development since the 50's of the 20th century. PRT and FRT are seen as a reliable, energy efficient and environmentally friendly transportation system. The PRT and FRT systems have many existing implementation such as in the new smart ecological city of Masdar (Abu Dhabi UAE), in the airport of Heathrow (London UK), in Morgan Town university (West Virginia, USA), in Hospital Rovisco Pais (Portugal), etc... A large part of the dedicated literature was only concerned with the investigation of the energy consumption (Mrad and Hidri (2014)) and the operational costs (Lees-Miller and Wilson, 2012), Lees-Miller and Wilson, 2011), Lees-Miller (2013)) of operating the PRT. However, one should note that the literature on the PRT and FRT was focusing mainly on the design and feasibility of operating distinctly these systems (Won et al., 2006; Teychenne and Bly, 2003) and that the FRT has kept little attention until now.

Based on the concept of connectivity between passengers and good movers, we propose in this work a combined and integrated PRT/FRT system. This later could be used as a stand-alone application or as a complement to other urban transportation tools in order to face challenges related to fast and ecological transportation in urban areas. Then, we'll focus on an operational context of the PRT/FRT system to formulate a related PRT/FRT routing problem for minimizing

the empty vehicles' movement within such a system and propose a solution approach to solve our problem.

The remainder of this paper is organized as follow. Section 2 presents several practices of sharing-based transportation. Section 3 presents the PRT/FRT system and our solution for goods and passengers transshipment in urban areas. Section 4 describes the routing model associated to the PRT/FRT operational transit problem and discusses its solvability. Section 5 details the simulated annealing-based solution approach proposed to solve the routing model. Section 6 provides preliminary results to validate the model and to illustrate the framework proposed. Finally, Section 7 provides conclusions and future work.

2 Sharing-based Transportation Practices

Integrating passengers and goods urban flows on the same transportation infrastructure or within the same transportation mode could create a lot of new opportunities. This is argued by the fact that the same need for moving goods and passengers could be reached using less infrastructure and vehicles thanks to the notion of consolidation. In that way, one could mention the MULI project in Germany proposing that buses take both passengers and goods in three German cities (Schäfer et al., 2003). The freight bus initiative has extended the MULI solution as it uses a sort of ecological buses that uses green energy[2]. Regarding guideways-based transportation options such as tramways and subways, several cities proposed recently shared network options as an alternative to expand the cities capabilities when roads 'capacity is becoming limited. For instance, the city of Zurich offers a "Cargo Tram" option to collect garbage and many other United-States, Japanese and Dutch cities that considered shared networks for their subways/tramways (Van Binsbergen and Visser, 1999).
Moreover, different academic studies and papers were published on this topic recently. Trentini et al (2012) proposed a two-tier city logistic model that offers to use and combine public transportation tools for goods movement. We could note also the share-a-ride-problem studied by Lie et al (2013) where it is suggested that people and parcels share the same taxi infrastructure. Further examples of sharing practices between goods and passengers, are found in Trentini and Mahléné (2010).

3 Personal Rapid Transit (PRT) and Freight Rapid Transit (FRT)

As mentioned, the Personal Rapid Transit provides a new and innovative transportation system. PRT offers an on-demand direct transit from origin to destination stations. PRT is oriented to serve passengers in urban areas and is designed to operate as any traditional taxi system. Therefore, the PRT is highly attractive for its users in comparison with traditional mass transit like bus or subway systems. The PRT uses small electric driverless vehicles (also called pod cars). These vehicles run on dedicated guideways in order to provide direct nonstop trips between origin and destination stations. This is made possible by the use of offline stations that are placed off the main line. This specific feature of PRT avoids for pod cars to stop at unnecessary stations. Guideways on such a system can be on ground, on tunnel or elevated, and are separated from other urban traffic and pedestrian zones. PRT systems contrary to other

[2] http://www.eprtransportationlogisticsnews.com/2008/12/08/freightbus-the-bus-that-delivers/

traditional modes run on a network of guideways rather than a group of simple lines. As illustrated in the left picture of *Figure 2*, PRT vehicles are made to take up to six passengers.



Figure 2: Example Of PRT and FRT Vehicles[3]

On the other hand, Freight Rapid Transit is an automated goods' mover that shares the same infrastructure and characteristics than a PRT system. However, it is made and designed to transport goods and wastes. FRT vehicles could handle up to 1500 Kg (McDonald, 2013) and could be adapted to handle different types of freight and waste. As illustrated in the right picture of *Figure 2* and on the example of *Figure 3* it is suitable for merchandise transportation in the form of parcels or pallets and loading operations are similar to other freight dedicated transportation modes.

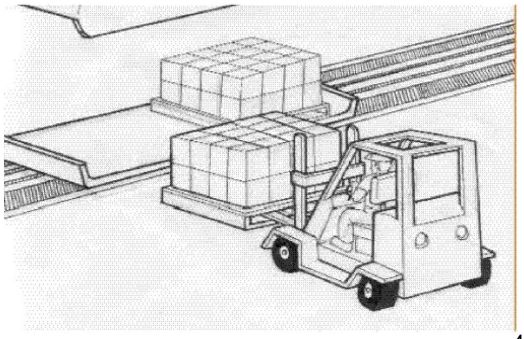


Figure 3: Example Of FRT loading operation[4]

The combination of both PRT and FRT on the same network of guideways presents an interesting alternative for urban zones to mix the flow of passengers and goods on the same shared network. These two intelligent systems supported by the new technological advances and existing connectivity features could represent a valid complement or alternative to private vehicles and trucks in some restricted areas of the cities. This is achieved mainly through different features and specific characteristics of the PRT and the FRT:

- They both use electric energy which make them environmentally friendly and energy efficient (Lichtenberg et al., 2010).
- As the vehicles are driverless, it requires operating less human resources than other traditional mass transit system.

[3] http://www.2getthere.eu/?pageid=912
[4] http://www.advancedtransit.net/atrawiki

- As the transit operations are generally made on demand, PRT/FRT offers a better service quality than other transportation systems.
- PRT/FRT is faster than any other transit mode (Carnegie et al., 2007).

Finally and in line with our vision to integrate different transportation systems, PRT/FRT should operate in connection with traditional public transportation modes. In urban areas, this could mean the coordination between PRT/FRT with tramway/subway line or bus line or a city goods distribution system in order to increase the zone coverage and reduce congestion. *Figure 4* provides an illustrative example of how the PRT/FRT system could be integrated in the transportation system of a given city. In this example, the PRT system could take passengers from a subway station and transfers them to their final destination during working hours. For out-of peak hours, the FRT could be appended to the PRT to move both goods and passengers in the urban zone. Therefore, goods will be first moved through mass transit system through urban area and then on a specific station they will be moved to dedicated FRT vehicles in order to ensure the last mile delivery.

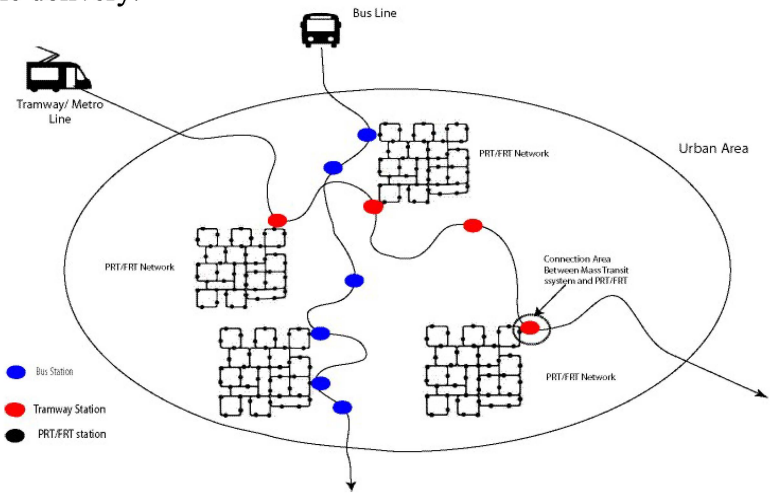


Figure 4: Overview of our proposed solution for urban mobility

4 PRT/FRT Routing Problem

In this section we focus on a specific context in which an urban PRT/FRT system is already implemented. our objective is to find the best tradeoff between the economic performance and the ecological performance of using such system by reducing the number of empty moves. With this latter criterion the system becomes more efficient in terms of capacity used and more sustainable in terms of energy consumption. For that purpose, we propose to study a static-deterministic PRT/FRT routing problem within an urban area.

First, we assume that the PRT/FRT network is already designed within an urban area and that for each transit vehicle the electrical battery has a limited capacity. At the operational level, the PRT/FRT mode offers a specific on-demand service, which results on a large amount of empty movements within the network on a daily basis. To respond adequately to this upcoming demand, the waiting time must be reduced in order to guarantee a good service level. This objective is conflicting with the efficiency of a PRT/FRT system since it necessitates to move empty vehicles to the demand points and thus alters the energy consumption of the vehicles and their daily capacity to serve on the network autonomously. For these reasons, the specific

objective of the PRT/FRT routing problem proposed here is to minimize the empty movements within the network. Recently, for a dedicated PRT system, Mrad and Hidri (2014) proposed a static model that minimizes the consumed electric energy; and Lees-Miller (2013) proposed a stochastic model that minimizes the average waiting time of passengers. Following these earlier works, we propose hereafter to generalize the routing problem to combine the PRT and FRT modes and to minimize the empty movements. This objective is subject to the constraint that all the requests, which are known in advance, must be served. Also, it must satisfy the constraints that vehicles have a limited electric battery capacity and that no waiting time for passengers is allowed. Our problem is based on the following assumptions:

• A PRT/FRT network is composed essentially of a set of M stations, one depot denoted by D and a set of lanes relying the set of stations (a dense guideways system is assumed to facilitate the move between each couple of stations).

• The PRT/FRT vehicles are powered by a battery that can be charged only in the depot station D. Each battery has a limited capacity B.

• We suppose having a list of trips (schedule) $T = 1,2,3,...,n$ that have to be satisfied.

• Each trip t_i is characterized by its departure time Dt_i, departure station Ds_i, arrival time At_i and arrival station As_i.

• We define a cost matrix $Cost$ that represents the shortest distance between any couple of stations. The shortest path can be calculated by using the *Bellman-Ford algorithm*.

Our objective is to find a set of routes, starting and ending at the depot, to satisfy all the sets of trip requests by using a fleet of identical electrical PRT/FRT vehicles while respecting the battery capacity B at the minimum cost. In addition, we define the following graph representation : let $G=\{V,E\}$ denotes the graph; let $V = 0,1,2,...,n$ denotes the set of vertices. The vertices in the subset $V^* = V \setminus 0$ are called the trips. The vertex $\{0\}$ refers to the depot in which there are initially located an unlimited number of PRT/FRT vehicles. The travel between the vertices i and j has an associated cost that is represented by a set of edges $\vec{E} = \{(v_i, v_j); v_i, v_j \in \vec{V}\}$. Each edge has a cost that represents the consumed electric energy. The set of edges $\vec{E}$ is defined as follows:

• If v_i, $v_j \in V^*$ with $At_i + Cost_{(As_i\, Ds_j)} \leq At_j$ then the arc (i, j) exists and has c_{ij} as a cost, which represents the energy consumed from the arrival station of trip i to the arrival station of trip j.

• for each node $i \in V^*$ we add an arc $(0,i)$ that has the cost of the consumed energy from the depot to the arrival station of trip i.

• for each node $i \in V^*$ we add an arc $(i,0)$ that has as cost the consumed energy from the arrival station of trip i to the depot.

The problem is to design a set of low-cost set of routes $R = r_1, r_2, ..., r_k$ such that each route begins and ends at the depot and each node (trip) is served exactly by one of the PRT/FRT vehicles. Therefore, for each vehicle, we assign a set of trips, and the sum of serving the trips within each route does not exceed the battery capacity B. This problem can be modeled as the asymmetric distance-constrained vehicle-routing problem (ADCVRP). ADCVRP is a vehicle routing problem where the total traveled distance by each vehicle should be less or equal to a certain distance or time (in our case, the distance allowed by the battery capacity). As in the graph G, the distance from node i to node j is different from the distance from node j to node i and

hence, our problem is asymmetric. The main difference between our problem and that of the ADCVRP is the low sparsity rate of graph G. In fact, for each node $v \in V^*$, if the arc (ij) exists, then the opposite arc (ji) does not exist, due to the predecence constraints that exists with the time window associated with each trip'node. Given the proven complexity of the ADCVRP, our PRT/FRT routing problem inhirits from the same solvability issues and thus, a heuristic solution approach must be developed to solve it.

5 Simulated Annealing-based Solution Approach

The simulated annealing (SA) technique is a heuristic random-search method proposed initially by Kirkpatrick et al. (1983). SA is an intelligent search method that is based on mathematical simulation of the cooling process of materials in order to have crystal with the minimum energy (Lin et al., 2011).

The SA algorithm starts the search from an initial solution s_{ini}. Let f denotes the objective function that for any given solution s returns its evaluation (cost in terms of energy use in our case). $f(s_{ini})$ computes the cost of the initial solution. Then, an iteration process is started where we randomly generate an intermediate solution s_{int} that is sampled from the neighborhood of the current solution. Let Δ denotes the variation between the current solution, denoted by s_{cur}, and the newly generated solution. the value of Δ is computed as follow:

$$\Delta = f(s_{int}) - f(s_{cur}) \quad (1)$$

As the simulated annealing is applied to a minimization problem, if the Δ value is negative then s_{int} is accepted and replace the current s_{cur}. Otherwise, if the value of Δ is positive which means that s_{int} is of a worst quality. Then a probability test is computed to know if the s_{int} should be accepted or not. The probability test is given by the metropolis criteria using $\exp(-\Delta / T)$, where T is the temperature parameter of the *SA* algorithm. The metropolis criteria accepts solutions with lower Δ value. The metropolis criteria also accepts solutions with bigger T values. This allows for the SA algorithm to accept even very bad solutions at the beginning of the algorithm. According to this formal description of our algorithm, three main components have to be defined in order to use SA for solving our problem: the objective function, neighborhood operators, temperature control. Details of our SA procedure are given by *Algorithm 1*.

- *The objective function*: We considered and adapted the Split function of Prins (2004) to our context which is based on permutation-based solutions. It takes a permutation and constructs an auxiliary graph that represents all the possible options for splitting a permutation into valid roads relative to some constraints (the battery capacity in our case). Then, the *Bellman algorithm* is applied to the graph in order to get the best splitting option and therefore the cost of the solution.

- *Temperature control:* As mentioned, this process is an essential feature of the SA algorithms. It determines the rate of decreasing the temperature parameter in our algorithm. The temperature T is decreased as follows:

$$T_i = T_{i-1} * 0.95 \quad (2)$$

Therefore, T is decreased by 5% in each step of the algorithm.

- *Neighborhoods operators:* Three neighborhoods operators are used in our algorithm, which are

the well-known exchange mutation, displacement mutation, and the insertion mutation.

Algorithm 1: Simulated Annealing Procedure

```
1   r = 0
2   x_best = ∅
3   Generate X0 Randomly
4   x_best = x_n
5   while (R < MT) and (T_r > 0) do
6      n=0
7      while n < EL do
8         Choose a Neighborhood Operator
9         x_new= x_n
10        Δ= f(X_new) - f(X_best)
11        if Δ < 0 then
12           x_best = x_new
13           x_n = x_new
14        Else
15           y=RAND(0, 1)
16           Z = e^(-Δ/T)
17     if y < Z then
18           n=n+1
19           x_n = x_new
20        end if
21  end if
22     end while
23     r=r+1
24   T_r = T_(i-1) * 0.95
25   end
```

6 Preliminary Computational Results

The *SA* algorithm was implemented in Visual C++ (2008) and it was tested on a large set of 1320 randomly generated instances by using a personal laptop with Intel i5 2.3 GHZ processor and 6 GB of memory. The set of instances are presented in *Table 1* and are based on the same assumptions than Mueller and Sgouridis (2011). We note that max-wait is a limitation made on the graph that defines the maximum amount of time that a vehicle could wait on a station before starting a defined trip. The solvability of the solution approach is tested on several values of number of trips, denoted by *n*. This later takes values ranging from 10 to 400 as given by *Table 2*. Then, we generated 40 instances for each value of *n*. The results for the simulated annealing algorithm are reported in *Table 2* and *Table 3* using the average assessment of the 40 random runs. We based our analysis on the *GAP* measure to define the quality of the proposed heuristic. The GAP is defined as follows:

$$GAP = \left(\frac{(SOL_{heuristic} - LB)}{LB} \right) * 100 \quad (3)$$

For each instance, we computed using CPLEX 12.1 the lower bound (LB) as the linear relaxation of the mathematical model as given in Kara (2008) for the resolution of the

asymmetrical distance- constrained vehicle-routing problem.

Table 1: Instance assumptions

Number of stations	12
Cost of arcs (in minutes)	Generated randomly between 1 and 15 minutes
Departure stations	Generated randomly between 1 and 12
Arrival stations	Generated randomly between 1 and 12
Departure time	Generated randomly between 1 and 3600 seconds
Arrival time	The sum of depart time and the duration of the trip.
Battery capacity	40 minutes
Max-wait	1000 seconds

Table 2: Results of the SA algorithm

n	Average solution Gap (in %)	Average solution Time (in seconds)	Average gap in service time (in minutes)
10	1.129	0.077	13.298
15	0.818	0.099	22.021
20	0.749	0.152	24.985
25	1.001	0.084	31.039
30	1.010	0.120	35.663
35	1.443	0.150	41.183
40	1.216	0.182	43.804
45	0.955	0.202	52.277
50	1.088	0.229	58.368
55	1.563	0.282	60.978
60	1.223	0.325	66.651
65	1.420	0.358	70.549
70	1.929	0.403	74.684
75	1.500	0.427	81.886
80	1.780	0.514	83.116
85	1.762	0.502	87.858
90	1.620	0.560	96.536
95	2.067	0.651	94.871
100	2.330	0.649	96.528
110	2.203	0.754	104.607
120	2.499	0.953	114.847
130	2.816	1.063	115.282
140	2.787	1.144	124.089
150	2.742	1.316	134.886
160	3.176	1.319	142.358
170	3.362	1.477	146.062
180	3.468	1.674	150.348
190	3.857	1.637	162.340
200	3.843	1.929	162.829
250	4.559	2.343	188.231
300	5.713	2.923	205.288
350	6.488	3.586	221.412
400	7.483	4.258	193.528
Average	**2.473**	**0.980**	**100.073**

Each value of the second and third columns in *Table 2* presents the average value for each

instance size class. The average solution time provided in *Table 2* shows the efficiency of the solution method to generate good quality solutions in a short time even for large size problems. This criterion is a crucial requirement in such operational decision-making problem

Table 3: Descriptive Statistics of the results for the SA algorithm.

Statistics	GAP (in %)	Time (in seconds)
Minimum	0	0.01
25% Percentile	0.8856	0.23
Median	2.006	0.58
75% Percentile	3.643	1.39
Maximum	10.69	6.04
Mean	2.473	0.9799
Std. Deviation	2.068	1.055
Std. Error of Mean	0.05693	0.02905
Lower 95% CI of mean	2.361	0.923
Upper 95% CI of mean	2.584	1.037

To test the feasibility of our PRT/FRT model, we compared its inherent performance for freight transportation in an urban context with a classical truck system. For that purpose, we generated based on each PRT/FRT instance the corresponding freight instance in which the same demand level is considered. To take into account of the congestion and limited speed limitation issues when trucks are used, the delivery time between the locations has been accentuated. To model the new generated truck delivery instances, we used a stacker crane modeling approach with one sided time window problem in order to generate a graph modeling of our new problem. These instances were solved using the CPLEX 12.2 MIP solver. Results of our instances were expressed in the time needed to perform all the transportation tasks.
The obtained results of the comparison test among the transportation systems are given in the last column of *Table 2*. The value computed is the difference of average service time (in minutes) between the PRT/FRT solution and a traditional Truck system. When a positive value is obtained, this means that the PRT/FRT system provides a lower cumulative delivery time. It also underlines, when all the testing instances of the PRT/FRT system are compared, that on average about 100 minutes are gained. This corresponds, on average to an approximate gain of one minute for each transportation task executed. This comparison shows also that when the number of trips increases (referring to a higher demand), the gap between the PRT/FRT solution and the classical truck system tends to become much higher. These preliminary results are encouraging as they comfort our conceptual view toward the use of the shared PRT/FRT transportation system in urban areas.

7 Conclusion and Future Work

PRT and FRT are emerging public transportation systems, relying on driverless electric vehicles that aim to offer a high quality transportation service to its users. In this paper, we investigated the potential application of a PRT/FRT system by combining both passenger's movers and goods movers in a shared network in an urban context. A static PRT/FRT routing problem with limited battery capacity is proposed with the aim to minimize the total energy consumption. To solve the problem a simulated annealing algorithm was developed and tested

on a large set of 1320 randomly generated instances. The obtained results confirm that our algorithm is efficient, as it found an average gap of 2.473% in 0.980 seconds. In addition, a comparative analysis with a simple transportation truck system was made and shows the promising gains offered by the PRT/FRT system in terms of delivery times in addition to the sustainability performance.

Our next steps will be first, the inclusion of additional realistic features such as limited parking places in the PRT/FRT stations or the possibility for vehicles to recharge their batteries in the stations. Second, the development of more sophisticated solution methods is necessary to enhance the solution quality and speedup the resolution time. Finally, dynamic and stochastic settings of the PRT/FRT system scheduling and routing problems are under investigation.

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Towards An Interconnected Distribution Planning Framework

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Abstract: *The recently introduced Physical Internet (PI) opens the way to more efficient and sustainable logistics enabled by smart interconnected networks of open hubs, distribution centers (DCs) and fabs. This paper focuses on interconnected distribution planning exploiting the PI-empowered Open Distribution Web that allows any business to dynamically deploy its products across geo-markets, in numerous open DCs owned and operated by other businesses. Such a context requires rethinking how distribution is to be planned as current frameworks are too static and constrained. The paper introduces an interconnected distribution planning framework structured through four interlaced levels: network, distribution, deployment and delivery. Each level has its specific set of decisions to be optimized in a dynamic rolling horizon context. Exploiting an illustrative case, the paper provides insights on the concepts and methods at the core of the proposed framework.*

Keywords: *Interconnected Distribution, Physical Internet, Open Distribution Web, Distribution Planning Framework.*

1 Introduction

Physical distribution is about channeling the products of a business to its customers. The set of decisions and operations within distribution induces various costs, including mainly transportation and inventory holding costs that represent almost 77% of logistics operations costs (Burnson, 2012). This makes distribution one of the most potentially value adding areas of logistics operations.

The goal of distribution planning is known to be providing the right product/service at the right place at right time with right quality to satisfy customers while optimizing profits. However, many studies have reported that current distribution systems fail to achieve this ideal.

For instance, it is reported that 8.2% of shoppers fail to find on-shelf the product(s) they are looking for. Retailers suffer 3.1% net lost sales while huge inventory valued 1.1 trillion$ available (Frankle, 2006). A significant portion of consumer products that are made never reach the right market on time, ending up unsold and unused (Montreuil, 2011). In addition, almost one-third of kilometers traveled by freight transport vehicles are run empty (McKinnon, 2000) and the mean load factor of road transport is approximately 70% (Pan et al., 2010). These are clear indicators of the inefficient and unsustainable performance of current distribution and

logistics, resulting in increasing economic logistics burden as well as increasing non-renewable energy consumption and greenhouse gas emissions.

In our opinion, several characteristics of the current distribution systems contribute to their present inefficient and unsustainable performance. These include inventory centralization, off-shore production centers, dedicated storage facilities and lack of standardization. To benefit from the economies of scale offered by full truck shipments, many companies centralize their storage in a few locations far from large parts of their geo-markets. Centralized distribution systems can be easily challenged by demand seasonality and instability. Moreover, they are not capable of competing with leading companies who offer same day or next-day delivery to the top metropolitan statistics areas. Also, the storage facilities dedicated to a company are mainly owned or leased using contracts with a three-year average commitment. The long-term commitment to these locations makes the adaptation of the distribution network to the changes in the demand and logistics cost very challenging.

From another perspective, many companies have off-shored their production to countries with low-wage labor markets, such as China, Vietnam, Mexico and India. In many cases the primary materials needed for feeding production are coming from the business's origin country or a third country. In addition, the largest markets of such companies are mainly located in the origin country. This imposes many unnecessary travels around the world.

Moreover, the lack of standardization in packaging and information system makes collaboration difficult. All together, these characteristics of present distribution systems force researchers to reach out for novel distribution systems, such as interconnected distribution.

The goal of this paper is twofold. First, it aims to introduce the concepts of Interconnected Distribution System and of an Open Distribution Web (ODW) enabled by the Physical Internet (Montreuil, 2011). Second, it aims to present the interconnected distribution planning framework developed to assist managers exploiting PI-enabled ODW.

The structure of the paper is as follows. Section 2 describes the interconnected distribution concept through a distribution systems categorization and an introduction to the Physical Internet and its enabled Open Distribution Web. Section 3 introduces the Interconnected Distribution Planning (IDP) framework. Finally section 4 synthesizes the paper's contributions and discusses future research avenues.

2 Introduction to Interconnected Distribution Systems

2.1 Distribution System categorization

Current distribution systems can be segregated as being either dedicated or collaborative. The former consists of a private distribution network in which the entire planning and operations are performed in order to add value to a single company. This contrasts with the collaborative distribution systems that are built upon the co-planning and/or cooperation of a set of partnering companies in shared distribution networks.

In a dedicated distribution system, at the strategic planning level, the location and mission of distribution centers are determined, as well as their capacity and technology, and the markets to be served by each DC are selected. The distribution facilities are either owned by the company or leased under contracts engaging the company for at least 2-3 years. Therefore, tactical and

operational level decisions such as inventory management strategy and deployment are bounded by strategic plans that cannot be easily and frequently altered.

As a result of long-term commitment to the private DCs, the dedicated distribution systems are weak for facing changes in the business environment. Demand seasonality leaves their capacities and technologies unused for parts of the year. Moreover, to stay competitive, companies need to keep up with those offering same-day or next-day delivery to their top markets. For companies exploiting vast geographical area such as North America, this may mean running at least 15 DCs located in proximity to the metropolitan statistics areas. The ability of a company to reach such fine performance level is overshadowed by the risk of investing in so many facilities. However, the challenges businesses encounter by distribution decentralization is not limited to the investment ability. Transportation cost from plant(s) to many DCs scattered in a large geographical area, and from these DCs to the markets, is efficient only if order quantities are large enough to perform full-truck shipments. Otherwise, products having to be stored closer to the top markets result in frequent small-quantity shipments and over-inventory through the distribution network, which is not economically and environmentally efficient and sustainable.

To overcome the shortcomings of dedicated distribution systems, companies have been interested in collaborative distribution. The main idea of collaboration is about identifying and exploiting win-win situations among companies. Pooling is one of the most practiced logistics collaboration, especially among European countries (e.g. Cruijsse et al. 2007, Pan et al. 2010). It consists of pooling logistics services and facilities between several companies to optimize the use and operation of the logistics function or to access a service unavailable individually. In general a collaborative distribution system allows actors to partially overcome the constraints of conventional systems by means of developing synergies with partners. The partnering companies can invest in new DCs jointly or share their current facilities to reduce their strategic costs. At tactical and operational levels, they can collaborate on transportation or hire a logistics service provider to transport and deliver their consolidated products.

Compared to the dedicated distribution systems, more network structure adaptability and distribution and transportation operations efficiency are offered by collaboration. However, collaboration is inherently challenged by some difficulties rising from areas such as partner selection, gain determination and sharing, negotiation and coordination, and finally information and communication technology capabilities (Cruijsse et al. 2007). Moreover, the performance gain by exploiting collaborative distribution systems in terms of shorter delivery delays and access to a larger number of facilities is still limited to the number of partnering companies and facilities being shared in the group.

Figure 1 shows a sample collaborative distribution web formed by five partnering dedicated distribution networks.

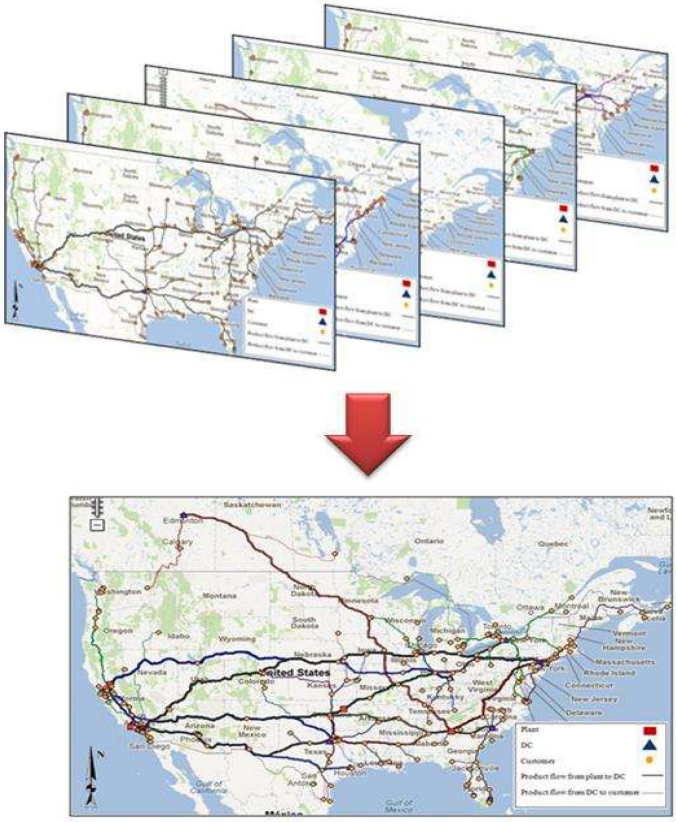


Figure 1. Contrasting a dedicated distribution web composed of 5 private distribution networks and a collaborative distribution web shaped by the same 5 companies (Sohrabi et al. 2012)

Concluding from our arguments above, we would like to point out to highly desirable characteristics for a distribution system. First, it should have cheap and flexible access (notably in terms of contract length restrictions) to DCs and warehouses adjacent to populated geographical areas. Knowing that only in United States over 500 thousands DCs and warehouses (Montreuil, 2011) and warehouses located almost anywhere in the country, the potential already exists. Imagine companies allowed to exploit the unused capacities in these facilities instead of investing in buildings or leasing new facilities. It would be challenging for DC owners to deal with a large and changing variety of product types, sizes and owners. Accordingly, distributing products stored in several locations owned by other companies might not seem secure and easily synchronized by user companies. Users should be aware of their products location and DC owners need to be able to easily and fairly access, handle and pick up the products of all companies exploiting their facility. Both parties certainly expect secure interconnection in terms of data and information privacy, also the financial transactions.

As previously discussed, a company decentralizing its distribution and targeting short and efficient delivery to its markets, surely needs a cheap, fast and reliable transportation system to operate deployment and delivery. Benefiting from economies of scale in transportation cost through consolidation, notably in full truck shipment, is a target for current distribution systems. Yet, ideally a distribution system should not have to incur delays and extra storage and transportation for reaching economic truckload shipping order quantities: it should be able to ship goods at the equivalent of case and pallet sizes nearly at the same price as full truckload prices.

The next section sheds light on the fundamentals of Physical Internet and more particularly, the open Distribution and Mobility Webs that it enables. PI offers a vision that can catalyze a fundamental rethinking of distribution systems. At the core, it aims to improve by an order of magnitude the worldwide efficiency and sustainability of logistics systems, by reshaping the way physical entities are being moved, handled, stored, realized, supplied and used all around the world. Due to the diversity of the concepts tackled in Physical Internet initiative and the focus of this research on distribution, the reader is invited to consult (Montreuil, 2011 and 2013, Montreuil et al. 2013) for a comprehensive overview of Physical Internet fundamentals.

2.2 Introduction to Physical Internet and Interconnected Distribution Web

From the highlights of the previous section, it stems that there would be highly significant gains from having a distribution system interconnecting the current dedicated and/or collaborative distribution systems. Interconnectivity refers to the quality of a system to have its components seamlessly interconnected (Montreuil et al., 2013). From a logistics perspective, it means easing the movement of physical entities from one component to another, their storage or treatment within any of its capable constituents, as well as responsibility sharing and contracting between actors (Montreuil et al., 2013). However, enabling such interconnection in an efficient and sustainable way requires major transformations in logistics from various aspects such as business model, production system, packaging, information technology and so on. The Physical Internet offers a vision for driving such transformation towards order-of-magnitude gains in logistics efficiency and sustainability (Montreuil, 2011).

The Physical Internet is an open global logistics system exploiting universal physical, digital and operational interconnectivity enabled by world standard encapsulation, protocols and interfaces (Montreuil et al., 2013). At the core, PI deals strictly with world-standard, modular, eco-friendly and smart π-containers that range from box size to cargo container size in a Lego way. It relies on a new breed of logistics equipment, facilities and systems designed for dealing efficiently with such π-containers. At the surface, similar to the web sites and applications built upon digital internet that are available for internet users, companies exploit PI through its enabled Logistics Web, schematically depicted in Figure 2. Montreuil (2011) defines:

"The Physical Internet empowers a global and open Logistics Web enabling producers, distributors, retailers and users to supply, realize, move and store for a fast, efficient and reliable response to quickly evolving demand. In a Logistics Web, products embedded in π-containers can be efficiently and seamlessly moved from sources to destinations through a Mobility Web. They can be dynamically deployed in numerous open logistics facilities all across a Distribution Web. They can be realized (made, assembled, finished, personalized, retrofit, and so on) in a wide variety of open realization centers spread across a Realization Web. Materials, parts and products can be supplied through a wide set of open suppliers, contractors and providers within a Supply Web."

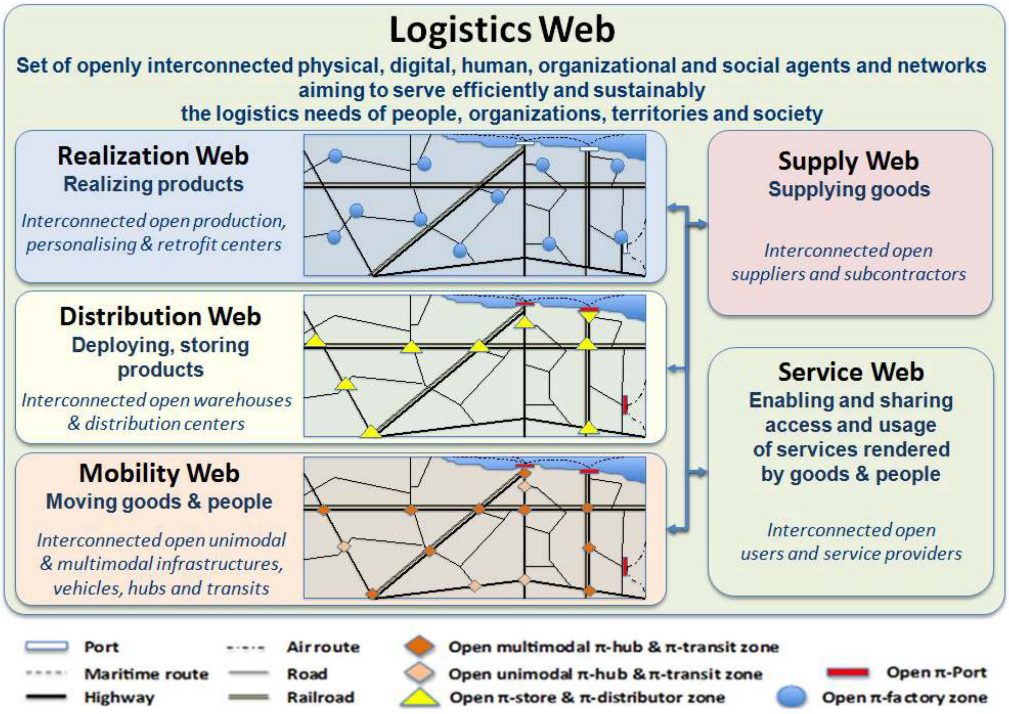


Figure 2. Physical Internet enabled Logistics Web and its key constituents (Montreuil et al., 2013)

Key to this paper is the Distribution Web enabled by the Physical Internet. This Distribution Web is the global set of openly interconnected physical, digital, human, organizational and social actors and networks. It aims to fulfill the worldwide dynamic and evolving needs for ever more efficient and sustainable distributed deployment and accessibility of goods (Montreuil et al., 2013). The Distribution Web leads the way to the emergence of open interconnected distribution systems within which distribution networks can be dynamically redesigned and adapted and finely attuned to the market conditions. It offers efficiency through better facility utilization, distributed near-market storage, faster and more reliable service to customers, and robustness in response to demand volatility and supply disruptions.

At this point, we focus on the planning and decision making process in the interconnect distribution system enabled by PI. Is it possible and desirable to plan and manage a system more complex and with higher expectations in terms of efficiency and sustainability the same way as dedicated and collaborative systems? In the next section, we argue that a new framework is needed to tackle interconnected distribution planning, first to master its inherent complexity and second to gain from the added degrees of freedom offered by a PI-enabled Distribution Web.

3 Interconnected Distribution Planning framework

We propose an interconnected distribution planning framework including four interlaced planning levels as depicted in Figure 3. Each of these levels is the subject of a specific subsection hereafter.

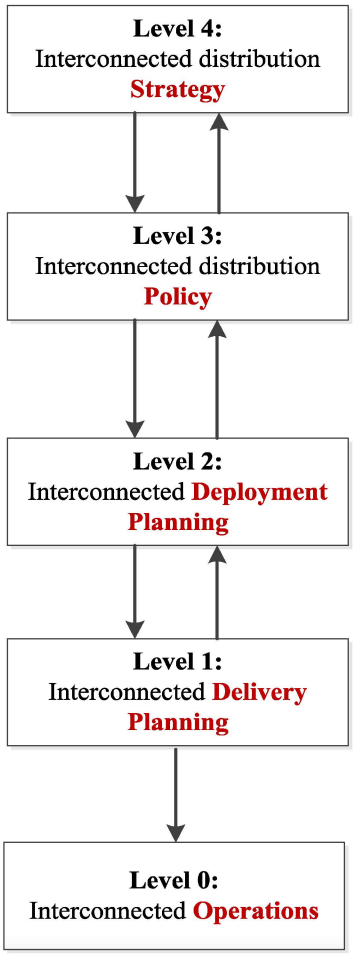


Figure 3. The interlaced levels of Interconnected Distribution Planning framework

Contrary to current hierarchical planning approaches such as Advanced Planning (Stadtler, 2005), each planning level can be dynamically updated. The predetermined planning horizon selected for each planning level indicates the time span of forecasts, decisions and activities to be planned at that level and it does not imply a fixed planning frequency. For instance if the planning horizon of a planning level is three months, it is not meant that this planning should be performed four times a year. It does rather mean that at any time the revision of this planning level is found necessary, it will be performed spanning the decisions over a planning horizon covering the next three months.

The call for updating a planning level is made by monitoring the value of some performance indicators (some instances are given in the following subsections). Noteworthy, at any time, whenever decisions at a level are updated, it implies that decisions in the lower planning levels may have to be revised.

3.1 Interconnected Distribution Strategy

The first planning level focuses on the interconnected distribution strategy for a relatively long-term horizon compared to the other planning levels. Depending on the clock speed of the company (Fine, 1998), this horizon may for example cover several years, a year, a season or a

month. The goal is to establish the interconnected distribution network configuration scheme and find the preferred open distribution centers to exploit.

The configuration scheme includes determining the number of DC echelons in the network, the target response time to offer markets and the number of DCs at each echelon required in each market region. Usually the larger the serving geographic area is the higher number of distribution echelons companies need to implement. The reason is simple; to supply distribution centers from close sources (upper echelon DCs) instead of waiting for the supply from plant (which might be located far from some market areas). The response time targeted for a market is influenced by its historical demand and/or population. For example, largely populated US states such as California, Texas and New York can be the top selling markets of almost any business and it is logical for some companies to offer them their quickest response time service.

Setting the target response time for each market, the minimum number of DCs can be determined. As an illustration, consider a sample manufacturer company aiming to serve the United States and Canada's markets. Figure 4 shows the population distribution in the company's target geo-markets. It also indicates the location of the top 40 metropolitan statistics areas.

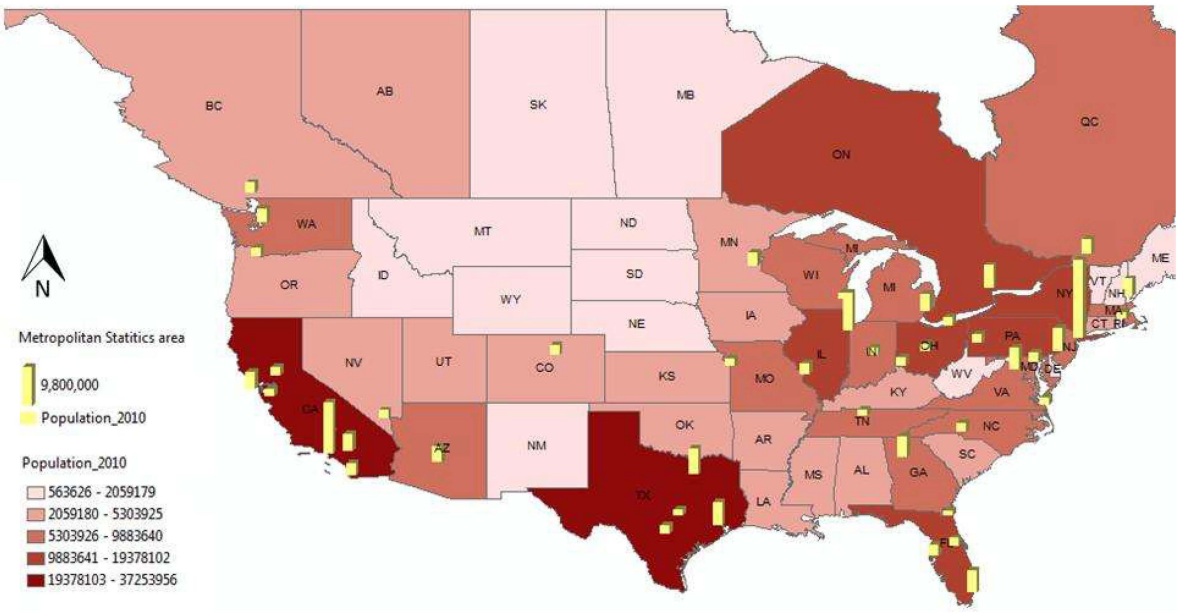


Figure 4. The distribution of population in US and Canada (based on census 2010 and 2011)

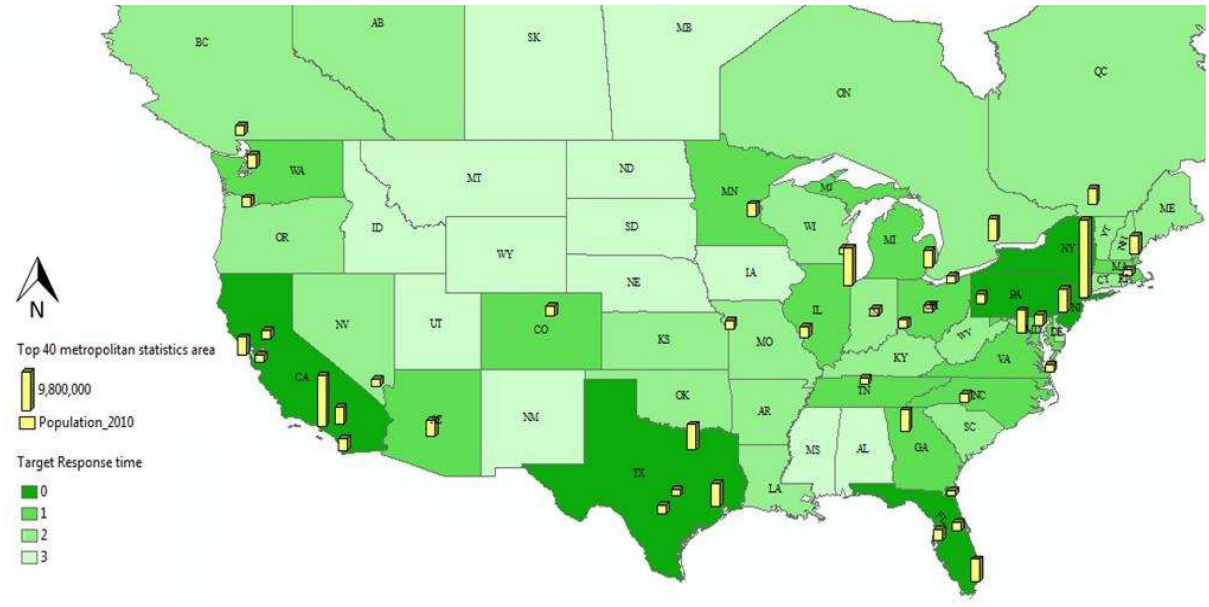


Figure 5. The desired response time offered to markets by sample manufacturing company

The manufacturer has to determine the delivery lead time it wants to offer to its customers in its targeted markets. Figure 5 presents such a potential offer highlighting the target delivery time in each U.S. state and Canadian province. It has decided to offer same-day delivery in six geo-market areas and a range from next-day to three-day delivery in the other geo-markets. Note that such a plan can be time-phased, for example with an offering for this year and more aggressive offerings in the years to come.

Continuing with the same company example, based on the vast geographical area it serves, its managers have opted for a two-echelon distribution system. The DCs in which inventory is to be held in the first echelon (e-1) have generally larger storage capacity, as they keep higher levels of inventory since they serve both their proximity markets and preferred second-echelon (e-2) DCs. The company is generally to store lower inventory in selected e-2 DCs that are located very close to markets and have higher inventory turnover. The minimum number of second echelon DCs to serve each market is determined by categorizing markets based on their geographical extent and population rank, respecting the target response time.

The preferred distribution network consists of the open DCs location to be exploited by the company and their mission in terms of being the primary or secondary source of the market(s). The primary sources DC can keep between 85-100% of the target inventory to serve a specific market. However the secondary source, stores a complementary low percentage of safety stock to supply the market in times the primary DC ends up running out of stock. Decisions such as the number of DCs to serve each market and the distribution of stock among primary or secondary DCs are strongly influenced by managerial insights. Here we present a typical interconnected distribution planning framework through the manufacturing company example which can be easily adjusted according to the characteristics of each individual company.

In order to configure the preferred distribution network of the sample company, applying a heuristic approach, a distribution network design problem is solved to find the location of first and second echelon DCs minimizing the total logistics costs (including transportation and DC exploiting and inventory holding cost) and respecting the target response time. Figure 6 shows

the location of 20 e-2 and three e-1 DCs, two of which are integrated to the production plants of the company. Noteworthy, the location of these DCs are subject to change at any time as pertinent during the planning and operations. The company does not own the DCs nor lease them. As the agreement between open DC's owner company and user company can be short-term, the distribution strategy level can be re-planned in accordance to the changes in the demand or costs.

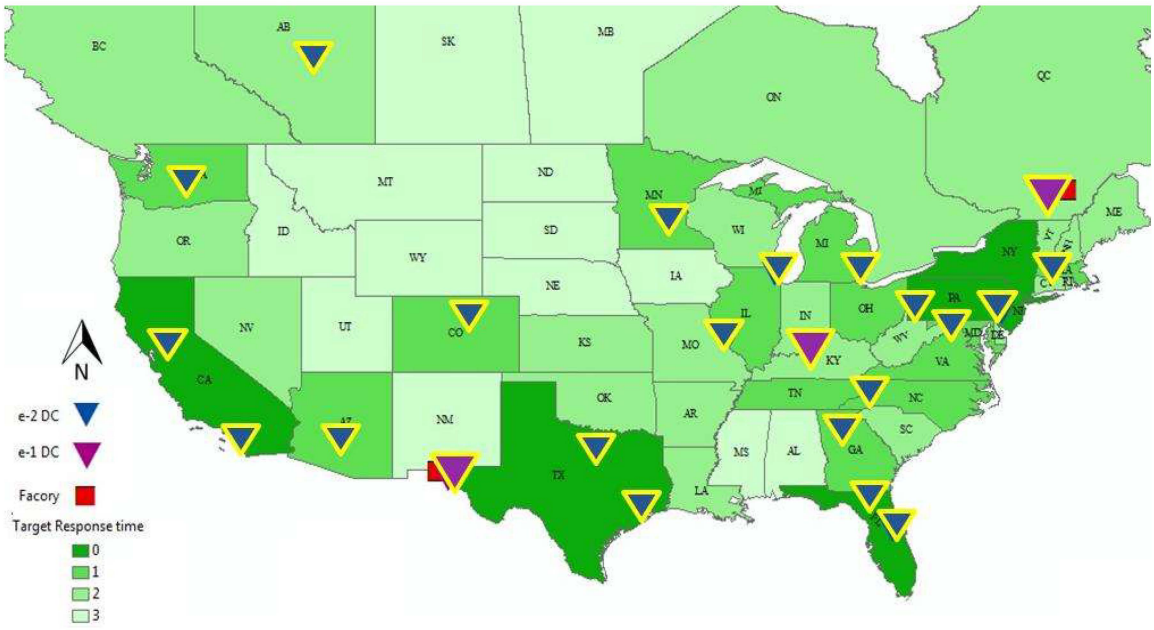


Figure 6. The preferred distribution network configuration of the sample manufacturing company

3.2 Interconnected Distribution Policy

The goal of this planning level is to set the distribution policy for a mid-term planning horizon (e.g. season, month) by determining the distribution policy system and parameterizing it. It is not intended here to enforce a novel distribution policy system; well-known (s,S) and (s,Q) or predetermined replenishment frequency can be applied depending on the managers insights. However the major element of this planning level is to parameterize the selected policy for each product (or product family) at each open DC concerning the markets they serve and the DC's role in terms of being the primary or secondary source. A one-size-fits-all strategy may easily fail in an interconnected distribution context, as the mission of each DC can be completely different from another one storing the same products.

For the sample company, a $(s,S)_{plt}$ system is selected which should be parameterized for each product p at each DC l and each month/season t. In order to attune the distribution policy to the changes in demand and mitigate the impact of errors caused by imperfect demand forecast, monitoring the percentage of the forecast error over the real demand allows updating the distribution policy parameterization process. Figure 7 presents a single product's distribution policy system at two e-2 DCs of the sample company.

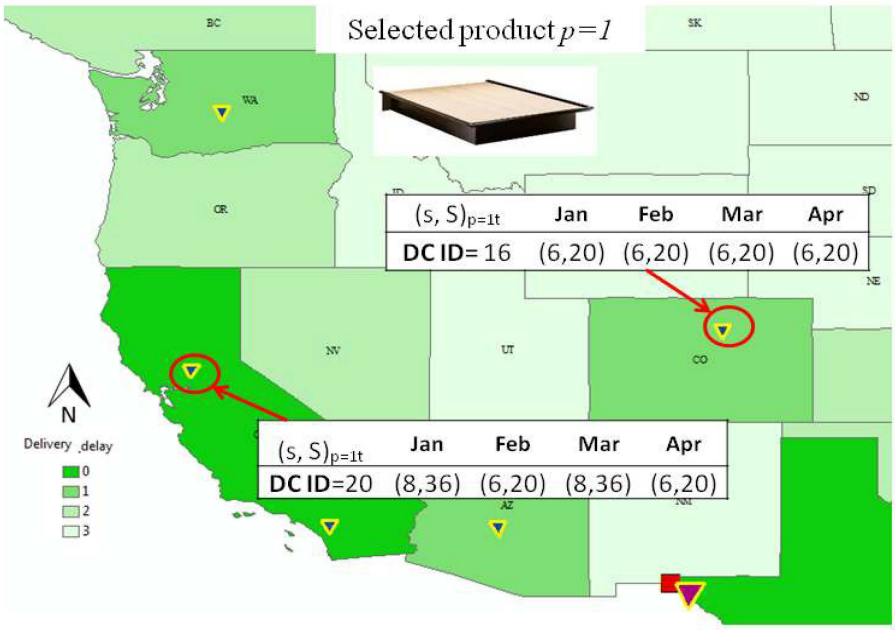


Figure 7. The interconnected distribution policy of the sample manufacturing company for a single product at two selected e-2 DCs for a four- month horizon

3.3 Interconnected Deployment Planning

At this level, for a relatively short-term planning horizon (e.g. month, week) the deployment of products within the preferred distribution network is determined. A novel approach is proposed for this purpose, capable of dynamically deploying products from multiple sources and redeploying them when required.

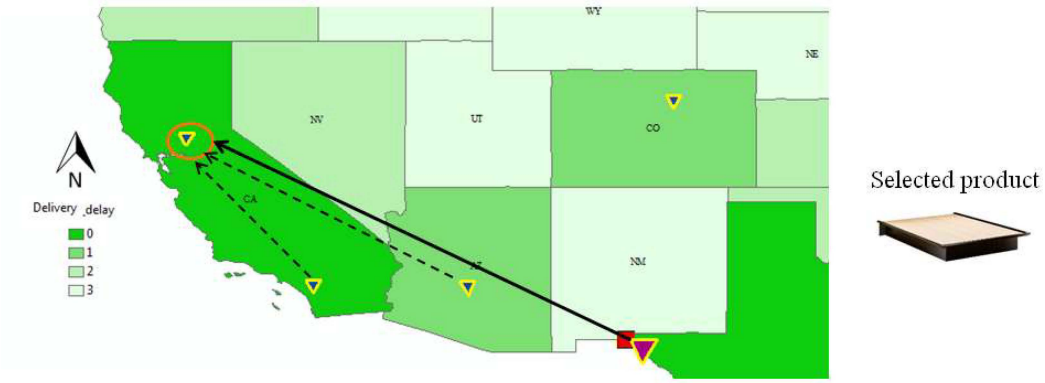
The interconnected deployment planning approach developed here is called dynamic deployment (DD). Basically, it is a Distribution Resource Planning (DRP) like approach defined to suit the dynamic context of interconnected distribution. There are similarities between dynamic deployment and the classic DRP method such as the fact that a rolling horizon planning approach is applied. Yet in dynamic deployment, the refresh pace is faster. For example, after orders arrive each day, the forecast error is calculated and the deployment planning is revised if the error is significant. There are major differences between DD and DRP, such as the fact that each DC can be supplied by more than one source (whether plant or other DCs). A hands-on example will help in understanding the differences deeper.

Table 1 shows a typical dynamic deployment planning table filled in for the selected product of the sample company with seven-day planning horizon starting from January first. The rows distinguished by different color present the changes regarding to the supplementary features of dynamic deployment approach compared to the classic DRP. Each DC can be the source of other DCs. When this is the case, the outgoing flow is indicated in the *Out transit* row. Moreover, DCs can be replenished from various sources depending on the availability of product at each source. The best fitting one with enough on-hand inventories to supply the DC whether partially or completely is specified in the DC source row and the lead time from DC to this source is considered in the ship date from the source.

Table 1. The dynamic deployment approach

DC ID	DC Echelon	Past Due	Day						
20	2		1	2	3	4	5	6	7
	Required *p*		8	9	3	2	10	17	2
	In transit *p*								
	Out transit *p*								
	Projected on hand *p*	28	20	11	8	34	24	7	5
	Planned shipment Receipt date *p*					30		29	
	DC source and lead time					e-1 at TX		e-1 at TX (16 units) and e-2 at CA (13 units)	
	Planned shipment Ship date *p*		30		16		13		

As indicated in Figure 8, selected DC (ID=20) main source is an e-1 DC nearby the closest plant (connected by a plain arrow). Also two other adjacent DCs can supply DC 20, in case of shortage. The inventory strategy determined in the previous planning level sets the reorder point and maximum inventory target of the selected product at DC 20 for the month of January to be (8, 36). As indicated in the figure, the first replenishment to be received on day 4 is sourced by the e-1 DC. However the second replenishment on day 6 is jointly sourced by two DCs, as the main source does not possess the total replenishment on hand (see the table at the bottom of the same figure). Noteworthy, the second replenishment could have been sourced solely from e-2 DC, but as this DC's main mission includes serving markets, it will only supply the other e-2 DCs in cases of shortage.



Source DC for 20	Lead time [Day]	On hand inventory per day						
		1	2	3	4	5	6	7
e-1 at TX	3	55	20	16	10	150	110	85
e-2 at CA	1	24	21	18	40	32	26	22
e-2 at AZ	2	16	16	10	10	10	8	4

Figure 8. The deployment plan for a selected DC of the sample company (single product)

3.4 Interconnected Delivery Planning

The last interconnected distribution planning level concentrates on customer delivery in a very short-term planning horizon (e.g. day, shift or hour). The goal is to select the source of each delivery among open DCs which are eligible to serve a customer. When the ordered product is available at the closest DC to the customer, selecting the delivery source is simple (the best delivery scenario). However, tight inventory at the closest DC may entail serving the customer from another DC in a way to minimize the total transportation cost and respect the target response time promised to the customer (transportation problem).

Figure 9 a) shows orders for a single day from all customers of a single market, here the California State. Part b) represents a delivery scenario where each preferred closest DC has sufficient inventory to deliver all its preferred orders, and part c) depicts a scenario where some products have to be delivered to a customer from a DC which is not the closest to it and optimization has to be performed to assign the delivery source for each ordered product.

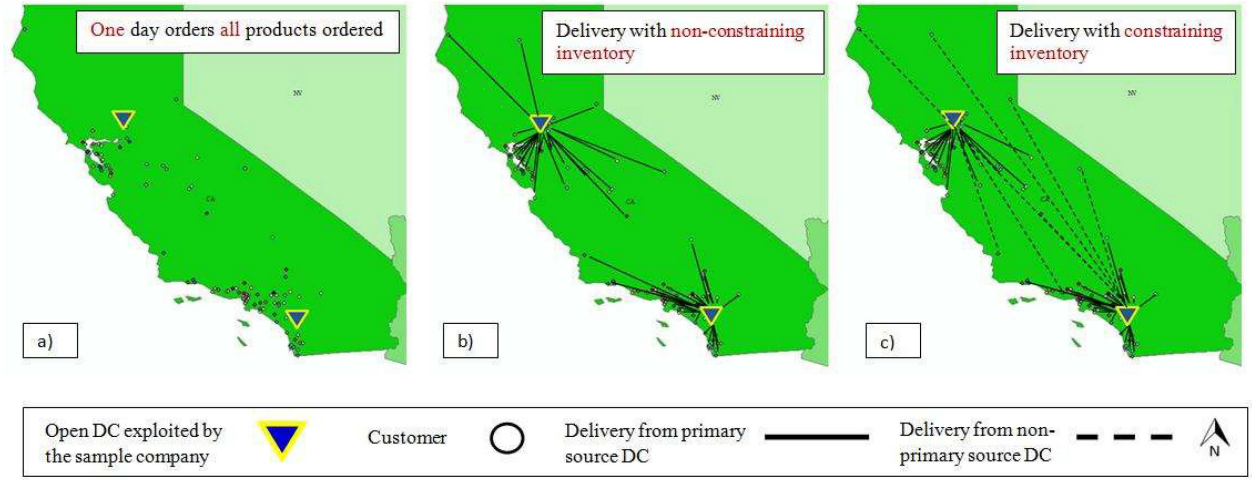


Figure 9. Delivery planning in the presence of non-constraining vs. constraining inventory at preferred DCs

The transportation operations in an interconnected distribution web are performed by exploiting PI-enabled Open Mobility Web that is built upon the interconnection of open transportation hubs, terminals and fleet. From each location, whether a plant or DC, products embedded in PI-containers (Montreuil, 2011) are shipped to the closest open hub. The PI transporting vehicles generally do not travel longer than 4-5 hours away from the hometown to enhance the safety and life quality of transportation workers, notably truck drivers. Thus, from each hub, received loads will be picked up, openly consolidated and transported to the next open hub towards the final destination, charged on a pay-per-use basis.

4 Conclusion

To leverage the efficiency and sustainability of current static and inflexible distribution systems, interconnected distribution systems enabled by Physical Internet are targeted in this paper. Such interconnection can be formed by exploiting openly available DCs and warehouses owned by a wide range of businesses, exploiting PI standard and secure encapsulation, protocols and interfaces. Decentralizing storage in as many open DCs as required within key geo-markets,

together with exploiting open mobility web, can potentially enable companies to improve their customer service and on-demand product availability in targeted markets, reduce transportation and distribution costs as well as the GHG emission generated by their operations. They can also adjust their distribution network to the changes in the business environment by dynamically redeploying products within the open Distribution Web.

In this paper, a four-level framework is presented to help managers plan their network design as well as their product distribution, deployment and delivery so as to best exploit the availability of an open Distribution Web. The planning horizon of each level is relatively shorter than in conventional distribution planning. In addition, monitoring key performance indicators, planning decisions can be revised at any time.

The conceptual framework presented in this paper is being applied to a real manufacturing company data in a team project in collaboration with another Ph.D. student Salma Naccache and two research professionals François Barriault and Edith Brotherton supervised by Professor Benoit Montreuil. In the course of this project we simulate both the dedicated (actual) and interconnected (proposed) distribution system of the company in order to investigate the potential efficient and sustainable performance to gain by exploiting PI-enabled open distribution web. The primary results of this project are published in the IPIC 2014 conference proceedings by Naccache et al. (2014 a & b).

Further research is needed to elaborate the proposed framework in more depth, to develop the models associated to the key decisions to be taken at each level, to develop the exact and heuristic optimization approaches to solve these models, to assess the potentiality of the framework analytically and through simulation, to conceptualize and prototype the decision support systems supporting the actors, and to field test the approach in living labs.

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A Collaborative Approach for Managing Data and Processes in the Physical Internet Using Modular Logistics

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Abstract: *This work is based on the activities performed, by the authors, in the European Research Project MODULUSCHA, and specifically in the Work Package 4, about digital interconnectivity. In this work we discuss and describe our idea on how Physical Internet and Modular logistic may be built upon existing systems, integrating the current processes with the needed data and the related operations. Seldom Physical Internet is a revolutionary approach for Logistics, the introduction of the modular containers and the related processes may be seen as an evolution rather than a revolution of the IT Logistics Supporting Systems. In our view, this means a greater degree of feasibility for the approach towards the realization of the Physical Internet. Main focus of the document is in the description of the main IT elements to be considered, i.e. standards, technologies and other relevant research project results. Logistics field involved in the analysis are the postal logistics and FMCG. Finally the document proposes a conceptual approach, with the description of a data model for the modular logistics and a processes overview in an interconnected logistics approach, which are consider for the definition of a conceptual software architecture.*

Keywords: *Modular logistics, interconnected shared network, intermodal, data sharing, process description, modular logistics conceptual approach.*

1 Introduction

The base idea of this work is that modular logistics may be built upon existing IT systems, integrating the current processes with the needed data and the related operation. The introduction of the modular containers and the related processes may be seen as an evolution rather than a revolution. They offer the opportunity to handle the information, related to the deliveries, in a more fine grained way. This enable the management of carriers with greater emphasis on the optimal filling, the booking and the cross-docking.

Achieving these objectives may be done considering existing IT technologies, no new discoveries or novel implementation have to be done. The logistics aspects of the scenario are prominent regarding the IT aspects, as in the actual world IT systems act in the role of supporting logistic processes and operation. It can be also true for modular logistic. What have to be introduced is a greater sharing of data and information between the actors involved. A greater level of collaboration need to be achieved

in order to fully exploit the modular boxes advantages. All of this may be done using actual software systems, extending and increasing the modularity and interoperability between them. Moreover, an open conceptual organization should be defined, in order to prepare the way for a reference architecture of the IT systems enabling the modular logistics.

The most relevant idea for the M-Box handling in logistic processes is driven by the Physical Internet Initiative (PI). PI is inspired to the way information is packaged, distributed and stored (packet switching) in the digital internet to improve processes. Researchers involved in the PI use the Internet as a metaphor for a new way to move physical objects through the supply chain. The Internet and the physical world are different, mainly because on the internet data moves at light speed and are "immaterial". A consequence of the internet metaphor for PI is the need for a standardization in the containers dimensions (π-container), which can allow an automated and efficient handling of the loads. Logistic π-network using PI approach is composed of π-link for delivering π-container.

During our activities, in order to enable the sharing of the data, a conceptual model for the management of the information related to the handling of modular units have to be defined. The basic idea focus on IT protocols for handling unitised movements from source-to-sink, considering the handling of the M-Boxes in the operations of pick-up and drop-off, and the reverse logistic for the empty boxes delivered within a business process, using a structured network, with a common carrier approach across multimodal logistics domains. In the handling of the M-Boxes, reverse logistics is particularly important, in order to reduce or avoid empty trips along the interconnections between the logistics nodes and granting the repositioning of the modular units.

Regarding the handling of modular units internal contents and arrangement, we use a black-box approach, considering as driving model the encapsulation principle defined in the physical internet. The encapsulation principle is inspired to the digital internet handling of the information, the internet does not transmit data: it transmits packets. The information inside the packet is not used during transmission, it is handled by original sender and final receiver of the packets only and are the "payload" of the packet. Packets are routed, through the digital internet, using only the header information. The Physical Internet encapsulates physical objects in physical packets. Similarly to the digital internet, handling of the M-Boxes is realized using the associated data model, which constitutes the "header" of the physical packets. In our proposed approach we aim at only considering nominal declaration of good's type and nature, i.e. the information needed for handling the M-boxes are available, without the need to open them.

The remaining of the document is organized as follow.

The second chapter presents scenario of the analysis and the more relevant research project, which are interesting for the modular logistics.

The third chapter is focused on the IT aspects, describing logistics support systems, technologies and methodologies of interest and relevant standards, which are valuable for the modular logistics.

Fourth chapter is dedicated to the description of an abstract structured network, i.e. a logistic network composed of interconnected networks, based on collaborative consignment and shared resources, which may realize the intermodal processes of consignment using modular units.

The Fifth chapter presents the common data model defined in the activities of the Modulushca research project, and the organization of data and level of accessibility of the information. The proposed common data model is aimed at enabling the interoperability between IT systems and actors for achieving the modular logistics.

The sixth chapter is aimed at presenting the processes in the interconnected logistics scenario, based on the structured network and common data model.

Seventh chapter contains a the proposal of a reference software architecture, as defined in the activities of the WP 4 of the Modulushca project.

Final chapter contains the conclusions and final consideration about the presented material, followed by the bibliographic references.

2 Achieving the modular logistics

In this section we consider projects and initiative that are valuable and useful in the definition of a conceptual approach at the modular logistics. Analysis of existing systems has been performed, considering the PI vision to apply Internet transportation model into physical transport model where data (goods/postal letters) are consolidated into packets (modular logistic container) that move freely from source to destination. In our digital connectivity idea, modular logistic containers represent the packets and goods represent the data. Focus of the analysis will be on the operations related to the handling of the logistic modular containers and on the transportation and delivery processes.

The data format described in this document, will be aimed at defining the architecture of the data, and, where needed, of the related protocols, standards, and interfaces.

The approach and the conceptual architecture will be described considering two main aspects:

- Process view: the description of the logistics activities associated with using modular units, for the realization of the B2B goods-flow;
- Data view: the information related to the business process, logistics activities and delivery of goods.

The two views are related between them. The former covers the aspects related to handling, routing and planning of the modular logistics. The latter, at same time, provides the information and data available, for the different roles, involved in the modular logistics.

2.1 Logistics fields of interest

The analysis focused on FMCG industry as well as the postal industry. This has been done by means of interviewing users and experts from key players FMCG and postal industry as well as from the transport sector. A fundamental and unavoidable aspect, which represents the principal difference between Postal and FMCG fields, is related to objective of the logistic services. The Postal field is oriented at offering products and services to consumers, which personally require the functionality, favours the minimization of the latency of the single transportation and could be compared to a pull strategy, in which it is the user to start the processes of the logistics system. The FMCG field, instead, is oriented to the production and delivery of manufactured goods, favouring throughput volume of

transportation and could be likened to a push approach, where the user is indirectly involved in the logistic processes, as final consumer. Synthesizing, we have:

Postal scenario:

- Many customers have access to the postal services and products;
- Logistic services cover all the territory of the country;
- They have strict SLA (in terms of time allowed for delivery items);

FMCG scenario:

- Uses a dedicated logistic network, that cover only some places and some routes;
- The logistic services are intended to cope with the demand of the retailers;
- There are storage issues to be handled;

Postal services are oriented at providing services to customers or companies that are, generally, interested in delivering of letters or packs to other people or companies, in the same country or abroad. Abroad delivery is realized through collaboration between the postal services of the involved countries. Moreover, the postal services may also receive letters or packs from abroad to be delivered in the country. In the postal scenario single requests from customers or companies have to be satisfied according to the time of delivery constraints and with Tracking & Tracing systems supporting each single item delivery in the whole logistics chain.

FMCG companies are oriented to production and delivery, to finale retailers, of their goods. They use third party companies to take advantage of their transport services for the delivery of the goods to finale destinations, the retailers. The manufacturer company is aimed at providing goods to other companies, which finally sell them to the final users.

Requirements from both the fields have been considered in the definition of the Modulushca approach to data and processes, in order to define a solution viable for both scenarios.

2.2 Physical Internet relevant concepts

Physical Internet Initiative[1] is a major supply chain project that has the potential of changing the way we handle, store, package and transport goods across the supply chain. Physical Internet (PI) would mimic the way information is packaged, distributed and stored in the virtual world to improve processes. Basically the researchers involved in the PI wondered whether supply chain professionals could use the Internet as a metaphor for a new way to move physical objects through the supply chain.

Computer networks have been interconnected through the last decades, with huge advantage, into a worldwide Digital Internet. Unlike their digital counterparts, logistics networks remain highly fragmented, still mostly dedicated to a company or a specific market. The recently introduced Physical Internet concept proposes to remedy this situation by interconnecting logistics services on a global scale.

In the same way of the seven-layer Open Systems Interconnection model of the Digital Internet, Montreuil (et al.)[18] proposes an Open Logistics Interconnection (OLI) model to structure the interconnected logistics services for easing the conceptualization, the implementation and the deployment of the Physical Internet. As the Physical Internet is at its conceptual infancy stage, it is

proposed to use a seven-layer service structure in line with the OSI model, with the understanding that practice may lead to unify some layers as was done with the TCP/IP model. Adopting seven layers offers richer and more rigorous representation at this early conceptual stage. The OLI model proposes the following seven layers: (1) physical, (2) link, (3) network, (4) routing, (5) shipping, (6) encapsulation, and (7) Logistics Web. In the following image there is a comparison between the layers of the OSI, TCP/IP and OLI models.

Table 1. Protocols stacks of OSI, OLI and the TCP/IP Internet stack [18]

Layer	OSI model: Digital Internet	TCP/IP model: Digital Internet	OLI model : Physical Internet
1	Physical	Physical	Physical
2	Data Link	Data Link	Link
3	Network	Network	Network
4	Transport	Transport	Routing
5	Session	Application	Shipping
6	Presentation		Encapsulation
7	Application		Logistics Web

As in the OSI model, a layer in the OLI model is a collection of similarly conceptual functions providing services to its upper layer and receiving services from its lower layer. In the OLI model, these services can be offered by software agents, automatons and equipment, or yet by humans (directly or through a software interface). They can be also encapsulated in organizations. Each layer instance provides services to instances of the upper layer and requires services from instances at the lower layer, in accord with (N/(N-1)) vertical communications protocols. Instances in the same layer do the same among themselves through (N-N) horizontal communications protocols (virtual communication). TCP/IP and digital internet layer of protocols work at the same way, with the encapsulation principle. The frames travel through the internet, delivering the packets, which contain the segments who brings the application data.

The main concept that emerges from this consideration is that the modular units, like internet packets, are the element that enables the revolution promised by the physical internet. IT logistics supporting systems have to evolve to exploit the opportunity arisen. They have to be leveraged for extending the functionalities of the existing systems in order to cover the new requirements emerging from the Physical Internet proposal.

2.3 Related projects

In this section we consider research projects that are relevant for the modular logistics in the view of the Physical Internet.

Obviously, the first project to be considered is Modulushca[2], related to the Physical Internet initiative and aimed at enabling interconnected logistics, using modular container (M-Boxes), digital interconnectivity of systems with modular container. The aim is to address current perceived inefficiencies in supply chain and to achieve the first genuine contribution to the development of interconnected logistics at the European level. The final goal is to provide a basis for an interconnected

logistics system for 2030. The key enabler is the development & use of modular logistics units of sizes adequate for real modal and co-modal flows of fast-moving consumer goods (FMCG).

iCargo[3] is a very relevant research project for the modular logistics concepts. iCargo uses a Common Framework that sets a semantic model for logistics concepts of data and their relationships. Its purpose is to be a standard dictionary to describe what it means a concept in terms of logistics and how it can then be specialized in the real word. The objective of the common framework is to define a "path of specialization" that could lead up to the concrete implementation of the concept. In addition iCargo aims to identify an ecosystem of services that enable cooperation and interoperability between information systems and logistics services. In iCargo the objective of defining a service ecosystem approach is pursued through Service Oriented Architecture, in which ICT services, in the virtual space, make available the features realized by logistics services, in the real world. The descriptive approach used by iCargo is oriented to semantics and could be useful to ensure that they support and complement each other, to consider also a semantic approach for data model description. Rather than use, however, semantic specific languages (such as RDF, OWL-S or WSDL-S) iCargo has preferred to use the XML language, possibly with the introduction of a specific schema definition, which can adequately describe the data and services. In a software implementation view, in addition to the usual SOAP/HTTP services, may be taken into consideration also the REST WS and JSON technology. The utility of using a semantic approach, for describing the entities of the logistics, is related to the possibility of an easier sharing of information between diverse systems. In fact, our idea is to use semantic for description of the common shared knowledge about logistic concepts supporting cooperation. We do not used semantic for automatic reasoning, at least not for now. Maybe future work may consider and exploit such feature.

The e-Freight[4] project represents another interesting work for the modular logistics. e-Freight project produces the appropriate framework to allow goods tracing in real time, ensures intermodal liability promoting clean freight transport, by creation and deployment of a single transport document in electronic form (electronic waybill), and an appropriate framework for the deployment of tracking and tracing technologies (RFID, etc.). Moreover it ensures that liability regimes promote rail, waterborne and intermodal transport.

The e-Freight developments that are providing the basis for policy recommendations are:

- A standard framework for freight information exchange: the e-Freight Framework.
- A single European transport document for all carriage of goods, referred to as the Multimodal e-Waybill.
- A single window concept that may be used for all forms of reporting to all authorities, independent of mode or combination of modes of transport.
- The e-Freight Connectivity Infrastructure.

The concept of e-Freight denotes the vision of a paper-free, electronic flow of information associating the physical flow of goods with a paperless trail built by ICT. It includes the ability to track and trace freight along its journey across transport modes and to automate the exchange of content-related data for regulatory or commercial purposes. The vision presented in this Roadmap is to achieve zero paper documents for planning, executing and completing any transport operation within EU. Independent of:

the parties involved, cargo type, transport mode or combination of modes, loading unit, authorities involved, type of service demanded, where the transport takes place, and liability regime.

FreightWise[5] is another interesting project considered in our analysis. It is an integrated project within the EU's 6th Framework Programme that aims at bringing together three different sectors:

- Transport Management: Shippers, Forwarders, Operators and Agents;
- Traffic and Infrastructure Management: Rail, Road, Sea, Inland waterways;
- Administration: Customs, Border Crossing, Hazardous Cargo, Safety and Security

FreightWise's overall objective is to support the modal shift of cargo flows from road to intermodal transport using road in combination with short sea shipping, inland waterways and rail. It will achieve this objective by means of improved management and facilitation of information access and exchange between large and small, public and private stakeholders across all business sectors and transport modes. The following projects, connected with FreightWise, provide interesting information.

ARKTRANS [9]: it represents the basis on which FreightWise has been developed. It produced a user manual from which it is possible to understand how to describe framework architectures.

Frame.net [6]: it provides information through a website on the European ITS architecture. It develops information tools from which it is possible to learn communication elements.

KonSULT [10] guidebook: even if it does not deal with FreightWise related issues, it is relevant for the format of multilevel guidelines it developed.

Finally there is another interesting project: SmartFreight[7]. It is aimed at making urban freight transport more efficient, environmentally friendly and safe by answering to challenges related to traffic management, freight distribution management, and a better coordination between the two following issues. Today, it is not possible to take traffic management measures towards freight vehicles, based on information about the current traffic situation, the profile of vehicles, the amount and type of cargo. Traffic management systems do not serve those organising freight transports in the city. Freight distributors do not benefit from more reliable traffic information and are not rewarded for 'desired behaviour' such as the use of backload and green vehicles. It is also difficult to predict the access to limited resources like loading and unloading areas.

3 Information technology in logistics

In this section we will consider the typologies of systems, which have to be integrated and evolved in order to support the digital logistics. Moreover, there is the presentation of the methodologies of interaction used in the logistics processes, which may be included in the definition of the conceptual approach for modular logistics.

There are, finally, some more IT related aspects, which may be:

- Design aspects
    - Federated system: participation of several actors, using different systems interactions, accessing to shared data that are owned and managed according to each actor's role and authorization. Data ownership and sharing may be performed also considering a cloud computing approach;

    - Application integration: existing applications may interact and collaborate in supporting these modular goods-flows and their associated logistics services. Interoperability of the different systems should be based on the communication through the internet;
- Programming functionalities
    - API (Applications Programming Interface): applications call a local set of pre-specified, re-usable routines, defined in software libraries, provided as support for the integration between systems;
    - SOA (Service-Oriented Architecture) & WSDL (Web Services Description Language): applications call remote services providing re-usable operations, which refers to enterprise IT Systems;

A federated database system is a type of meta-database management system (DBMS), which transparently maps multiple autonomous database systems into a single federated database. The constituent databases are interconnected via a computer network and may be geographically decentralized. Since the constituent database systems remain autonomous, a federated database system is a contrastable alternative to the (sometimes daunting) task of merging several disparate databases. A federated database, or virtual database, is a composite of all constituent databases in a federated database system. There is no actual data integration in the constituent disparate databases as a result of data federation. Distribution of data in an FDBS is due to the existence of a multiple DBS before an FDBS is built. Data can be distributed among multiple DB which could be stored in a single computer or multiple computers. These computers could be geographically located in different places but interconnected by a network. The benefits of data distribution help in increased availability and reliability as well as improved access times. Through data abstraction, federated database systems can provide a uniform user interface, enabling users and clients to store and retrieve data in multiple non-contiguous databases with a single query - even if the constituent databases are heterogeneous. To this end, a federated database system must be able to decompose the query into sub-queries for submission to the relevant constituent DBMS's, after which the system must composite the result sets of the sub-queries. Because various database management systems employ different query languages, federated database systems can apply wrappers to the sub-queries to translate them into the appropriate query languages.

Summarizing, the IT approach is more aimed at integrating existing application than in writing new ones. The IT system for supporting modular logistics, in our view, will be realized through collaboration and interoperability.

3.1 IT Logistics Support Systems

The use of digital systems, for supporting logistics processes, origin by the needs of systems that allows the planning, management and optimization of the flows either along the whole supply chain or in the interchange nodes, as the intermodal nodes, and the tracking and tracing of goods in a real time context along the whole supply chain. Here we discuss, briefly, the typology of IT systems needed for supporting logistics processes.

The Transport Management System (TMS) is an Enterprise Resource Planning (ERP) tools allow the societies of transport to store the orders in the relative issues, to organize the planning and to send information to the trucks automatically as the information on the available loads, assets, the

information on the stopping area or on the periods of guide and rest. Reversely, the Transport Management System processes the feedback information sent by the drivers so that a right determination of the costs can be made.

Achieving the modular logistics and the practicability of processes that uses modular units is strictly related to the track and trace functionalities of the IT systems. The tracing is the action of retrieving information concerning the whereabouts of cargo, cargo items, consignments or equipment. In the detail, the tracing attend to relating resources, activities, and cost objects using the drivers underlying their cost causal relationships. The purpose of tracing is to observe and understand how costs are arising in the normal course of business operations. The tracking is the function of maintaining status information, including current location, of cargo, cargo items, consignments or containers either full or empty. The tracking and tracing (T&T) allow to monitoring and recording shipment movements from origin to destination. T&T allows the transport companies to monitoring in real time their fleets. The current situation, as the information of the position of the vehicle, is sent to the central server of the driver, by means of GPRS systems. In this way, the TMS can, following the GPS position, evaluate the distance achieved, the velocity of the vehicles as their direction, so that it can be ease to determine the Estimated Time of Arrival (ETA). The tracking and tracing systems enhance the efficiency of the TMS and drivers allowing to correct the planning on the base of the actual information. As a consequence, the T&T allows to easing/simplifying the billing system and the whole logistic chain from the origin to destination. The tracing information stored can give a global view to the logistic societies, through an historical of the routs, giving to the drivers, and feedback information on the routs achieved, with a supporting set of information, as the stop or minimum threshold time of the vehicle.

A Supply Chain Management System (SCMS) is a software application that supports the management of information within a supply chain. The aim is to make the decision-making and planning within the supply chain easier and therefore work more efficient and successful. To reach its main aim - which is to have the right item, in the right quantity, at the right time, at the right place, for the right price, in the right condition, to the right customer - three different flow processes take place within the supply chain. The product flow includes the movement of goods from a supplier to a customer, as well as any customer returns or service needs. The information flow involves transmitting orders and updating the status of delivery. The financial flow consists of credit terms, payment schedules, and consignment and title ownership arrangements. According to these information goods are produced. Starting with the first supplier finally the right good will be delivered to the end-customer. Additionally money has to flow from the ordering party to the supplier. This process is also known as “order-to-payment”. The challenge is to manage the flow of information, goods and money in an efficient way so that success factors are generated for the participating companies in the Supply Chain. This process is called Supply Chain Management.

Fleet management is the function that oversees, coordinates and facilitates various transport and transport related activities. It will cover vehicles involved in the movement of goods; the management of light vehicle fleets used in the transportation of people and light cargo; possibly motorbikes and other equipment such as generators and warehouse handling equipment. Fleet management underpins and supports transport related activities through the management of the assets that are used. Effective

fleet management aims at reducing and minimizing overall costs through maximum, cost effective utilization of resources such as vehicles, fuel, spare parts, etc.

A Warehouse Management System aims to control the movement and storage of materials within a warehouse and process the associated transactions, including shipping, receiving, put away and picking. The systems also direct and optimize stock put away based on real-time information about the status of bin utilization. A WMS monitors the progress of products through the warehouse. It involves the physical warehouse infrastructure, tracking systems, and communication between product stations. More precisely, warehouse management involves the receipt, storage and movement of goods, (normally finished goods), to intermediate storage locations or to a final customer. In the multi-echelon model for distribution, there may be multiple levels of warehouses. This includes a central warehouse, a regional warehouses (serviced by the central warehouse) and potentially retail warehouses (serviced by the regional warehouses). Warehouse management systems often utilize automatic identification and data capture technology, such as barcode scanners, mobile computers, wireless LANs and potentially radio-frequency identification (RFID) to efficiently monitor the flow of products. Once data has been collected, there is either batch synchronization with, or a real-time wireless transmission to a central database. The database can then provide useful reports about the status of goods in the warehouse.

In our view it is possible to implement the modular logistics, basing IT support on the integration of the analyzed systems, through sharing of data and information, and interoperability in the execution of processes.

3.2 Supporting technologies

This section presents and discusses the more relevant and interesting IT technologies, which have to be considered in the ideation of a conceptual model for the modular logistics.

A technology that have to be considered is the XML (eXtensible Markup Language)[11]. The widespread use of XML has led to the development of multiple industry-specific XML versions of such basic documents as purchase orders, shipping notices, and invoices. While industry-specific data formats have the advantage of maximal optimization for their business context, the existence of different formats to accomplish the same purpose in different business domains is attended by a number of significant disadvantages as well. Developing and maintaining multiple versions of common business documents like purchase orders and invoices is a major duplication of effort. Creating and maintaining multiple adapters to enable trading relationships across domain boundaries is an even greater effort. The existence of multiple XML formats makes it much harder to integrate XML business messages with back-office systems. The need to support an arbitrary number of XML formats makes tools more expensive and trained workers harder to find.

The OASIS Universal Business Language (UBL)[12] is intended to help solve these problems by defining a generic XML interchange format for business documents that can be extended to meet the requirements of particular industries. Specifically, UBL provides the following advantages. A library of XML schemas for reusable data components such as “Address,” “Item,” and “Payment”, the common data elements of everyday business documents. A set of XML schemas for common business

documents such as “Order,” “Despatch Advice,” and “Invoice” that are constructed from the UBL library components and can be used in generic procurement and transportation contexts. UBL is designed to provide a universally understood and recognized commercial syntax for legally binding business documents and to operate within a standard business framework such as ISO 15000 (ebXML) to provide a complete, standards-based infrastructure that can extend the benefits of existing EDI systems to businesses of all sizes. UBL is freely available to everyone without legal encumbrance or licensing fees.

UBL schemas are modular, reusable, and extensible in XML-aware ways. As the first standard implementation of ebXML Core Components Technical Specification 2.01, the UBL Library is based on a conceptual model of information components known as Business Information Entities (BIEs). These components are assembled into specific document models such as Order and Invoice. These document assembly models are then transformed in accordance with UBL Naming and Design Rules into W3C XSD schema syntax. This approach facilitates the creation of UBL-based document types beyond those specified in this release. They were developed during Freightwise project, from one hand they fill the gap which was present in such logistics solutions but from the other hand the presented solutions are hardly used by market as it is quite new standard.

Another technology that for sure have to be considered, in the road to achieve the Physical Internet, is the EPCIS[8] (Electronic Product Code Information Services). EPCIS may be considered as a complete approach for tracking and tracing goods, and all the other elements of the logistic networks, using unique universal identification numbers. The important advantage, from an IT point of view, is the open nature of the ECPCIS framework, which may use different tracking and tracing technologies. On the other and the EPC global services allows a way of sharing info between different logistics support systems by means of “exchanging traceable modular containers”, which provides the key for accessing to the information.

The goal of EPCIS is to enable disparate applications to leverage Electronic Product Code (EPC) data via EPC-related data sharing, both within and across enterprises. The EPCIS approach defines a standard interface to enable EPC-related data to be captured and queried using a defined set of service operations and associated EPC-related data standards, all combined with appropriate security mechanisms that satisfy the needs of user companies. In many or most cases, this will involve the use of one or more persistent databases of EPC-related data, though elements of the Services approach could be used for direct application-to-application sharing without persistent databases. With or without persistent databases, the EPCIS specification specifies only a standard data sharing interface between applications that capture EPC-related data and those that need access to it. It does not specify how the service operations or databases themselves should be implemented. This includes not defining how the EPCISs should acquire and/or compute the data they need, except to the extent the data is captured using the standard EPCIS capture operations. The interfaces are needed for interoperability, while the implementations allow for competition among those providing the technology and EPC Information Service.

EPCIS operates within enterprise IT environments at a level that is much more diverse and multi-faceted than the lower levels of the EPCglobal Network Architecture. In part, and most importantly, this is due to the desire to share EPCIS data between enterprises which are likely to have different solutions deployed to perform similar tasks. In part, it is also due to the persistent nature of EPCIS data. And lastly, it is due to EPCIS being at the highest level of the EPCglobal Network Architecture, and hence the natural point of entry into other enterprise systems, which vary widely from one enterprise to the next (or even within parts of the same enterprise).The EPCIS framework is designed to present the following features.

The framework have to be layered. In particular, the structure and meaning of data in an abstract sense is specified separately from the concrete details of data access services and bindings to particular interface protocols. This allows for variation in the concrete details over time and across enterprises while preserving a common meaning of the data itself. It also permits EPCIS data specifications to be reused in approaches other than the service-oriented approach of the present specification.

The framework have to be extensible. The core specifications provide a core set of data types and operations, but also provide several means whereby the core set may be extended for purposes specific to a given industry or application area. Extensions not only provide for proprietary requirements to be addressed in a way that leverages as much of the standard framework as possible, but also provides a natural path for the standards to evolve and grow over time.

The framework have to be modular. The layering and extensibility mechanisms allow different parts of the complete EPCIS framework to be specified by different documents, while promoting coherence across the entire framework. This allows the process of standardization (as well as of implementation) to scale.

3.3 Electronic Data Interchange System

Electronic Data Interchange (EDI)[13] is the computer-to-computer exchange of business documents in a standard electronic format between business partners. By moving from a paper-based exchange of business document to one that is electronic, businesses enjoy major benefits such as reduced cost, increased processing speed, reduced errors and improved relationships with business partners. Each term in the definition has the following denotation.

Computer-to-computer. EDI replaces postal mail, fax and email. While email is also an electronic approach, the documents exchanged via email must still be handled by people rather than computers. Having people involved slows down the processing of the documents and also introduces errors. Instead, EDI documents can flow straight through to the appropriate application on the receiver's computer (e.g. the Order Management System) and processing can begin immediately.

Business documents. These are any of the documents that are typically exchanged between businesses. The most common documents exchanged via EDI are purchase orders, invoices and Advance Ship Notices. But there are many, many others such as bill of lading, customs documents, inventory documents, shipping status documents.

Standard format. Because EDI documents must be processed by computers rather than humans, a standard format must be used so that the computer will be able to read and understand the documents. A standard format describes when each piece of information is and in what from (e.g. integer, decimal, mmddyy). Without a standard format, each company would send documents using its company-specific format and, much as an English-speaking person probably doesn't understand Japanese, the receiver's computer system doesn't understand the company-specific format of the sender's format. There are several EDI standards in use today, including ANSI, EDIFACT, TRADACOMS and XML. And, for each standard there are many different versions, e.g. ANSI 5010 or EDIFACT version D12, Release A. When two businesses decide to exchange EDI documents, they must agree on the specific EDI standard and version. Businesses typically use an EDI translator – either as in-house software or via an EDI service provider – to translate the EDI format so the data can be used by their internal applications and thus enable straight through processing of documents.

Business partners. The exchange of EDI documents is typically between two different companies, referred to as business partners or trading partners. For example, Company A may buy goods from Company B. Company A sends orders to Company B. Company A and Company B are business partners.

3.4 Supporting standards

This section describes the standard, already in use or proposed, as identified in the analysed sector of postal logistics and FMCG. Standards are paramount for enabling interoperability between different systems and exchange of data. So they are an important component in the approach to a conceptual approach for modular logistics.

Each shipment, in Postal Services, complies with national legal obligations, and it is harmonized with UPU (Universal Postal Union) deliverables and standards for an international postal environment. So international postal interfaces organized through UPU standards for gateway hubs, in a national environment have, obviously, the related standards on a national scale.

The postal logistic supporting information systems usually manage two types of data: data about entire processes monitoring (tracing, tracking, transport, ownership) and data about customers' billing. However the basic idea is that each physical event (in the real world) corresponds to an informative event (in the IT systems), with all the information for supporting it. In the considered scenario, then, there is a correspondence among respective national informative events, in an international environment managed by UPU's activities and through the negotiation of a technological DIA (Data Interchange Agreement) (mostly used are EDIFACT-based (Electronic Data Interchange For Administration, Commerce and Transport) and XML-based massages). Standards are important prerequisites for effective postal operations and for interconnecting the global network.

The UPU's Standards Board develops and maintains a growing number of standards to improve the exchange of postal-related information between postal operators and promotes the compatibility of UPU and international postal initiatives. It works closely with postal handling organizations, customers, suppliers and other partners, including various international organizations. The Standards

Board ensures that coherent standards are developed in areas such as electronic data interchange (EDI), mail encoding, postal forms and meters.

The UPU Standards may be used, in the modular logistics, for handling the border crossing between different country, enabling the provision of relevant data to the custom authorities

In our view, in fact, once the goods or the mails are sealed inside a modular box, which is labelled with the strictly necessary information, the delivery may be accomplished treating the modular container with a black box approach. Moreover this approach is already used in Poste Italiane, with the use the so called II level containers that, in our view, are the real world container nearest to the M-Box idea, in terms of handling by means of an IT system.

Some point have to be highlighted:

- Postal logistics have to deal with each single item (mail or pack) in order to deliver it fulfilling the related SLA (Service Level Agreement).
- In postal scenario the starting event of the logistic process is related to a single item, with a customer requiring a service;
- The postal logistics provides the dispatching, i.e. grouping items with common destinations, which are delivered maximizing the cross-docking and minimizing the storage.

Now we can consider what may could happen in a shared network were postal products and FMCG goods are shipped using modular containers.

In such a view the modular containers may be considered as meta-items in the postal logistics view. Each M-Box, in fact, contains item that have to be delivered to a common destination. The M-Box may be filled in two principal ways:

- Grouping together postal items, executing the “dispaccio”, i.e. the dispatching of mails and packs, and inserting the items with a common destination in the same m-box;
- Taking all the items of an order (in a FMCG scenario) and splitting them up in several m-box, filling them.

In both cases the result will be an M-Box with an unique ID (barcode, RFID, QR code, whatever…) that allows for associating to the M-Box a set of data inside the information system supporting the modular logistic.

Those information are related to the following area:

- Data related to the box and present on the box itself, they may be referred as data model for the M-Boxes;
- Data present in the IT Systems that have to be exchanged with different partners during the interaction along the supply chain.

At this point M-Boxes may be shipped in a shared logistics network, using the PI approach, and using operational processes similar to the postal one, i.e. maximizing the cross docking, minimizing the storage and monitoring an SLA for each single meta-item, i.e. each single modular box.

We consider, now, the analysis and description of the AS-IS in FMCG logistics processes and related information handling. From a Logistic service provider company, FMCG (Fast Moving consumer Goods) is a logistic scenario in which there are three main actors involved:

- The Manufacturer or Shipper, which is the source where the goods are retrieved for the delivery;
- The Wholesale or Retailer, which is the requestor of the goods and is the destination for the delivery;
- Logistic Service Provider (LSP) is the actor who performs the delivery of the goods between the source and the destination.

The Purchase use case is related to the scenario when the Wholesale/Retailer wants to buy goods by a Manufacturer/Shipper. It is a business use case in which the request of buying a set of goods is sent to the Manufacturer/Shipper. Then, it is not a logistic processes on its own but is the motivation for having a logistic process: the delivery.

The Delivery is the logistic process in which a Logistic Service Provider performs the activities of retrieving the goods from the Manufacturer/Shipper and transporting them to the Wholesale/Retailer.

GS1 (Global System One) organization previously EAN/UCC is world leader in the delivering standards solutions regarding automated data acquisition, data carriers and electronic messages in global trade specially FMCG sector. GS1 is dedicated to the design and implementation of global standards and solutions to improve the efficiency and visibility of supply and demand chains globally and across sectors. The GS1 system of standards is the most widely used supply chain standards system in the world.

Global identifiers are the foundations of automatic data processing in nowadays electronic data interchange in trade and transport and logistics sector. GS1 identifiers are identifying goods, transport and logistics units, locations, transaction parties, shipments and consignments, means of transport and transport equipments but also documents and services. The most common known identifiers which covers almost whole world are global trade item number GTIN which identifiers every single product in retail sales. Other very important and widely used identifier is the single shipment container code SSCC which is used for marking the single logistics units like pallets, packages, bulks it is very often connected with SSCC logistics label and electronic messages like dispatch advice for example. This one should be first option for modules marking. Other very important from transportation point of view are identifiers of shipment GSIN and consignments GINC. GSIN number is a proposal of World Customs Offices (WCO) as a correct identifier Unique Consignment Reference (UCR).

For the automatic data processing GS1 is using the Application identifiers that Data Element Strings can be correctly processed in users' application programmes. An Element String is the combination of a GS1 Application Identifier and a GS1 Application Identifier Data Field. Thanks to the application identifiers the automatic processing of Element Strings in business applications is possible and is easier to implement. It requires information about the type of transaction to which the transferred data refers. Element Strings can be carried by GS1-128, GS1 DataBar Symbology, GS1 Composite, and GS1 DataMatrix Symbols).

The Global Trade Item Number (GTIN), is used to uniquely identify trade items (products or services) that may be priced, or ordered, or invoiced at any point in any supply chain. Each trade item that is different from another is allocated its own separate GTIN. Their main function is to provide a way to uniquely identify any item so it can be looked up in a database – for example to get its price, record its sale, confirm its delivery or identify its order – and this, at any point during the supply chain and from any place in the world.

The Global Location Number (GLN) is the GS1 ID Key used to identify locations and legal entities. Being able to identify locations with a unique number is vital to many business processes; GLNs are also the essential building block for a variety of EPC/RFID applications built around location. Using a GLN rather than a proprietary internal numbering system for locations gives a company significant advantages, because it provides a standardized way to uniquely identify entities and locations throughout the supply chain.

The Serial Shipping Container Code (SSCC) is the GS1 ID Key used to identify individual logistic units. A logistic unit can be any combination of units put together in a carton, in a case, on a pallet or on a truck, where the specific unit load needs to be managed through the supply chain. The SSCC enables a unit to be tracked individually, providing benefits for order and delivery tracking and automated goods-receiving. The serial reference component of the SSCC provides virtually unlimited number capacity, simplifying number allocation and guaranteeing unique identification.

The Global Returnable Asset Identifier (GRAI) is used to identify returnable assets such as re-usable transport equipment like trays, crates, pallets or beer kegs that are used and then returned to be used again. The GRAI can be used simply for asset identification and tracking purposes, or it can be as part of a hiring or rental system where two or more companies collaborate, as it allows enterprises to scan assets into and out of their businesses.

The Global Individual Asset Identifier (GIAI) is used to identify fixed assets of any value within a company that need to be identified uniquely, for the transportation purposes this can include a truck, a trailer, a Unit Load Device (ULD), a container, a rail car, and so forth.

The Global Shipment Identification Number (GSIN) is a number assigned by a seller (sender) of the goods. It provides a globally unique number that identifies a logical grouping of physical units travelling under one dispatch advice and/or one bill of lading as part of a specific seller/buyer relationship: from the consignor (seller) to the consignee (buyer). The GSIN fulfils the requirements of the Unique Consignment Reference (UCR) of the World Customs Organisation (WCO), which can be used by Customs authorities to identify shipments subject to import or export processes.

The Global Identification Number for Consignment (GINC) identifies a logical grouping of goods (one or more physical entities) that has been consigned to a freight forwarder or carrier and is intended to be transported as a whole. The GS1 ID Keys are complemented by GS1 Application Identifiers (GS1 AIs). GS1 AIs act like a code list of generic and simple data fields for use in multi-sector and international supply chain applications. Each GS1 AI consists of two or more digits and provides the definition, format and structure of the data field encoded in a GS1Data Carrier. For example, a GS1 AI exists for

each GS1 ID Key, allowing them to be encoded in GS1 BarCodes or EPC/RFID tags. Supplementary data is always associated with a GS1 ID Key and, while the intention is that the GS1ID Key is used to find information about the identified object in a database, GS1 AIs exist for supplementary data that cannot be looked up in a database by reference to the GS1 ID key.

The Global Document Type Identifier (GDTI) - is the Identification Key for a document type combined with an optional serial number and used to access database information that is required for document control purposes. The GDTI is assigned for the life time of the document type and may be bar coded using Application Identifier (253).

The Global Service Relation Number (GSRN) - is the GS1 Identification Key used to identify the recipient of services in the context of a service relationship. It is used to enable access to a database entry for recording recurring services. The GSRN is normally assigned by the service provider and may be bar coded using Application Identifier (8018).

4 Structured network

Physical Internet is inspired to the way information is packaged, distributed and stored (packet switching) in the digital internet to improve logistics processes. Researchers involved in the PI use the Internet as a metaphor for a new way to move physical objects through the supply chain.

The Internet and the physical world are deeply different, mainly because on the internet data moves at light speed and are “immaterial”. Data are stored, if you lose it, you can often retrieve it and there is no great incremental cost to ship more data. In the physical world, on the other hand, the equipment move at limited speed, it is terrible to lose a pallet, and there is an additional cost every time someone touches an object.

In the Digital Internet, the data packets that constitute an overall transmission, such as an email, travel, independently, through a series of routers and cables, dynamically moved from origin to destination, through a routing algorithms. Packets forming a message are not restricted to travel together. Each may end up travelling its distinct route, then the overall message is reconstituted upon the arrival of packets at final destination.

A consequence of the internet metaphor for PI is the need for a standardization in the containers dimensions (π-container), which can allow an automated and efficient handling of the loads. Logistic π-network, using PI approach, are composed of π-link for delivering π-container from a π-hub to another. A π-hub is a node in the network, which play the role of the nodes in the internet.

An important aspect to be considered of Digital Internet is that may be considered as realized as a network of networks. In the same way the π-network should be considered as an aggregation of different logistic network, merged through the use of the π-containers.

We have to consider different types of π-hubs:

- entry points in the structured network, which may be identified as gateway;
- intermediate transit nodes, simply identified as hub (or repeater);

- nodes interconnecting network managed by different companies, that may be considered as router.

Following we provides details on the network and the related components.

4.1 Logistic centre

A Logistics Centre is the hub of a specific area where all the activities relating to transport, logistics and goods distribution – both for national and international transit – are carried out, on a commercial basis, by various operators [14].

The operators may be either owners or tenants of the buildings or facilities (warehouses, distribution centres, storage areas, offices, truck services, etc.) built there. In order to comply with free market rules, a Logistics Centre must be accessible to all companies involved in the activities set out above.

A Logistics Centre must also be equipped with all the public facilities necessary to carrying out the above-mentioned operations. If possible, it should also include public services for the staff as well as users' equipment. In order to encourage intermodal transport for goods handling, a Logistics Centre should preferably be served by a variety of transport methods (roads, rail, sea, inland waterways, air).

It is vital that a Logistics Centre be managed as a single and neutral legal body (preferably by a Public-Private-Partnership) if synergy and commercial cooperation are to be ensured. Finally, a Logistics Centre must comply with European/International standards and quality performance in order to provide the framework for commercial and sustainable transport solutions.

The Logistics Centre concept is based on three important elements:

1. Territorial planning alongside infrastructure rationalization
2. Transport quality
3. Intermodality development

These in turn generate other relevant effects from economics and transport standpoints. Location is a key factor for all the transport operators whose main activity is moving freight from one place to one another using different modes of transport.

Optimization – or rather reduction – of the delivery time to the final destination or to the following passage of the logistics/transport chain is one of the elements that could make that important difference when a transport operator is being chosen.

Assuring fluidity between all the transport connections and coordinating all the transport modes are some of the tasks of a Logistics Centre. This is why most Logistics Centres are located in hub points for transport and distribution activities. Location at a hub point means, in short, being near the main railway, motorway and seaway arteries.

4.2 Structured network description

A structured network is the conceptual approach that may allow in realizing the modular logistics, as proposed by the Physical Internet, i.e. considering the Digital internet as a driving example.

The idea of a structured network is related to a configuration of logistics nodes, hierarchically interconnected by backbone connection or inter-regional (the coach layer), regional (the bus layer) and last mile (the taxi layer). Conceptually it may be seen as a directed graph. The nodes provide an abstraction of the logistics centre (or hub) while the edges, oriented in the direction of the flow, model the transportation routes between nodes.

In our discussion of the structured network we consider the example depicted in the following figure.

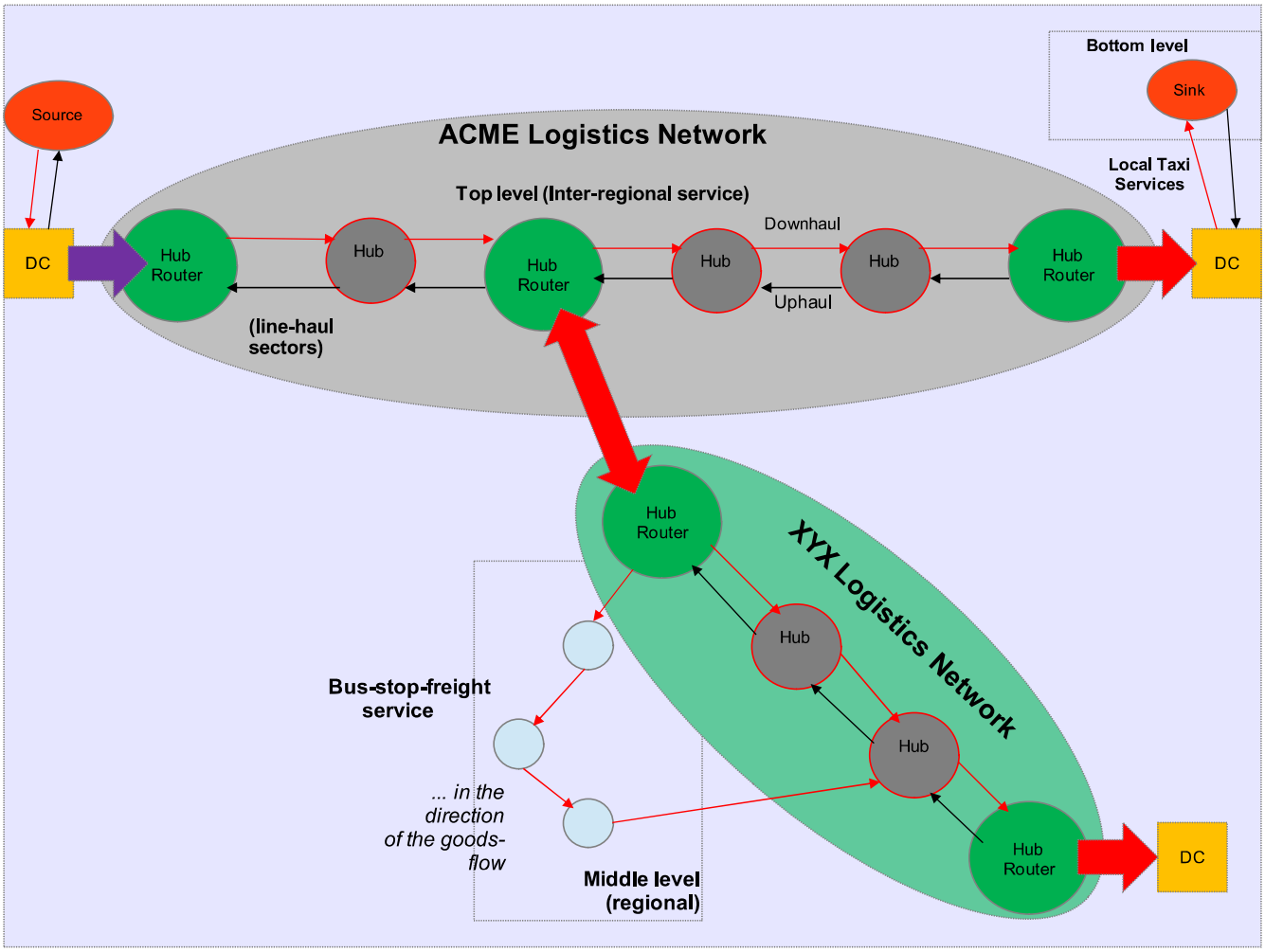


Figure 1. Structured network concept

A structured network may be modelled as a line-of-route profile: the main concepts of the route are the Hub, the Node Manager and the Addressing of the nodes of the network.

Addressing: the real world location is related to the shipments (source and sink) and the hub/gateways that facilitate the box-flows. The Addressing is satisfied through a Routing table for the main nodes of the logistics network or a Location Address Table for the consignment to the final customer or Retailer. In handling this aspect several approach may be considered and combined together: GLN, latitude and longitude and postal codes.

Sectors: abstraction of the real world connections between nodes, allowing for moving the cargo from one node to another.

The Hubs are the responsible of the routing within the logistic network that switch boxes from one means to another (performing cross-docking and buffering storage) with also support planning and booking. Structurally the Hub is a node of the network that may be an interconnection's node of different logistics network (as in the intermodal transport so as it can be a border node) or an inner node (as in the uni-modal transport from one logistics centre to another one) of the network. The first one, the Hub Router (or outer hub), is really required at the border of a logistics network, for the physical internet is the interconnection of different logistics networks. A hub is also needed within a logistic network (inner hub) in order to handle the cross-docking, the storage, the reverse logistics and the assets management.

We consider a structured network realized by the interconnection of two distribution networks, of two LSPs. In analogy with the internet, which is composed of several kind of networks, we may consider the logistic network as composed of sub-networks. Each sub-network has its own IT systems, for managing planning, booking, transport, capacity, and so on. The two LSPs may be considered as 4PL or they may be postal services, anyway they are organization capable of maintaining their own IT systems and able to handle modular logistic. Distinction between them is not important at the abstract level we are reasoning. The modular logistics domain covers all the operation between the nodes in the networks. The DC are the entry point for the modular logistics. In order for the goods (or postal products) to be carried they are encapsulated in the modular boxes, and then handled with a packet switching approach.

The Distribution Centre (DC) are connected to the structured network but are really outside of it. The business processes are related to the consignment between two business partners. The structured network is the domain of the modular logistics, used for the transportation of goods encapsulated in modular boxes.

Each hub/router that can be independent or part of a sub network, is managed by a Node Manager, which handles:

- Node capacity, in terms of time and cost of the outbound and return sectors between adjacent nodes.
- Acts as a reporting gateway for the logistics modular units, where they may switch from one service to another.
- Participate in the planning of the deliveries, checking carriers availability, cost and time windows for logistic operations, acting like a broker for the scheduling, asset management and booking of the delivery.

Each hub is more or less autonomous (depending if it is an outer hub or an inner one), self-contained and self-accounting and may support associated logistics activities.

The network Node Manager is responsible of maintaining a routing table, with all the available carriers (communicating the up to date version to the other nodes), timing and costs of the delivery, then prices its capability and capacity of the node to the market.

IT Systems of each logistic operator, working in the hub, have to interoperate (through a standard interfaces, i.e. based on services interaction) with the Node Manager system, in order to retrieve and deliver M-Boxes.

The Node Manager has to manage the "Directory of local addresses" (ONS and GLN could be useful standard for this approach) for the planning of shipments and last mile delivery.

The Node Manager have to consider local authorities laws, rules and constraints with respect to the means available.

The main functions for a π-Hub/LSP IT-Systems are the planning, the booking, the cross-docking, the storage, the track and tracing of the goods that can be realized through a Routing Table for the nodes of the backbone and a Local Address Directory for the last mile delivery.

Hub/router are the nodes within the line-of-route profile that models the structured network, they are responsible for:

- Node management (planning, routing, capacity, asset management, pricing, etc.)
- Maintenance
- Driver rostering
- Transfer
- Pullback (relocating units for reuse)
- Directory of local area addresses

Following there are some of the elaboration areas more relevant for the descriptions of the nodes in the network.

In computer networking a routing table, or routing information base (RIB), is a data table stored in a router or a networked computer that lists the routes to particular network destinations, and in some cases, metrics (distances) associated with those routes. The routing table contains information about the topology of the network immediately around it. A routing table is used by TCP/IP network routers to calculate the destinations of messages it is responsible for forwarding. Routing tables contain a list of IP addresses. Each IP address identifies a remote router (or other network gateway) that the local router is configured to recognize. For each IP address, the routing table additionally stores a network mask and other data that specifies the destination IP address ranges that remote device will accept. Routers simply forward all outbound traffic to the Internet Service Provider (ISP) gateway which takes care of all other routing steps. In the logistics network the IP addresses for the logistics centres (ΠΙ-Hub, warehouses, distribution centres or consolidation centres) can be identified with a GLN (Global Location Number).

The Local Address Directory contains the destination's addresses of the consignments; the unique identification of these addresses can be realized with the construction of a code obtained with the concatenation of the GLN of the last logistics centre of the route and the code of the recipient (the retailer or the consignee).

A distribution centre for a set of products is a warehouse or other specialized building, often with refrigeration or air conditioning, which is stocked with products (goods) to be redistributed to retailers,

to wholesalers, or directly to consumers. A distribution centre is a principal part, the order processing element, of the entire order fulfilment process. Distribution centres are usually thought of as being demand driven. A distribution centre can also be called a warehouse, a DC, a fulfilment centre, a cross-dock facility, a bulk break centre, and a package handling centre. The name by which the distribution centre is known is commonly based on the purpose of the operation. For example a "retail distribution centre" normally distributes goods to retail stores, an "order fulfilment centre" commonly distributes goods directly to consumers, and a cross-dock facility stores little or no product but distributes goods to other destinations.

Distribution centres are the foundation of a supply network, as they allow a single location to stock a vast number of products. Some organizations operate both retail distribution and direct-to-consumer out of a single facility, sharing space, equipment, labour resources, and inventory as applicable. A typical retail distribution network operates with centres set up throughout a commercial market, with each centre serving a number of stores. Large distribution centres for companies such as Wal-Mart serve 50–125 stores. Suppliers ship truckloads of products to the distribution centre, which stores the product until needed by the retail location and ships the proper quantity. Since a large retailer might sell tens of thousands of products from thousands of vendors, it would be impossibly inefficient to ship each product directly from each vendor to each store. Many retailers own and run their own distribution networks, while smaller retailers may outsource this function to dedicated logistics firms that coordinate the distribution of products for a number of companies. A distribution centre can be co-located at a logistics centre.

In Logistic the term Cross-Docking is defined as the operation for which the goods, which arrive in a sorting centre from multiple origins, are unloaded (at least partly) and are directly reloaded on other trailers, without stopping to the ground, or at least, as soon as possible, in such a way, it reduces the manipulations of the goods. This requires, however, an optimum coordination of the input and output flows. By extension, it is called Cross-Docking, also if the goods are unloaded, sorted and loaded in a very short time (i.e. a few hours).

The term cross docking refers to moving product from a manufacturing plant and delivers it directly to the customer with little or no material handling in between. Cross docking not only reduces material handling, but also reduces the need to store the products in the warehouse. In most cases the products sent from the manufacturing area to the loading dock have been allocated for outbound deliveries. In some instances the products will not arrive at the loading dock from the manufacturing area, but may arrive as a purchased product that is being re-sold or being delivered from others company's manufacturing plants for shipment from the warehouse.

4.3 Virtual consignment

If we consider the way the digital internet work it is possible achieve a better exemplification of the modular units approach in the structured interconnected network.

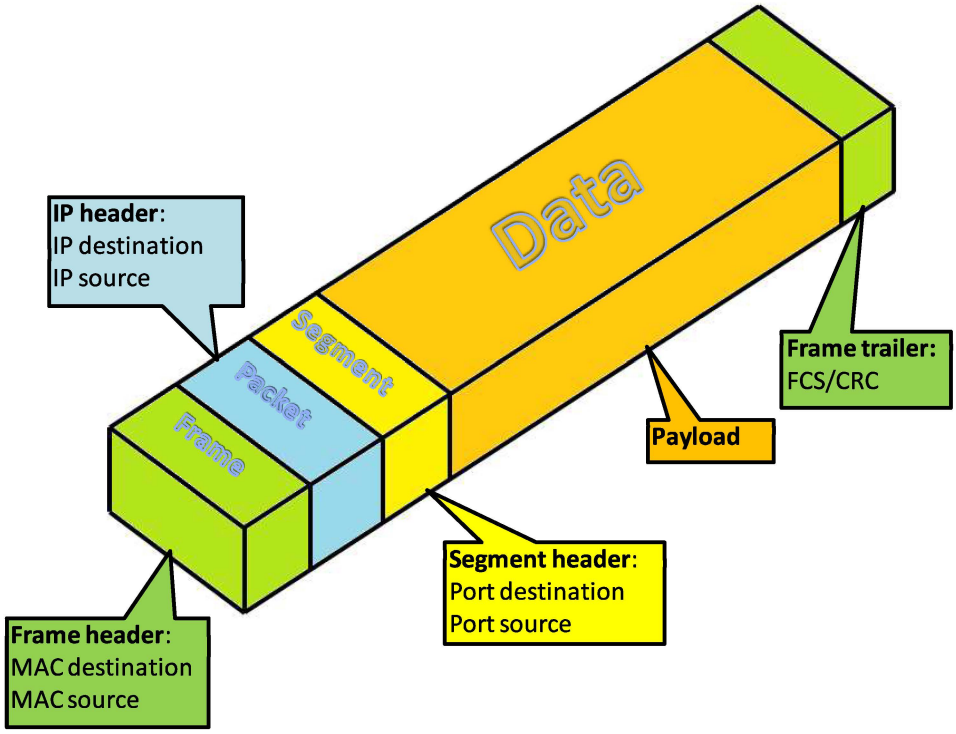


Figure 2. TCP/IP data encapsulation

We may consider a message, in the digital internet, which have to be exchanged by two computers, different in the nature of the operating systems and in the kind of hardware. The two remote programs interact one with the other using an application layer protocol (i.e. http, smtp, ftp, and so on). The two program used the underlying TCP protocol to exchange the message. It is subdivided in several "fragment" all of the same dimension, and encapsulated in a segment (the TCP modular unit) which is basically composed of the data and an header with information about sender and receiver in the TCP layer of the stack. These segment are, then, encapsulated inside a packet (the IP modular unit) which is the data exchanged between the IP layer programs handling the communication. Those packets are, finally, inserted as payload inside a frame of the physical and data link layers, which are responsible of their delivery.

The frames travel through the internet, delivering the packets, which contain the segments who brings the application data.

The routing of the modular packets are handled by the network autonomously. The network operates using point to point connections along the backbones with the use of the methodology Store and Forward: maintaining a copy of the message until it is completely received by the other end of the point to point channel.

The communication protocol is based on ARQ (Automatic Repeat reQuest): it is an error-control method for data transmission that uses acknowledgements and timeouts to achieve reliable data transmission over an unreliable service. If the sender does not receive an acknowledgment, before a

prefixed timeout, it re-transmits the frame/packet until it receives an acknowledgment or exceeds a predefined number of re-transmissions.

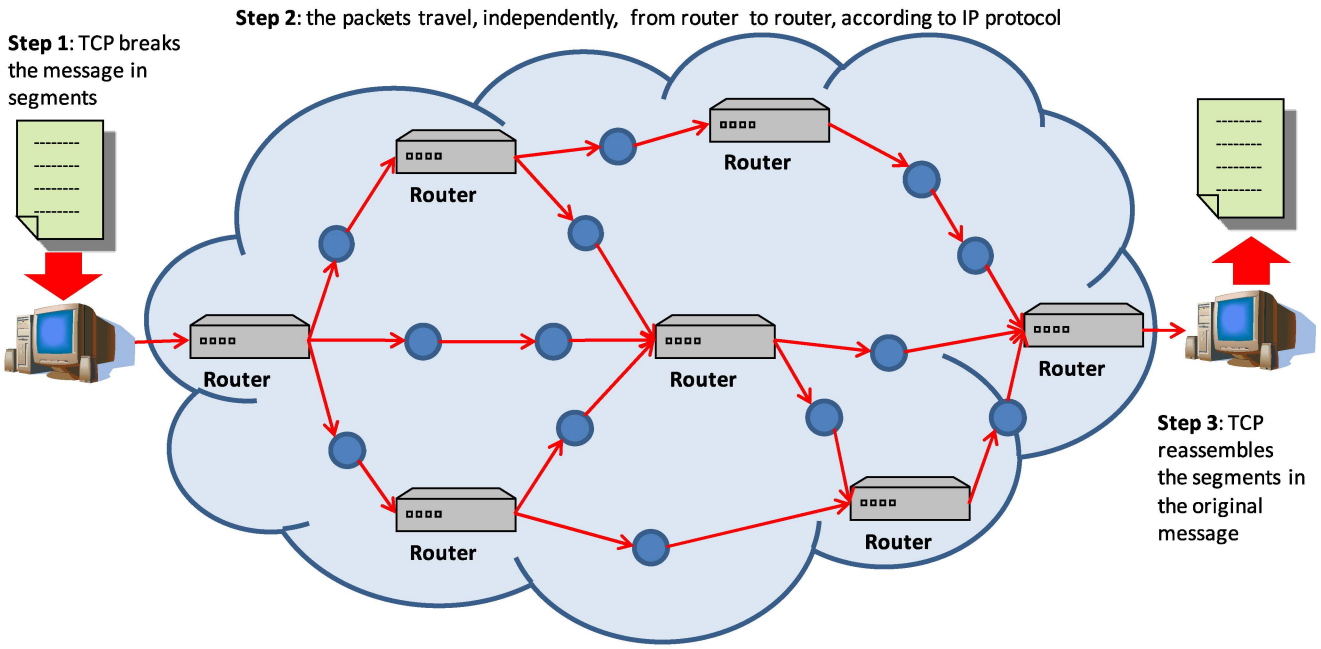


Figure 3. TCP/IP conceptual data handling

Main differences are: in the Internet information is transmitted, therefore an immaterial payload, while logistics is aimed at moving loads of materials and the principal problems are:

- freight may be not stored and forwarded at the same time and may not be re-sent
- freight handling is a costing operation
- bandwidth and linking is related to physical presence of the carriers and of their moving capability
- Items have physical parameters (weight, dimension, etc.) and may be valuable or fragile

Tracking and tracing approach were investigated for addressing lack of store and forward and ARQ.

Logistic nodes planning must be based on the carrier availability on the links (cargo routing) aiming at maximize cross-docking and minimize storage.

M-Boxes modular dimension allows for optimal filling and ease loading and unloading.

The objective is the digital integration:

- unique identification of the M-Boxes, where the unique id is the key for retrieving the related information (sender, destination, etc.);
- allowing access to information with different access rights for different roles;
- forwarding information along the supply chain;
- locating the boxes (in space and time) in order to trace them;
- observe events in the real word in order to bring them in the IT world;

Integration of existing IT systems has to be realized introducing connectors and adapters for enabling interoperability between them; the main aspect to be defined are:

- Definition of a software architecture, based on a layered approach. Each layer deals with a specific problem;
- It is possible to consider several protocol, in the same layer, offering different service level;
- Definition of the collaboration information to be exchanged by the partners along a modular supply chain, in order to allow tracking, tracing and planning

Completing our analogy we may say that the message to be exchanged in the PI may be defined as virtual consignment. They handle MBoxes in the same way the internet deal with the packets. The difference is that while the internet work with bit and electrical signals the PI exchange atoms, inside the modular units. The header and the trailer of the modular boxes/packets are, really, exchanged by the IT systems interoperating. Association between digital exchanged data and physical packets are realized using the MBox UUID, as explained in the "coloured model" presented in the following chapter of the document.

5 Data management in modular logistics

As said before we consider the logistic network is represented as a structured network composed of logistics nodes, hierarchically interconnected by backbone connection or inter-regional (the coach layer), regional (the bus layer) and last mile (the taxi layer).

A common carrier approach is desirable, though the management of this common effort is still a big issue, in order to avoid side effects and other unwanted behaviour; the shipment is performed with a common effort of all actors collaborating in conveying the boxes, so as transfers, optimizing the flow-time and at minimal cost.

The type of transport is oriented preferably for multimodal or intermodal logistics: the boxes are able to be carried by different means of transportation (multi-modal) without being unpacked.

5.1 Modulushca Common Data Model

In order to enable the modular logistics and for enabling encapsulation of the goods a data model has been defined, in the frame of the Modulushca project. The following sections describes the model, the related information and interactions. We refer to the data model as the Modulushca Common Data Model.

The access to the information handled by the Modulushca Common Data Model is connected to the context. In our approach the context, may be considered as a window allowing to see only part of the information, depending on the role of the actor who is accessing to the information and the situation in which this access is performed.

This contexts have been modelled in the common data model, considering the data differently tagged by a colour. Diverse colours, means different level of accessibility for the data. The red tagged data are the most reserved while the green tagged data are the totally public, accessible by anyone.

The model is schematized in the following image. It is important to clear that the model, seldom schematized using XML, is a conceptual model. Moreover, the model is based on XML Schema Definition Language and the defined XSD types are extensible and may be updated.

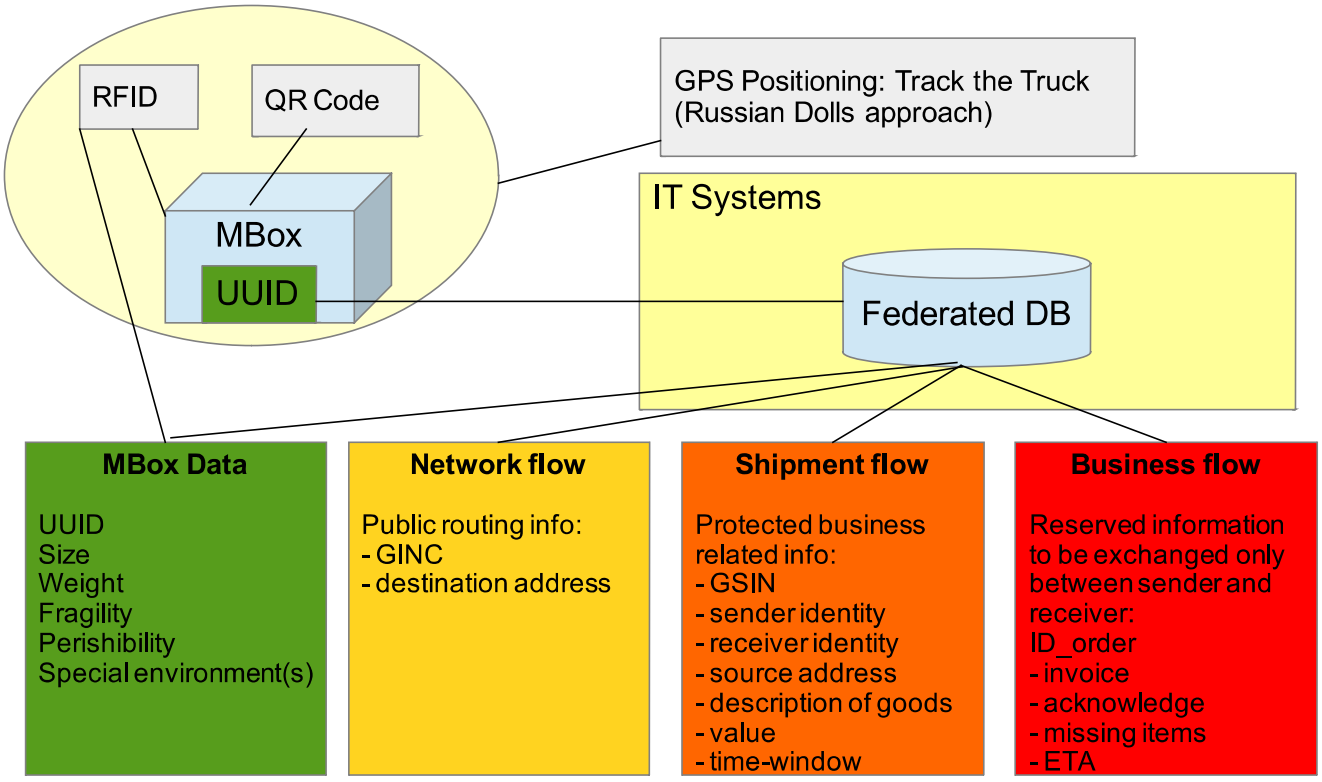


Figure 4. Modulushca Common Data Model concept

The modular unit is tagged with devices (i.e. RFID) or description (i.e. QR Code), or both of them, which enables to read the "green data" directly from the Mbox, itself, or by accessing to IT Systems (by means of the UUID) and retrieving them. The green data, defined MBox data, are needed for correct and safe handling of the modular unit and of its content. They may be read by humans operators directly with portable device or by automated systems. They enable and ease, the loading, unloading, stacking, cold storage and so on. Moreover, the RFID are used for enabling the EPCIS, for the handling of track and trace, and for the generation of events to be processed in the IT systems. On the MBox there is, also, an UUID (Universal Unique IDentifier) that allows for accessing to the IT Systems, in order to retrieve more information about the box. Regarding the tracking and trace we consider a Russian Dolls approach, exploiting encapsulation of goods, inside Modular Boxes, inside pallets (or inside modular boxes of greater dimension), and inside carriers (trucks, trains, etc.). The tracking of each single box is obtained tracking dynamic aggregation of boxes, that travels by one node to another.

IT Systems, in our conception, are federated systems, which together constitute a distributed system, interconnected through the internet, enabling the several actors involved in modular logistic to exchange information and data, perform collaborative planning, exchanging track and trace information, and so on.

Next layer in the model are the yellow data, which we identify as the network or routing data, related to the transport layer of the network. They are slightly more reserved than the green ones and are accessed and processed in order to provide the correct handling of the boxes, through the network, in order to satisfy the transport needs and guarantee the satisfaction of the consignment. This data (together with the previously described green data) are involved with the how of the consignment, i.e. the use of physical resources and means in order to complete the delivery.

Following, in order of increased secrecy, there are the orange data, which are related to the shipment of the boxes, and involved with the logistics value of the consignment. They deal with the who, the where, the what and the why of the delivery process.

Finally there are the red data that are the most reserved, being aimed at the business and financial aspects of the delivery. They have to be exchanged only between the original sender and the original receiver, in order to fulfil the business needs.

In the following we describe the data, how they have been modelled using the XSD formalism.

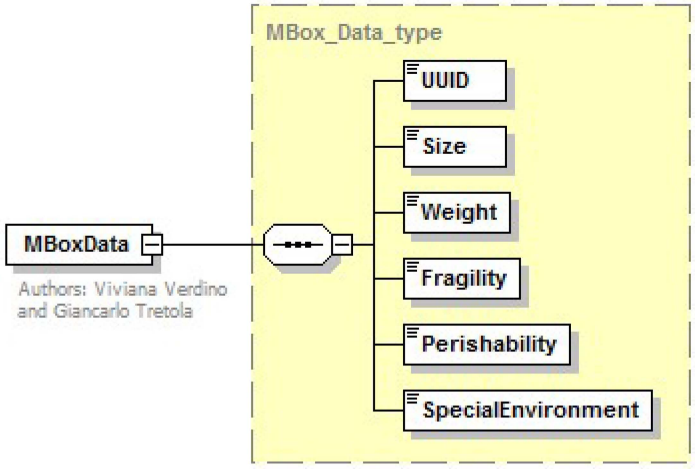


Figure 5. Modulushca Common Data Model: MBox Data

The green data or MBox data are encapsulated in a single XSD, which is a XS Complex Type, composed by atomic information, defined as XS Simple Type in the model. As defined the MBox provides: the UUID of the box, its size, its weight (as loaded by the goods), the fragility of the contents (useful for handling it correctly), the possible perishability of the content (and consequent need for cold storage, for example) or the need for use of special environment (for chemicals, flammable or other kind of dangerous contents). This set of data allows for the black-box handling of the modular units: without the need to open the box, the operators or the automated systems may know all the basic and fundamental information for the handling of the box at the best.

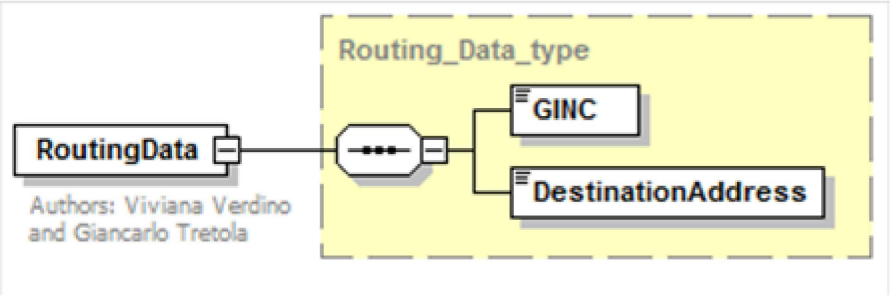


Figure 6. Modulushca Common Data Model: Routing Data

The Routing Data (or Network data), tagged in yellow, is used for the routing of the boxes in the network. IT systems at this level may operate using a planning-checking approach. Using the routing data the box consignment is planned (in advance or dynamically just in time) and the box loaded on a carrier. Routing data are also used for detecting and correcting routing errors. The XS Complex Type is composed by: GINC, Global Identification Number for Consignment, providing the information needed for the consignment handling, and the Destination Address used for the routing and planning.

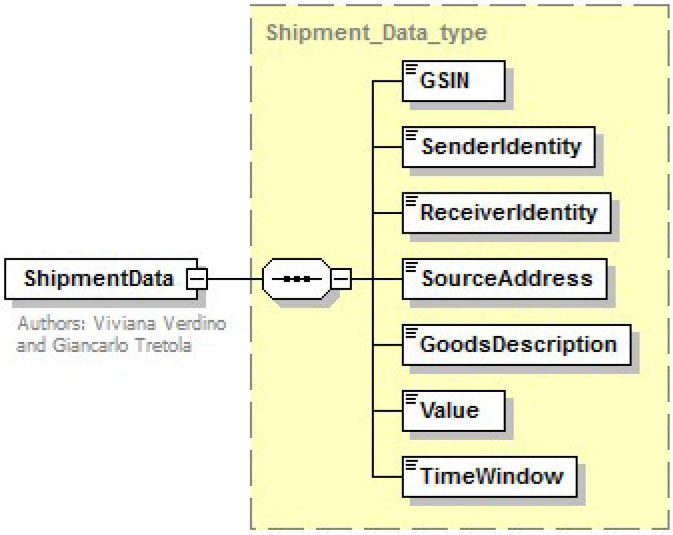


Figure 7. Modulushca Common Data Model: Shipment Data

The Shipment Data, or orange data, is a XS Complex Type, which is involved with the logistic value moved by the consignment. The information available, at this level, are related to the what, the where, and the when of the delivery. The XS Complex Type composed by: the GSIN, Global Shipment Identification Number, information about the sender and the receiver identity, the source address where goods have been picked up, a description of goods, their value and the time window for the delivery. These information may be used in the IT systems for providing planning constraints, defining SLA (Service Level Agreement) and other restrictions to be considered while performing the consignment.

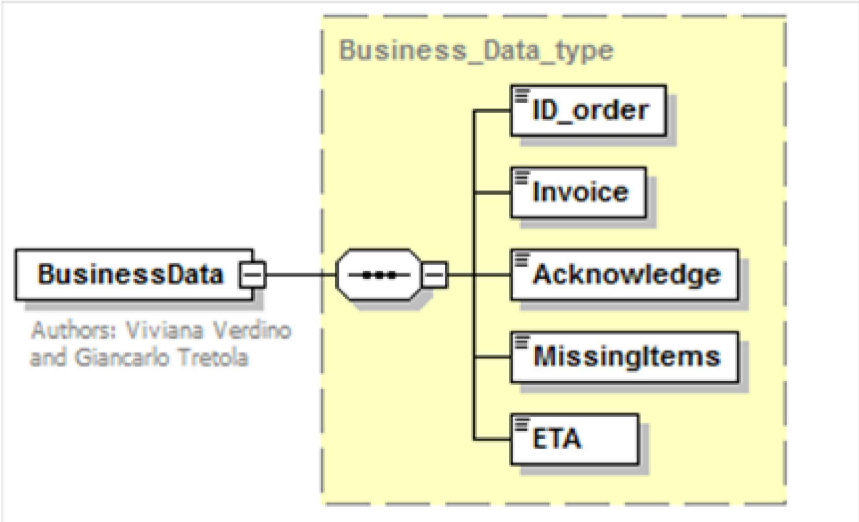


Figure 8. Modulushca Common Data Model: Business Data

Finally the Business data, or red data, is a XS Complex Type, allowing the exchange of reserved information between the business partners of the delivery. Involved data are related to the purchasing order, the invoicing, the acknowledgment of the delivery, the missing items and ETA (Estimated Time of Arrival).

This XSD elements, are the elements of the Modulushca Common Data Model, which may be used for enabling interoperability. In fact they may be used as standard arguments (i.e. variables to be provided) for the operations of the standard interfaces between the interconnected systems.

5.2 Security

Additional stakeholders have to be considered, which are not part of the reference logistics value chain but play an important role in logistics chains:

The Authority/Customs (A/C) for governing the goods flow based on (inter)national laws and regulations. There is a variety of authorities, each with their own specific requirements on information exchange, e.g. customs, inspections, and river police involved in handling vessels in ports and on sea.

Customs broking or Customs brokerage is a profession that involves the "clearing" of goods through customs barriers for importers and exporters (usually businesses). This involves the preparation of documents and/or electronic submissions, the calculation and payment of taxes, duties and excises, and facilitating communication between government authorities and importers and exporters.

Custom brokers may be employed by or affiliated with freight forwarders, independent businesses, or shipping lines, importers, exporters, trade authorities, and customs brokerage firms.

Customs brokers must pass an examination and background check to become licensed by the U.S. Customs and Border Protection. They are not government employees and should not be confused with "customs officers" (in other countries, however, the two terms may be interchangeable). Customs brokers need to be familiar with the tariff schedule, a listing of duty rates for imported items, and the regulations governing is an importations found in 19 CFR, the Code of Federal Regulations Title 19.

To illustrate, a customs broker may need to advise an importer on the marking requirements of the country of origin, or complete paperwork for a clothing shipment subject to quotas and visa requirements. Knowing the requirements of each type of import can avoid costly delays or merchandise seizures.

The customs authorities structure includes:

- the Federal Customs Authority;
- regional customs departments;
- customs offices;
- customs checkpoints.

Data privacy and security is very important in logistics. Logistics data contains commercial relations between organization including agreements and costs and should therefore only be disclosed to authorized organizations and persons. As Logistic Service Providers (LSPs) and carriers are responsible for handling (high value) products of others, they are also liable up to a certain amount.

What data is required by an LSP or carrier for actual value exchange? In case a service provider does not have and does not require data of for instance the actual content of a container but only a broad description (STC: Said To Contain), that provider can only be held liable for loss or damage for a particular amount, e.g. cargo weight.

Who has access to particular (real-time) data, e.g. for collaboration or inspection (to govern security and food safety)? Data visibility is not only required for collaboration amongst organization operating in logistic chains, but also from an authority perspective. Different mechanisms can be implemented, e.g. Role Based Access Control is probably the most well-known and applied in practice. However, in a dynamic environment roles of an organization differ per supply chain configuration.

Access control thus needs to be related to one' s role in a particular supply chain, also with respect to goods flows. Organizations like shippers/consignees, LSPs and carriers basically can have access to data of others if they have agreed as such for collaboration. However, they should only have access to that data of business transactions in which they are service provider and customer, unless granted otherwise (e.g. full supply chain visibility). Authorities should only have access to data of incoming and outgoing cargo flows types of goods (e.g. agricultural goods) in the territory they govern.

Liability and data visibility require identification and possibly other IT security mechanisms like electronic signatures giving proof of data stemming from a particular source.

Logistics is faced with safety and security measurements dealing with terrorism, smuggling, and related security accidents with a high societal impact.

It arises the necessity of the realization of a flexible platform for sustainable and secure data exchange between collaborating global supply chain actors. Such a platform allows shippers, authorities, logistic service providers, and carriers to be fully interoperable across closed communities, to perform paperless logistics, and to adhere to societal demands of security, safety, and sustainability[15][16].

For the realization of the platform, a hybrid solution consisting of central and decentralized systems is possible with a combination of several IT components implemented by one organization or operating on behalf of more than one organization, either owned by these organizations or offered by a commercial service provider as a type of cloud service.

A hybrid solution requires interoperability amongst all IT systems supporting the functionality. This aspect also relates to governance and standardization issues relevant to communities: is there one common semantic model or do we need to have multiple (bilateral) transformations based on standards and models agreed in different communities. Having a hybrid solution implies that also more than one identification mechanism with different types of certificates needs to be supported.

Authorities operating in the government layer within a country will for instance define their identity mechanism that can be used in collaboration with them. Traders can also make particular agreements on the identification mechanisms used. Protocols need to be established for collaboration and business transactions amongst organizations utilizing different identification mechanisms. Having these protocols makes it possible for an organization to use its certificate globally, it will for instance offer a customs authority access to a foreign database to retrieve all required data of incoming and outgoing goods flows in the territory of that authority. The biggest challenge here is to build up international chains of trust.

In transport law, carrier liability determines how much the carrier must pay if the cargo is lost, damaged or delayed during transport. The level of carrier liability (i.e. how much must be paid) is determined by the liability rules which are applied to the contract of carriage for the transport booking. A transport document or waybill is not a contract of carriage. That is, the document itself is not the contract on which the rights and obligations of the parties are based. Rather, it is the evidence that a contract and related contractual regime exists[17].

The terms of the contract and applicable liability regime influence the choice of document used for a given transport and so transport documents are inextricably linked with the issue of liability.

The coloured model addresses this needs, providing already public data, directly accessible on the modular unit. More restricted data may be required and accessed, basing on the roles of the requestor.

All the actors involved in the logistic processes may be tagged with a role, which allows for accessing to the data, which may be colour tagged. In our conception the role may be the follows:

- green role: access granted only to the green data (i.e. systems and operators not involved in the logistic process but only in the handling);
- yellow role: access granted only to green and yellow data (i.e. logistic service provider involved in the transport);
- orange role: access granted to all but red data (i.e. the shipper managing the shipment, the authorities);
- red role: access granted to all data (i.e. original sender and original receiver, enacting the business processes).

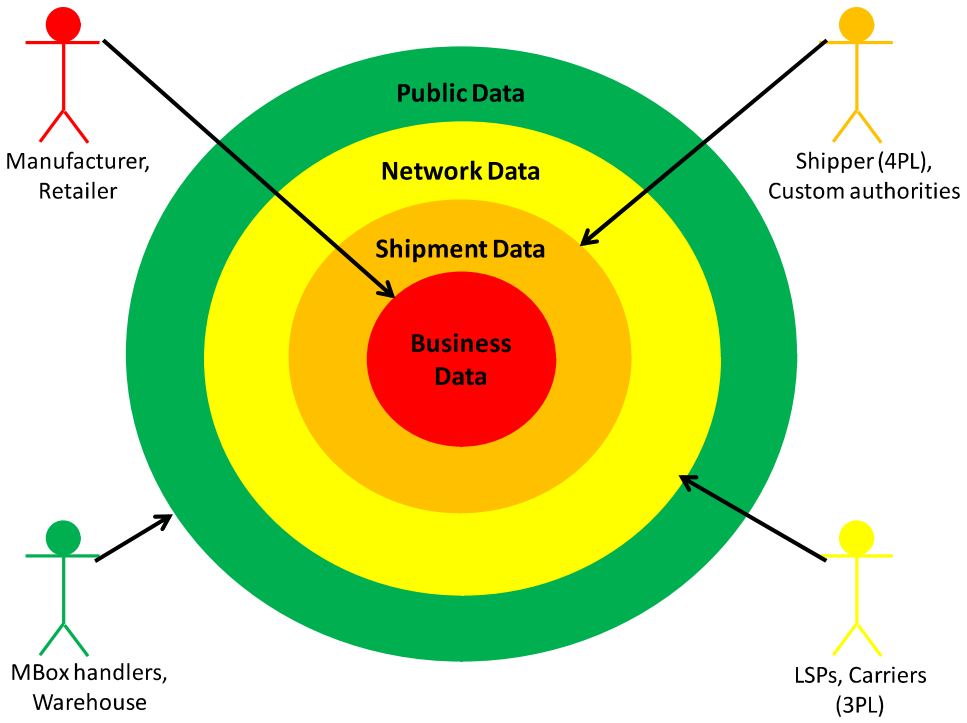


Figure 9. Symbolic exemplification of roles access to data

The above image summarizes the roles involved in the collaborative logistics scenario and the access granted to the different shells of the Moduluscha Common Data Model.

5.3 Asset tracking

Auto-identification is a basic element for implementing efficient positioning, identification and status and authenticity systems in the supply chains. The most important identification techniques for goods are barcode and RFID (Radio Frequency Identification). Barcode is currently the most widely used method, but RFID is better suitable for automated identification since it allows to handle larger reading distances, has the possibility to identify multiple items in a single reading, and can identify the target in motion.

Barcodes are the most popular and widely used identifiers and information carriers in transport and logistics and FMCG sectors. When it comes to logistics, the GS1-128 Data Carrier is the gold standard. GS1-128 barcodes can carry all GS1 ID Keys, as well as variable information like serial numbers, expiration dates, and measures. It is a linear symbology, with the advantage of being more compressed than other linear technologies. GS1-128 cannot be used to identify items crossing a retail point of sale; instead, its main role is in the transport and logistics sector and the healthcare sector. The GS1-128 bar code has taken on considerably greater importance in recent years, owing to the increasing requirements of more stringent product traceability: indeed, a transport label with a GS1-128 barcode on it is the centrepiece of any global standards-based tracking and tracing system.GS1-128 is very flexibly configurable, making it quite adaptable to a wide variety of needs and use cases. It can be read with a variety of commercially available laser scanners.

Unlike the other GS1 symbologies, GS1 DataMatrix is a two-dimensional symbology that allows a wealth of information to be encoded in a very compact space. However, it is not intended to be used at high volume “omni-directional” retail point-of-sale environments like supermarkets, because it is only compatible with applications whose reading systems use camera-based scanners. A particularly noteworthy feature of the GS1 DataMatrix is that it can be used to apply markings directly to products, components, or individual parts. In such cases, the code is etched or laser-engraved directly onto the surface of an item, making it indelible, even under harsh operating conditions. For example, a GS1 DataMatrix engraved in this way can be used in the presence of grease in industrial applications or for items that are exposed to the elements. This makes the GS1 DataMatrix quite suitable for applications whose conditions do not allow for the use of conventional barcodes.

RFID stands for radio frequency identification. It is an automatic identification technology whereby digital data encoded in an RFID tag or “smart label” is captured by a reader using radio waves. Put simply, RFID is similar to bar code technology but uses radio waves to capture data from tags, rather than optically scanning the bar codes on a label. RFID does not require the tag or label to be seen to read its stored data - that's one of the key characteristics of an RFID system. RFID works via a microchip, which stores the relevant data (including the EPC) and reflects the data to a reader-antenna by means of electromagnetic waves. Since these waves can pass through solid materials, the chips may be shielded by adhesive film or integrated directly inside the packaging or product.

RFID systems consist essentially of two parts: a transceiver and tags.

Using well-known expressions of telecommunications does not reflect the full nature of the functional technical components of RFID systems. Used transceivers do not have only the ability to read information from tags, but also to save them. Additionally, the recent trend has also appeared significant enrichment are used in the firmware, which is more and more additional functions (built-in components EPCglobal Network, etc.).

From the viewpoint of logistics and storage, the most important are the following frequency bands:

HF (typically 13.56 MHz) used by systems of public transport ticketing, banking cards, transportation, etc.

UHF propagation systems - 865-870 MHz (in Europe) - mainly used for automatic identification processes in the production, storage and distribution of fast-moving goods.

Russian Dolls approach

To optimally fill a container or loading space, packaging must meet certain size and shape requirements. When one opens a container or loading space, one is often reminded of a matrioshka - the colourfully painted Russian dolls shaped like an egg. More and more packaging comes to light, and this packaging may then contain progressively smaller packaging. Frequently, several layers of packaging have to be opened before the actual good appears. The concept of modular packing here ensures economical use of capacity.

In the physical internet approach, there is the idea of using multiple modular containers of growing size, to provide increasing encapsulation of the goods. For example a hierarchy of containers, of increasing dimensions, has been proposed by PI researchers:

- P-container: the packaging container for encapsulating goods;
- H-container: the so called modular unit for modular logistics, object of the Modulushca project;
- T-Container: the transport container, which represent the maximum level of encapsulation.

The encapsulation is exploited, together with the structured network, for enabling: routing, T&T, reverse logistics and so on. Modular units, in fact, are loaded in a carrier, managed in the IT systems as a dynamic aggregation of modular units, and then go to another node in the structured network. When the carrier arrives in the destination node, the load of the carrier, the dynamic aggregation of units, is tracked in the new location and routing, planning and error tracking procedures are executed.

6 Processes in interconnected logistics

The processes are structured by characterization layers of logistics processes, grouped in terms of levels of information and interaction: the complexity level of information increases as you move up in the hierarchy of levels (from the physical layer to the business layer), inversely to what happens to the level of details, which are more related to the physical world objects, descending in the layers. The considered layers are:

- Business layer;
- Logistic layer;
- Transport layer;
- Physical Layer.

In our analysis we consider that logistics (the first two layers) is involved with the value of moving the product, so considering the who, the what, the where and when of the consignment. On the other hand, the last two layer are involved with the handling of the units and the managing of the assets (carriers, warehouses, etc.).

Following description, synthesizes the layer starting from the more abstract one and descending in the hierarchy.

Business Layer is the topmost one, which handles business data and logic to perform business functions, when a purchase order is issued. The business processes are driven by the Retailer (or a supplier, or a 3rd party warehouse) issues of a purchase order. The Business process, driven by an order, is the higher layer process, involving manufacturer, defining one or more shipments, and is related to business data (invoicing, payment, etc.).

The second layer is the Logistics Layer that handles shipment data. Shipment involves the realization of one or more consignments from a Consignor (source) to a Consignee (sink) with related activities (planning, booking, monitoring, etc.)

The Shipper or the Consignor sends a shipment to the Consignee, through a freight forwarder and a Logistic Services Provider (LSP).

These role and their interaction are considered regarding Freightwise Common Framework [1].

Logistic Demand is the domain of the following roles:

- Consignor;
- Consignee;
- Logistics Services Client (LSC).

The domain deals with all activities defining the need for transport and identifying the appropriate services (in industrial transport mostly based on pre-existing agreements).

Where there exists an order between Consignor and Consignee, information about the need for transport may be extracted from the order.

Logistic Supply is the domain of Logistics Service Providers (LSP) and may be divided into the following three sub-domains:

- Commercial Operations Management deals with handling all interactions with Logistics Services Clients. In performing these activities there is close interaction with following sub-domains.
- Transport Operations Management makes sure that all transport and logistics operations agreed with Logistics Services Clients are being performed as agreed, with the best possible use of resources.
- Vehicle, equipment and cargo operations deals with all operations related to movement of vehicles, operating cargo handling equipment (cranes etc.) and cargo (including load units).

The Transport Layer is the third layer and is responsible for the handling of goods, as they move from Source to Sink, in a consignment.

The Consignment is performed in the physical world by means of logistics activities (pick up, packaging, loading, unloading, stocking, cross-docking, etc.). Every shipment may involve more than one consignment, and every consignment may involve more than one M-Box. In the handling of the data, we consider a one to one relation between a consignment and a M-Box.

Execution of a shipment involves the following main activities:

- Individuation of the routes from the source to the sink;
- Evaluation of the time and cost, considering constraints from the business process;
- Booking the space on the carriers, (this is an optional activity, depending on the approach);
- Loading and unloading;
- Tracking the position and handling errors;

The Physical Layer is the bottom one and its purpose is to collect the “raw” data coming from the M-Boxes, by truck, by the container, the location of the M-Boxes themselves, which will then be used by the upper levels to compose the standard electronic documents. The physical layer handles unit data and the identification of units.

The higher layers (the business layer and the logistics layer) are related to the B2B (Business to Business) processes, while the lower ones (the transport layer and the physical layer) are involved in the S2S (Source to Sink) processes.

Finally, the definition used in the following are related to two events, fundamentals in the processes: the commissioning and decommissioning.

- commissioning: the activity of encapsulating the goods inside the MBoxes, and the following associations of information, in the IT systems, between the boxes, the shipment and so on.
- decommissioning: the termination of the associations between the shipped goods, and the re-usable or shared resources (boxes, containers, etc.).

In the description of the data we considered the following roles.

In the Business Layer two entities or roles are identified: the Manufacturer and the Retailer. The Retailer is a business or person that sells goods to the consumer, as opposed to a wholesaler or supplier, who normally sell their goods to another business actor. A purchase order is issued when the retailer sends the request to the Manufacturer.

In the Logistics Layer for any order that is confirmed, a shipment is issued. The roles involved in a shipment are: the Shipper, the Consignor, the Consignee and the Forwarder. While the Freight Forwarder is a person or corporation who arranges transport of goods on behalf of either the seller or buyer, assuming the legal liabilities of acting as a carrier, the Carrier is a person or company that transports goods for any person or company and that is responsible for any possible loss of the goods during transport. Shipper is the person or company who is usually the supplier or owner of commodities shipped. Also called Consignor. The shipper may also bear the freight cost. The Consignee, is a role related to the place or business entity which defines the final destination of the goods. The processes are related to the activities to be performed, in the following categories. There are a set of hub management activities, for examples some of them are:

Maintenance: processes and activities related to keeping the logistic node operative, which cover not only the physical operation but also the updating of the information related to the connection with other nodes in the network.

Rostering: the processes and activities involved with the availability of the human resources and their roles in order to keep the node operative.

Pull back: the processes and activities aimed at considering the repositioning, handling, assembling and disassembling of the modular units, needed for having them where they are needed and for optimizing the reverse logistics processes.

Hubs and IT system have to collaborate in order to guarantee the assets management processes, examples of which are the following:

Leasing: the shared resources are managed with a pooled approach, so it is possible that they are leased to the participant in the processes, and the related data have to be handled.

Deployment: all the elements of the processes have to be deployed for being in the right place at the right time, in order to be used and to enable the processes enactment.

Accounting: costs and their attribution have to be handled, so the financial interaction between the participants have to be managed.

Hub transfer/storage/buffering: the logistics nodes are involved with loading and unloading of carriers. The boxes have to be handled, through cross-docking operation or they have to be stored. All this aspect have to be integrated between the different actors.

Rescheduling due to delays factors: the delivery operations may be slowed down by errors or malfunctions, the processes have to address this events, allowing rescheduling and updating of the delivery operations.

The logistic process of execution of a shipment involves the following main activities.

The first operations to be performed are those aimed at the individuation of the abstract routes from the source to the sink. Collaboration between it systems' participants is needed in this case. They have to make available and share information about the location, and the addresses. Each node should keep up a register of the local addresses in their area, maintaining it updated and allowing nearby nodes to look up for destination. Identified the original address and the final destination address, the nearest logistics nodes are, respectively, the source and the sink. The virtual consignment, using the M-boxes is handled inside the domain of the structured network. The boxes will be aggregated to define a consignment in the source node, and then will be handled by the logistic network, up to the sink node, where their content will be delivered. In this phase it is important to consider the commissioning and the decommissioning of the boxes. The commissioning have to be performed between the original sender and the source node, and is the activity of filling the boxes and closing them in order to starting the virtual consignment. The decommissioning is the activity to be performed for opening the M-Boxes and delivering the content to the intended receiver. The decommissioning have to be performed between the sink and the final destination. Identification of the source and sink allows for using a collaborative planning approach for defining all the possible routes, between the two nodes. The outcome of this phases is the identification of all the possible abstract routes from the source to the sink.

Next operations to be executed are the evaluation of the time and cost, considering constraints from the business process. The identified routes, obtained by the planning phase, are only defined in terms of potential connection, using the existing links in the structured network, for identifying a path of delivery. The different routes, now, have to be considered from the point of views of the time, the cost, the capability of the nodes and of the participants in the process. All the routes are, then, detailed with this information in order to identify the options compatible with the business process requirements. The outcome of this phase is the set of all the concrete routes, which allows for the consignment to be performed, considering the time and the cost allowed.

The following steps are performed considering the possible concrete routes. The consignment may be performed using only one of the routes or it may be performed using more than one of them. The IT systems of the participants have to collaborate in order to perform the booking of the space on the carriers. This phase may be performed in several different ways. As we will see in the following, the booking may be statically defined in advance or defined just in time.

When the route, or the routes, are defined the delivery processes will start with the commissioning operations. Then the modular units will be handled through activities of loading and unloading, in order to move them between the nodes using the links.

All along the virtual consignment there are the execution of the operation of tracking the position and handling errors. Modular units, considering the PI encapsulation principle, are considered travelling in a carrier. They are tracked while leaving a node, move along a link, and then are detected entering in the other end node. Inside the node the m-Boxes are tracked individually, in order to handle them. Errors in routing are, also, detected and managed through the tracking.

The described processes and activities may be performed in different ways. We may consider, at least, two possibilities: static or dynamic approach. We will describe this approach in the following. We want to make clear the fact that the delivery have to be realized through a collaborative approach between the participants. Each of them provides the resources and the logistics sub-network of the structured network. Collaboration and information exchange are based on the data model defined, but each of the participants continues to use its own IT systems for managing its own activities and assets.

Following images shows representation of a structured network, modelled as a simplified directed graph. This graph is used for the collaborative interaction during the planning phase, in order to define the abstract routes and the concrete routes. It is constructed considering the information available by each nodes, and defining an explicit planning graph.

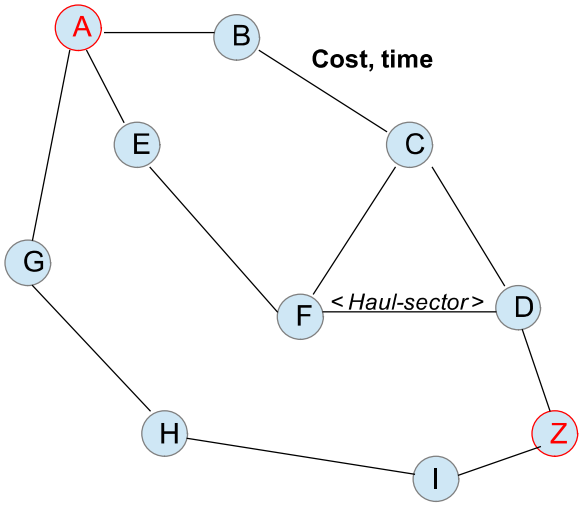


Figure 10. Example of a structured network represented as graph

From the business process the needed shipment or shipments of goods are organized in one or more consignment of MBoxes that have to be planned, scheduled and booked across the structured network considering the collaborative methodology of the common carrier approach.

This means that carriers:

Share the operations related to the shipments, leasing their own resources and assets and share the accounting of the revenues.

The participants uses MBoxes collectively owned (or pooled), and leased for the use by them during the logistics operations.

Are able to provide, in advance, their logistics capability (in term of time windows and cost). This aspects is used for the collaborative planning, the definition of the abstract and concrete routes. Again, each participants manage their own resources and assets, making available only the details needed for the planning, the cost assessment, and the time definition.

The gateway and router logistics nodes (where the goods enter or exit in the structured network domain or where more than one sub-network insist) should have a Node Manager, acting like a broker, which has to collect information from the participants in order to maintain routing tables and the aggregated marketplace offer.

In order to exemplify the ideated approach, we will describe two possible way of handling the delivery of the goods.

In the static approach all the decisions, related to the loading, unloading, routing, and delivery are taken before the starting of the processes, defining time and cost of each step, and planning in advance the operations. Anyway, problems detected during the delivery may be addressed re-planning the remaining part of the delivery. Using a real life metaphor we may consider this kind of consignment as a travel, planned and booked in advance. Time and cost are predefined. Only problems to address are the delays and other adverse events which will require an adaptation of the travel plan, with a possible increase in the cost and of the time of arrival at destination.

Static approach

A hub operates in a collaborative P2P manner, connecting with the its adjacent neighbourhood nodes.

In order to perform a consignment of MBoxes from source (A) to sink (Z), the following procedure have to be executed:

1. Find all the alternative routes from A to Z that allow delivery within the stated criteria or time-window

2. Definition of the time and cost for each alternative and aggregate the line-of-route pricing components S2S

3. Selection of one or more deliveries and booking of the preferred routing

At each hub, T&T and global information about the delivery are used for detecting errors in routing or constraints (time and/or cost) violation.

In the dynamic approach the business process and the related shipments provides the information for handling the routing at global level. Routing is performed individually for each MBox, in each hub, considering the final destination, time and cost restrictions. The network manager still act like a broker and the collaborative effort is performed in each step of the consignment, with local information considering the actual state of the node and links. Using, also, a real time example we may consider this kind of approach like a trip without a predefined travel plan.

Dynamic approach

Each single MBox is routed independently from source to sink.

The MBox are available at node A and the following procedure have to be executed by A and by each further node crossed during shipment:

For each MBox, considering final destination, a "next node" is selected

Time and cost constraints are considered for booking a carrier

MBox is delivered to the "next node"

At each hub, T&T and global information about the delivery are used for detecting errors in routing or constraints (time and/or cost) violation.

The two described approached are totally different between them and defines the two extreme situation. Other approaches may be defined as a mix of the presented two.

7 Reference software architecture for Modulushca

In Modulushca project an effort for defining a reference software architecture is ongoing. Here we summarize the main concepts and ideas. It is worthy to note, however, that this activity is still in execution and have yet to obtain a final result.

However, we would to formulate a proposal, for IT Systems interoperability, which may satisfy what has been analyzed up to now. The objective is to propose a possible architectural solution, which may address considered ideas.

Previous image represents a scenario of logistics processes using the collaborative shipment approach. Interaction as started, as presented in the use cases section, business process is the higher layer of the involved processes. In the case of the FMCG scenario all the operations are driven by a purchase order, involving manufacturer, defining one or more shipments, is related to business data (invoicing, payment, etc.). At this layer interaction is supported by EDIFACT and GSIN standards. In the case of the postal scenario, shipment is related to the postal products that have to be delivered to the final users. Seldom the two scenario are different, as we described, both of them refer to transportation of modular units, from source node to sink node. Inside the modular logistics scenario, where the virtual consignment are performed, the goods, or the postal products, are encapsulated inside the modular units. They are handled with the black box approach, and their delivery is monitored using the russian-dolls (matrioska) approach. Encapsulation uses UUID, used for unique identification of the M-Boxes, useful for both association of unites with their content than for pooling and leasing of the modular units. Other GS1 standards are used for unique identification of the items, locations and processes performed inside the modular logistics domain. The Logistics Service Providers (4PL, 3PL, and carriers) collaborate in planning the delivery and in booking the needed resources. The business process, originated by the order, is then coupled with a logistics processes: the shipment, identified by the GSIN. It involves the realization of one or more consignments from a Consignor (source) to a Consignee (sink) with related activities (planning, booking, monitoring, etc.). This layer is involved

with the network and transport flow of information, uses GINC, UUID and GLN for handling the shipment. We may consider that each single M-Box is managed through a consignment process. The shipment, at global level, is managed by the shipper, the 4PL o 3PL that is responsible of the delivery for the consignor. The shipper is responsible of the creation of the e-Waybill, as we seen in the e-Freight section. Information, about the shipment, are shared through the EAP. The e-waybill is not the only document exchanged, as we seen the Modulushca Common Data Model, also, is used for defining roles and grants in the access to the data, as we discussed previously. Finally the delivery is realized through the transportation operation performed, collaboratively, by the LSPs, which collaborate in creating the common structured network.

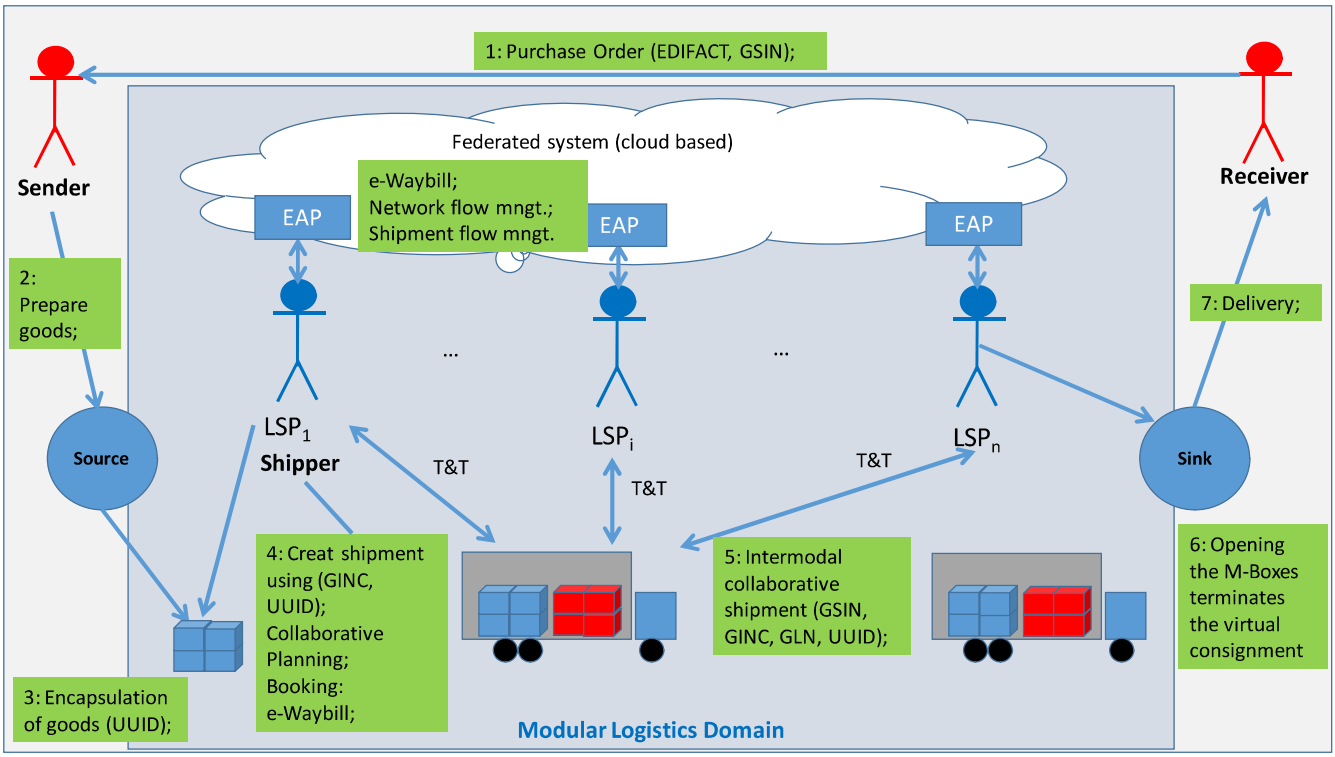


Figure 11. Modular logistics scenario

The following image depicts the proposed organization, of the IT systems, of a LSP who participate in a structured network, for interconnected logistics using modular units, which we may call Modulushca network. The LSP, in a Modulushca network, may be one of: 4PL, 3PL or carrier. The depicted architecture is based on the principles discussed, regarding the interoperability between system, which from the lower level to the upper one are:

- Physical and link layers are supported by the EPCIS system, which enables tracking of the modular units, using RFID (and QR code as needed) and M-Box info, leveraging the UUID for the access to the information in the Modulushca Common Data Model, and the GS1 standard for the unique identification of assets and locations. As explained the EPCIS section (in D4.2) the system may provide horizontal information flows, exchanged between partners, for the T&T activities, and vertical information flows, feeding up events to the above levels.

- Existing IT supporting systems, already available for the LSP, are interconnected using an ESB approach, enabling interoperability inside the boundary of the organization, providing information about, capacity offered, availability of resources, and other information needed for enabling the collaborative planning. The systems, through the ESB, are connected to the EAP (e-Freight Access Point), which supports exchange of information. For the Moduluscha network objectives, it is needed to extend the functionalities of the EAP, in order to provide the access to all the information of the Moduluscha Common Data Model, and not only to the e-waybill. These data have been labelled as the network flow and the shipment flow. Extension of the EAP, means definition of new operation for the interfaces of the component.

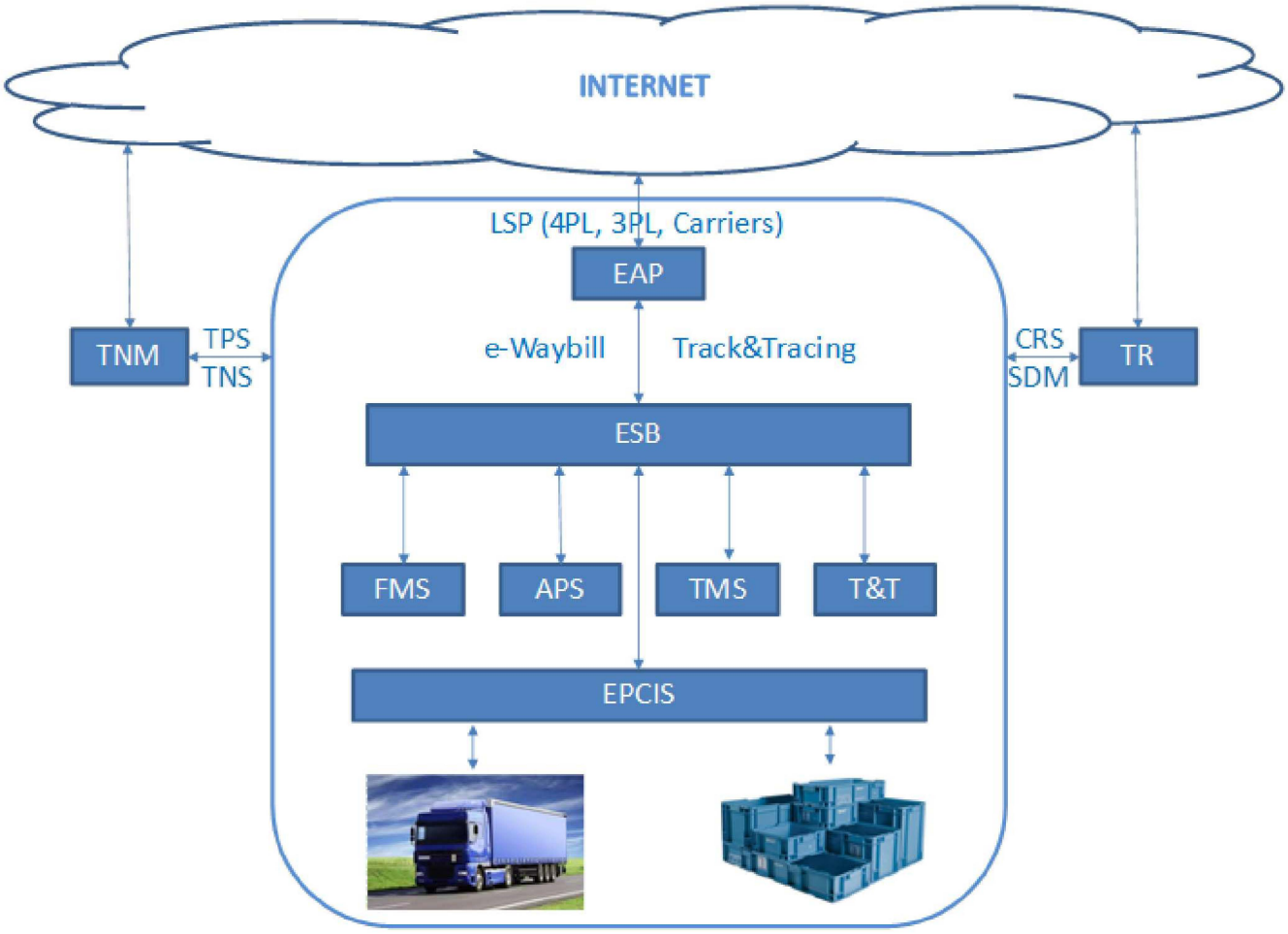


Figure 12. IT Systems of a Logistics Service Provider

Whit this internal organization, the T&T enabled by the EPCIS, the standardization of the identification provided by the GS1 and the interoperability granted by extended e-Freight EAP, the LSP is ready to interoperate with other partners in the Modulushca network. The Global Location Number (GLN) is part of the GS1 systems of standards. It is a simple tool used to identify a location and can identify locations uniquely where required. Location identified with GLN could be a physical location such as a warehouse or a legal entity such as a company or customer or a function that takes place within a legal entity. In the following image it is depicted a scenario with four LSPs, collaborating in a structured

network, with another participant providing warehouse capabilities, and two business partners, in FMCG business processes.

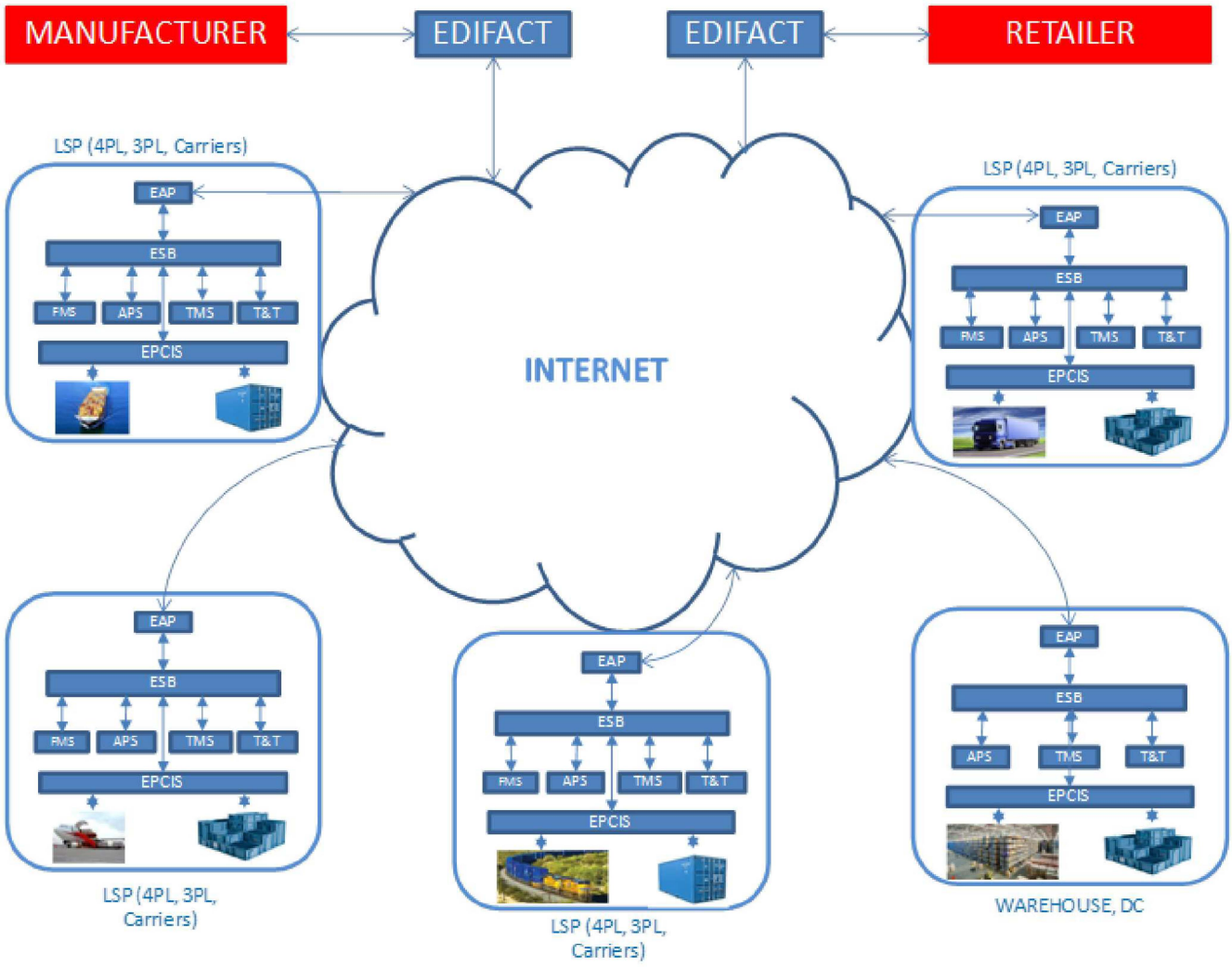


Figure 13. Modulushca distributed systems conceptual architecture

Putting all the pieces together, we may outline a complex structured network. The LSPs interoperate, through the EAP, which communicate between them using the internet. At same time, also the business partners, retailer and manufacturer, interact through the internet. They exchange EDIFACT messages and, as we have seen, the business process drive the logistics processes. The manufacturer, interact with a LSP, which act as the shipper. He could be a 3PL company, which collaborates with other 3PLs and carriers in order to deliver the shipment. He could be a 4PL company, which manages the logistics activities of the manufacturer, coordinating other LSPs (3PL and carriers). The internal architecture, we describe before, is a reference model. The real internal organization is defined by each actor, depending on its own capabilities and needs. Participants in the Modulushca network must comply in:

- using EPCIS, for T&T purposes, for error handling and for reverse logistics management;
- providing an extended EAP interface for exchanging and accessing e-Waybill and other information (network and shipment data, of the Moduluscha Common Data Model), this

enables the federated system approach, with the owner of the information able to control the access to the data;
- participating in collaborative planning and booking, sharing information about capacity offered, time and cost of delivery, constraints, and other information useful for the management of the delivery in a collaborative fashion;
- progressing physical level for correct handling of modular units, managing cross-docking, loading, unloading, pooling and all the other operations needed for exploiting M-Boxes;
- using of the GS1 standards, for identify assets (SSCC), shipment (GSIN), consignment (GINC), location (GLN) and so on, for enabling exchange of information.

Execution of a shipment involves the following main activities:

- Individuation of the routes from the source to the sink;
- Evaluation of the time and cost, considering constraints from the business process;
- Booking the space on the carriers (this is possible but is not a must);
- Loading and unloading;
- Tracking the position and handling errors.

It is possible to perform this activities in different ways. We may consider two possibilities: static or dynamic approach. Really these are the two ends of the possible spectrum of operations. Different variations and combinations may be considered: booking part of the shipment (i.e. regarding movement by train or by ship) and dynamic (on the fly) loading on trucks for the remaining part of the process.

It is important to note an important aspect of the described scenario: what have to be defined are only the interfaces between the systems, exploiting EPCIS and EAP, in order to allow access to the Modulushca Common Data Model, to enable T&T all along the supply chain, and providing the sharing of information for the collaborative approach. Interfaces defines the operations that may be executed between the partners, with the data to be provided (parameters of the operations). The concrete implementation of the systems that provides the concrete component providing the interfaces is responsibility of each participant. Each one of them must have the possibility to continue to use its own IT systems, in order to orchestrate their own processes. The interfaces enable interoperability while the implementations allow for competition.

Furthermore, introduction of semantics in the interface description, using meta-data, may enable automatic reasoning and planning. In this way it is possible to have systems that are able to solve problems, planning solution, handle exception, without the need of a constant human intervention. This may be done considering classic AI approaches, as automated planning, genetic algorithms, and neural network. More complex methodologies may be considered, i.e. proactive distributed agents or autonomic computing approach.

8 Conclusions

The analysis of the related work has discovered interesting convergences, in several projects, of which we summarize here the more relevant. The eFreight project is involved with definition of a European Single Transport Document and an appropriate framework for carriage of goods with all the necessary legislative support. This is realized by mean of a single access point for administrative procedures in all

modes in order to have simple, harmonized border crossings for all modes of transport for EU member States. Furthermore, they aim at simple procedures and the necessary infrastructure to establishing secure and efficient transport lane between Eurasia and USA.

The Physical internet approach is based on three layers of interconnectivity: physical, digital and operational. The interconnectivity is based on the following concepts:

- encapsulation;
- interfaces;
- protocols.

The present document describes an approach for handling the information about modular boxes, in a interconnected logistics scenario. The proposed coloured model has been obtained considering the encapsulation approach, proposed by the Physical Internet and is the base for the definition of interfaces and protocols. The former, in fact, may be defined through a set of operations, usable by the IT systems in order to interoperate one with the other for exchange data as defined in the proposed Modulushca Common Data Model. The latter, is the description of interaction between actors using the defined interfaces and the types proposed in the Modulushca Common Data Model. The proposed model, then, is an important contribution in the direction of defining a model for interoperability of IT Systems. The model has been defined using XML and XSD, in order to be platform independent, extensible and human readable.

Future work, regarding the data model may be the following. Further evolution of the model will be needed in order to address completely the needs of the modular logistics. Another point of interest, in the refinement of the model, could be the introduction of semantic description of the data and operations. An ontology may be developed for the introduction of meta-data and for the semantic annotation of the services. Such approach may allow a high level of interoperability and integration between the systems, because introduce and enable the machine understandable description of services, the automatic service composition.

Another important contribution of the present document is to define how to reach the objective of the Digital Interconnectivity using M-Boxes in existing logistics processes. One feasible way to proceed is to go toward the new approach modifying as less as possible the existing IT systems, adapting them to the new ideas of modular logistics. One possible way to proceed is to consider that the logistic processes and the data managed by the actual IT logistic systems (Postal and FMCG) have to work in the same manner as they work up today with the only difference they have to use M-boxes for their delivery. To meet this objective M-Boxes have to provide to their IT systems the same information, so the existing logistic systems can use the iso-modular boxes without to have to introduce too much relevant changes.

There are some issues that have to be addressed, in future works, related to the structuring of the interconnected network and of the IT systems interoperability. We need to define, in the IT systems, a higher layer for the logistic processes management that uses the underlying levels to deliver the M-Boxes in an interconnected and intermodal way, taking advantage of the modularity.

- Integration of existing IT systems has to be realized introducing connectors and adapters for enabling interoperability between them. Gap is filled working on the "M-Box side" while existing IT system will not be changed
- Definition of a software architecture, based on a layered approach. Each layer deals with a specific problem. Moreover it is possible to consider several protocol expressing different service level
- Definition of the collaboration information to be exchanged by the partners along a modular supply chain, in order to allow tracking, tracing and planning
- GS1 Global Standards for identification of boxes, containers, products, location, etc.
- EPCGlobal initiative for allowing interoperability and information exchange
- UPU Standards is interesting as an example of handling information interchange and forwarding between "abroad" partners and borders crossing
- Tracking of M-Boxes dynamic aggregation in order to simplify the tracking and tracing approach
- The conceptual approach for the Modulushca System is based on the distributed systems approach, considering interoperability supported by the Modulushca Common Data Model (following the CDM approach) and enabled by the e-Freight reference architecture.

Poste Italiane delivery processes already uses grouping of items (letters, and packs), using two "level" of re-usable containers; items are dispatched (common destination items are grouped and handled as a unique item).

FMCG delivery processes works in a similar way to Poste Italiane, TMS Booking Systems performs a regrouping of items with common destination; their IT Systems uses a ESB for interconnecting with other IT Systems, in order to allow interoperability.

This approach may lead to the integration of existing logistic networks, in order to built a structured interconnected network in which the base for the interconnection is the modular unit. Like the digital internet data packets, the modular units are the way of interacting between diverse platform. In the same way, different logistics supporting IT systems may interact one with the other loading, unloading, storing, grouping, ungrouping, tracking and tracing, and so on, the modular units.

Acknowledgments

The research activities, leading to the results presented in this paper, has been executed in the frame of the Modulushca projects [2], which has received funding from the European Union Seventh Framework Programme.

We thanks Dario Biggi (Poste Italiane, Italy) and Peter Cunningham (SKI, UK), for their active contributions, for providing useful and interesting ideas, and for their fruitful activities in the execution of the WP4 tasks.

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Crowdsourcing delivery: New interconnected business models to reinvent delivery

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Abstract: *In the last two years, a new industry is born. Social delivery aims to reinvent delivery by crowdsourcing. Several startups have been founded, with divergent destinies. We examined 18 startups in the industry based on available public documentation. We contribute toward gaining a better understanding of stakeholder value creation in the industry. We introduce a typology of existing business models helping to stress the inherent limitations of the industry. Then, based on the Physical Internet concept, we propose a paradigm change in that nascent industry. Crowdsourced delivery has to become interconnected, beyond point-to-point, embedded in the Physical Internet, as one of the alternative solutions to build the Mobility Web.*

Keywords: *Crowdsourcing, crowdsourced delivery, social delivery, business model, typology, Physical Internet, Mobility Web.*

1 Introduction

Crowdsourcing is a type of participative activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task (adapted from Estellés-Arolas and Gonzalez-Ladron, 2012). As far as transportation is concerned, crowdsourcing is not new. Alternative practices have been around for some time, such as hitchhiking and carpooling. In the goods delivery domain, it has until recently been much less exploited, even though Naredi (2014) reports that a market study by muber.com revealed that 80% of travelers have transported goods for somebody else at least once.

Crowdsourced delivery is an answer to the growing expectations of customers for faster, more personalized and cost efficient delivery service. It exploits technological potential (geolocalization, mobile apps) and the social trend of sharing and collaboration (Rifkin, 2014). For two years, crowdsourced delivery has been bursting. Several start-ups have been launched and some have attracted millions in investment. Currently leading are Posmates and Deliv that have respectively acquired investments totalling more than 22 and 14 million US$ (Lawler, 2014a ; Lawler, 2014b).

Development of e-commerce is a key reason for the situation. From a business perspective, the shipping price is a frequent obstacle to online purchase; and brick-and-mortar stores suffer from the competition of online stores. They search for a way to equal the comfort of shopping from home. From a societal perspective, the number of single parcel deliveries is growing. The required logistics services have environmental impacts (pollution, noise, traffic jam, etc.), which are gaining a growing attention in the public's eye.

Major players are experimenting new delivery services. The same-day delivery is tested by Amazon, Google and eBay. In November 2013, eBay acquired Shutl, a same-day delivery start-up, for its online platform and algorithm (Wohlsen, 2013).

Walmart is running several projects. The Walmart To Go same-day delivery program is a partnership with Fedex. It is currently tested in 25 stores. Walmart is also exploring how in-store customers could deliver packages on their way home to online buyers. Customers who accept to deliver packages would receive a discount on their purchases (Barr and Wohl, 2013).

Walgreens has partnered with TaskRabbit, an online platform for outsourcing simple tasks. Here is how TaskRabbit works. For example a person confined to home is requesting delivery of her medication specifying a preferred time. The task is then published on the Task Rabbit platform and can then be accepted and fulfilled only by a preapproved person. Medication is delivered by the selected person (Cabebe, 2014).

In September 2013, DHL launched the MyWays Platform. It facilitates last-mile deliveries in Stockholm through crowdsourcing. An app allows individuals requiring flexible deliveries to connect with commuters who accept to transport parcels along their daily routes for minimal fee (Post&Parcel, 2013).

For Brick-and-mortar stores crowdsourced delivery is a competitive advantage against online retailers. Start-ups like Deliv, WunWun or Zipments are offering services that enable customers to place orders from home and to be delivered at the hour of their choice. With crowdsourced delivery, local shops can annihilate the ecommerce advantage of buying from home. They are best positioned to marry the tangible experience and immediacy of physical retail with the simplicity of online selling, by offering one-hour or same-day delivery.

Beyond Amazon, eBay and Google, numerous start-ups are launched. They aim to create disruptive business models, based on their low cost structure and the power of the community, in order to propose delivery services that are more efficient and cheaper. "Ship outside the box" as Barnacle, one of the start-ups, is stating. The claimed objective, to reinvent delivery, warrants closer analysis, especially given little scientific literature is available.

This exploratory paper aims at having a better understanding of the crowdsourced delivery industry and at contributing to its evolution. More specifically:

- Understand the benefits of crowdsourced delivery for the stakeholders of the industry.
- Propose a typology of the current business models in the crowdsourced delivery industry.
- Analyze the limitations of the crowdsourced delivery business models and the obstacles to their growth.
- Discuss how interconnected crowdsourced delivery embeds in the Physical Internet, enabling to overcome current limitations and opening avenues of opportunities.

The paper is organized as follows. In section two, we describe our methodology and examine the businesses of the sample. In section three, we analyze the gains for the stakeholders. Then we analyze the components of business models in section four and propose a typology of business models in the industry in section five. We discuss in section six the inherent limitations of the crowdsourced delivery model, and the obstacles to the growth of the businesses of the industry. In section seven, based on the seminal concepts proposed by Montreuil (2011) we will discuss how crowdsourced delivery can be embedded in the Physical Internet, as one of the alternative solutions to build the Mobility Web. Finally, in section eight, we provide conclusive remarks and propose avenues for further research.

2 Methodology

A total of 26 businesses were identified in the online press. Eight (8) were eliminated: 5 were no longer operating (Deliverwithme, Deliverish, Deliver.it, DeliveryCrowd, GoFellow) and one business serviced only Russian speaking clients (Carryandcash). For the latter, the language proved to be an issue. Our final sample counts 18 businesses: Barnacle, Bistip, Deliv, Easybring, Friendshippr, Instacart, Kanga, mmMule, Muber, Parcelgogo, PiggyBee, Postmates, Rideship, Shutl, Stuff2Send, TaskRabbit, WunWun, Zipments. Table 1 provides some key facts and figures about the businesses in the sample.

Table 1 – Facts and figures about companies in the sample

Barnacle "Ship outside the box" United-States	gobarnacle.com ATR*: 980,222	Founded in April 2013 Over 5000 drivers
Bistip "Gat anything from everywhere" Indonesia	bistip.com ATR*: 606,911	Founded in March 2011 9688 routes Most active trip route: Singapore-Jakarta Transactions value: $180, 293,
Deliv "Delivery. Shortened" United-States	deliv.co ATR*: 398,705	Founded in 2012 Raised nearly US$12,4 million since 2012 Partnered with four mall operators (running 660 centers across the US)
Easybring "Every movement" Norway	easybring.com ATR*: 412,901	Founded in 2011 15,000 people have signed up to its website in Norway 14,000 delivery requests a year Plan to launch in Sweden and in the UK
Friendshippr "Your friends will get it" United-States, operations in Dubai and UAE	friendshippr.com ATR*:1,631,426	Founded in 2013 Received $670,000 from angel investors in Dubai
Instacart "The best way to shop for groceries" United-States	instacart.com ATR*: 24,296	Founded in 2012 Operates in 10 US cities. Plan to be in 17 by the yearend. 50 fulltime employees 1000 independent shoppers (couriers)
Kanga "Together, we deliver" Atlanta	getkanga.com ATR*: 1,009,554	Founded in March 2014 Raised $1 million in Seed funding
mmMule "Get anything you want, from anywhere in the world by	mmmule.com ATR*: 984,407	Founded in 2010 Not-For-Pofit organization

rewarding a traveller for delivering it" Australia		
Muber "Find anything you want delivered, personnaly" United-States	muber.com ATR*: 828,574	Founded in April 2013
ParcelGoGo "We do deliveries within the Harare area" Zimbabwe	parcelgogo.com ATR*: 5,343,340	Founded in 2014
PiggyBee "Eco-friendly shipping by travelers" Belgium	piggybee.com ATR*: 935,547	Founded in April 2012 1,200 active users 25,000 fans on Facebook Available in 9 languages
Postmates "Everyone's favourite delivery service" United-States	postmates.com ATR*: 87,153	Founded in 2011 Total funding is $22 milllion Operating in New-York, San Francisco, Washington, Chicago and Seattle Postmates' mission is to become the on-demand delivery infrastructure for every major city in the world 20,000 restaurants on the platform
Rideship "Get a ride, give a ride, for your packages, pets, even yourself"	rideship.com ATR*: 3,855,786	Founded in 2012
Shutl United Kingdom	shutl.com ATR*: 279,979	Founded in 2008 Launched in the US in February 2013 Acquired by eBay in October 2013
Stuff2Send "A smarter way to send. Delivered." United Kingdom	stuff2send ATR*: 5,545,871	Founded in 2009 6281 carriers
Deliver Now – TaskRabbit United States	taskrabbit.com/deliver-now ATR*: 15,149	Launched in 2012 Partnership with Walgreens 9307 delivery tasks in SF Bay Area
WunWun "On-Demand Delivery from Every Place in Your City" United States	wunwun.com ATR*: 432,774	Founded in November 2012 Operates in Manhattan and Brooklyn
Zipments "Deliver your way" United-States	zipments.com ATR*: 489,737	Launched in May 2011 Operates in New York, San Francisco, Seattle Now serving Vancouver 200 delivery boys in SF, 35 in Seattle, 50 in NY

* ATR: Alexa Traffic Ranking is a valid rough estimate of a site popularity (Bakeri, 2012)

We used a four-step methodology:

1. Data collection is based on an extensive public document review including articles, companies' websites, blogs, YouTube videos, etc.
2. Description of the business models is based on the collected information. A comparative table enabled the identification of patterns within the business model.

3. Proposition of a typology of business models is based on the identified patterns.
4. Comparison with literature on the Physical Internet in order to assess and position the crowdsourced delivery concept and conclusion.

3 Gains of crowdsourced delivery for stakeholders

We here examine the gains offered by crowdsourced delivery to customers, retailers and society at large.

3.1 Gains for the customers

Crowdsourced delivery promises four benefits to the customer.

Speed.

As Deliv states with its slogan "Delivery. Shortened", speed of delivery is a central feature of the promise. Intra-urban one-hour delivery service is offered by the most promising start-ups (Deliv, Kenga, TaskRabbit, WunWun,, Zipments, etc.).

The processes of traditional companies in the parcel logistics industry like FedEx or DHL, propose only one delivery tour per day. In the crowdsourced delivery model, the intra-urban or interurban delivery is immediate if a carrier is available. The power of crowdsourcing is supposed to create a huge pool of carriers. The claim is that the probability to have one available carrier within a short delay is very high.

Personalization.

In crowdsourced delivery, each parcel is managed individually. A high level of personalization is made possible regarding time schedules, management of unexpected situations. In most companies, carrier and customer can contact one another in order to adjust the delivery process. For example, they can agree on giving the parcel to the neighbour, or on rescheduling, especially when a customer needs to leave in a hurry. In crowdsourced delivery, convenience is the key factor.

As Barnacle explains, "*Our drivers will work with you to arrange a delivery schedule and provide special care for your transportation needs* » (gobarnacle.com).

Access to new products

Crowdsourced delivery provides access to products that were not accessible before in the following cases:

- When the seller (retailer or restaurant) is not selling online or has no delivery service.
- When products are sold in foreign places and are not available for sale online. This niche is occupied by mmmule, muber and Piggybee. Muber explains: "*Ever wanted an item not locally available? Or probably you could not buy it because of expensive shipping costs? Post your request online and find your personal courier to buy and deliver it for you at affordable prices*" (muber.com).
- When delivered goods are unique, oversized or fragile and not accepted by traditional courier companies. Rideship.com promises: "Get a ride for your packages, pets, even yourself". The

following emotional story demonstrates the power of crowdsourced delivery. A family located on the west coast fell in love with a dog living in a shelter on the east coast. Yet pet transport services, costing in some cases more than two thousand dollars, seemed a definitive obstacle, until the family tried Rideship. The request was posted on the website and a trucker, traversing the United States, proposed to transport the dog for just US$300. A week later the family met the trucker and the dog at a highway service area near their home (Blachman, 2013).

Price.

Low prices are a selling point. Rideship questions: "*Need to ship a package pronto but want to avoid those outrageous "express" and "priority" costs?*" (rideship.com/pages/about).

Same day shipping is proposed by the crowdsourced delivery companies for the same price as standard shipping. Deliv.com announces on the homepage of its website: "*If you're offered same-day delivery for the price of 3-5 day shipping, you'd be delighted. Obviously*" Zipments compared prices for a 10-lbs parcel delivery. The price was 79,17 US$ for a next-day service with UPS, US$8,99 for UPSGround service (3-5 days), and US$ 2,99 for US Postal mail service (3-12 days), versus 9 US$ for a same-day delivery with Zipments.

Intra-urban deliveries typically start between 3,99 US$ and 10 US$ with incremental charges for rush service, larger/heavier loads, and longer distances to travel. Additional fees are applied. Postmates adds a 9% service fee to the purchase price of the items. Also, financial fees are added when an escrow service is used.

WunWun has a different business model. The delivery is free for purchases over 10 US$. The company makes money through prices negotiated with stores. When the order does not involve a store — for example, picking-up food from a restaurant, having someone picked up from the airport for you, or having someone pickup your dry cleaning - there is a 20 US$ fee.

A survey by BCG (2013) provides a better understanding of the relative influence of the four points (speed, personalization, access to new products and price). It shows that free delivery, lower prices, free returns, faster delivery options and opportunity to specify delivery windows are more important to surveyed consumers than same-day delivery. Same-day delivery may be a niche market, yet most promising start-ups target this niche and therefore jeopardize their success for the future. To succeed, the crowdsourced delivery business model needs to reach a critical mass. It requires lots of carriers to insure a fast service and lots of customers to feed the carriers.

What remains to be determined is whether the niche is large enough to reach critical mass. Things may change. The affluent Millennials are consumers aged 18 to 34 with household incomes exceeding US$150,000. These consumers are accustomed to immediate access: 56% are more likely to purchase same-day delivery than the average online consumer.

3.2 Gains for retailers

Online retailers can lower the delivery costs, which are a frequent obstacle to online purchase. For example, M. LaFrance, vice-president of logistics and supply chain solutions at 1800flowers.com, New York, explains: "*Deliv's crowdsourced model allows for more driver flexibility and increased package densities from other retailers which will drive down the company's costs*" (Saettler, 2014).

Click-and-mortar retailers can better compete with online retailers, and widen their markets. For example, leading mall owners have signed on with Deliv in order to provide same-day delivery for customers who order online or purchase in store. This offer opens the door to a disruptive business model innovation within the retail industry. As an industry expert states: "*The idea of using your stores not only as a showroom or a retail center, but also as a mini distribution center, is somewhat new to the business*" (Borchersen-Keto, 2014).

Businesses can also reduce their operating costs by using crowdsourced delivery. For example Barnacle is targeting start-ups and small businesses that "*prefer Barnacle drivers for their reliability and flexibility*" (gobarnacle.com). mmMule.com is targeting NGOs: "*Become an AngelMule and use part of your travels to deliver stuff to an organization in need*".

Click-and-mortar retailers can also reduce the need to stock balance inventory amongst retail stores by using distant open distribution centers located at the periphery of towns or partnering with other stores (Tompkins and Loftis, 2014)

3.3 Gains for society

Crowdsourced delivery is supposed to minimize the environmental footprint and the traffic jam in cities. The number of cars is supposed to be reduced because the crowdsourcing principle is based on the utilization of "drivers already en route" (gobarnacle.com) and because the companies promote alternative transportation methods like bicycles or public transportation systems.

Two nuances have to be considered.

Firstly, the most promising start-ups are relying primarily on professional couriers or people who are dedicated to delivery, and not commuters or occasional travelers. For example, 95% of Zipments's couriers are professionals.

Secondly, crowdsourced delivery manages parcels individually, while companies like UPS or FedEx are aggregating parcels.

Crowdsourced delivery contributes to creating wealth. It allows already-on-the-road commuters or travelers to generate opportunistic complementary revenues that help cover the costs of the journey. RideShip: "*maybe you're already taking a trip and would like to pocket some gas money by delivering someone's cell phone to their house or hooking their 1972 Ford up to your trailer*" (rideship.com/pages/about).

As well, it offers an opportunity for people who want to dedicate themselves to delivery, to create their own flexible job. The customized working schedule is a key benefit. As Instacart explains, "*You'll only work during times that work for you! Just set your availability each week for days and times that fit your own lifestyle*" (instacart.com/shoppers).

4 Start-up business model components in crowdsourced delivery industry

Amit and Zott (2011) define a business model as: "a new unit of analysis, offering a systemic perspective on how to "do business," encompassing boundary-spanning activities (performed by a focal firm or others), and focusing on value creation as well as on value capture (Amit and Zott, 2011).

The tetrahedral business model framework (Caisse and Montreuil, 2004) is used here to guide the exploration of the crowdsourced delivery industry start-ups. It is composed of four interdependent poles. Character is the essence of the business: its credo, mission, vision, values, etc. Stakeholders are the actors affected by the business (clients, employees, investors, suppliers, partners, etc.). Offers are the value proposition made to the different stakeholders (e.g.: products, services, shares, careers, etc.), Creation is the way the business operates. In the framework, all poles are linked pairwise by dyads and interlinked pole triads form faces of the tetrahedron. Each dyad and face has a purpose and subject to design and analysis as the poles.

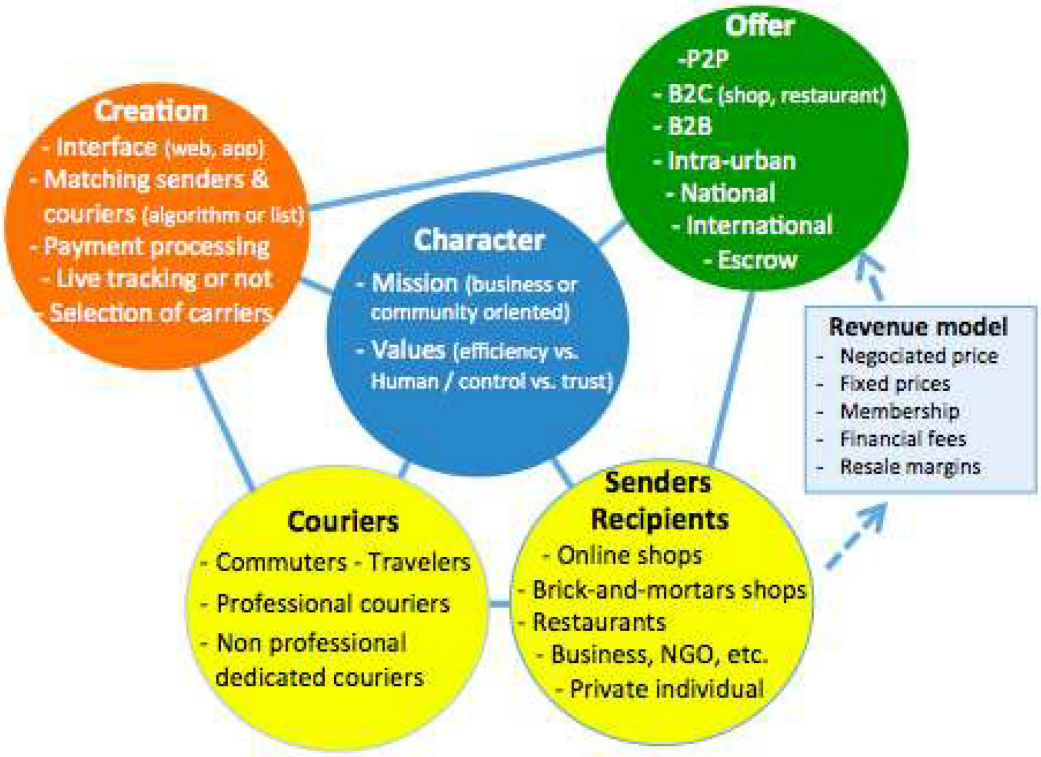


Figure 1: Components of business models in the crowdsourced delivery industry

In this paper, the business model components to be considered in the crowdsourced delivery industry are presented in Figure 1.

- Character pole
  - Are the organization's mission and values business or community oriented?
- Offer pole
  - What types of services are offered?
- Stakeholder pole
  - Who are the senders, who are the recipients, who are the couriers?
- Creation pole
  - How do the businesses operate?
  - How do they interface with the customer?
- Exchange dyad, with focus on the revenue model
  - How do customers pay for the offer?

4.1 Offer Pole

The B2C (Business to Customers) market is apparently the most promising segment today. Two situations are possible:

- The customer places an order by phone or on the web site of a retailer, a pharmacy, a restaurant, a dry-cleaner, etc. Crowdsourced delivery is an option in the online checkout process. If chosen, a task is created and managed by the crowdsourced delivery company. The strategic objective for the latter is to develop partnerships with retailers in order to generate continuous flow of tasks. For example, Deliv has signed partnerships with Foot Locker, L'Occitane, Sony, and others (https://deliv.co/pages/stores). Walgreens has partnered with Task Rabbit.
- The customer places an order on the website or on the app of the crowdsourced delivery company. He indicates the retailers on the website where the products are available. A task is created. The courier visits the stores, finds the requested items and delivers them. Instacart is specialised in this service to the point where couriers are named "personal shoppers", "*smart, friendly people who enjoy shopping for groceries, meeting others, and exploring their city"* (instacart.com/shoppers).

Other companies are targeting the P2P (Peer to Peer) market. They aim at matching people who want to send packages with people who accept to go there (dedicated carriers) or are already going there (commuters or travelers). The sender details the type of package, its dimensions, the address of pick-up and delivery specifications (addresses, time schedule, etc.). A carrier executes the task.

Crowdsourced delivery can be used by businesses, when they have to send something to a client, a partner, or else. We name it B2B. Some crowdsourced delivery companies like Barnacle or mmMule are specifically targeting this niche.

Several companies are offering escrow services in order to secure payments.

Crowdsourced delivery is offered at three geographical scales.

- Intra-urban services are the most frequent. Companies offer delivery services inside big cities where the B2C demand is the highest.
- Interurban services rely on travelers from town to town.
- Global services rely on travelers in order to connect locals who want stuff with travelers who can buy and deliver it.

4.2 Creation pole

The process is globally the same over the nascent industry.

- One customer describes a delivery to be made.
- A task is created on the platform of the crowdsourced delivery company.
- Sender and courier are matched.
- A price is fixed.
- Task is managed by the courier.
- Courier, sender and recipient can contact each others if needed.
- Recipient and sender rate the courier.

Many variations can be observed at every stage of the process. The objective of this paper is not to detail the operational aspects of crowdsourced delivery. We rather focus on key differences that are structural in business models:

- Interfaces are different. Some companies are using only websites, others, younger and more fortunate, have developed mobile applications. Some use both technologies. Mobile apps permit to use geolocation.
- Matching of tasks and courier can be automated (using an algorithm that optimizes the execution). Or, in a low-tech process, carriers and senders can register on the website. The requester chooses within a list the carrier or the task that better suit his needs.
- Some companies offer online tracking of parcels, others do not.

4.3 Exchange dyad: Revenue models

Five revenue models are present in the sample. Some company combine two of them.

Fixed price

In intra-urban B2C, P2P or B2B delivery requests can be standardized. A fixed price is possible. Base price currently vary depending on the companies from US$3,99 to US$10. Additional charges also vary. Depending of companies, incremental charges apply:

- for rush service,
- for larger or heavier loads that need larger vehicles,
- for longer distances,
- according to the time of day or day of week,
- when the courier has to wait at either the point of collection or the point of delivery without prior instructions,
- when the address changes,
- when the courier is required to do additional duties above et and beyond delivery to the door.

The company keeps a commission on every payment for a completed task.

Negociated prices

When requests are customized, in particular in interurban delivery, price is not fixed, but results from a negotiation between senders and couriers. In general, senders set a target price, couriers bid and the final price is negotiated.

Zipments charges fixed prices, but it uses the bidding approach for more unusual or custom requests. The sender is routed to the delivery marketplace where price is negotiated.

As to TaskRabbit, like any other task on the platform, the workers, or "Rabbits," make bids on deliveries.

The company keeps a commission on every payment for a completed task. At TaskRabbit, the fee is 20%.

Financial and matching fees

Companies act as escrow in order to ensure safety and assurance in two situations: when prices are negotiated between requester and courier (Bernacle, Bistip, Kanga, Muber, Rideship), and in international delivery (mmMule, Muber, PiggyBee).

Indeed the revenue model of international crowdsourced delivery companies is very fragile. Service is free. The requested is committed to reimburse the carrier who bought the order, and to reward him. mmMule lists ten types of rewards: food or drinks, local experiences, local tips and info, accommodation, language lessons, cash rewards, free equipment use, travel discounts, eternal gratitude and other (mmmule.com/wants#). In this business model, social values are central. As muber.com enthusiastically claims "*say hello to a meaningful, social buying experience delivered personally to you by just rewarding a friendly traveler*" (muber.com). Receiving fees from being an escrow is the only source of revenue for these companies.

The escrow process is as follows: "*Payments are made at the time of reservation and held in escrow. The company will disburse payment to the driver's account upon delivery confirmation*" (gobarncacle.com). The courier receives net payment, after processing fees and financial fees have been deducted. RideShip's commission is 10%. Easybring charges what they have entitled a matching fee of 15%.

Resale margin

In the case of B2C delivery, some companies make money by marking up negotiated retailer prices. Markups vary on a store-by-store basis. Every order delivered earns the carrier a commission. The amount of the commission is based on many factors, including the number of items ordered by the customer. Some customers choose to tip too, and Personal Shoppers receive 100% of tips from customers on top of their commissions.

Instacart combines resale margin and fixed prices for delivery.

The most original and surprising revenue model is WunWun's. The company offers delivery from stores for free. Wunwun founder, Lee Hnetinka unveils the revenue model: "*While users are able to specify particular brands or stores that they want products from, many users do not particularly care where their tea or coffee comes from. For that, WunWun has an option called "Pick for me". WunWun has partnered with numerous retailers, and directs these purchases to them. The retailers enjoy the added business, and WunWun gets a cut.*" To prevent loss of revenues if users do specify a non-partner retailer, WunWun has partnered on both the retail and the product side. The company can nudge the users towards its partners on the product side. For example, should the customer request a "cereal". The algorithm detects the keyword and suggests the user buys a particular brand. The suggestion can be considered as a highly targeted advertisement (Porges, 2013).

Membership.

The only company in the sample that uses membership as a revenue stream is Instacart. With Instacart Express, for US$99 / year, all the "in the next two hours" scheduled grocery deliveries over $35 are free.

Kanga is envisaging to develop new revenue streams like premium subscription services, value-added services, and perhaps even promotional placements for local businesses (Start-Up beat, 2014).

4.4 Stakeholder pole: Couriers

Couriers are a key resource in the business model. Their number varies depending on the company. There is however a direct correlation. The greater number of couriers, the greater the impact on crowdsourcing.

There are three types of couriers.

- Commuters or travelers are opportunist couriers, who decide to take care of a delivery task in order to reduce their costs or make their journey profitable. Those are mobilized in interurban or international delivery.
- Non-professional dedicated couriers are individuals who decide to accept some tasks. They can self-determine their schedule. For some of them, it is a part-time job in order to complement their main activity. For others, delivery has become their main source of revenues. Those are concerned by intra-urban delivery.
- Professional couriers find complementary revenues in partnering with crowdsourced delivery companies.

The types of couriers that companies are working with vary. 95% of Zipments's couriers are professional delivery people with more than four years of professional delivery experience on average. By contrast, both Deliv and RideShip work with more "lifestyle" drivers, such as graduate students, real estate agents or freelancers looking for extra income (Drake, 2013).

4.5 Character pole

Business philosophies vary widely from company to company, as illustrated in Table 2. Motivational and economic factors can be traced on a continuum illustrating that organizations can offer a more business orientation or a community orientation. The former delivery models are business oriented. Market share, profitability, Return on Investment and so forth are essential means of measurements. The Community model, illustrated by the newer players, is deeply rooted in the collaborative economy. Such players aim at being useful for their community. As mmMule explains: "*mmMule allows you to connect with likeminded people in order to get anything you want from anywhere in the world or to experience authentic, local travel experiences, not to mention make awesome new friends from around the globe*."

Table 2: Difference between business oriented and community oriented business models

Business oriented	Community oriented
Efficiency	Human touch
Control	Trust
"*Time is money. We give you something priceless: time. Delivery fees start at $5. An hour of your time is worth way more than that*." (Postmates)	"*Say goodbye to expensive shipping costs; say hello to a meaningful, social buying experience delivered personally to you by just rewarding a friendly traveler."* (Muber)
	"*mmMule is a social travel network connecting locals who want stuff with travelers who can deliver it. In return for delivery travelers are rewarded with fun, local travel experiences".* (mmMule)

5 A typology of business models in the crowdsourced delivery industry

Comparison of the business models components of the companies in the sample reveals some patterns. We identified five types of business models in the crowdsourced delivery industry as illustrated in table 3.

Table 3: Typology of business models in the crowdsourced delivery industry

Name	Clients	Offer	Character	Couriers	Revenue model
Courier	B2C	Deliver an order from a shop, a restaurant, a pharmacy, etc. Intra-urban	Business Efficiency Control	Professional or non-professional dedicated couriers	Fixed prices
Intendant	B2C	An order is placed on the cie's website. It is the courier who purchases the article from a shop and delivers the article to the customer Intra-urban	Business Efficiency Control	Professional or non-professional dedicated couriers	Fixed prices Resale margins Financial fees
Intra-urban	P2P or B2B	Deliver a parcel Intra-urban	Business Efficiency Control	Professional or non-professional dedicated couriers Commuters	Fixed prices
National	P2P or B2B	Deliver a parcel Inter-urban / National	Business Human Trust	Travelers	Negociated prices Financial fees
Social delivery	P2P or B2B network	An order is placed on the business website. The courier proceeds to purchase, then to delivery National / International	Community Human Trust	Travelers	Reward Barter Financial fees

6 Obstacles to the development of crowdsourced delivery

Crowdsourced delivery is facing several issues in ensuring its development. Two are crucial in determining the adhesion of customers to the concept of crowdsourced delivery: trust and service quality.

6.1 Trust

Trust building is a key success factor in every crowdsourced process. In the crowdsourced develivery process, the question is bidirectional:

- How to create trust in the sender mind?
    - Indeed with crowdsourced delivery, a requester entrusts his parcels to an individual, more than to a company with anonymous employees like FedEx, DHL or UPS.
- How to protect couriers from hazardous or illegal substances, products?

Start-ups have explored different ways to reinforce trust between requesters and couriers.

- The most business-oriented companies have implemented rigorous selection processes for couriers. At Deliv an aspirant has to fill a questionnaire, complete in person or Skype interview, submit a copy of his licence and vehicle registration, complete a secure background check, and finally complete a short orientation program. 95% of Zipments's couriers are professional delivery people. For those servicing the national and social delivery networks, the selection process is absent. Profiling couriers is impossible. Couriers are opportunist travelers.
- Most of companies have implemented feedback systems in order to evaluate couriers in the form of a star rating and comments. Rideship explains: "*RideShip relies on user feedback to make sure our community stays populated with conscientious and reliable folks!"* (rideship.com/pages/about/). Based on the track record of every courier, a ratings system enables Deliv to give priority to the highest-ranked delivery people (Lawler, 2013).
- Couriers have personal pages or spaces on the companies' websites. This permits requesters to investigate if needed. Pages on Zipments's website are very complete with pictures, number of deliveries and rating, seniority, short presentation, etc. Muber and Barnacle uses Facebook pages. When connecting as a requester or a sender on Barnacle's website, the "Log-In with Facebook window" appears with the following text: "*To establish trust in the community, we require that drivers sign up using their Facebook accounts*". Muber states: "*We all want to know how much degree of separation we are from our peers. Through integrating with the major FB, we let you know how much close your social circle with each other"*. (muber.com/safety)
- Companies are encouraging direct contacts between requesters and couriers through telephone and email. Muber has implemented its own secure messaging system.
- National and social delivery networks business models integrate secure online payment systems. As Muber explains: "*Requesters pay through our secure online payment system. Travelers receive payment through Muber as soon as the requester receives the item. No worries on the transactions, no awkward moment. We take care of that"*. (https://muber.com/safety)

- Several companies have insurances. For example, Zipments self-insures this risk up to $250, but the firm encourages its couriers to buy additional coverage for higher-value packages.

6.2 The question of critical mass: the chicken-and-egg problem

The power of crowdsourced delivery is based on the network effect. A critical mass of couriers is needed to insure fast, flexible and cheaper delivery, and to attract customers. But a critical mass of customers is needed to attract couriers. Crowdsourced business models are less easily capable of solving the chicken-and-egg problem than traditional business models. The latter can internalize resources (for example a team of couriers) to start the wheel. Whereas crowdsourced business models need to convince both requesters and couriers. Even the major actors are having trouble. USPS suspended one pilot same-day delivery program called Metro Post due to a lack of participation from retailers. As another evidence, eBay downplayed in February the company's same-day delivery service eBay Now (Steiner, 2014).

Start-ups in the crowdsourced delivery industry are adopting different strategies to create the network effect. Courier, Intendant and Intra-urban business models focus only on big cities to access to a large volume of potential customers.

Several companies partner with high-volume retailers who see the potential of crowdsourced delivery. For example Walgreens with TaskRabbit, Deliv with four of America's largest mall operators who manage over 660 malls including thousands of retailers across the country, or mmMule with NGO.

7 Crowdsourced Delivery and the Physical Internet

The crowdsourced delivery business model, as it is now, has two main limitations:

(1) It only supports point-to-point deliveries.

- This creates a less flexible delivery network, in particular for inter-urban delivery. Indeed, crowdsourced delivery is only possible if a courier passes by the starting point and the address of destination.

(2) Processing the parcels individually limits the overall positive impact.

If we look at crowdsourced delivery from the conceptual perspective of the Physical Internet, opportunity is huge to overcome these limitations.

“The Physical Internet is a paradigm-breaking vision – inspired by the Digital Internet – that enables organizations to move and deploy physical products seamlessly though logistical networks like data packets move through heterogeneous equipment respecting the TCP/IP protocol of the Digital Internet in a way that is transparent to the user” (Montreuil et al., 2012)

The Physical Internet catalyzes a new era of smart interconnected logistics with order-of-magnitude gains in efficiency and sustainability. It enables the emergence of an open and global Logistics Web spanning four interlaced layers. The first involves seamlessly moving objects encapsulated in standard, smart, modular and designed-for-logistics containers through an open multimodal Mobility Web engaging numerous transport providers and open hub operators. The second allows dynamic encapsulated product deployment and storage in numerous open warehouses and distribution centers across a Distribution Web. The third layer is dedicated to designing and manufacturing objects through a Realization Web. The fourth one is about

sourcing and procuring products through an open Supply Web comprised of a vast set of certified suppliers. Finally, the fifth layer is about providing access to the functionality of objects through a Service Web, in the spirit of open car and bicycle sharing (e.g. ZipCar, Bixi) and open apartment sharing (e.g. AirBNB), but for a much wider spectrum of physical objects.

With the Physical Internet enabled Mobility Web, point-to-point and hub-and-spoke transportation are not the dominant logic anymore. Interconnected logistics is based on distributed multi-segment intermodal transportation. Distinct carriers and/or modes take charge of the transportation between open nodes. At each node parcels are routed to the next one. Simulations by Montreuil (2011), Sadilek et al. (2013) and Sarraj et al. (2014) have demonstrated the superior efficiency of distributed multi-segment delivery.

The multi-segment multi-carrier idea has been worked out by DHL and a group of German design students. The exploratory project, named bring:BUDDY, is a social web of people who carry parcels and letters for other people in their area. An algorithm analyzes the daily routes of the members and anonymously assigns parcels to people who can take them along. The parcels therefore find an optimized way through the city. It is easy to imagine how this could be applied in crowdsourced delivery. The multi-segment logic, with couriers relaying, would extend the coverage of delivery, in particular for interurban delivery.

Integration of crowdsourced delivery requirements in the design of cars, bicycles, trucks, etc. would optimize the process. Space enabling easy handling and securing of modular containers could be embedded in every vehicle. Thus, containers can pass easily from a vehicle to another, or between a vehicle and a hub.

The second key aspect of the Mobility Web is the aggregation of parcels (Montreuil et al., 2010; Montreuil, 2011). Standardized modular containers enable to aggregate smaller containers to become composed container in order to optimize handling and bulk. At each node, a container faces three options:

- the unitary or composed modular container continues its route,
- the modular container is aggregated to a bigger composed container in order to ease its handling or to be transported in a bigger vehicle, respecting the legal weight carrying limitations for both vehicle and courier.
- the composed modular container is dismantled and the smaller containers are dispatched to different routes. The smaller ones can be aggregated to containers going to the same direction.

Today aggregation of parcels is not a common practice in the crowdsourced delivery industry. Tasks are managed individually by independent couriers.

Now, imagine how the Mobility Web is to impact crowdsourced delivery in future years. Someone wants to send an object to a distant town. He connects to the online delivery platform with his computer, an app using his mobile device, or a terminal at the deposit – pick-up point. The pick-up point may be a pharmacy, a service station, an accommodation store, or a computerized locker. He enters his request: the destination, the price he is willing to pay, the preferred delivery time window, etc. An algorithm considers the request, the state of the Mobility Web at the moment and in the near future, and propose alternative solutions. The client makes his decision. The object is put into an appropriately sized modular container. The operation might be automated or manual depending of the place of the deposit point in the Mobility Web

and the volume of parcels that have to be treated. The tracking system will monitor and guide the container in the Mobility Web. In case of incident, the parcel might be re-routed. The client can track the container online anytime.

The Mobility Web is in the process of becoming reality. Crowdsourced delivery is one of the alternative viable solutions. Others include traditional logistics companies (like FedEx or UPS), truck/trailer transport companies, personal cars, public transportation systems, taxis, railway and airway transportation companies, etc.. Depending on the requirements of the delivery (nature of goods to deliver, source and destination locations, budget, delivery time window, etc.), and the configuration of the Mobility Web at the moment, an optimized configuration is built which combines definition of the multi-segmented routes and choice of the actor for each segment.

The advent of the Physical Internet and its Mobility Web enables an evolution toward interconnected crowdsourced delivery. It is dynamic, it does not function independently, and is not limited to specific tasks. It is a viable alternative solution for the Mobility Web. It is flexible and agile. Interconnected crowdsourced delivery may have a competitive edge against other solutions (logistics service providers, taxis, public transportation system, etc.) for key segments in the following situations. This includes, intra-urban delivery when population is dense and delay is short, taking charge of the last segment from last deposit point to final destination, the delivery of very fragile objects or living animals, and generically as a smart complement to other means on all inter-hub routes by taking advantage of the huge flow of commuters and travellers.

8 Conclusion

This study is amongst the first to examine in depth crowdsourced delivery business models. After a critical analysis of 18 startups in the crowdsourced delivery industry, we propose a typology of five archetypal business models. We can observe that B2C intra-urban models are currently dominant. With no surprise, they concentrate the bulk of investments. In an industry where critical mass is a key success factor, the B2C intra-urban business model has two advantages: they partner with retailers, and they operate in highly dense population cities. But a doubt remains about their capacity to grow and to develop in smaller towns and in interurban delivery.

We propose a paradigm change toward interconnected crowdsourced delivery. Based on the Physical Internet concept, (1) we suggest to stop considering each crowdsourced route to be dedicated to a single parcel from its source to its destination, but rather an openly consolidated segment for sets of parcels heading to the same next hub in their relayed way to their final destination; and (2) we also suggest to stop considering the crowdsourced delivery as an isolated industry that answer to specific needs, but rather as one alternative solution to build the Mobility Web.

The capacity to interconnect the players within the industry and to interface with actors of the Mobility Web (traditional logistics and transportation companies, public transportation systems, auto-sharing companies, etc.) may be one key success factor for the future of the industry.

The main limitation of the study is its data collection method. We used public documentation, with no access to first-hand information. The crowdsourced delivery industry is very young and far from maturity. Things change very fast. Journalists are typically one step behind the industry. They are still fascinated by the concept. Information about business models, strategies and vision of the industry future is rare.

We propose four avenues for future research. First, further qualitative and quantitative studies are required to better understand the business models, challenges and success factors of the new born actors in the industry. Second, simulation experimentation is needed to better assess the potential of interconnected crowdsourced delivery and to find ways to optimize the whole ecosystem. Third, instrumental research is needed to create a new generation of algorithms, protocols, vehicles, containers and platforms enabling interconnected crowdsourced delivery. Fourth, there should be field based pilot studies validating the feasibility, efficiency and sustainability of the proposed interconnected crowdsourced delivery innovations.

Acknowledgements

We thank the Canada Research Chair program and the Discovery program of the Natural Science and Engineering Research Council of Canada for their support of this research.

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1st International
Physical Internet
Conference

Towards a smart interconnected era
of efficient and sustainable
logistics, supply chains and transportation

May 28-30, 2014 - Québec City, Canada

Assessing the Readiness of Africa for the Physical Internet

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Abstract: *In general, infrastructure is a real handicap to be overcome to achieve business performance in Africa. This raises the problem of truthfulness with rationality, sustainability and logistics efficiency identified by the notion of the Physical Internet. Based on content analysis, this paper reflects the reality of Africa and provides an assessment of African logistics economically, environmentally and socially. The logistics sectors covered in this study are: air, land across the road and rail, maritime and river, and telecommunications. The study highlights the African logistics challenges, weaknesses, threats, strengths and opportunities. It also highlights the level of each sector and how logistics in Africa is implemented at regional and national level (intercontinental) and intercontinental. In order to attract the attention of stakeholders on the challenges, a readiness map is proposed relative to the operationalization of the Physical Internet in Africa.*

Keywords: *Physical Internet, Interconnected Logistics, Africa, Readiness*

1 Introduction

In order to enable more efficient and sustainable logistics worldwide, researchers suggest applying the principles of the Internet to logistics and propose the conceptualization and operationalization of a Physical Internet in order to streamline logistics and transportation in all their forms (Montreuil, 2011, 2013; Montreuil et al., 2013). Thus, as happens on the Internet, the proposal of the Physical Internet would transform logistics so that there are routers, logistics centers and transit points that facilitate the movement and storage of physical objects in a very rational way (Sarraj et al., 2012). In this context, objects and goods to distribute, store, ship, should be packed in containers made for this purpose to minimize the loss of space and to ease their seamless standardized flow through the Physical Internet. This should notably help moving from dedicated point-to-point and hub-and-spoke systems to openly distributed intermodal transportation system minimizing travel cost, time, energy consumption and greenhouse gas emission (Montreuil, 2011, 2013).

The Physical Internet manifesto draws the attention to the fact that throughout the world, logistics is currently done in a way that is neither efficient nor sustainable from economic, environmental and societal perspectives. It is estimated that at the economic level, the logistical burden represents 5-15 % of most countries and is growing faster than world trade. Environmentally, logistics in its current form is one of the largest emitters of greenhouse gases, energy, polluter and waste materials consumer. Socially, the conditions of logistical work are often precarious and there is a lack of accessibility and mobility fast, reliable and affordable Physical goods for the vast majority of the world's population.

Montreuil (2011, 2013) reveals a set of thirteen key symptoms justifying the call for urgent and important change.

In recent years, under the umbrella of the International Physical Internet Initiative, a number of projects have been undertaken to investigate the feasibility and operationalization of the Physical Internet. Research centers, companies and governments in Europe and North America have begun to recognize the power of the Physical Internet vision. China is launching its First Physical Internet Research Lab.

The Physical Internet is an open global logistics system. At term the aim is to have it implemented all across the world, including Third-World and developing countries. This is where this paper takes its roots: what about Africa? What is the current state of African logistics efficiency and sustainability? What about the logistics infrastructure? Could the continent gain from being a part of the Physical Internet? Could this do to logistics in Africa what the mobile phone technology has done to African telecommunications? Could it instill further economic growth while contributing to environmental and social sustainability in Africa, which presents itself as the continent of the future? Among all African countries, which ones are readier than others to contribute to Physical Internet investigation and operationalization?

This paper reflects the reality of Africa in its facets pertinent to the Physical Internet, namely transportation and logistics, yet also security. It provides an assessment of African logistics economically, environmentally and socially. Logistics sectors covered are: air, land across the road and rail, maritime and river, and telecommunications. These sectors are presented via an analysis that highlights issues, weaknesses and threats, strengths and opportunities. The analysis also points at each sector, how logistics is being currently implemented in Africa at intra-continental (regional and national) and intercontinental levels.

The paper is structured in four parts. Section two presents the research methodology. Section three describes the different modes of transportation in relation to the Physical Internet as modules by region and country with respect to socio-economic and environmental issues. The resulting debate is in section four. Finally, section five is devoted to the conclusion that not only provides information on the limitations and directions for future research, but also for conditionality implementation of the Physical Internet in Africa.

2 Methodology

The Physical Internet is an emerging concept for which scientific research is still at the level of conceptualization. The literature has only begun to lay the beacons that guide research in this area. This means that the writings are still rare. This is why we conducted the literature review in both academic and non-academic channels, so as to better grasp the real situation and consider the applicability of the Physical Internet project in Africa.

Content analysis was chosen as the method of analysis, because it is generally considered a useful measurement technique in Social Sciences (Okazaki, 2004: 86). The technique is needed among social scientists who evaluate historical documents, newspaper stories, political speeches, interviews, diplomatic messages, psychological journals and official publications (Weber, 1990: 5).

The information collected was analyzed at several levels (images, words, statistics, etc.), creating a wide range of research opportunities (Lombard et al., 2002: 588) and interpretation. Content analysis refers to the material rather than providing a summary of the current literature.

Other documents consulted are developed by specialized agencies of the United Nations such as the Economic and Social Commission for Africa, the International Office for Transport and the United Nations Environment. For additional data, we also consulted the archives of ministries, organizations of

African civil society, and newspapers that are also rich in information. The interpretation of these documents is the basis of our analysis.

To do this, we first decomposed into its constituent African countries before trying the regions in terms of economic, social and environmental as well as inner and outer connectivity considerations. This allowed subsequently aggregating into a continental outlook on the reality of the logistics infrastructure.

2.1 Collection, preparation and filing of documents

With reference to our research topic, we have proposed to search and analyze papers (atlas, magazines, scientific articles, etc.). All documents necessary for the implementation of this work have been made available. In order to prepare reports on the content analysis, we have listed and ranked documents of our bibliography in alphabetical order.

2.2 Evaluation and preliminary reading documents

Content analysis requires an assessment of the documents to be analyzed (Dépelteau, 2010). It involves reading the contents of documents, identifying initial ideas revealed by these documents, and analyzing them in a rigorous way. A pre-analysis was made to allow us to identify some key ideas to guide the entire analysis toward achieving the objectives. We performed an evaluation of documents, checking their origin and their status. This involved notably to ensure that the documents indeed have information pertinent to help us refine our work. The content of each document was briefly assessed versus the accuracy of the information they contain.

2.3 Selection and definition of codes

According to Dépelteau (2010), the codes are: "Applied to groups of words identifying symbols, collect and classify the different information obtained from interviews, observations, or other means ... they can also be units of meaning, that is to say a special atmosphere situated in the broader context of the document ... they must be comprehensive, clear, objective, relevant, consistent and numbered". As part of this work, the following codes are available:
Examples of valid codes for analyzes: These codes combine sequence numbers, numbered letters followed by 2 sets of numbers. Each component has a special meaning.

- 01, 02 , ..., = numbers of the various documents
- A1 = All relevant and revealing statement designating the rail ;
- A2 = All relevant and revealing statement designating the river ;
- B1 = All relevant and revealing statement designating the sea ;
- B2 = All relevant and revealing statement designating telecommunications;
- C1 = All relevant and revealing statement designating the air;
- C2 = Any statement revealing and relevant designating the road;
- Any figure "X" = page number where the information was found;
- Any figure "Y" = paragraph number where the information was found.

One document can for example have the following code: 01- A1-C1-18-02; meaning Document 01 - Statement meaning " rail " - statement meaning " air " - Page 18 of the report - Paragraph 02 .

2.4 Analysis and interpretation of data

This is the last step of our methodology. This part was made on the basis of a system based on a critical analysis of the results from the content analysis of the studied documents and articles. Analysis and

interpretation of data collected in the various documents allowed us to realize, for example, that North Africa and Southern Africa are the two regions in Africa that have the necessary characteristics for considering implementing the Physical Internet.
Other economic and infrastructural studies meet this choice (RMB, 2013; ICA, 2013). This has helped us to propose the continuation of our work, a cartography of the logistics implications of the Physical Internet on the continent.
Also, to analyze and interpret the data collected, we designed a scorecard system, which allows us to investigate the logistics of the entire African continent. Also sectors, rail, sea, river, air, road and telecommunications in each country of the continent have been reviewed through the amplitude of logistics movement indicators (existence, connectivity, and use), characteristics of "doing business", environmental impact, and social impact based on the following criteria:

- indicator turns green if the performance of the sector belongs to the interval $[\frac{5}{6} - \frac{6}{6}]$
- indicator turns yellow if the performance of the sector belongs to $[\frac{4}{6} - \frac{5}{6}[$
- indicator turns red if the performance of the sector belongs to $[\frac{3}{6} - \frac{4}{6}[$
- the indicator turns gray in the absence of information on the sector's performance
- When the indicator is not applicable to the sector concerned, a square is placed at the place of evaluation.

Similarly, the calculation of the average of each country and the overall average of each sub- continent followed the same scoring system.
As regards the interpretation of the scorecard, different colors denote the level of performance of each segment. This performance is evaluated based on six indicators: sectorial existence of infrastructure, effective connectivity sector use (activity), sectorial Doing business (World Bank, 2013), social impact, and environmental impacts. To this end, the green color with the sign (+) means that the performance of the sector is satisfactory. The yellow color marked (O) means that the sector's performance is moderately satisfactory. Red color with the sign (-) means that the sector's performance is unsatisfactory. In the absence of information, sector performance is not rated and the indicator turns gray. When facing a non-applicable case, a small square is registered instead of the evaluation. The application of all criteria listed above enables to compile and to draw a scorecard as displayed in Table 1 for North Africa or a more detailed scorecard for each country, as Mauritania is reported in Table 2.

Table 1: Scorecard Summary for a region: North Africa

Internet Physique Balanced Scorecard Africa 2014																					
Indicators/ Year	**North Africa**																		**Average North**		
	Mauritania			**Morocco**			**Algéria**			**Tunisia**			**Lybia**			**Egypt**					
Appreciation		O			+			+			+			O			+			O	

Caption: Green light and dark (with +) = Satisfactory and very satisfying; Yellow (with O) = Moderately Satisfactory; Red (with -) = Unsatisfactory; Gray = no information; Empty cell framed = Not applicable

Moreover, to distinguish the green we apply the light green color (effervescent) when the performance of the country is very satisfactory and the tern green color for a satisfactory country's performance.

Table 2: Scorecard of a country: Mauritania

Indicators/ Year	Mauritania																					Average Country		
	River			Rail			Sea			Road			Air			Telecommunication								
Existence		+			+			+			+			+			+			+			
Connectivity					O			+			+			+			O			O			
Use					O			+			+			+			O			O			
Doing Business																				-			
Social Impact					O			+			O			+			O			O			
Environmental Impact					O			+			O			+			O			O			

3 Presentation of results

3.1 Logistics connectivity in North Africa

North Africa gathers all the Mediterranean part of the African continent. It consists, in the North, of the Mediterranean coast and, in the South, of a vast desert zone marking the separation with sub-Saharan Africa. Still called the Maghreb, North Africa comprises six countries: Algeria, Egypt, Libya, Morocco, Mauritania and Tunisia. This region covers an area of six million km^2, with a population around 152 million (Atlas, 2009). The most populous countries in the region are Egypt (73.4 million), Algeria (34.1 million) and Morocco (31.7 million). As displayed in Figure 1, the main activities in the region include farming, fishing, minerals and hydrocarbons extraction. Indeed, these features provide increasing development of domestic markets fueling intense import requirements and export needs. The intensity of this international trade requires logistics and transport infrastructure, moreover adapted to the Physical Internet.

Several factors make the southern and eastern Mediterranean a strategic supply chain area for companies targeting Europe, Africa, the Middle East or Central Asia. First, through the Mediterranean is transiting 30 % of the world container traffic, between Port Said in Egypt and Gibraltar in Morocco (Atlas of Africa, 2011). In a context of increased competitive pressure, this zone offers a stopover area and a one-unloading stop for East-to-America lines.

North Africa countries are separated from Europe, their main trading partner, by the Mediterranean Sea, which means that foreign trade is highly dependent on their port infrastructure. These are an obligatory passage point for both exports and imports, and a potential bottleneck (Overmann, 2012). In fact, North Africa via the Mediterranean is a global corridor for goods in transit via Suez, Gibraltar and the Bosphorus, the waterway dominating foreign trade.

Port infrastructure are key elements of national economies and are therefore subject to great works of upgrades to facilitate receiving the largest shippers (Port Said, Tripoli eventually Enfidha, Cap Djinet). For example, large investments have been made in Morocco to make TangerMed one of major "hub" ports of the Mediterranean in particular and Africa in general (Colombo, 2011). Management of Mediterranean ports has also following the global trends, such as with the introduction in recent years of global operators such as Singaporean PSA (TangerMed), Hong Kong's Hutchinson Port Holding (Alexandria), or Emirati Dubai Port World (Algiers) (Network, 2008).

Concerning land transportation, the motorway and road network is unfortunately still fragmented at national borders, which considerably limits the regional transport by land. Its level of connectivity is also not optimal, especially between ports. Rail, mainly used for the transport of bulk, suffers from decades of under-investment in a context of state monopoly. However, the situation is improving rapidly with strong political support for work modernizing highways (Mediterranean bypass in Morocco) and rail networks (TGV high speed trains in Morocco) (Colombo, 2011).

In terms of logistics, situations are quite different depending on the country. Morocco and Tunisia, which have previously been important exporters of manufactured goods, have already begun to make significant progress. According to a World Bank ranking, Morocco has achieved record growth in logistics performance, climbing from the 113th rank in the world in 2007 up to 40th rank in 2012 (Khelifa, 2013) with logistics platforms now covering an area of 1,338 ha. Such logistics platforms are developed in large urban areas and near container platforms, resulting in the establishment of global operators and the development over the recent years of specialized infrastructure in the major economic centers of the country, notably in the areas of Casablanca and Tanger (Barthel and Planel, 2010).

Tunisia follows the same path. It also registers, the establishment of global logistics operators. Yet the supply of logistics space is still very limited and represents a major obstacle to quality development of logistics services in the country.

Egypt shows a paradoxical situation. It represents a huge potential market with a population of nearly 80 million people. Furthermore it has a privileged location in terms of logistics. Indeed it is at the crossroads between Europe, Africa and Orient, and the point of passage between the Mediterranean and Asia. Yet, unfortunately, logistics services are poorly developed in Egypt and there are just a few global operators operating in the country.

Even though it has significant potential, the current logistics situation concerning Algeria is not bright. Indeed, in 2012, the logistics ranking by the World Bank positions Algeria at the 125th position out of 154 countries (World Bank, 2012; Khelifa, 2013).

In addition, the importance of Europe for North Africa economies clearly appears when looking at trade figures: trade (exports plus imports) with Europe represents around two thirds of the total for Algeria (64%), Morocco (63%) and Tunisia (72%). In the case of Egypt, the proportion is minor, but still quite significant (26%) (World Bank, 2012).

The social situation in the region was shaken by economic and political crises that challenge people's expectations. Political reforms and revolutions in countries such as Algeria, Libya and Tunisia are all social realities that have weakened the region and caused some distrust of foreign investment in the region. Even if there are some political tensions between Morocco and Algeria, it is clear that the Maghreb peoples have everything to gain through their union and/or cooperation instead of the interstate separation they endlessly suffer (Guerroua, 2011).

3.2 Logistic Connectivity in Western and Central Africa

West and Central Africa are bounded to the west by the Atlantic Ocean and occupy a south area of the Sahara, bounded on the east by countries from Chad to the Democratic Republic of Congo, DRC (Atlas of Africa, 2009). It is a vast area covering 25 countries with a total population of about 415 million people, which is just over 6% of the world population. Traditionally, the union of West Africa and Central Africa is defined as including the following countries: Benin, Burkina Faso, Cameroon, Cape Verde, Congo, Ivory Coast, Gabon, Gambia, Ghana, Guinea, Equatorial Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Central African Republic, DRC, Sao Tome and Principe, Senegal, Sierra Leone, Chad and Togo (IOM, 2009).

Western and central Africa is singularized by the disparate situation of its railroad network. For example, countries like Congo, Ivory Coast, and Nigeria hold a good rail infrastructure serving multiple locations. Privatization of the railway between Dakar and the Malian capital complements this positive evolution of the regional rail transportation landscape (Atlas de l'Afrique, 2009). Existing railways are mostly a legacy of colonization. Perpendicular to the coast and disconnected from each other, they have as their main function the export of large quantities of ore (iron, bauxite, phosphate). Unlike roads, they now play an integrator role. The takeover by the private sector of the Abidjan - Ouagadougou and Dakar - Bamako lines is now opening new perspectives in rail transportation in this region (Atlas de l'Afrique, 2011).

Regarding roads, only countries of the Mano River (Guinea, Liberia and Sierra Leone) and neighboring Guinea Bissau seem to suffer from a net deficit in road infrastructure. A road is built and then is deteriorating because it is misused and poorly maintained. A long decade of instability and conflict caused a double phenomenon of rapid urbanization and deterioration of communication networks. In addition, some interstate routes remain to be built or improved. The exception is Nigeria where the infrastructure is mainly financed by local resources (Igue, 1995). However, the quality of its network is very variable.

West Africa has twenty commercial seaports with traffic of more than 500,000 tons/year, excluding oil terminals. Five of them are located in Nigeria. The number of vessels approaching the West African coast has increased from 15 000 in the early 90s to over 20,000 during the 2000s. These movements of ships generate a trade volume (excluding crude oil exports) of more than 140 million tons, representing approximately 25% of African maritime traffic, yet only 1.5% of world seaborne trade. The competitiveness of a port depends not only on its infrastructure and its services (Abodohoui, Nie, & Liu, 2010), it also lies in the quality and fluidity of land transport networks that serve mostly regional interconnection routes (Atlas de l'Afrique, 2009).

The supra region of West and Central Africa is one of three navigation areas and maritime regions served by shipping lines of conferences and other maritime companies that are off-conferences; the other two being the East Africa and Southern Africa (Indian Ocean), and North Africa (Mediterranean Sea). Indeed, the economies of countries in the maritime region of West and Central Africa are largely hooked on maritime transport and transit. Twenty coastal states, located along the north and south side of the Atlantic Ocean and five landlocked countries served by the coastal ports, generated in 2003 approximately 247 million tons of cargo, representing 4.8% of the global tonnage amounting to 5,129.4 million (Merckelbagh, 2009).

Maritime and transit transport is not only a vital activity for international trade; it has in itself an international character as it is its modus operandi. Opportunities, problems and policy issues related to maritime and transit transport transcend national boundaries and are best addressed at the ECOWAS, UEMOA, CEMAC regional and international integration levels (Akanni-Honvo, 2003).

Countries in a given maritime region share common problems of demand and supply of maritime transport services, and of security, safety and pollution of marine waters. Therefore, the maritime area lends itself to sectorial integration in this range. Shared concerns often pointing to concerted resolutions include promoting maritime security and environmental protection by the elaboration of effective emergency plans for the prevention and the fight against pollution; strengthening the efficiency of the maritime administrations; and implementing control measures of the flag state and the control of ships by the port State.

It is also necessary to note that West African transport and logistics are reputed to be slow, unpredictable, expensive and not successful with a very weak productivity. It ends in consumer prices pointlessly raised for the goods imported for the region in genera and for the landlocked countries in

particular (Bernault, 2001; Debrie and Steck, 2001). Accordingly, this severely limits the capacity of the companies in the region to compete in continental and global markets. In this case, research has shown that high costs are due to a combination of factors including:

1. Trucking (which represents the majority of the costs of transporting goods) is not competitive. The anti-competitive provisions not only discourage competition but also encourage the use of old trucks that are not roadworthy, making trucking inefficient and expensive.
2. Procedures at ports, borders and final destinations are heavy, entailing significant delays.
3. Customs and other agencies require too many documents, even when the systems are computerized.
4. Informal costs, such as corruption, increases not only transaction costs but also slows the movement of goods, making delivery times unpredictable.
5. Documents and unnecessary costs slower movement and increase costs.
6. Certain rail infrastructures remain to be mine cleared (i.e. DRC) (Wolf and Lusinde, 2012).

In West Africa and Central Africa, people face chronic poverty, recurrent food insecurity and inadequate diets. There are about 50% of the populations who live below the poverty line (Ouattara, 2011). Cyclical drought, overuse of limited natural resources and outdated agricultural practices hinder food production in the Sahel region. In 2010, nearly 10 million people have had to face a severe food crisis and 859,000 children under five years old needed treatment against severe acute malnutrition (Ouattara, 2011). It should also be noted immigration problems reducing the human capital competitiveness of the region. Indeed, a total of 4, 225,066 immigrants in 2000 in target countries from around the world, there were 3,488,592 from ECOWAS (or Mauritania), that is 83 % (DRC, 2007).

3.3 Logistic Connectivity in East Africa

From North and South Sudan to Tanzania, East Africa is a vast and populated area with about 215 million inhabitants. Therein, Kenya (37 million), Tanzania (38.7 million), Uganda (28.5 million) and especially Ethiopia (77 million) concentrate the largest populations.

The landscape shows strong irregularities with collapsed sections (Rift Valleys aligned over 4000 kilometers in a north-south axis) and raised portions such as the Senior highest plateaus over 1,000 meters above sea level and the Ruwenzori massive in Uganda). Even though volcanism completes this rugged landscape, the zone has enabled the development of a diversified agriculture in countries such as Ethiopia, Kenya and Uganda. The Great Lakes region has also favored the establishment of a large population around the practice of fishing and agriculture.

Roads constitute the densest transportation network. Truck based transportation is developed between regional cities. Coastal cities of Dar es Salaam (Tanzania) and Mombasa (Kenya) are homes not only for seaports but also for international airports. Even though landlocked, Uganda has good roads that make this country a hub between Sudan, Kenya, Congo and neighboring Rwanda. Similarly Lake Victoria is a relay with Tanzania.

In addition to roadways, transportation is also provided by airways. Aircraft lines serve major cities leaving the service secondary airports to local companies (Atlas de l'Afrique, 2011).

In the eastern region, lake transportation is more important than river transportation with lakes Tanganyika (natural border with the DRC), Victoria (linking Entebbe, Kisumu, and Mwanza) and Malawi (southern Tanzania).

The rail network evacuates Congo's minerals and various Tanzanian goods (outflows) to the Indian Ocean and transports the incoming flow in the opposite direction. In addition, the Tanzanian rail is operated along a north-south axis connecting the town of Mbeya (near Zambia) to Mwanza (Lake Victoria) via the capital, Dodoma and Tabora (Atlas de l'Afrique, 2011).

From a viewpoint of connectivity between different countries in the region, Ethiopia with Addis Ababa (by road or flight) and Somalia with Mogadishu (road and air) could provide access to the shortcut Asia region by exploiting Djibouti and Mogadishu as important hubs (Atlas of Africa, 2011). Unfortunately, terrorism acts perpetrated in this part of the continent do not allow Djibouti (commercial port, oil terminal) to play its roles in the amount of traffic transit: International autonomous Port, transit Ethiopian and Djibouti International Airport, railway to Addis Ababa (Ethiopia) (Atlas de l'Afrique, 2011).

The succession of dry seasons in this part of the continent coupled with the rising prices of essential commodities, and all-out conflict, has been and still is a problematic situation for the people of this region. This has exacerbated the flow of goods and services, and the difficulty in reaching populations in need. This situation has also left millions of people in Kenya, Somalia, Ethiopia and Djibouti into a humanitarian crisis, the consequences of which are still visible today. According to the UN, at least 13.3 million people, including children, are malnourished and are exposed to disease and violence (CIDA, 2013).

The problem of dilapidated rail and road infrastructure, far from being a problem for some African countries, is a common feature in almost all countries in all regions of Africa, with the road and rail infrastructure dating colonial times. In addition, another important issue is the rapid and progressive desertification (Atlas de l'Afrique, 2011) that threatens the opening of areas already affected by landlocked and long famine.

3.4 Logistics connectivity in Southern Africa and the Indian Ocean

Southern Africa, from Angola, Zambia and Mozambique to South Africa, is a region with 130 million people, corresponding to about 14% of the continent's population and 4% of the world population in 2008 (ADB, 2001). Near Southern Africa, the islands in the Indian Ocean have original physiognomy and demography with the islands of Comoros, Seychelles and Mauritius.

South Africa, with its demographic superiority and its stronger economy carries an undeniable political leadership across the region. Countries are industry oriented with oil (Angola), agriculture and livestock, mining (Botswana), commercial ports and fishing harbors. Southern Africa has great potential for the production of electricity, but the low level of investment results in shortages. Intra-regional trade as a share of total trade remains very low compared to other developing regions. Manufactured goods dominate intra-regional exports, while exports on the world market are mainly raw materials (Atlas de l'Afrique, 2011).

Compared to other regions, Southern Africa has more infrastructures required to support the exchange as described above. Take railways as an example, Southern African railways have 36% of the operated lines on the African level (Atlas de l'Afrique, 2011). Similarly, the capacity of air, road and sea transportation are better developed, because of the location and the presence of South Africa that acts as an engine in this sub-continent. For example, this country alone holds a large share of the global reserves of rare and precious metals that allow it to develop its export. It is the world's largest gold producer, second in chromium and titanium, and third when it comes to manganese (Atlas of Africa, 2009).

As in other parts of Africa, most of the trade is done on road, rail and air infrastructures. In addition, the country itself has railways, of which more than two thirds that are electrified, to form a complete network connected to neighboring countries. It totals 182,600 km of roads, 7 international level ports including several that are specialized like Richard's Bay with 75 million tons in 2006.

Also, many foreign companies operate, connect and facilitate trade between countries in the region. Commercial trade between the region, other regions of Africa and the world are very facilitated by

these large groups. For example, to facilitate the movement of goods, the French group Bolloré has 85,000 m² of parks and warehouses across South Africa. Anchored in Southern Africa, this group operates not only the global maritime transport / transit, but also the overall air transport departing from South Africa to the rest of the region, other regions of Africa and outside the continent. The international way is also used for land trade. However, despite a relatively advanced level in infrastructure, compared to the other sub-regions of Africa, these facilities need to be developed in countries such as Lesotho.

There are social issues related to logistics and transportation in Southern Africa. Despite the availability of infrastructure, some areas remain isolated, such as Zambia, Zimbabwe, Malawi and Botswana. Even in South Africa, where the availability of infrastructure is higher, many communities remain isolated because they lack economic interest towards investments. In the other countries of Southern Africa, including Namibia, Mozambique, and Zimbabwe, isolation and displacement remains a major challenge (Atlas de l'Afrique, 2011),

In Southern Africa, the environmental problem does not arise in the case of many logistical infrastructures. Trains are not part of the list of biggest emitters of greenhouse gases. The reason is that these old steam trains that once emanated huge columns of smoke are no longer widely used due to too outdated rail infrastructure and bankruptcy declared by state companies that ran the railways. If we stick to the countries of the region that still use the railways for the movement of mineral resources and goods, it must be admitted that the infrastructure is partly renovated, as well as the locomotives (Atlas de l'Afrique, 2011),

4 Analysis of results

From the analysis of the above results of different sectors (rail, sea, river, air, road, telecommunication), we created a map of Africa displayed in Figure 2 that highlights not only the current state of logistics, but also in a pictorial way, the readiness of the countries relative to the operationalization of the Physical Internet.

When considering the different regions, a rather heterogeneous picture emerges. Many African countries are facing extremely heterogeneous economic situations. The map of Figure 2 enables to understand the state of the continental logistics efficiency and to introduce a typology of countries (light green, dull green, yellow and red) relative to Physical Internet readiness. We hereafter analyze in further detail what the readiness map has synthesized.

For the six states of North Africa, despite the identification of certain barriers such as inefficient trucking and low transportation volume, aggressive customs authorities, low and inconsistent quality of products, as well as ineffective border transit procedures (Devlin et al. , 2005 : 1) , it remains that the countries of this region have a certain capacity for Physical Internet readiness. Indeed, four countries in this region meet our criteria for potential contribution to the operationalization of the Physical Internet. These are Algeria, Egypt, Morocco and Tunisia. It should nevertheless be noted that Algeria, Morocco and Tunisia are geographically interconnected countries. Thus, much improved border connections can be beneficial for the implementation of our project. Being separated from the Western block of North Africa by Libya that is not ready for adhering to Physical Internet principles at the time being, Egypt is disconnected by land and will have to wait for logistics capacity in Libya to be improved to get interconnected through land with the rest of North Africa.. Meanwhile Mauritania has not met, like Libya, the conditions conducive to Physical Internet readiness. In addition to individual state efforts, governments join regional economic organizations or communities. Thus, the North African Arab states, except Egypt, belong to the Arab Maghreb Union (AMU). The development of the Physical

Internet in North Africa could spread rapidly in some countries of West Africa (via Senegal, Mali and Niger) and Central Africa (via Chad)

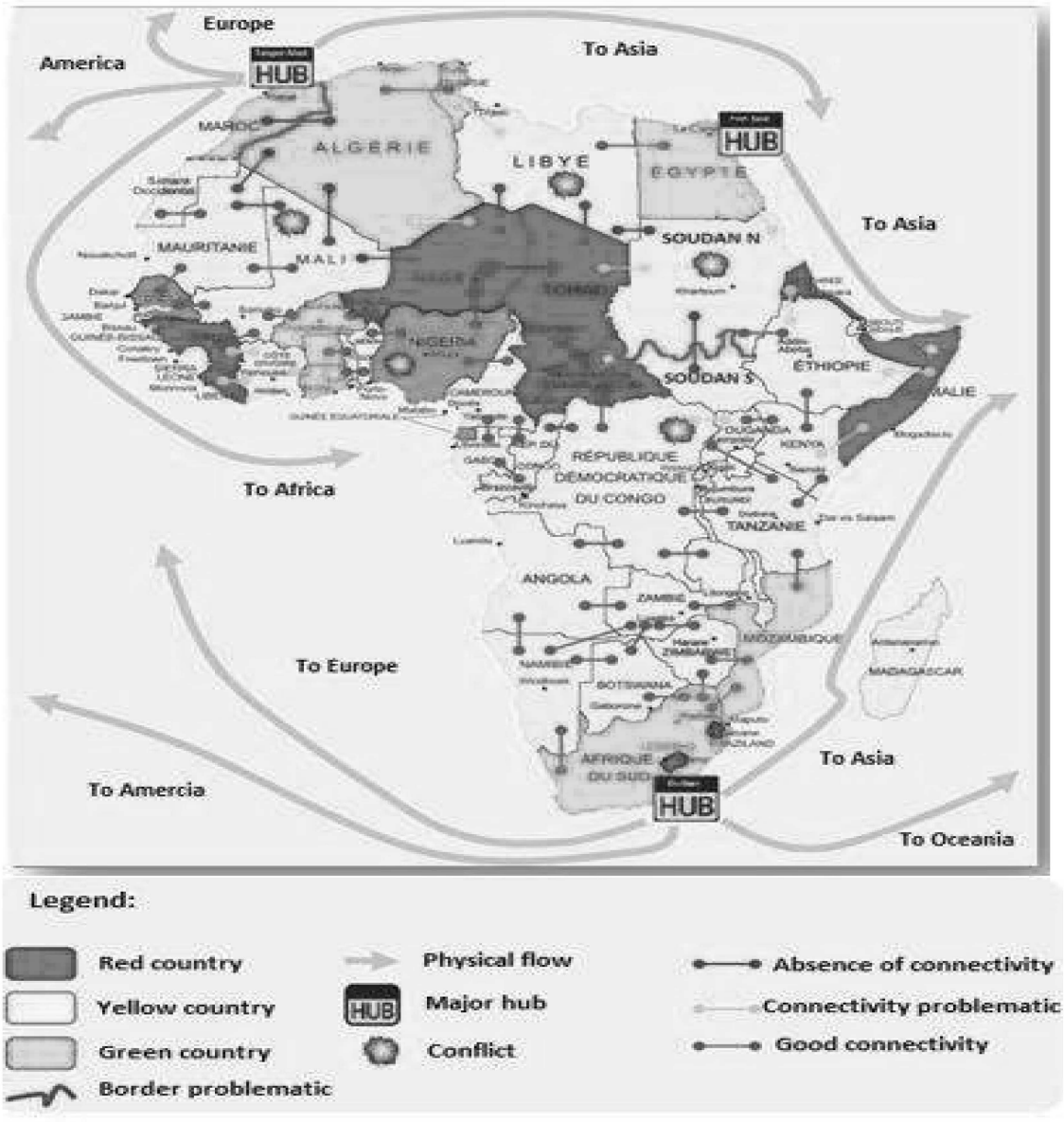


Figure 2: Physical Internet Readiness Map of Africa, as of 2014

However, the weaknesses in these countries mortgage any possible link. Indeed, in this region, most countries have a yellow readiness ranking. By cons, there are still countries that have an almost unbearable logistics capacity. Countries along the west coast (Guinea Bissau, Guinea and Liberia) and those in the south of Algeria (such as Niger, Chad and the Central African Republic) are red; they are an obstacle to the development of the Physical Internet. Their logistical capacity is very low. The Sahel is probably for something in this situation. Algeria, a paradoxical country, has many advantages such as a very large domestic market, a strategic geographical position, yet it still has a low level of connectivity with the southern region. So the short-term priority is mainly to complete the network infrastructure and promote its East-West and North-South integration. In the medium term, because of

its many strategic assets, the situation in Algeria will be such that it will become essential to develop logistics platforms and foster the development of international logistics operators as do its neighbors.

Senegal and Nigeria show intermediate readiness level (countries in dull green). But the distance from the green countries postpones the applicability of the Physical Internet. The Community of Sahel-Saharan States (CEN-SAD) is an international organization of 28 African states. Among its key objectives are promoting foreign trade through a policy of investment in the member states, as well as increasing land based and air based transportation and communication between the member states through the implementation of joint projects (African Union, 2014).

However, several countries in East and Central Africa have a relatively low level of Physical Internet readiness (yellow countries). Among them, there are two that, thanks to their potential for intra-regional and interregional connectivity, could consolidate the implementation of an African PI. This is the Cameroon and the DRC. These "regional connectors" respectively would link the West with the Centre and the Centre with the East and the South. The DRC is at the same time a member of Common Market for Eastern and Southern Africa (COMESA) and the Southern African Development Community (SADC) and Economic Community of Central African States (ECCAS). In contrast, the economic life in West Africa is structured around the Economic Community of West Africa States (*ECOWAS*) (AfDB, 2011).

In Southern Africa, two countries have been positively evaluated Physical Internet readiness: South Africa and Mozambique. Compared to other countries in the sub-region, they are very advanced regarding the development of infrastructure. Their coastal contiguity and their mutual trade intensity should proof fertile ground for Physical Internet implementation. This is also a real asset for the trade between the different cities of the two countries. The proximity of the South Africa-Mozambique duo and Madagascar is a factor that benefits the future extension of the Physical Internet Network (PIN) to countries in yellow of neighboring areas. Similarly, the fact that these two countries are coastal promotes the development of intercontinental exchanges. With Tanzania, Madagascar and Seychelles, the countries of southern Africa are governed by the South African Development Community (SADC) (AfDB, 2011).

At the moment, it would be difficult to start PI projects in East Africa simply because there is no green ranked country in the region. However, if some countries in the region were to be drained by countries of Northern or Southern Africa, the strategy of interconnecting regions would be possible. In addition, Burundi, Kenya, Rwanda, Tanzania and Uganda are organized in East African Community (EAC) (AfDB, 2011).

Moreover, beyond natural disasters, Africa is also, on one hand, a scene of conflicts that threaten the political, economic and social stability of nations. Six states are home for fratricidal wars (Libya, Mali, Niger, Sudan, CAR, DRC and Somalia). It is surprising that these countries delimit the countries in red in the northern hemisphere of the continent. Secessionist tendencies, that divided Sudan in the East, have not yet given birth to an independent state in the north (Western Sahara). The cold diplomatic climate between Morocco and Algeria, the recurrent tensions between the DRC and its eastern neighbors (Rwanda, Uganda) and the recent unrest in the former Sudan hamper the effective connectivity between these countries whose target boundaries are far from the preparation of a fertile ground (red borders on the map) for the Physical Internet project. On the other hand, due to the new map of jihad in the Sahel, the renewed activity of several jihadist groups in a vast territory on the borders of Mali, Algeria and Libya worries the intelligence services. This, combined with the non-flow connectivity in North Africa, argues in favor of Southern Africa as the readiest area for launching PI projects.

Nevertheless, some regional economic communities are working toward regional integration in Africa and invest in a convergent manner towards the establishment of a continental free trade zone (CEA, 2012a; 2012b).

5 Physical Internet and logistical involvement

The efforts for bringing the African continent into the PI initiative should consider three types of entities: countries, regions and continents. These entities are intimately intertwined so that the operation of logistics within each entity, the operation of logistics between entities as well as the connection of Africa in world trade are crosscutting concerns whose mechanisms should be defined and established modularly. This involves grouping functions interconnected by interfaces, which will be local (central and peripheral) and/or service interconnection with overseas modules. These functional connections or interfaces are sorely lacking for sectorial level transport, so that the gap within countries and regions, and even the continent, between urban (centers of manufacturing, consumption of services) and rural (agricultural producers) has deepened.

Internally, communication networks exist in several countries, but the continent suffers from logistical obsolescence and inefficient interconnection between sectors. Aided by the global donor funds (such as China, the European Union, multilateral development banks, and regional development banks), different economic communities and national governments have engaged in work to resolve this national issue at the regional level.

Externally, Africa's main cargo ports are pivotal for it to do business in world trade. Mundy and Penfold (2008) found in Sub-Saharan Africa that the port of Durban and Port Said in Sudan handle nearly 9 million tons of annual cargo through its transiting freighters. The container ports Tanger Med, Port Said and Durban handle close to 3.5 million TEUs (Institute of Shipping Economics and Statistics, 2010). These ports provide access to major shipping routes as follows:

- *Tangier Med* by the Atlantic Ocean to northern Europe , North America, South America , West Africa and South Africa ; to Asia via Port Said.
- *Port Said*, to Asia and to East Africa, also to *Tanger Med*
- *Durban* by the Indian Ocean to Africa, Asia , Oceania; by the Atlantic Ocean to West Africa , South America , North Africa and Europe.

These three ports are not only connected to major extra-continental shipping routes, they also allow intra-continental connectivity by road, air and/or rail. In this sense, they are major hubs and are recognized internationally as a symbol of regional integration of African trade.

Southern Africa has one of the three largest hubs of the continent and serves regional, interregional and international (transcontinental) transportation needs. South Africa is a green-ranked country due to the existence, use and connectivity of logistics infrastructure. It offers many more opportunities for cross and internal connectivity than the other two (Morocco with *Tangier Med*, Egypt with *Port Said*). In addition, the European Development Fund (EDF, 2006) has identified eight priority corridors for transportation in Africa starting in South Africa until the others countries without leaving any region. South Africa, Botswana, Tanzania, Rwanda, Burundi, Angola, Mozambique, Namibia, Chad, Sudan, Kenya, Nigeria, Djibouti, Senegal, among others, are the main countries related to that program. In addition, the ongoing construction of a line of railway between Kinshasa and the river port Ilebo Kasai will bring the whole of Africa to the South African port of Durban.

Two key observations result from our study. The first is related to the management of logistics in Africa by foreign private companies, such as the *Bolloré group*. States seem to be satisfied with the collection of taxes, but did not participate in innovative thinking relative to the transport sector that has

significant impact on entrepreneurship and the economy. The second is related to our assumptions with respect to the effective implementation of the Physical Internet in Africa.

Regarding the first observation, the review articles and other documents allow us to examine companies using facilities available to transshipping goods and, through these, connecting various African countries with other continents. For example, through its African subsidiaries the *Bolloré Group* has over 85,000 m^2 of parks and warehouses distributed across the South African territory and it has an important fleet of trucks. Expert in logistics management of industrial projects, mining infrastructure sectors, energy and gas, *Bolloré* bases its strength on its meshed pan-African network to connect South Africa to all landlocked countries of Southern Africa. However, the strategy of multimodal solutions for deliveries to locations across the continent applied by *Bolloré* is subject to an uneven mesh because (1) it uses transportation axes that are without alternatives and (2) it is designed for use by a single actor, being dedicated to Bolloré. For example, its tracking policy is designed and built only for goods ordered by its customers.

With the Physical Internet, logistics and transportation are not only multimodal. It is also about intermodal and technological efficiency and reliability that engages and interconnects an entire social community of operators, enablers and users (economic, social, environmental, government and civil society). In addition, the rational management and implementation of PI-enabled interconnected logistics foster potential order-of-magnitude improvement in environmental, social and economic efficiency and sustainability. Table 1 contrasts for key characteristics the Physical Internet with the current logistics system as pertinent to Africa. This remains here at a qualitative level as there is a huge lack of data supporting a quantitative assessment. In this context, a preliminary study estimating the economic, environmental and societal costs of current logistics on the continent would be highly pertinent and beneficial.

Table 1: Key comparisons of current vs. Physical Internet logistics systems as pertinent to Africa

	Before PI	**After PI**
Intermodal logistics	Weak	High
Asset utilization/exploitation	Personal	Public
Performance of critical parameters *	Isolated, private, sensitive	Synchronic, collective, superior

** Speed, service levels, reliability, safety and security (Source: created by the authors)*

The African PI implementation would gain from adopting the common objectives of the Regional Economic Communities (RECs) and of the International Physical Internet Initiative. Growing the PI implementation in two majors Free Economic Zone (FEZ) in Africa should be considered: (1) the South East FEZ group including COMESA, SADC, EAC and IGAD along the South Africa, and (2) the Northwest Centre FZE group including ECOWAS, CEN-SAD, ECCAS and AMU along the Morocco - Mauritania - Senegal – DRC axis. The full logistic interconnectivity of the continent would then be based on the East-Central and South-Central junction. From another perspective, all African countries should independently and collectively address how the PI can help them develop sustainably and building a pragmatic roadmap from their current logistics system to an interconnected logistics system, providing an opportunity to interconnect in priority the readiest regions to build success and momentum and to pull the overall continent.

6 Conclusion

Sustainable development of the continent relies to a large extent on infrastructure and services associated with logistics and transportation. Networks and well developed, safe and affordable transport services are essential for true mobility and timely accessibility to goods and services.

The African transportation system lags behind the rest of the world, with a level of development still lower than other developing countries in Asia (CEA, 2012a). For many, the African continent remains associated with roads dotted with crevasses; flood in rainy seasons; and overloaded, old and outdated railways; inefficiently exploited inland waterways; and often inexistent or capacity-lacking airways. At ports, containers of different sizes are sometimes half full and disintegrate gradually due to the rain and sun.

However, this not-shining portrait of African infrastructure is progressively modified. This has led some foreign operators to get active in the continent, amid redefinition of transport policies in Africa, including Bolloré Africa Logistics (BAL), DHL, Dubai World, Getma (NCT Necotrans), Maersk, Mediterranean Shipping Company (MSC) and Mitsui OSK Safmarine. These are very interested in the development of transportation and logistics in Africa and in developing strategies to cover enough sectors to expand their market.

The Physical Internet builds on the network effect, getting ever more effective as it gathers more users. It must gather critical mass, first exploiting existing infrastructures and means, then gradually fostering innovation. Even though it is to be ultimately global it will have to grow first in fertile domains, to be collaboratively supported by key leaders from industry, government and academia (Montreuil, 2011)

On African soil, several reforms are undertaken in various sectors to support the economic recovery of the countries. Virtually all African countries, whether democratic or not, are making efforts to access the Digital Internet and to realign their infrastructure (Beche, 2012; Pelgrum and Law, 2004). Still others create the institutional structures or organizations responsible for regulating these reforms in the telecommunications and implementation of transport infrastructure. In terms of facilitation, safety and security of transport, several international and bilateral agreements and protocols to simplify and harmonize trade and interstate transportation have been signed in Africa. Central, Southern, Eastern and Western African States have signed conventions and protocols, many of which are implemented. These instruments relate to road-based goods transportation, multimodal transport, regulation of transport of dangerous goods, rules of the road and civil aviation, maritime cooperation, common vehicle insurance schemes, common border posts, and corridors management mechanisms. Focusing on the Millennium Development in Africa, these agreements and protocols have the support of the UN, ADB, the European Commission, the World Bank and the Secretariat of the African Infrastructure Consortium (CEA, 2012a). In addition, the 2013-2022 integration strategy toward the transformation of Africa by the African Development Bank includes chapters on transportation and telecommunications (BAD, 2013).

Preparatory studies finding, diagnosis and planning conducted by several institutions (ICA, The Infrastructure Consortium for Africa; AICD, Africa Infrastructure Country Diagnostic, and World Bank, PPIA, ADB, African Development Bank; ECA, etc.) have passed to the operating phase in infrastructure development. In 2012, funding provided U.S. $ 18.7 billion from various sectors ranging from public to private. Disbursements of ICA members totaled $ 12.7 billion, which the energy received the lion's share (37.5 %), followed by transportation (32.3%), water (20, 7%), multi-sector projects (3.9%), and ICT (1.9%), with 3.7% unallocated. African national governments and external sources (public and private funds) finance the development of Africa's infrastructure. Key groups of actors include Asia (China, Japan, South Korea, and India), the group of Arab coordination, Europe

(EC, France, Germany and the United Kingdom), the Americas (Canada, USA and Brazil), multilateral development banks and regional development banks (ICA, 2013).

This means that, overall, there are opportunities for the realization of the Physical Internet in Africa. Moreover, our study revealed the existence of certain areas with green-ranked logistics readiness for the Physical Internet.

If nothing is done to support reforms and maintain focus, lethargy and vices of underdevelopment helping, the already bleak conditions will worsen, thereby reducing the chances of achieving the Physical Internet across the African continent.

Getting engaged in the International Physical Internet Initiative would enable Africa to conceive and implement interconnected logistics solutions to the situation of each country and region. Overall there is an opportunity for reversing the decay state of transportation networks and drastically improving the currently weak connectivity. Indeed, taking into account economic, social and human aspects, the initiative focuses on the logical PI logistics intermediation between geographical points. Hubs built in "Zone of contacts and exchanges" also represent the interfaces between management, organization and computer (Lalo et al , 1970: 26). In this logic, it will therefore be necessary to conduct detailed studies on specific themes in the various sectors related to logistics. This would notably analyze in operational and strategic terms how Africa could progressively implement the Physical Internet on the extent of the continent. Air, land and maritime telecommunication infrastructure should be allowed to assist in the development of Africa through the implementation of the Physical Internet. The primary condition is that the States through their leaders are involved, including private operators on the continent. Beyond the realization of investments for the modernization and rehabilitation of infrastructure in all its forms, the challenge for Africa in the coming decades is to strengthen the interconnection of existing networks. Countries also need to invest in the construction of new lines to avoid traffic congestion and provide circulatory alternatives to develop intra-African and intercontinental trade. As Physical Internet engages in this sense, its planned deployment should be beneficial, yet it will have to overcome numerous challenges. The security challenge is in top list. It is not just about terrorism and natural disasters. Aircraft accidents and traffic are likely to disturb the smooth operation of the PI whose effectiveness lies in a continuous functional system.

This work has significant limitations. The first is the scarcity of statistics on the goods transportation and warehousing. The inaccessibility of these secondary data makes difficult the quantification of Physical Internet readiness. A thorough research should be continued in this direction. Secondly, the gray literature requires considering the information conveyed with caution. Reliability cannot always be guaranteed. As a research avenue, in the light of the regional division of Africa, is to dwell on the study of Physics Internet zones, allowing for a closer view of the current reality superimposed on the potential realization of this great initiative.

Transportation and logistics are strategic sectors playing a key role in efforts to achieve sustainable economic growth and to reduce poverty, thereby enabling the sustainable development of Africa. For this sector to play their role, they must be developed in a coordinated manner with the ultimate objective of establishing an interconnected logistics and transportation system for both people and goods that is reliable, efficient, safe and environmentally friendly. The PI initiative is exactly suited to respond to this overriding concern.

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May 28-30, 2014 - Québec City, Canada

Using Cloud computing as a Model to Design the Service Web

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Abstract: *The purpose of this paper is to provide insights into the Service Web, which is one of the five components of the Logistics Web enabled by the Physical Internet. Specifically, it aims to present potential benefits for using a Service Web and it also highlights challenges and concerns surrounding it. After a brief review of the literature on the Physical Internet and cloud computing, the authors present a conceptual model of the Service Web. A key concept is that what the Service Web represents for the Physical internet is similar to what cloud computing represents for the Digital Internet. Following this thought, it is proposed that cloud computing be used as a model to initiate the development of the Service Web. To demonstrate the proposed conceptual model of Service Web, it is contextualized in the construction industry as an example. Current practices within the construction industry are first highlighted, then an illustration is provided of how construction companies can benefit from the use of Service Web. This paper offers a perspective on the utility and value of the Service Web for companies that will be using the Physical Internet. It is to be useful to researchers and companies interested in the new Physical Internet paradigm and notably on the potential for interconnected open pooling to improve the accessibility and utilization of assets and goods.*

Keywords: *Physical Internet, Service Web, Cloud computing, Construction supply chain*

1 Introduction

In an era where globalization dominates and international competition is fierce, companies feel the pressure to seek new management and organization approaches. The development of the Physical Internet is aligned with addressing the ongoing sloppiness, disorganization and unsatisfactory practices in global logistics as well as the societal concerns of global environmental destruction and global economic burden. In other words, Physical Internet is an answer enabling a significant reduction of these global problems through standard sets of collaborative protocols, modular containers and smart interfaces. The Service Web, as one of the five components of the Logistics Web enabled by the Physical Internet, is a basis for open sharing of goods and assets. It enables communication between owners and users of the goods,

as well as professional service providers and professional service seekers, and facilitates the operational process associated with the flow of goods.

One of the most well-known success stories of efficient sharing systems in recent years is ridesharing. Grouping passengers into fewer cars had several advantages for everyone. The drivers can share the fuel costs; the passengers can travel spending the least and at the same time, as the fuel consumption in passenger vehicles is reduced, economical and environmental benefits can be gained.

Another well-known sharing system is the cooperative apartments. In the low cost "co-op", each room is rented to one person and the common areas are shared. The new trends are luxury apartment sharing and the owners sub renting their apartments when they are away. Instead of booking a room in a hotel, the whole apartment or a room in a luxury apartment can be rented.

If seats in cars and rooms in apartments are getting shared, there are so many other idle resources out there that may also be used collaboratively. Instead of having resources sitting idle in their warehouses or storage yards, companies owning these resources can make them available for other companies that cannot afford spending a fortune in purchasing, leasing or hiring these resources or for those companies that need to exploit these resources occasionally or once in a while on a short-term basis. This is called resources sharing. Resources sharing can be smart sharing. Aside from its obvious purchasing cost savings benefits, it has the potentiality to save money on maintenance, to favor effective and efficient collaboration among the involved parties, to maximize production while meeting deadlines and to be sustainable. Modern technological advances in connecting users and systems, tracking physical objects and accessing remotely places and resources, make the concept of resource sharing and thus, the Service Web feasible.

Aiming to introduce a general conceptual model for the Service Web, the structure of this paper is as follows: in the next section, an overview of the Service Web and cloud computing is presented. The proposed conceptual model is discussed in details in section three. Section four lists some of the most important benefits and challenges regarding the application of the Service Web in practice. In order to provide a clear vision of the Service Web and its benefits, an application in the case of the construction industry is discussed in section five. Finally we conclude by summarizing our main contribution and by pointing out the future research avenues.

2 Service Web and cloud computing

According to Montreuil et al. (2013), "the Physical Internet (PI, π) is an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols. It is a perpetually evolving system driven by technological, infrastructural and business innovation." The Physical Internet enables an open Logistics Web that has five key constituents: the Mobility, Distribution, Realization, Supply and Service Webs, as depicted in Figure 1.

As defined in Montreuil et al. (2013), "in general, a web can be defined as a set of interconnected actors and networks. In the PI context, the types of actors and networks can be characterized, leading to define a web as a set of interconnected physical, digital, human, organizational and social agents and networks. A logistics web is defined as a web aiming to serve logistics needs of

people, organizations, communities and/or society. A Logistics Web is a logistics web that is both open and global."

While the other components of the Physical Internet have been studied in the literature, little could be found on Service Web. Montreuil et al. (2013) referred to the Service Web as "a web aiming to serve the needs for physical object usage. It is focusing on the accessibility of the services provided by, through, and with physical goods and beings. The Service Web is expected to enable efficient and sustainable collaborative consumption on a worldwide basis." (p.2) In other words, Service Web is about making idle resources available for sharing purposes across the world.

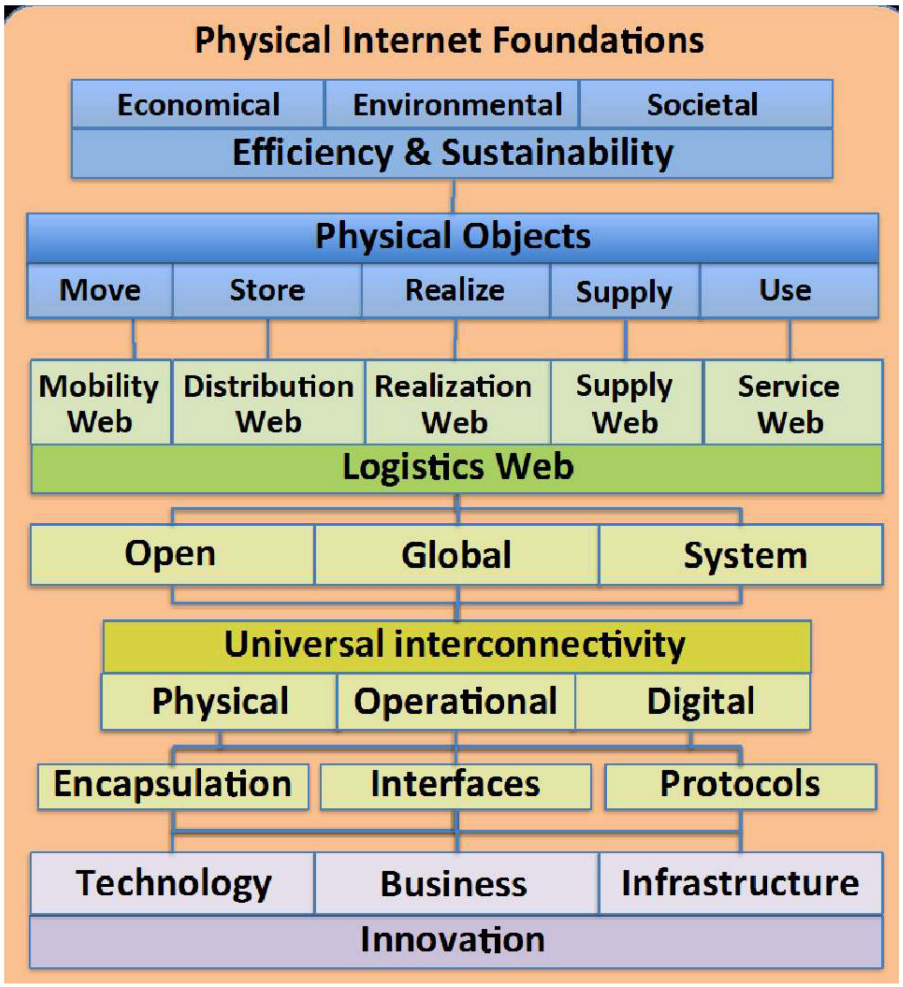


Figure 1. Physical Internet Foundations Framework, Montreuil et al. (2013)

What makes the realization of the Service Web a challenge is how to share the resources and have access to them on a real time basis. The notion of Physical Internet is built on a metaphor of the Digital Internet. How PI is enabling the Logistic Web resembles how the Digital Internet has enabled the World Wide Web. Therefore looking at the Digital Internet enablers and concepts can be of help to define and design the Service Web. In the Digital Internet, the problem of sharing and accessing resources and spaces has been significantly resolved by introducing the "cloud computing" notion and its enabling technologies.

"Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." (Mell & Grance, 2011, p. 2). According to Vaquero et al. (2008), the cloud is a large pool of resources, which can be easily used and accessed.

Following these definitions, we introduce a π-cloud as a large pool of physical objects and human resources that can be shared and accessed through the Service Web. Therefore, before introducing our conceptual model of the Service Web, having a quick look at the characteristics of the Service Web and its π-clouds, based on cloud and cloud computing literature seems to be required.

2.1 Service Web Characteristics

The Service Web has characteristics similar to cloud computing. Users rent the resources from owners and pay them for the rented resources. In other words, owners are given the opportunity to make their idle resources available to those that are in need. This characteristic is called shared resource pooling in cloud computing terminology (Zhang et al., 2010).

Geo-Distribution and ubiquitous network access (Zhang et al., 2010) is another characteristic of the Service Web. Although due to transportation and other related costs, the resources may not be available for rent worldwide, they can be accessible anytime and anywhere within the defined region.

The Service web is service-oriented as each owner offers its resources according to the service level agreement. The resources can be obtained and released on the fly. Therefore, it prevents huge fixed costs of owning the resources, which gives Service Web dynamic resource provisioning characteristics. Users and owners can manage use of the resources according to their needs. The companies can get more agile as they are able to respond more quickly to rapid changes in the environment using Service Web.

In Service Web, the users of the idle resources are to be subjected to a utility-based pricing system. Multi-tenancy (Zhang et al., 2010) is another characteristic of Service Web which can only be applied to human resources for example. Indeed it allows different users to benefit from the services provided by the same human resource.

2.2 Π-Cloud Deployment Types

In the cloud computing literature, four cloud deployment models have been identified (Mell & Grance, 2011). These deployment models are also applicable to π-clouds in the Service Web context.

Public: providers of service web use these types of clouds to offer their services to the public. In other words these clouds are open for public use.

Private: these clouds are also referred to as internal clouds. They are specifically designed to be used by single organization.

Hybrid: these clouds are a mixture of public and private clouds. They also have the advantage of addressing the limitations of each type of clouds by expanding their capacities or capabilities

Community: these clouds are suitable for a group of organizations that share common concerns among which security, privacy and compliance. A group of companies that use community clouds share the space available on these clouds as well as the costs related to the use of the clouds. An example of group of organizations using community clouds can be a group of construction companies.

The three basic types of cloud computing are known as Infrastructure as a Service (IaaS), Software as a Service (SaaS) and Platform as a Service (PaaS) (Genez et al. 2012). Based on these basic services, several other services have also been introduced, such as Identity as a Service (IDaaS), database as a service (DbaaS), etc. In this paper we introduce physical object as a Service (PoaS) and Human Resource as a Service (HaaS); Service web is therefore, combination of the PoaaS and HaaS.

We define π clouds within the Service Web as providers of the physical objects. Following the cloud computing terminology we try to define the conceptual model and architecture of the π clouds.

3 The conceptual model of the Supply Web

Using the cloud computing terminology and concepts, π-clouds provide a pool of stored and shared resources which includes human and physical resources. Figure.2 provides the schematic view of a π-cloud. Standard protocols are required to link different layers within each cloud (Data, Physical objects, Human resource, etc.) and allow them to communicate.

Different elements of the Service Web are as follows:

Cloud providers: the cloud can be created using the company`s own infrastructures or using the available resources on the cloud.

Manufacturer: Equipment and machinery producer, suppliers of durable material can offer facilities (e.g. storage space), services (e.g. repair and maintenance), or physical objects for rent.

Owners: those companies, organizations or individuals having idle resources and willing to make their resources available over the cloud to be shared and used by other members of the cloud.

Resources: including human and physical object resources.

Storage space provider: they may be members of the cloud by providing storage space for the physical objects, parking space, etc. These companies are part of the Distribution Web and each time the storing service is required, Service Web will get connected to the Distribution Web.

Transportation companies: they are responsible for moving the objects; basically they are part of Mobility Web. Whenever the resource needs to be moved, the link between Mobility Web and the Service Web will get activated.

Users: those are companies, organizations or individuals borrowing equipment, physical objects or human resources for the leasing period.

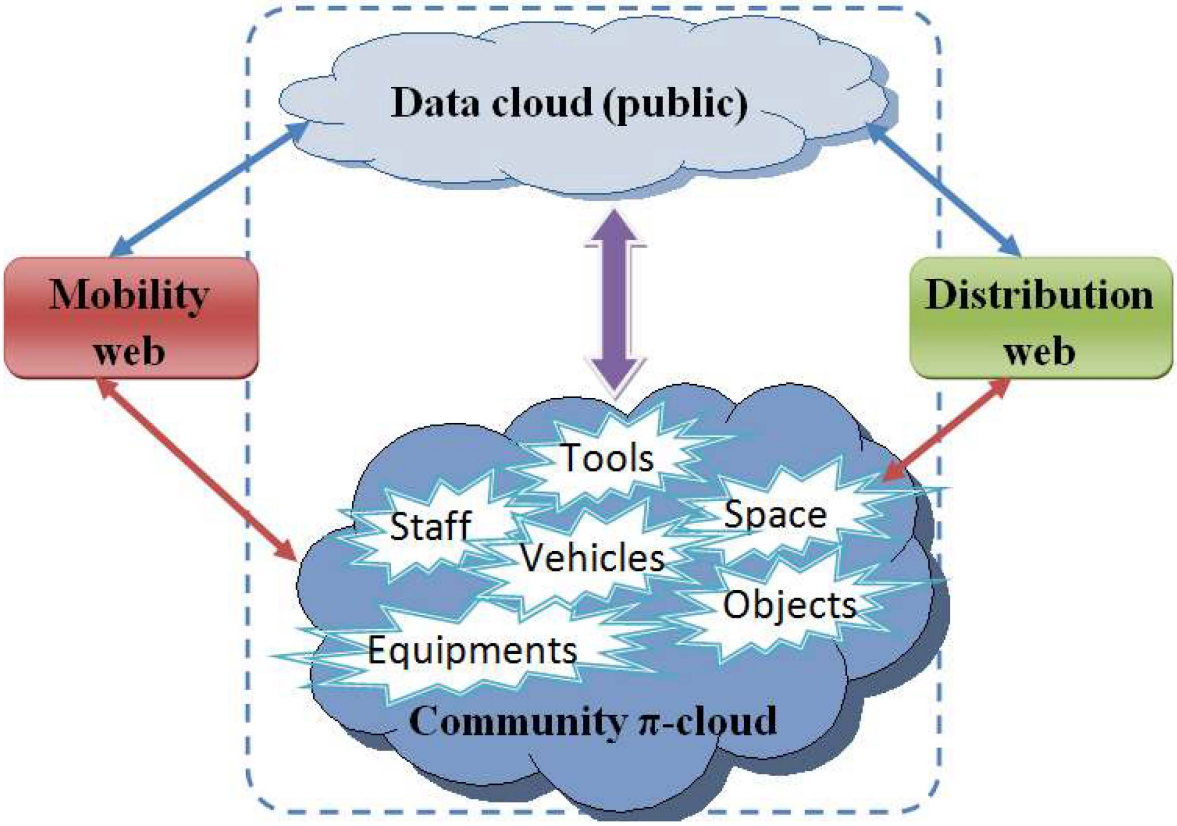


Figure.2. The clouds

We also define four processes within Service Web for sharing and using the resources, namely: Finding, Obtaining, Using and Returning (FOUR):

Finding: Sharing the resource and requesting a resource from the resource pool is linked to the finding process. The owner needs to put the information about the type, characteristics, price and availability of the resource on the public π-cloud. The users will search this public cloud to find the best fitting match. The Abstraction process will take place at this phase, which is a process used to create the resource pools by mapping an address for each resource (Sosinsky, 2010). Using the Service Web, the user is directed to the available resource pool. When the user requests a resource from the pool, the system uses a scheduling algorithm to assign the request. The π-cloud is then searched to find the best fitting match for the request. The fastest delivery time, the working schedule of the product owner, the needs-fitting characteristics of the requested resources, the lowest price and the lowest transportation costs are among the criteria taken into account at this phase. The π-cloud needs to get connected to the Mobility and Distribution Webs to check the moving and storing possibilities to provide the user a list with different options to choose from.

Π-Cloud providers need to make resources available in the air. Based on current locations and the company's profile, the resource will be assigned to a center in the π-cloud. The following factors will normally be taken into consideration: current location of the company, nearby π-hubs and other facilities by searching the Mobility and Distribution Webs, the working schedule of the owner company so that the resources will be returned to the owner on time.

When the user initiates searching the data cloud, the query is sent to the server. The pool of addresses is searched and the geographically closest options are offered. Verification and Virtualization of the pool take place at the same time to have access to the most update information. Virtualization is a process of managing the resources. It is dynamic and changes the address assigned to each resource dynamically in line with the rapid changes in their condition (Sosinsky, 2010).

Obtaining: The obtaining process is handled through the π-cloud. It includes the renting, storing and other related fundamental processes. Hosting, storage, the platform, application services and the tools are all provided by the π-cloud provider. Each resource is equipped with remote controlling or information devices; its exact location is controlled using GPS, RFID and other technologies. Encapsulated in π-containers, the objects move freely through the Mobility Web and get stored / parked in the Distribution Web facilities.

Using: Whenever a user receives the physical object, it evaluates its condition. It compares the object with the specifications and conditions mentioned in the database. All objects are equipped with tracking systems, any misuse of the equipment is recorded and the π-cloud provider is notified. The exact location of objects is always known via the system. The π-cloud provider later evaluates users of the objects based on these records.

Returning: When the lease period is over, the physical objects need to be sent for maintenance and repair as pertinent. The object's condition is checked and the system evaluates the user. We define a reciprocal evaluation system within the returning process. For a human resource, the user evaluates the human resource who also shares his/her experience with the company, as depicted in Figure 3.

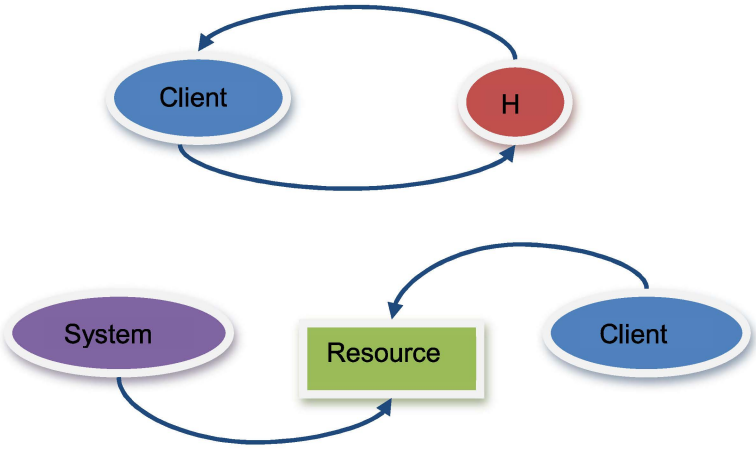


Figure. 3. Evaluation system

After the lease period is over, the user is sending the object back to the π-cloud; the equipment needs to get checked and after checking and maintenance, several options are possible: either it is sent to the storage space, or it is sent to the next user or it may be sent back to the owner to be used for their own work.

The proposed conceptual model for Service Web is synthesized in Figure 4.

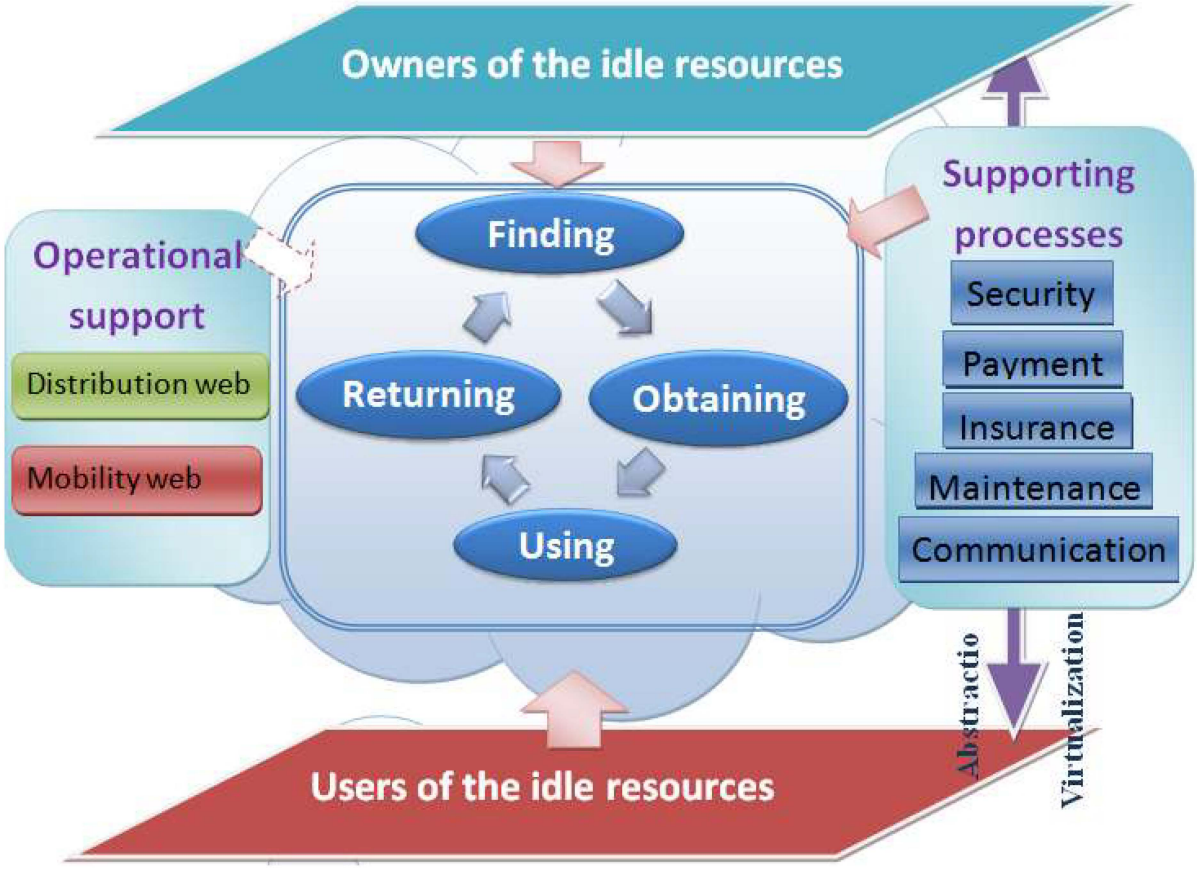


Figure 4. The conceptual model for the Service Web

4 Benefits and challenges of using Service Webs

The Service Web offers great potential to companies, organizations and individuals. Those that own idle resources can make profit out these resources. They can also reduce the costs for maintenance, the costs for storing physical options as well as the costs of hiring human resources. Meanwhile, they can fast track the conditions of their resources.

Just like those that own idle resources, those who use idle resources can also benefit from the pay-per-use option that the Service Web has to offer them. Pay-per-use can improve information sharing capabilities, decrease supply chain complexity, increase operating effectiveness, enhance constant availability of resources, improve higher flexibility and agility in response to changes, provide many alternatives for acquiring physical objects, open access to rare or expensive resources and allow users to make profit by avoiding huge fixed costs of buying physical objects. Finally, the Service Web offers π-cloud providers the opportunity to make significant profits.

Even though the Service Web can offer numerous benefits for companies, organizations and individuals, it also poses some important challenges that should not be overlooked. One of these

challenges is related to the security and confidentiality of the data. Companies, individuals, physical objects and all the other resources are registered on the cloud; the data is accessible by all pertinent users and all transactions are conducted through the cloud. Therefore, the security challenge of the cloud has to be carefully addressed.

Other challenges of the Service Web are technical concerns that have to be addressed and solved by π-cloud providers before offering the service. Π-Cloud providers need to be prepared for issues such as: How huge instruments and equipment can be moved and stored using the Mobility Web and the Distribution Web facilities; how smart, standardized π-containers may be used.

A significant fraction of the resources owners are willing to share them when they are idle under the condition that they will be back to them whenever needed, therefore the π-cloud provider needs to be flexible and robust enough to make both users and owners satisfied with the offered services. How and where maintenance and repair can and should be done? Who is paying for that is another issue that needs to be addressed.

The π-cloud providers also need to be prepared to deal with the cases of lost, stolen or broken objects, or any case of accidents. Who is going to be responsible and how the insurance will be paid, is highly dependent of the exact location of each object. Hence, the π-cloud provider needs to be prepared to provide real time data and on-time service.

5 Exploiting the Service Web: the construction industry as an example

Construction supply chains consist of many companies that work together in order to finalize a project. Depending on its size, especially in medium or large scale, the project can involve hundreds of different companies providing materials, components and a wide range of construction services (Dainty, Briscoe & Millet, 2001). In other words, a medium to large scale construction project requires a diverse group of participants such as contractors, architects, engineers, workers, suppliers, etc. This requirement of a diverse group of participants is due to the high fragmentation of the industry. According to Cheng et al. (2010), the top eight architectural and construction engineering firms control less than 20% of the market share. This represents a small percentage compared to other sectors as, for example, the largest aerospace companies in the same country control more than 60% of all trades in the industry. This phenomenon, according to the same authors, is due to the fact that the construction industry is mostly composed of too many small to medium size companies with different activities.

The economic growth of a nation can be measured through its physical development (roads, bridges, buildings etc). This means that construction industries are at the heart of nations' economic development. It is in this perspective that Ye et al. (2009) mentioned that the construction industry has positive impacts on the European economy in terms of employment and gross product. However, this instrument of economic growth has been facing challenges. These challenges, according to Lam et al. (2008), Toor and Ogunlana (2010) as well as Wang and Huang (2006) have contributed to the complexity of construction projects and of project success definition. In this sense, actors (clients, contractors, construction companies,

etc.) involved in the construction industry face numerous challenges among which budget compliance, increase complexity in design, delays in project delivery (Doloi, 2009).

Budget constraints: Considering that resources are generally limited, budgets constitute a major challenge in achieving the objectives of projects. Although all stakeholders agree on the importance of respecting the limits of the project's budget, it is very common that the costs become difficult to control as the project is progressing. For these reasons, it is very important that prior to the implementation phase, data that can impact the budget be identified and reported. Additionally, tools must be put in place to ensure that the financial commitments of the project are met (MCC, 2005; Xue et al., 2007).

Scheduling and Timing constraints: Time constraint is the second major challenge in the process of project implementation. The work must be delivered to a predetermined schedule, which generally corresponds to the date of the client's operations. This forces the project manager to establish its schedule depending on the following factors: availability of resources, availability of sites, access to financing, complexity of the proposed interventions, job scheduling and the construction's seasons and market conditions. Examples of time constraints are unrealistic expectations on the behalf of the general contractor, uncertain lead time regarding the availability of material and equipment and unrealistic program times (MCC, 2005; Xue et al., 2007).

Changes constraints: During the construction process, decisions have to be made. These decisions are usually based on prior experiences of the professionals involved in the project as well as on existing information that is made available to them. However, some internal or external factors may require that minor or significant modifications or adjustments be done on the project. Thus, any of these modifications can affect certain aspects of the work that have already been completed (Sun et al., 2006).

Communication problems: It is important that effective communication be established among actors involved in the construction process. Lack of transparency, limited communication and poor information are all sources of communication problems (Xue et al., 2007)

Behavioral issues: Misconduct is also part of challenges that the actors of construction projects face. Behavioral issues include: arrogance, lack of recognition for good performance, exclusion of some of the professional from the early involvement phases, narrow minded "win-lose" attitude (based on price) and adversarial relationships among actors (Xue et al., 2007)

Facing all these challenges, efficient exploitation of the resources is a necessity in construction industry. Construction companies need to be rapid, flexible and agile enough in acquiring resources (raw material, machinery, equipments, tools and even human resource) to cope with all uncertainties and pressures from the ever changing work environment. They need to respect the budget and time schedules, cope with the peaks of the work, reduce operating cost, make the best use of their idle resources when they are not involved in any project, reduce the huge cost of ownership and therefore their fixed costs. The Service Web offers the opportunities for the construction companies to overcome the challenges they are facing; it enables them to be more profitable and flexible at the same time.

The Service Web connects the stakeholders in construction industry. The cloud provider offers community π-clouds for the stakeholders. Equipments, tools, warehouses (space), human resource, equipments, machinery, etc. are offered on the π-clouds and can be accessed by all who have registered to use the services (Finding phase on Figure 4).

To offer the service, the cloud provider needs the stakeholder to register by providing, all the exact addresses, and type of service, their specifications and the leasing period using an interface. All the data is saved on a π-cloud and this data cloud can be accessed by the public.

Later, the cloud provider needs to save the project scheduling of each owner on a private cloud in order to schedule the return of the object or the human resource to the owner.

As shown in Figure. 4 using abstraction, each resource is given an exact address and it has to get equipped with tracking and monitoring devices. At this phase all resources are put on the construction π-cloud. Access to this cloud is restricted and each time a match is made between an owner, a user and other parties on the Mobility and Distribution webs, the access will be granted to them. At the same time, the cloud provider performs all the supporting processes in the construction π-cloud. The payment, insurance, maintenance, communication, and security issues are resolved on the cloud and managed by the cloud provider.

The operating process for the construction π-cloud is as follows:

Whenever a match could be found between a user and the owner, service level agreements are prepared and then the provider exploits the Mobility Web and moves the object to the user (obtaining phase on Figure 4). When the resources is obtained by the user, the providor needs to update the information on the public cloud.

While the user exploits the object or uses the services of the human resource, the provider evaluates the user and the user also sends its feedbacks to the provider (mutual evaluation system of users and owners). Any misuse or any case of loss, accident and other special cases will be reported to the cloud provider on real time, so that the provider is able to react timely and prevent any delays in returning the resource to its owner or to the next user (using process on Figure 4). The Service Web allows the users to benefit from the services offered by human resources of other companies without hiring them. These services can be offered on site or using online services. For example, whenever idle at the owner`s site, the workers can be sent to the user`s construction sites, or other services such as accounting, consulting and so on can be offered online, the files, documents, reports and pictures and be sent to the experts, analyzed by them and be sent back to the user.

When the leasing period is over the resource needs to be either stored by searching the Distribution Web or moved to the next user or be back to the owner by searching the Mobility web for the options. Whatever the decision is, the virtualization need to take place and the π-cloud get updated.

Each object it is required to be sent for repairing and maintenance. Where this maintenance has to be conducted, and which party is paying for the repair and regular maintenance depends on the type of the object and it specifications. The provider needs to be prepared with plans for repair and maintenance.

The great opportunities Service Web provides will make it an indispensable part of the business in construction companies in near future, but before its realization it is vital to deliberately ponder the following issues:

The cloud providers need to be prepared and well planned to manage all the data and resources for industries as big as the construction industry. The amount of data shared, required work, coordination of the resources will be unbelievably huge on the Service Web. Especially at the beginning, it is required that the cloud providers offer secure, reliable and robust π-clouds to build trust. Another important issue is the current way of doing business in construction industry. Companies that are winning the bids, making huge profits are mostly those which own resources. One of major way to gain comparative advantage in today's business is to access or own the scares resources faster than the other competitors. By using the Service Web, the resources will be offered to and accessible by any company no matter what their size is. Therefore, it is required that the construction companies define new business models before facing the shocks of doing business in new open global systems.

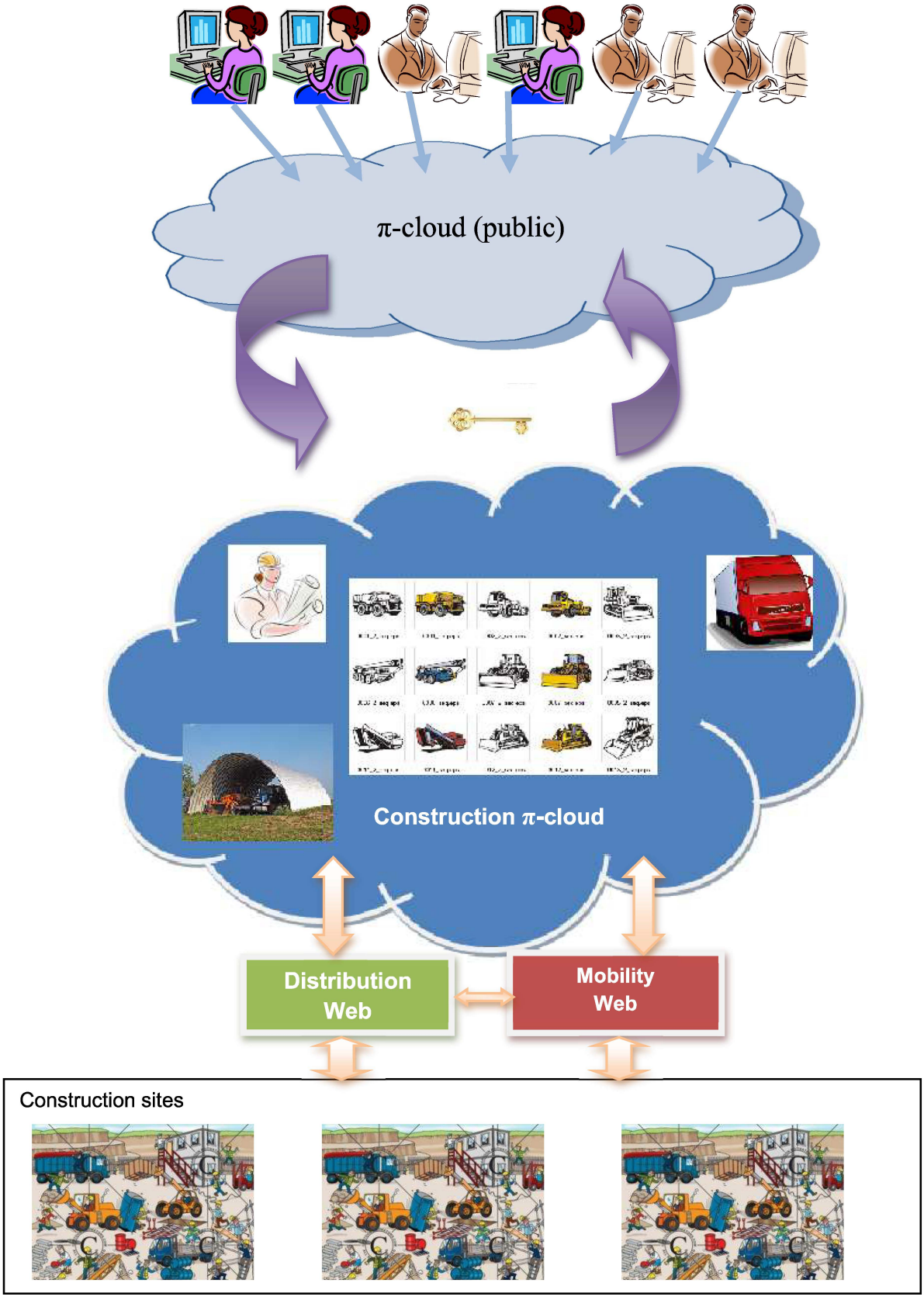


Figure 5 Illustrating π-clouds in the construction industry

6 Conclusion

Companies, organizations and individuals seek new more efficient and sustainable ways to manage their supply chains, to reduce their cost of ownership and to gain competitive advantage by providing timely and cost efficient products and/or services. The technological advances are forcing them to adapt their business models to open global systems. New open global systems bring along opportunities as well as the challenges. Within the paradigm of the Physical Internet, the Service Web is expected to help avoiding high cost of ownership, to respond rapidly to the ever-changing business environment, to gain benefit from the idle resources and to reduce the operational costs.

By identifying and exploiting the similarities between the Service Web and cloud computing, a conceptual model for realization of the Service Web is introduced. The Service web provides the opportunity of making profit from idle resources for the owner of the resources and the opportunity of paying less for accessing the object functionality for the users of the service. The conceptual model of the Service Web and its π-cloud has been introduced, illustratively sketched for the construction industry and its link to the Mobility Web and the Distribution Web enabled by the Physical Internet has been shown.

By introducing the conceptual model exploiting the cloud concepts, this paper attempts to take the first step into realization of Service Web. This work can be expanded upon in order to lead into future research. To evaluate the conceptual model and to realize the Service Web, simulation may be used. Following the new trend in sharing ride and space, the results of exploiting the Service Web and its π-clouds in terms of time and cost savings need to be assessed and disseminated so that companies start to grasp and see in practice the real benefits of open global systems.

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