2018

Contribution of Physical Internet Containers to Mitigate the Risk of Cargo Theft

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Abstract— **Different from current dedicated goods distribution solutions, the goods in the Physical Internet are encapsulated in modular dimensioned standard easy-to-interlock smart containers in an open interconnected logistic system. This paper aims to study the performance of the application of this cross-chain innovative packaging solution, especially its potential against cargo theft risks. To attain this, both qualitative and quantitative studies are carried out. With a scenario-based cost-justification model, different case studies are examined. Results suggest that through the modularity and standardization, the application of Physical Internet Containers will significantly improve the logistics performance and reduce cargo theft risks.**

Keywords— Physical Internet, Cargo theft, Modular standard containers, Risk mitigation

I. Introduction

Cargo theft is a worldwide issue decreasing economic as well as logistics performance of companies and nations. It refers to “the criminal taking of any cargo including, but not limited to, goods, chattels, money, or baggage that constitutes, in whole or in part of a commercial shipment of freight moving in commerce” (FBI). In Mexico, Cargo Theft causes a loss of 42’210 million pesos (1.8 billion euros) in 2017[1]. Furthermore, based on TAPA (Transported Asset Protection Association), in EMEA (Europe, the Middle East and Africa), economic losses increased 18.5% year-on-year in January with a value of 8 million euros[2]. For this zone, the most frequent modus operandi for cargo theft are: curtain slashing (49%), pilferage (22%), hijacking (9%), vehicle theft, facility theft, theft of full truckload, fuel theft, last mile courier, deceptive pick up. For the location, 80% of cargo theft crimes occur when the trucks are on the way, and 17% happened at parking places before final delivery of products.

To evaluate and mitigate cargo theft risks, existing solutions fall in four categories (Burges 2012): i) by improving physical security such as by using hard protective cover trailers or secure parking locations; ii) by improving information security such as using electronic security systems with infrared sensors; iii) by buying insurance; and iv) by law enforcement. However, many middle small companies declare their financial capacity limits to update their lorries with these sorts of measure or to pay for expensive assurances (Klima, Dorn, and Vander Beken 2011). Thus, despite of the efforts, the crime has been continuously rising. The Cargo Theft Report[3] by Freight Watch International reports 23 million euros loss in EMEA for the third trimester of 2017, an increase of 49% in total number of crime compared to the number of the same trimester in 2016. With regard to this gap, this paper explores how pooled innovative goods encapsulation solutions contribute to mitigate cargo theft risks. Here we explore the potential of Physical Internet handling Containers (PICs) as an innovative goods encapsulation to cargo theft risks.

Applying Digital Internet as a metaphor, the Physical Internet (PI) is an emerging logistic concept that aims to interconnect heterogeneous logistics networks into an open global system for increased efficiency and sustainability (Ballot, Montreuil, and Meller 2014). Like the information embedded in data packets routing in the Digital Internet, the goods are encapsulated in modular dimensioned easy-to-interlock smart PIC routed in an open logistic system. Further studies are taken out in (Meller, Lin, and Ellis 2012, Sallez et al. 2016, Yang, Pan, and Ballot 2017b, a, Montreuil, Ballot, and Tremblay 2014) for the design, conception, sizing, and global potential assessment for FMCG chains. Following the research stream, this paper analyzes how PICs mitigate cargo theft risks both from physical (protection and mixing) and information aspects.

The reminder of this paper is organized as follows. Section 2 gives a brief literature review to supply chain security management. Section 3 describes the major differences of goods encapsulation and distribution in the PI against in current organizations. Section 4 proposes an evaluation model to assess the potential of PICs in reducing cargo theft risks, followed by case illustrations in Section 5. Finally, Section 6 concludes and gives further perspectives.

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1 http://diario.mx/Nacional/2018-01-10_6bf4e262/cuesta-crimen-a-ip-42-mil-millones/

2 https://www.tapaemea.org/news-detail-view/an-ominous-start-to-2018-as-losses-rise-185-year-on-year-and-cargo-thefts-with-a-value-exceed-EUR8.html

3 http://www.freightwatchintl.com/system/files/security-reports/2017_q3_emea.pdf

II. STAKES AND LITERATURE REVIEW

As economic world is becoming a complex interconnected network of flows of commerce, companies as well as governments are looking for increasing logistics reliability while reducing costs and vulnerability of flows to security disruptions. However, since for companies and governments a security breach represents not only economic losses (sales, insurances, re-order costs, administrative costs, paying claims, and others), but reputation damages, an ''Iceberg Effect'' exists. Thus, the "true cost" of a security breach is uncertain (Jones et al., 2009). Supply chain security is multidimensional in nature.

For example, in Mexico, product type cargo thefts vary between regions. Electronics thefts frequently occur close to metropolitan areas in the central region of the country where a black market for this kind of products is more developed, while steel and other metals are more targeted in the north where suppliers of automotive production sites are located. Since there are many different risk factors involved for every product and its combinations with other products, methods for security risk classification has been proposed (Cedillo-Campos et al., 2015). Likewise, according to European Parliament's Committee on Transport and Tourism (2007), almost 41% of cargo theft arise when the vehicle is in movement and involve threats against the driver. In 15% of incidents, the vehicle is stolen along with the goods.

Based on De La Torre et al. (2014), there are three main factors to take into account when measuring risk of Cargo Theft: i) the geographical zone where cargo will pass; ii) the type of transported goods; iii) the reliability of human factor with access to cargo information. First, concerning the geographical zone, to be successful criminal gangs require to take control of a specific territory, and acquire particular technology and competences to develop distribution channel efficiencies for delivering a group of products to the black market. It could lead "a geographically-linked supply chain disruption" Ekwall and Lantz (2015). Second, related to the type of goods, high-value items, food and products with a stable demand remain the most stolen, as they are readily sold or marketable (U.S. Overseas Security Advisory Council, 2014; De La Torre et al., 2014). Concerning food and consumer goods, criminal gangs require a certain level of volume to have profitable operations. Finally, since the information concerning the type and volume of products, location of cargo inside of the vehicle, and the vehicle routing plan are critical to criminal gangs, the level of reliability of employees with access to this information should be part of risk assessment.

In this context, to increase the cost for criminal gangs of clearly identify the type and volume of products as well as the routing plan, could reduce the level of risk of cargo theft.

III. GOODS TRAVEL IN PI VS. CURRENT ORGANIZATION

Under current logistic organization, for goods distribution, firstly products are placed in primary packaging also called sales packaging that constitutes sales unit for final consumers. Primary packaging is often designed for marketing purposes. Then the primary units are combined together as secondary unit load in order to ease the handling, transportation and storage. Typical secondary unit loads can be found as trays, totes, crates or boxes of various materials such paper or cardboard. To facilitate handling and transportation activities, tertiary packaging such as palletization is often used. Examples can be found as pallets, shrink-wrap, dollies, roll cages etc. Then the pallets will be loaded on shipping containers and distributed across the pre-determined logistic organizations.

In the PI, standard smart modular open goods encapsulation solutions are applied to protect and distribute goods across an open logistic system. The concept of PI arose from the metaphor of Digital Internet. In Digital Internet, the data of messages and addresses are embedded in digital data packets through standardized universal codes and protocols. With all the information in the digital data packet as well as the protocols in Internet servers and routers, the digital data packet routes automatically and independently of infrastructure among the interconnected servers / routers in the Internet until it reaches its destination.

Inspired by this metaphor, the PI intends to do it the same way for goods encapsulation and distribution. In other words, just as data packets and servers in Digital Internet, the goods in the PI are encapsulated in standard modular PICs that route among PI hubs. PICs are material-equivalent to data packets in Digital Internet. Instead to be transported in a dedicated chain, PICs aim to encapsulate and protect goods in open interconnected logistics networks. We conclude the following two major differences of PICs from actual packaging solutions: global modularity and physical protection, and capability of mixing products in each shipment.

A. Modularity and physical protection

A challenge ahead current supply chain for goods encapsulation, is the different solutions used by many stakeholders when assembling unit loads. That is, goods encapsulation is often designed from half chain view where each actor focuses on his own part rather than on an across chain total optimum. For example, (Meller, Lin, and Ellis 2012) declared that a company uses 258 different packaging cardboard boxes for 494 different products.

This results in a wide variety of unit load dimensions and too many standards differing from country to country. Established international standards are not always used. Global inefficiencies arise by the diversity of goods encapsulation solutions such as increased material waste, inefficiencies in handling such as packing and repacking among partners to feed into new systems, poor utilization of transportation means and storage space across the chain, increased time for preparation of orders, inefficient reverse logistics, and increased cargo theft risks. This is where the real challenge takes place.

Instead of diverse dedicated solutions, the PI proposes a standard set of smart modular PICs both from a dimensional perspective and from a functional perspective. Figure 1 shows the dimensional modularity of PICs. The objective is to provide a set of universally adopted standard dimensions by key stakeholders and by the industry. Illustrative sets of modular cube dimensions can be found as {12; 6; 4.8; 3.6; 2.4; 1.2} m3 as larger spectrum and {0.64; 0.48; 0.36; 0.24; 0.12} m3 as smaller spectrum (Montreuil, Ballot, and Tremblay 2014).

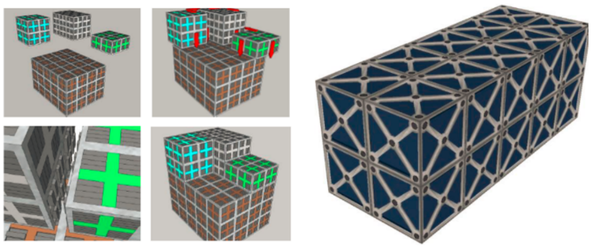

Figure 1. Modular PICs (Montreuil, Ballot, and Tremblay 2014)

Apart from dimensions, the PICs propose to standardize the key functionalities of goods encapsulations to facilitate the interconnection of logistics services. Firstly, to be able to protect encapsulated goods, the PICs are designed to be robust and reliable from physical regard. Using standardized interfacing devices, they are easily to be interlocked with each other and to be hanged to other equipment and structures. Besides, the PICs are designed with easy-to-seal capability for security purposes.

B. *A mix of products in each shipment*

Another major difference of goods travel in the PI and in current organization lies on the capabilities of the PICs to contain different products and even different orders from different clients. As illustrated before, the goods encapsulation solutions and current logistics services are often specialized for the use of one actor. It is naturally difficult for the pooling of goods encapsulation solutions among different actors. For example, full homogenous pallets are often distributed from suppliers to retailers. Even that there exist pooling solutions for transportation means such as by externalization of logistics services, it is complicated to pool secondary and tertiary packaging solutions under current logistics organization.

Instead, in PI, products encapsulations are anonym and mixed in PICs that are transported by numbers of certified transportation and logistics service providers across multiple modes. They are to be handled and stored in numerous certified open logistics facilities, notably for consolidated transshipment and distributed deployment across territories. They are to be used from production line all the way to retail stores and homes. Theoretically, the pooling and mix of products and orders can even happen at the smallest units of PICs. By this way, all users including suppliers, shippers, retailers, and consignees can share this same logistic system, which enables full horizontal and vertical coordination in logistics networks and drives supply chain efficiencies.

IV. ASSESSMENT POTENTIAL: ACCORDING LOGISTICS COSTS AND RISK REDUCTION

This paper tries to assess the potential of PICs against current packaging solutions across the chain, especially its impact on cargo theft risks. The goal is to outline key drivers for PICs. For this, we firstly develop a reduced set of typical Fast Moving Consumer Goods (FMCG) chains weighted according to their market share and size of products. Then a set of assumptions and a calculation model in excel will be proposed to quantitatively identify quick wins. To simplify the problem, we apply a small set of standardized modular boxes proposed by (Meller, Lin, and Ellis 2012), which is demonstrated as optimal set of modular boxes by an optimization study. Business case studies with industrial partners are further taken out. Results and analysis are validated together with industrial partners.

A. *Assumptions:*

For the developed evaluation tool, we apply the following assumptions.

a) To favor introduction of modular PICs, they must be compatible with major pallets dimensions. In the PICs scenario, only a maximum of one floor pallet is taken into account. The following four modular boxes in {{600x400x240}, {400x300x240}, {600x400x120}, {400x300x120}} in mm3 are assumed to be secondary PICs used in this paper which is demonstrated as optimal set of modular boxes by an optimization study (Meller, Lin, and Ellis 2012).

b) For the reutilization, recycling or disposal of packaging material, two methods are considered: close loop and open loop. Close loop ships the materials back to the origin while open loop pools materials together and repositions to the nearest consolidation center for reutilization.

c) Average shipping unit height and weight will be used instead of actual loads.

d) The goal of this study is not to evaluate all costs associated to the utilization of a specific RIC in FMCG chain but rather to compare the major differences induced by the utilization of PICs instead of actual boxes and support. The difference should be big enough to justify the switch from one system to another.

e) A product could be packed in boxes of different sizes according to the demand.

f) A PIC box can contain a single type of product or different products.

g) We should ensure a conservation of product flow from end to end of the supply chain.

h) We suppose that PICs are considered pooling packaging solutions as standard pooling services for pallets. Customers pay for the use and reconditioning of the materials instead of owing them.

B. *A set of typical FMCG chains:*

There are many different supply chains in FMCG. To encompass this diversity and avoid focusing on a specific example, we propose to categorize them according to volume sold by product (from best sellers to slow movers), the size of the point of sale (from super markets to corner shops and home delivery), as well as the product size (big, small). This classification will help to define the importance of each case and a typical SC organization for each. We outlined following four typical FMCG chains, described in Figure 2.

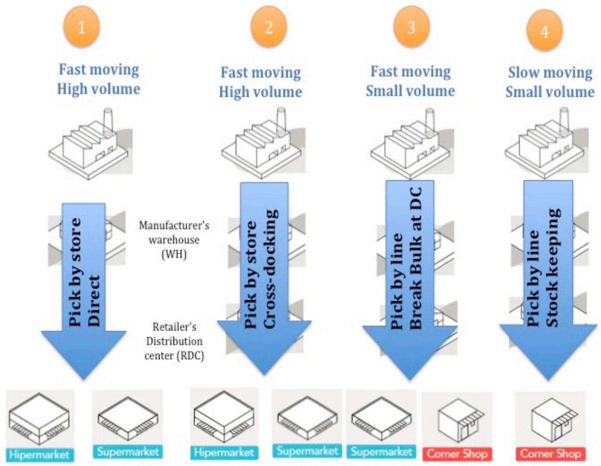

Figure 2. Typical FMCG chains

Firstly, for all scenarios, goods are assembled as homogenous full pallets at the manufacturer plants and are further delivered to their warehouses for next operations. As shown in picture, in Scenario 1, as distribution flows are quite frequent and often with high volumes, the merchandise are assembled for individual store orders at the manufacturer warehouse and are then delivered directly to the retail store, by passing retail-stocking facilities. Examples see as Coca cola, bottles of water, etc.

The second scenario represents a distribution system where the products received at a warehouse or distribution center are immediately picked and assembled for shipment to retail stores. At the manufacturer warehouse, the full homogeneous pallets are broken down and cross-dock heterogeneous pallets of individual store orders are assembled. Each order is cross-docked intact at retail distribution center and allocated for consolidated shipment to store. Examples often can be found in grand Cosmetic companies with different products or grand retail companies.

Scenario 3 represents the fast-moving products sold with small volumes such as fast-moving products sold to corner shops. In this scenario, to improve the efficiency, individual store orders are often grouped into one bulk order. At the manufacturer warehouse, the full homogeneous pallets are broken down and heterogeneous pallets for bulk replenishment orders are assembled. The heterogeneous pallets for bulks are further broken down at retail distribution center and re-allocated to individual stores for consolidated shipments.

Finally, for Scenario 4, the merchandises that are sold relatively slowly with small quantity usually require stock keeping at warehouses or distribution centers. In this scenario, the packaging operations resemble those of scenario 3.

C. *Objectives of the model:*

The following key factors impacted by PICs were analyzed in the cost-justification model:

i) Cube utilization: This refers to the use of boxes, pallets and transportation means.

j) Handling and ergonomics: We consider three types of handling: a) breakdowns, when boxes are manipulated from one pallet to another; b) piece picking when a product is manipulated from one box to another; c) loading and unloading from transportation means at handling unit level.

k) Material consumption: number of boxes and supports used per year.

l) Circulation/ Recycling/ Waste Disposal of packaging material after use.

m) Supply Chain Security: risks measurement of PICs vs. current boxes against cargo theft.

With assumptions and scenarios analysis, we establish a calculation model in excel. The model is based on real industrial data. The following industrial information and data are considered as inputs: logistic operations and packaging solutions of an end-to-end distribution scheme, characteristics of products and supports delivered, and all cost settings associated. Except the results of key differences presented before, the average total cost per item product delivered will be obtained including transportation cost, handling cost, stocking cost, as well as recycling or disposal cost of secondary packaging units.

Next section will present average values of different case studies and give a case illustration of how the calculation model works.

V. Results Analysis and Case Illustration

With the calculation model, 8 scenarios of case studies have been carried out (4 typical chains * 2 products sizes). Figure 3 presents the average percentage of savings of replacing current packaging solutions by PICs in total cost per item product delivered from the production line until the points of sales, including transportation cost, handling cost, stocking cost, and recycling/disposal cost of secondary packaging units. From the figure, we have found that using modular PICs will reduce the total cost per product delivered from manufacturer to end customers compared to current diverse packaging solutions. The best scenarios with averagely 39% reduction of total cost are scenarios with small slow-moving products for small medium sized points of sales. These savings could be considered as investment for transformation solutions towards PICs.

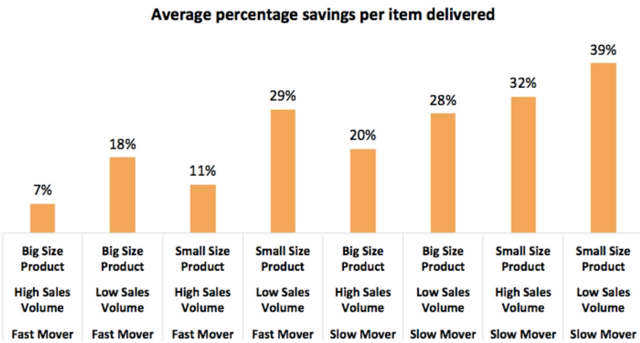

Figure 3. Average percentage of savings by PICs vs. current solutions

To analyze where come the gains, we give a case illustration of scenarios with small slow-moving products for small medium sized points of sales. Figure 4 gives an example of the distribution and packaging scheme for these scenarios.

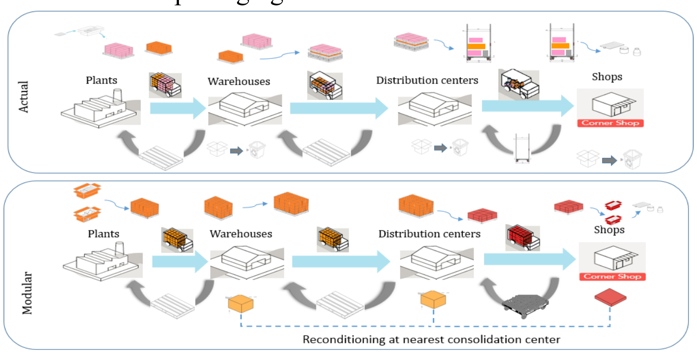

Figure 4. Scenario small slow moving products for small sized points of sales

Under current packaging solutions, firstly, goods are firstly packaged in suppliers' boxes with adapted size that are then stacked on full homogeneous pallets. Then, homogeneous pallets are delivered to the suppliers' warehouses and broken down to prepare sandwiches pallets with other products for orders from retailers. After that, sandwiches pallets are decomposed at the distribution centers of retailers. Goods are repacked in smaller boxes of retailers and assigned to rolls for further delivery of orders from points of sales. Across the chain, cardboard boxes are disposed at the end of use. The pallets are collected and transported to their origin points to reuse. In the case of modular PICs, instead of the diverse boxes, the four modular PICs are used. Instead of sandwiches pallets, here we can compose mixed complete pallets with different products in the same types of boxes. At the end of the use of packaging materials, modular boxes and standard pallets are collected to the nearest consolidation center for reuse. Figure 5 illustrates the average percentage of savings for these scenarios. From results, we found that the advantages of PICs are mainly from improved filling rate on pallets and trucks, from less consumption of pallets and packaging materials, and also from more efficient reverse logistics. Besides, the savings are mostly from retailers' side, especially in reduction of retailers' handling cost by much less pack-repack operations across the chain.

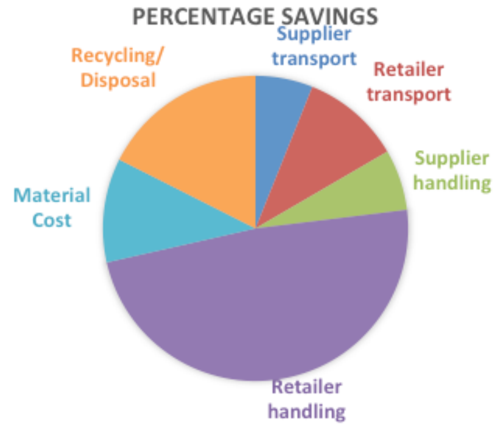

Figure 5. Percentage of savings for best scenarios

With regards to the saturation of means, we found the fill rates of means will be improved. The gains come from two sides: the modularity/stackability of PICs and the ability of mixing different products in the same boxes. For example, for a customer order of 6 products A {(232*233*171) mm3, 1545 gr, 60 euros} and 240 products B {(49*154*39) mm3, 131 gr, 3 euros}, we need: under actual solution, 2 boxes type 1 (244*528*247) mm3 and 5 boxes type 2 (163*330*320) mm3, with averagely 84% utilization of boxes; for PICs, 3 PICs of type (600*400*240) mm3, with 89% utilization of boxes.

For supply chain security perspectives, we find that the application of PICs will significantly reduce cargo theft risks. From the physical aspect, the PICs may reduce cargo theft risks by the following two approaches. Firstly, the PICs are designed with the ability of containing different products in the same container or in several containers. This property is initially for the purpose of fully usage of assets. From analysis, we also find that this property will reduce the crime possibility and the theft loss by mixing high and low value products together like the "shell game". It will not only greatly increase the difficulty to find the "right products", with the chain of receivers, among different products between different containers but also reduce the loss when the full truckload is hijacked. Secondly, the PICs are designed in modular sizes with composition-decomposition and interlocking property. This property will increase difficulties for curtain slashing incidents as it will be much more difficult to get out one hard cover container which is interlocked with others, compared to stealing a box from current pallet.

From the information aspect, the PICs are designed with unique codes and are traceable in the logistic system, thanks to LoRa and others technologies. The real-time identification and traceability of PICs provide instant visibility of assets leaving and entering the premise as well as identifying where the assets are located at any given time when needed, which could prevent theft risks. Furthermore, the PICs are equipped with self-state monitoring and communication property. That is, the PICs are able to monitor their own states such as temperature, shock, location, information of products contained, etc. If the information doesn't match to the information stored in the system, it may place an alert to the system to prevent further losses. In addition, the PIC can be designed with e-seals that would greatly increase the difficulty for thefts to access the products, for example, e-seals with block-chain technology support.

VI. Conclusion

In conclusion, this paper studies the potential of application of open modular pooling packaging solution across E2E FMCG chains. From result analysis, we conclude the following five key benefits for modular PICs:

1) High handling productivity: Non-value adding operations will be reduced through modularization, such as with less packing and repacking to feed into new systems among partners. Handling efficiency will be improved through application of automatic picking systems with adapted solutions going directly to shelves.
2) Maximized space utilization within the box, handing unit and transportation means through versatility of mixing products in same boxes, less void at handling unit and transportation means through modularity and stackability.
3) Lower environmental footprint via reduced raw material consumption and less CO2 emission by more efficient transportation.
4) Efficient reverse logistics due to the standardization of boxes with reduced transportation cost.
5) More secure distribution by physical and technical design of modular PICs against cargo theft risks.

Furthermore, through the modularity and standardization, the PICs are used as open pooled solutions for logistic users such as today's standard pallets renting services, resulting in much lower expenses compared to high implementing costs of todays' cargo theft prevention solutions. Future research is needed to propose a statistic model to quantitatively study the impact of PICs in mitigating cargo theft crime probability and risks.

Acknowledgment

The authors would like to thank the Consumer Goods Forum for the support of industrial data and exchange of the project of Modularization taskforce.

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