Omnichannel Business-to-Consumer Logistics and Supply Chains: Towards Hyperconnected Networks and Facilities

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Abstract

This paper deals with omnichannel business-to-consumer logistics and supply chains. Its key contribution is the conceptualization of hyperconnected network and facility design options for enabling to meet the challenges toward achieving omnichannel logistics efficiently and sustainably while meeting the timely expectations of clients. These design options exploit key Physical Internet concepts. They encompass the transportation, pickup and delivery of ordered goods, the deployment of products across territories to enable fast response to orders, as well as on-demand production of products across networks of facilities while engaging multiple parties. The options range from current practice to prospective ones that are associated to a more mature level of implementation of the Physical Internet. The paper identifies key relative advantages and disadvantages of alternative options, synthesizes strategic insights for industry, and provides research challenges and opportunities.

Keywords

Omnichannel; Business-to-Consumers; Logistics; Supply Chains; Facilities; Physical Internet; Networks; Hyperconnected Logistics; Last-Mile Delivery; Smart Lockers; Product Deployment; Transportation; Distribution; Production; Design Options

1. Introduction

Omnichannel business aims to let customers order anytime from anywhere, in person or through digital and mobile devices, and be fulfilled at their convenience, delivered or picked up at their preferred time and location (e.g. Brynjolfsson et al. 2013; Tetteh & Xu 2014). The omnichannel customer interaction and ordering is transforming the retailing and marketing faces of businesses (e.g. Verhoel et al. 2015), yet the focus of this paper is on omnichannel logistics, notably encompassing last-mile delivery and pre-positioning deployment of goods, that is proving a huge challenge for businesses, regions, cities and people. Omnichannel logistics requires rethinking supply chains and logistics systems on a grand scale.

Omnichannel logistics is tackled in this paper mostly from a business-to-consumer (B2C) e-commerce intensive perspective, in the spirit of Brynjolfsson et al. (2013) and Tetteh & Xu (2014). In this context, emphasis can be put on three key distinctive characteristics:

1. There is a thousands-to-one difference in the number of final points for the B2C supply chain as compared with the traditional business-to-business (B2B) chain. In the B2B chain, the end point is the point-of-sale (PoS), an office or a factory. Consumers are outside the realm. The PoS is responsible to deal with consumers who are responsible to get to the PoS to shop for their goods. In B2C, thousands of consumers that a typical store is dealing with independently in a locality are now being dealt with directly by the supply chain of the B2C business, be it an e-retailer or a brick-and-click retailer.
2. In B2C, an order from a consumer is usually atomistic, being for one product unit or a set of distinct product units, and filling at most a few multi-product cases or totes, as contrasted with B2B where an order is usually composed of a set of single-product-dedicated cases or pallets.
3. In an omnichannel context, the consumer expects to be able to buy desired products from a variety of channels, including websites, mobile devices and physical stores; and to be able to be delivered according to his preferences in terms of space and time, from home and car-trunk delivery to pickup at specified smart locker, e-drive or retail store, as soon as possible or within a specified time window.

The current huge challenges in omnichannel logistics and supply chain can be captured as follows: how to satisfy the consumers' expectations for vaster choices and lower prices than traditional retail while getting their orders to them at the time they want it (fast and/or within a satisfying time window) and at a location most convenient to them (with minimal compromise to avoid extra surcharges).

Underneath the surface, B2C businesses and their supply chains struggle to meet these challenges efficiently, having to deal with eaches (single product units) and to often deploy high inventories, and suffering from difficulties in efficiently using storage, transportation and consumer-pickup assets.

This paper aims at conceptualizing hyperconnected network and facility design options to meet the challenges of achieving omnichannel logistics efficiently and sustainably while meeting the timely expectations of clients, exploiting key concepts of the Physical Internet (Montreuil, 2011). The design options for transportation, distribution and production networks and facilities introduced in this paper aim to contribute toward addressing these challenges, helping shape strategic evolutionary and transformative visions for businesses engaged in omnichannel B2C logistics.

The paper is structured as follows. Sections two and three respectively provide a synthesized introduction to the Physical Internet and to omnichannel B2C logistics. Then, aiming to enable the design of highly efficient and sustainable omnichannel B2C logistics, sections four to six respectively provide options for interconnecting omnichannel B2C transportation, distribution and production that exploit a new generation of hyperconnected facilities. Section seven addresses the critical synergies with hyperconnected city logistics initiatives. The last section provides concluding remarks and avenues for further research and innovation.

2. Physical Internet: hyperconnected transportation, distribution and production

The Physical Internet (PI, π) is pivotal to this paper as it is underpinning all introduced propositions. The Physical Internet was introduced as a solution to the grand challenge of improving by an order of magnitude the economic, environmental and societal efficiency and sustainability of the way physical objects are moved, deployed, realized, supplied, designed and used all across the world (Montreuil, 2011, Montreuil et al. 2013, Ballot et al. 2014). PI is a global hyperconnected logistics system enabling massively open asset sharing and flow consolidation across numerous parties and modes through standardized encapsulation, modularization, protocols and interfaces. Hyperconnectivity is achieved through physical, digital, operational, transactional, legal and personal interconnectivity, ultimately anywhere anytime. The Physical Internet can be further expressed through its core set of key characteristics:

- Exploits open market for goods transportation, storage, realization, supply, design and usage;
- Encapsulates goods in transport, handling and packaging containers that are standardized, modular, designed-for-logistics, smart, connected and eco-friendly (Landschützer et al. 2015; Montreuil et al. 2016; Sallez et al. 2016);
- Exploits a new generation of handling, transportation and storage technologies and facilities for seamless, fast flow & exchange of loads (Montreuil et al. 2010; Ballot et al. 2014, Meller et al. 2014; Montreuil et al. 2014);
- Employs standard protocols and interfaces for seamless open asset sharing & consolidation across interconnected networks and modes (Montreuil et al. 2012);
- Builds on critical mass, as it is designed to serve a vast community of users;
- Drives capability and performance improvement through service provider certification and ratings-by-users;
- Enforces continuous tracking & monitoring of modular containers, vehicles, etc.;
- Enables and relies on smart, fact-based, proactive, distributed routing, deployment, and production decisions.

In this paper, the emphasis is on moving, deploying and realizing goods in an omnichannel B2C context, exploiting Physical Internet enabled hyperconnected transportation, distribution and production (Montreuil et al. 2013).

Hyperconnected transportation is about getting goods, encapsulated in modular containers, from their source to their destination through relay-based routing from open hub to open hub (Montreuil, 2011; Ballot et al., 2014). Flow is consolidated across multiple parties at each certified hub, getting containers heading in the same direction to be loaded together in a timely way in the most appropriate vehicles from certified providers exploiting the most pertinent mode of transportation:

- Airways: from large cargo airplanes to tiny drones;
- Waterways: from huge post-Panamax ships to riverboats and barges;
- Railways: from transcontinental cargo trains to local lightweight trains;
- Subways: from metropolitan subway systems to subterranean conveyor or pipeline systems;
- Roadways: encompassing freight-dedicated truck-trailers, delivery trucks, green urban vehicles, motorcycles and bicycles; as well as public transit tramways, buses, taxis and crowdsourced vehicles serving both people and freight.

Studies have shown that hyperconnected transportation has the potential to reduce overall induced costs by over 30% and greenhouse gas emissions by over 60% as compared to current practice: A simulation study of consumer goods logistics in France based on Carrefour, Casino and their top 106 suppliers (Ballot et al., 2014; Sarraj et al., 2014); A simulation based study of cross-industry semi-trailer transportation based on the Québec province of Canada (Hakimi et al., 2015); and quantitative analysis of the effects on sustainability and profits when shifting to Physical Internet based open horizontal collaboration in interconnected logistics systems (Meller et al. 2012). Businesses are putting these potentials to the test in industry. For example, CRC Services has started implementing a network of open pallet-centric crossdocking hubs in France. It was recently awarded the Supply Chain King award in France as its Southwest hub implementation already achieving significant cost improvements and greenhouse gas emission reductions for its clients (Desmedt, 2016). Rouges and Montreuil (2014) have documented the crowdsourced delivery business models emerging around the world and emphasized the potential for them in exploiting hyperconnected transportation concepts.

Hyperconnected distribution is about dynamically deploying goods, encapsulated in modular containers, across a web of open certified logistics centers so as to be readily positioned near points-of-demand for enabling fast order delivery and/or pickup (Montreuil, 2011; Montreuil et al., 2013). It brings to the material world the capabilities of cloud storage now gaining momentum in the digital world. Open facilities may encompass the likes of warehouses, mixing centers, distribution centers, fulfillment centers and smart lockers that are offering their space openly to multiple parties.

Sohrabi et al. (2016a, 2016b) show through a distribution network design optimization study involving ten North American based supply chains that hyperconnected distribution enables over 33% and 25% cost reduction, respectively over current dedicated and collaborative distribution. In industry, pioneering leaders such as ES3 and Flexe.com are currently leading the way to hyperconnected distribution. ES3 exploits its 300-acre world-class DC campus in York to serve numerous manufacturers and retailers in the consumer goods and food industry (www.es3.com). It inducts on the order 70,000 pallets and ships 5 million cases every week (Hambleton, 2016). It is expanding its network, notably with a center in Atlanta. For manufacturers, it already achieves 10-20% reduction in warehousing costs, over 50% reduction in picking costs and over 30% reduction in delivery costs, with over 30% overall savings; for retailers, it achieves 50%

cost reduction in both inventory and delivery, contributing to above 30% overall savings (Hambleton, 2016), while enabling higher frequencies of deliveries to stores. The emerging flexe.com is aiming to become the AirBnB of storage space. It currently focuses on connecting pallet-based storage space providers and demanders. It is growing at high pace, having started with sites in a single state in the USA and now having rapidly developed to having sites in 26 states (Morris, 2015; www.flexe.com).

Hyperconnected production is about realizing products on demand through a web of open certified production facilities (here nicknamed open fabs), supplying these open fabs and shipping from them in modular containers using hyperconnected transportation. Realizing products encompasses combinations of manufacturing, assembling, finishing, personalizing, packaging, refurbishing, etc., as pertinent. Hyperconnected production extends subcontracting, outsourcing and contract manufacturing capabilities. Open fabs can be stand-alone factories such as semiconductor fabs and contract electronics assembly plants. They can also be embedded in logistics facilities, for example completing the personalization of ordered products according to a postponement strategy.

Hyperconnected production is to exploit plug-and-play production modules, movable by being framed as modular containers and dynamically configurable using modular resources (e.g. Marcotte and Montreuil, 2016). The European F3 project has been pioneering research and innovation on containerized manufacturing (F3, 2014). Bayer and Procter & Gamble are engaged in field-testing containerized production and are developing strategic visions toward hyperconnected containerized production (Sibomana et al. 2015).

Additive manufacturing technologies, better known as 3D printing, are highly promising in terms of hyperconnected production. They simplify supply chains and enable positioning of production near point-of-use, eventually even in homes for simple usages. Key with open 3D printing fabs is feeding them securely, efficiently and sustainably with digital product printing specifications and the appropriate printing materials.

In subsequent sections, the Physical Internet and its enabled hyperconnected transportation, distribution and production are to be integrated into the elaboration of options for hyperconnected omnichannel business-to-consumer logistics.

3. Omnichannel business-to-consumer supply chains

In business-to-business supply chains, the customer is a business that may or not sell products to consumers. Typically, identical product items are unitized as a single load (e.g. in a case) after their production or assembly in a factory, grouped on a pallet, shipped to a warehouse or mixing center, transferred to a distribution center, re-palletized into a mixed-load pallet, then shipped to the final client. In this client location (e.g. a retail store), the pallets are broken into cases and then individual product units are taken out of the cases at their point of use or point of sale (e.g. display for consumers on shelving in retail store). B2B supply chains are mostly geared to deal with cases and pallets of cases, not individual product units.

In business-to-consumer supply chains, the customer is a consumer who most often orders either a single product unit or a set of distinct product units, ranging from a small box to a few larger cases. As discussed earlier, in omnichannel B2C supply chains, the customer has a wide variety of choices relative to how he may order/buy the goods he wants, and relative to where he is to pick up or be delivered the purchased goods. Omnichannel B2C supply chains thus have to deal much earlier with specific product units and to be profitably capable of getting them to the consumer specified location with the expected combination of delivery speed, timeliness, reliability and cost.

Focusing on grocery retailing, Hübner et al. (2015) provide a framework for omnichannel logistics that split it into back-end fulfillment and last-mile distribution, encompassing a strategic interplay between picking location, automation and integration, delivery mode, delivery time, delivery area and returns.

Beyond transportation and distribution, from a production and assembly perspective in the omnichannel B2C chain, there are two basic avenues: products are made to consumer order (MTO) or they are made to stock (MTS) and then picked to consumer order. The bulk of the consumer goods currently take the second avenue while the first avenue is appropriate for specialized, personalized and very-low-demand goods. Additive manufacturing promises a potential shift toward printing to order consumer orders for more products, yet currently it is yet mostly limited to prototyping and showcasing products, and to make personalized high-value items (e.g. spare parts and hearing devices).

Along both avenues, MTO and MTS, when the consumer orders several items, there is a spectrum of choices between having the items individually flowed to the consumer or grouped in a single unit load to be jointly flowed to the consumer. Furthermore, specific product items (eaches) have to be picked and packed in unit loads that offer sufficient protection against the hazards (e.g. drops, bangs) associated with handling, transporting and delivering them.

An omnichannel B2C supply chain is depicted in Figure 1, distinguishing the types of facilities and flows, notably using colors. This supply chain is not meant to be comprehensive or prescriptive, but rather representative of the essence of such supply chains. It is in line with the findings of previously published research such as Morganti et al. (2014) focusing on France and Germany.

Figure 1 starts at the plant and omits upstream actors such as the factory's suppliers. Supply chain players may take on various roles in Figure 1. For example a manufacturer may get engaged in home delivery of its products.

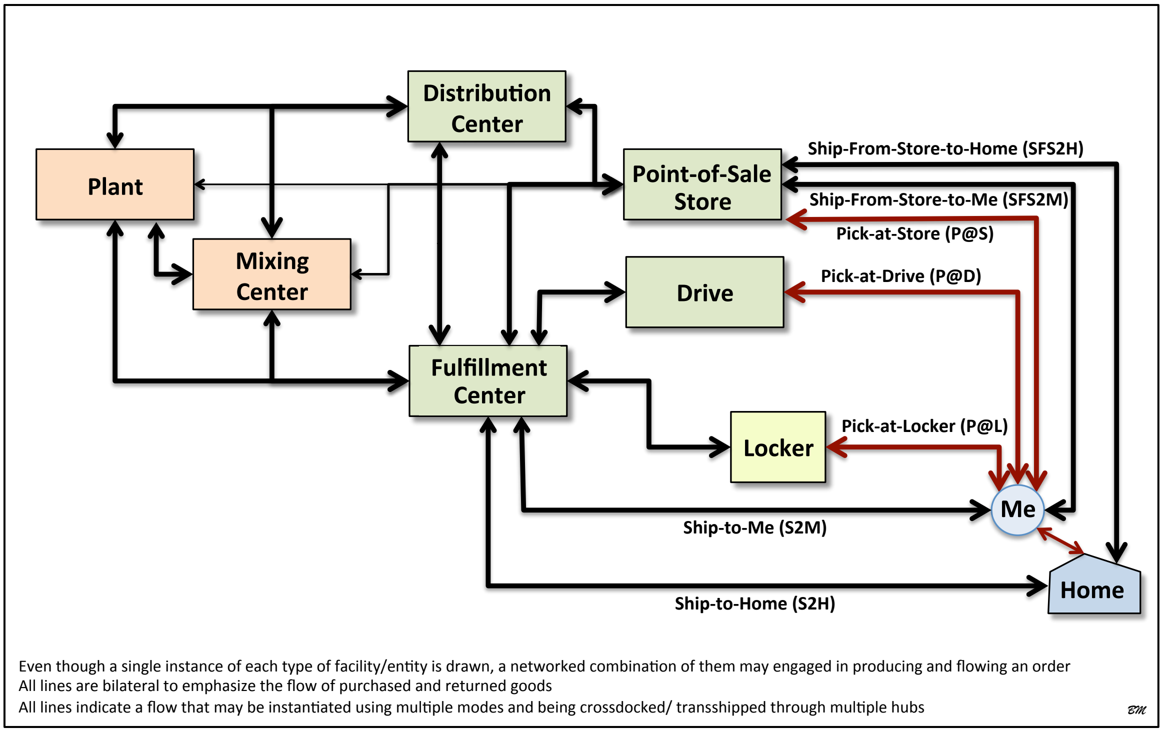

Figure 1. Omnichannel business-to-consumer supply chain

In the center of Figure 1 are the green-colored facilities such as distribution centers, fulfillment centers and drives exploited by players active in the retail and distribution market. They include e-commerce players, often considered to be pure-play, such as amazon.com; click-and-mortar players such as WalMart that exploit retail stores of various sizes and e-commerce through global and/or country-specific websites and supply chains (e.g. walmart.com and country specific versions such as walmart.ca); brick-and-mortar retail players absent from the e-commerce front; and logistics service providers such as DHL, FedEx, UPS and myriads of smaller players exploiting facilities used by the retail and distribution players. Smart lockers have been distinguished from the other central facilities by using a yellow color, as these are often not owned or operated by/for the retail and distribution players, rather put in place by companies specialized in smart lockers or by third-party logistics service providers expanding their scope to such lockers.

On the left side are the orange-colored manufacturers' factories and their mixing centers (or factory-specific warehouses). Examples of players are Coca-Cola, Nestlé, Procter & Gamble and Unilever, as well as myriads of small and medium size manufacturing and import enterprises. Manufacturers are currently mainly keeping a low profile on the omnichannel e-commerce front, notably pondering the risks associated with jeopardizing their relationships with the e-commerce players described above. Yet some manufacturers are going directly to consumers, partly or entirely taking over the central roles in Figure 1 mostly filled by retailers, as it relates to their products. Southshore.com is an example of a SME that is in the middle of this complex strategic interplay as it is a preferred furniture supplier of giants such as amazon.com and walmart.com, while it has its own transactional website (southshore.ca) complementing the e-retailer channel with innovative and wider-scope decor-oriented solutions offered directly to consumers.

On the right side are the blue-colored consumers and their homes, used here as a surrogate for hotels, offices, workplaces, and any other place where they can use and enjoy the acquired product(s). Depending on the flow path through the supply chain of Figure 1, the product is brought to the consumer's home by either by the latter or a third-party service provider.

In Figure 1, seven types of B2C flows are distinguished, as perceived by consumers.

First is pick-at-store (P@S). It has long been attractive to retail players already having an extensive retail point-of-sale network. Three P@S use cases are dominant:

1. Consumer shops in a store and gets immediately her/his desired goods;
2. Consumer orders online and picks up her/his ordered goods from the most convenient store;
3. Consumer shops in some store of the retailer yet her/his desired products are not readily available in that store, so goods are picked up at some other convenient store within an acceptable time window.

There have been huge failures with pick-at-store in the past, mostly related to the fact that in the traditional case-1 supply chain, the consumer used to do the work of picking up the goods in the store, while in case-2 and case-3 supply chains, the consumer is not expecting to do so, wanting to simply pick the order already packed.

Recently, businesses have started to re-design their retail stores so that they are laid out and operated to profitably ease order pickup by their consumers (Ishfaq et al., 2016). This induces a number of retailers to reduce the space devoted to merchandising so as to include order fulfillment zones allowing efficient storage, picking, packing and pickup. Ultimately, the merchandising floor space becomes a showcasing and/or experiential space (Stephens, 2013).

Second is pick-at-drive (P@D) that is growing in popularity. As with P@S, P@D requires consumers to come pick up their e-commerce purchased goods at a facility of the business. For the consumer, the difference lies in the fact that these facilities, often called drives, are specialized in dealing with such e-commerce pickups. For the business there are two key differences, as in the pick-at-drive case:

1. Orders gathered online are forwarded to a fulfillment center where consumer specific unit loads are created by individually picking the goods ordered by the consumer.
2. These unit loads are shipped to the drive most conveniently located for the consumer, as was often done in the past for catalog orders. This drive is normally relatively small, replenished on a daily basis, or even multiple times a day. Fast moving high-demand items are sometimes stored at the drive and joined as

pertinent to the other goods ordered by the customer when he arrives to the drive.

The perceived advantage of P@D over P@S is that drives are generally much less expensive to implement and to operate than a store, and can therefore be deployed in greater number nearer to the consumers, ideally in a much more efficient way.

Third is the currently emerging pick-at-locker (P@L). Conceptually, it is between pick-at-drive and ship-to-home. It delivers it to a smart locker nearby the customer's home. Instead of having a significantly staffed and equipped drive facility, it relies on simple smart lockers that are basically an upgraded version of the lockers found for decades in bus terminals and railway stations across the world, or postal lockers in local neighborhoods not home-served by postal services.

Either through an on-site terminal as in Figure 2, or using a smart phone or device, the consumer identifies himself and gets access to his ordered goods. As contrasted with pick-at-drive, pick-at-locker requires a significantly more intensive network of smart locker facilities and significantly more delivery effort, yet significantly less than home delivery.

Figure 2. Illustrative smart locker implementation

Fourth is ship-to-home (S2H), the current most used by e-commerce. Its convenience stems from the fact the consumer does not have to do extra travel and efforts to pick up his e-commerce ordered goods. Here home is meant in a wide sense to express wherever the consumer wants as long as there is an associated address. As with pick-at-drive and pick-at-locker, each order gathered online by the e-commerce-active business is digitally forwarded in most cases to the business's order fulfillment center nearest to the consumer. It is then picked, packed and shipped to the consumer according to the agreed delivery option in term of location and time.

Ship-to-home requires significant delivery efforts and costs, with tiny deliveries to a vast number of distributed points. Even though S2H is often advertised as being free to the consumer, it induces a highly significant cost either directly charged to the consumer or absorbed through margins from various other products and markets, mostly in a war to capture significant shares in markets having strategic competitive importance for the business.

Fifth, ship-to-me (S2M) is a logical extension from ship-to-home. It encompasses getting it shipped to the consumer's vehicle trunk or to him at the exit of a train or airplane, or any similar setting. It is in its infancy, currently inducing significantly larger costs as the supply chains are not geared to efficiently achieve it in large volume. It requires, synchronization, precision and flexibility beyond the capabilities of most players.

Finally, sixth and seventh, are ship-from-store-to-home (SFS2H) and ship-from-store-to-me (SFS2M) that are inbound specified variations on S2H and S2M. These capitalize on the retailer store network like pick-at-store, getting the ordered products shipped to the consumer's home or to him as in the above described ship-to-home and ship-to-me, yet from the store where the consumer is currently shopping or from the most delivery-convenient store.

As it was earlier made explicit, omnichannel logistics networks are currently vastly dedicated to specific manufacturers in the upstream of the supply chain, to specific retailers in the downstream of the supply chain, and exploit third-party logistics providers providing integrated distribution and/or delivery services. The subsequent sections introduce a spectrum of omnichannel logistics network options beyond current practice exploiting Physical Internet concepts and principles, aiming to enable efficient and sustainable hyperconnected transportation, distribution and production.

4. Interconnecting omnichannel B2C transportation

Most players in physical and e-commerce retail, distribution and manufacturing that are engaged in omnichannel business have acknowledged that they do not have enough critical mass to justify exploiting their own delivery fleet to perform all flows in their supply chain (e.g. all flows in Figure 1). This has led the vast majority of e-commerce centric retailers to sign a strategic agreement with third-party delivery service providers (3PD) such as Chronopost, DHL, FedEx, Purolator or UPS.

Figure 3 uses the omnichannel supply chain of Figure 1 to exemplify as a first option the exploitation of interconnection with third party delivery services providers that act as partners to the business (e.g. Fairchild 2014). In the illustration, the supply chain relies on three 3PDs and the customers to perform all transportation flows across the supply chain. As sketched in Figure 3, the 3PDs take over all deliveries assigned to them, mostly using their own fleet and exploiting their own crossdocking hubs, indeed their own logistics network. The 3PDs interconnect the deliveries of their clients, notably having them share transportation and delivery vehicles, and going through the same sortation systems in their crossdocking facilities.

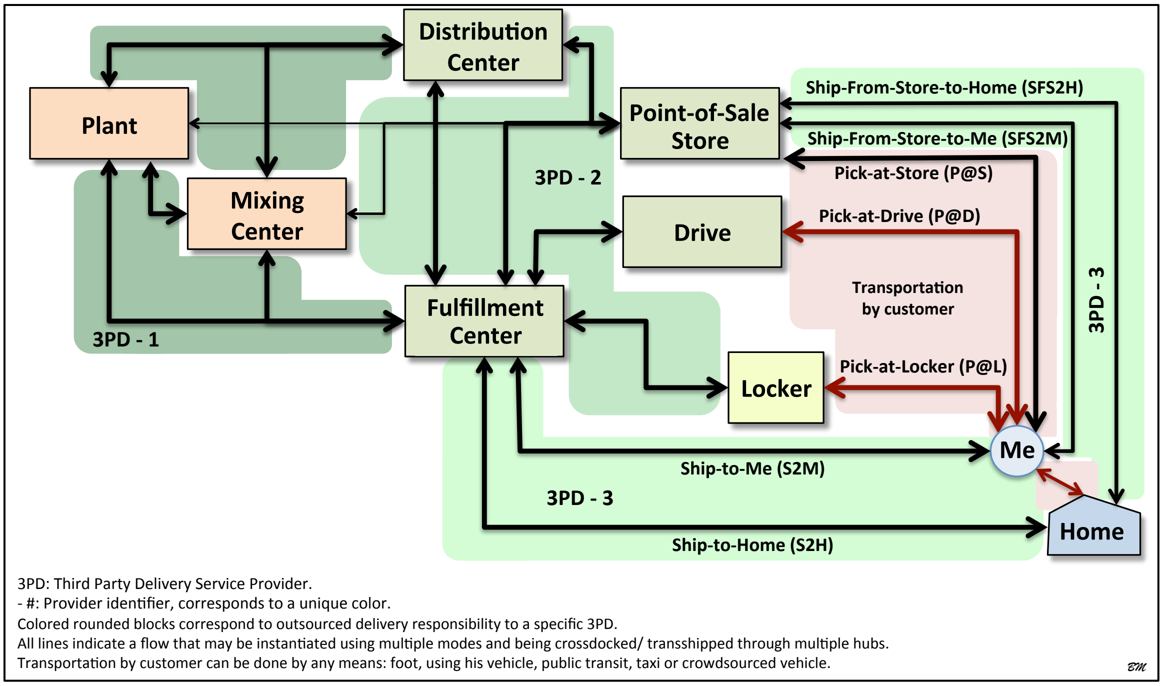

Figure 3. Omnichannel B2C supply chain exploiting third-party delivery service providers

Upstream, the first 3PD takes over all flows related to combinations of plants, mixing centers, distribution centers and fulfillment centers. The second 3PD takes charge of all upstream flows with point-of-sale stores, drives and lockers, linking them with the distribution centers, fulfillment centers, mixing centers and plants. The third 3PD takes over all ship-to-home and ship-to-me deliveries. Consumers individually take responsibility for all self-transportation to and from stores, drives and lockers for pickup purposes.

The key advantages of this option from the business perspective are:

- It allows players such as retailers and manufacturers to concentrate on their core competencies, simplifying their job drastically logistics-wise;
- It builds on the competency and network effect of 3PDs to exploit synergy among their clients to drive delivery costs and prices down.

Its key disadvantages are:

- It forces players such as retailers and manufacturers to engage in long-term agreements with a limited set of 3PDs, limiting their dynamic agility and adaptability;
- Each 3PD is limiting their flow pooling to their client deliveries and their dedicated fleet and crossdocking hubs.

From a holistic territorial perspective, even though much less than exploiting dedicated fleets, this option induces waste such as (1) trucks from multiple delivery service providers passing/stopping in front of a given site within a few minutes, with each of these trucks traveling while lightly loaded; (2) goods waiting much longer than desired so as to fill enough vehicles to justify launching a route due to the 3PDs' limited set of client loads; and (3) routes being much longer than minimally possible due to 3PDs' limited hub-and-spoke network.

Figure 4 depicts a second option that exploits Physical Internet enabled hyperconnected transportation (Montreuil, 2011). It builds on a multitude of openly available certified transportation providers and a multitude of geographically distributed, designed-for-interconnectivity logistics hubs enabling efficient multi-party transshipment and crossdocking, here termed open hubs (e.g. Montreuil, 2011, Montreuil et al. 2010, Ballot et al. 2014, Meller et al. 2014 and Montreuil et al. 2014).

These lead transportation to become relay based from hub to hub with open consolidation of flow and open vehicle and hub asset sharing. According to this option, goods out of a facility are brought to the nearest hub where they are consolidated according to next (hub) destination with goods from many other parties, and loaded into vehicles heading for the appropriate next hub. The process repeated until the goods get to a hub near to their final destination, where they are grouped for an efficient route to their target.

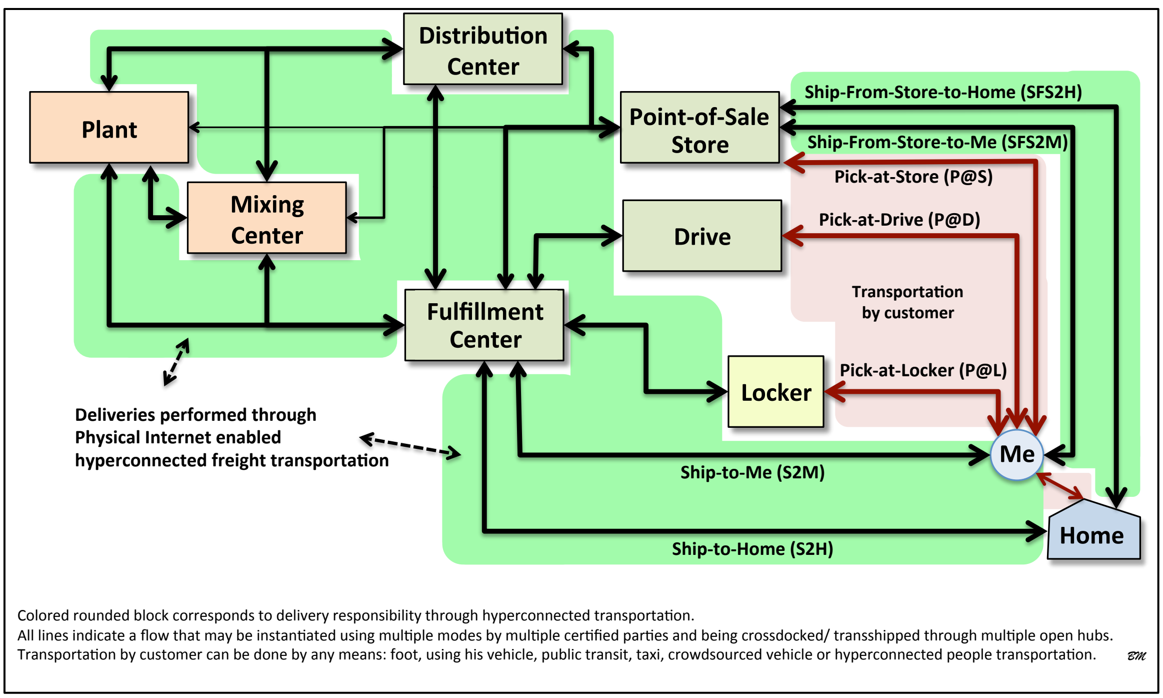

Figure 4. Omnichannel B2C supply chain exploiting hyperconnected transportation

The key advantages for the business of this second option are:

- It has access to a much larger solution space in terms of product delivery decisions, with the wider pool of open transporters and transportation hub facilities, exploiting hyperconnected system-wide economies of scale;
- It controls all the key product delivery decisions;

- It does not have to sign strategic agreements with the open transportation service providers and the crossdocking and transshipment hub owners/operators, as it may pay for spot usage as needed, yet it may sign such agreements whenever pertinent to gain economies-of-scale;
- It has the potential to induce significant cost reductions and environmental footprint from system-wide economies of scales induced by the open pooling and flow consolidation.

The main disadvantages for the business are:

- It requires more decision making and asset/product tracking effort from the business, delegated to 3PDs in option 1;
- It dynamically involves many more players involved in the routing of products, requiring to respect effective protocols and interfaces;
- It has the potential to lose contract-specific economies associated with signing long-term partnerships with 3PDs.

A third option combining facets of the first and second options consists in exploiting hyperconnected transportation as described above for option two, yet delegating to contracted delivery orchestrators (DOs) the actual routing, pooling and consolidation decisions. Figure 5 shows an underlying hyperconnected transportation playground coupled with the exploitation of three DOs, in this case corresponding to the responsibilities of the three delivery service providers of Figure 3 in option one.

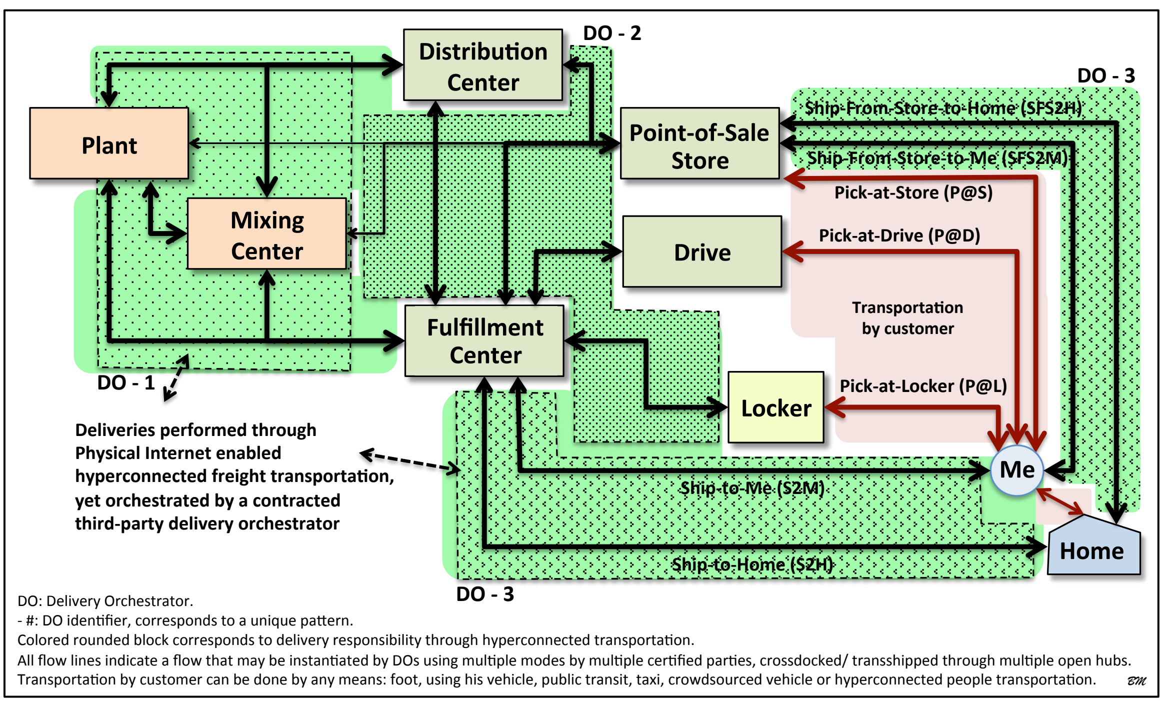

Figure 5. Omnichannel B2C supply chain exploiting hyperconnected transportation and delivery orchestratorsThe key difference with

option one is the DOs do not own and/or operate dedicated assets such as vehicles and hubs, they rather exploit the Physical Internet enabled multimodal mobility web with its numerous open transporters and hubs in order to offer the best service to their business clients.

As compared to the second option, the main advantages of this third option for the business are:

- It simplifies drastically the complexity and efforts associated with exploiting dynamically the mobility web;
- It has the potential to gain from economies of scale induced by the multi-client nature of the delivery orchestrator.

Its main disadvantages are:

- The extra cost charged by the delivery orchestrator, which may be partially or completely compensated by the leaner internal resource requirements for supporting product deployment;
- The reliance on one delivery orchestrator for a given type of transportation activities may cause strategic issues over the long run as the business may become dependent on it.

In order to provide a different complementary take at interconnecting delivery, consider a case involving an international shipment from a fulfillment center in some country to a home in another country, requiring air travel so as to meet the delivery time promise to the consumer. Figure 6 provides five examples of interconnection options enabling to complete the airfreighted B2C delivery, starting at the fulfillment center in the supplying country. The first two examples are typical of current logistics systems while the Physical Internet induces the latter three examples.

In option 1, the business deals with a single 3PD relying on its own ground network in the originating country, its own airfreight network to move the goods from the originating country to the destination country, and its own ground network in the destination country. In each country, the 3PD moves the goods using its own fleet between its internal hubs (drawn in red) for flow consolidation. In the originating country, using one of its vehicles, it first picks up the goods at the fulfillment center, often through a multi-client route ending at the first internal hub. The same happens in reverse in the destination country from the final hub to the consumer homes, the 3PD often delivering to many clients using one of its delivery vehicles, each client having to receive goods ordered from various businesses.

In option 2, the business interconnects three third-party delivery service providers: 3PD 1 and 2 in the originating and departing countries respectively, and 3PD A for flying the goods between the two countries. Each of the 3PDs acts as was described for option 1 within its responsibility spectrum.

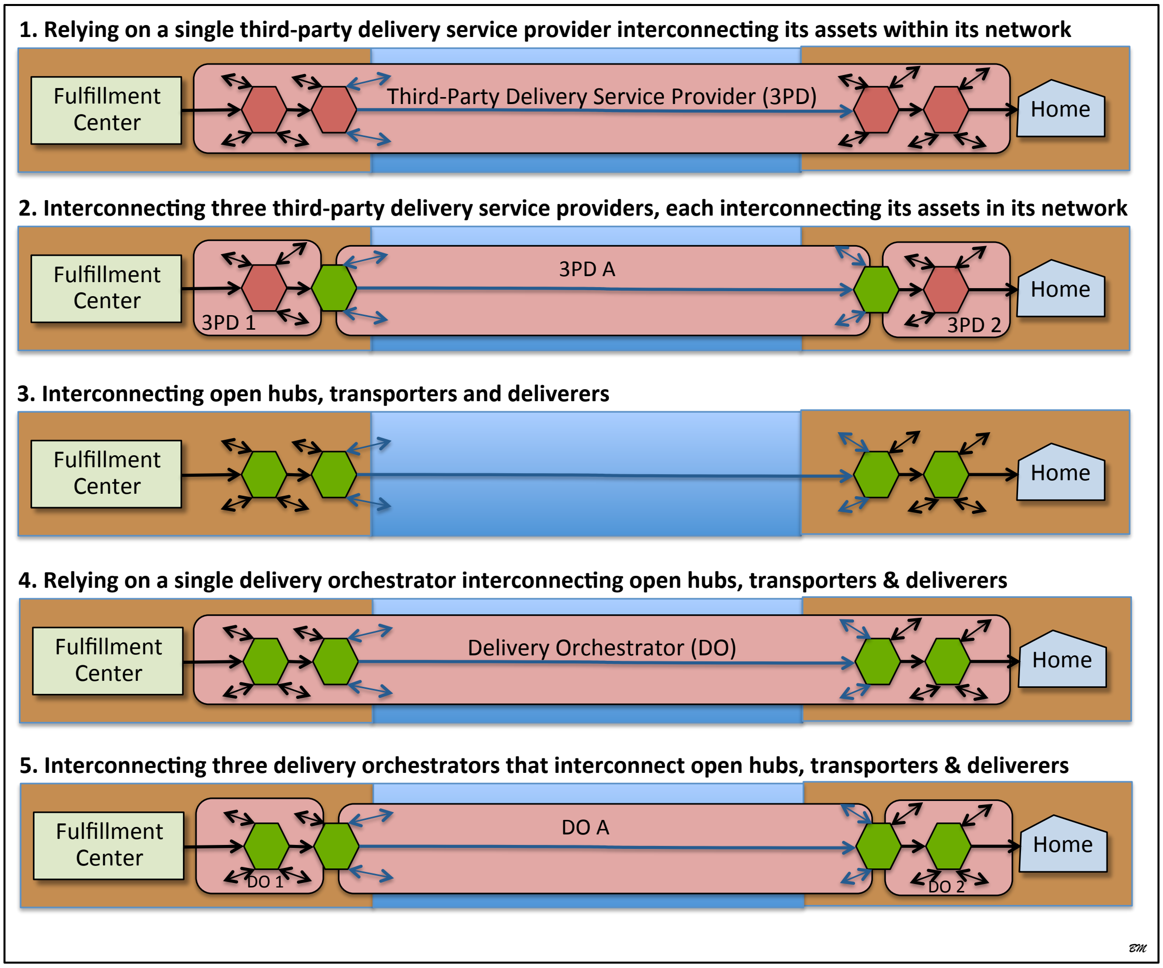

Figure 6. Options for interconnected international airfreighted B2C delivery

By interconnecting the 3PDs, at the price of more selection and orchestration efforts, the business aims to avoid using a single 3PD having a limited network in one or two of the main shipping legs, preferring to deal with the 3PD offering the best service-price combination for each leg. To do so, it relies on the fact that these 3PDs are well, if not entirely seamlessly, interconnected. This interconnection happens physically at open hubs (distinctively drawn in green) where the 3PDs are both active, such as is often the case in cargo-focused airports.

In option 3, the business does not deal with a third-party delivery service provider. It exploits its own talented staff to dynamically select and orchestrate networks of open hubs, deliverers and transporters, while in line with the Physical Internet's hyperconnected transportation logic and the business delivery needs. On the positive side, it avoids the indirect costs carried by the 3PDs and it has access to a wide portfolio of potential open hubs, deliverers and transporters, enabling it to potentially generate better networks than when dealing with the 3PDs. On the negative side, it gets much more engaged in the overall delivery process than when the 3PDs took over that charge.

In option 4, the business does not interconnect directly with the open hubs, deliverers and transporters as in option 3, nor does it exploit traditional 3PDs as in options 1 and 2. It rather deals with a delivery orchestrator. As previously described, such a DO does not own nor operate a fleet and/or a network of internal hubs. It deals with open hubs, transporters and deliverers, as well as, if pertinent, with traditional DSPs. It dynamically creates and manages delivery networks most appropriate for their client needs. Compared to option 3, the business pays the DO to do the selection and orchestration that it was performing, easing its workload and betting on the DO's capability to put together better networks and manage them better than it could by itself.

Option 5 differs from option 4, as the business does not deal with a single DO, but rather with three DOs whose decisional scope corresponds to those of the three 3PDs of option 2. It bets on the specific specialization of the DOs and their exploitation of the open mobility web accessible within their territorial scope.

These options are illustrative of the spectrum open by exploiting hyperconnected logistics for dealing with the shipment of goods from the fulfillment centers to consumer homes, and similarly to smart lockers and drives. The three latter ones have to rely on designed-for-interconnectivity open logistics hubs.

Overall, the shift to hyperconnected transportation in omnichannel B2C supply chains requires shipping, transshipment, crossdocking and receiving facilities to be designed or retrofitted so as to enable seamless, fast, cheap, safe, reliable, distributed, open multimodal transport and handling (e.g. loading, unloading, sorting, grouping, de-composing) of standardized smart modular transport, handling and/or packaging containers originating from and heading to multiple potentially competing parties.

The shift also induces the emergence of two key transformations in the transportation/delivery/pickup facility landscape. First is the emergence of hyperconnected hub zones with multiple competing/complementing facilities near ports, airports, borders, highway intersections, metropolitan areas, and so on. Second is the emergence of vast networks of hyperconnected near-to-consumers capillary facilities. These are often to be small, smartly automated, and offering easy and efficient accessibility and usability for consumers and B2C transportation and delivery actors.

5. Interconnecting B2C goods deployment, pickup and delivery

In order to grasp the potential offered by interconnection in B2C goods deployment, pickup and delivery, first consider the case of Figure 6 used to illustrate interconnection options for an international B2C delivery. The main question at stakes is: why did the goods have to be shipped from another country to satisfy an online order from a consumer?

If delivery time is not an issue, then it is a cost savings decision exploiting centralization of operations and stock in the originating country. However, as delivery time becomes a more important issue, then fast delivery is required on ground and on air, cumulating to high delivery costs. In many cases, the foreign e-commerce business selling the goods does not have enough critical mass in the destination country to operate a fulfillment center there; thus justifying reliance on international delivery with its significant costs.

In the current general situation, setting up a fulfillment center costs millions or tens of millions of US$ depending on scale and location. Setting up a drive costs a few hundred-thousand to a few million US$, and setting up a smart locker set in a specific location costs a few ten-thousand US$.

The current pull for fast precisely-timed availability leads to the need for up to multiple fulfillment centers per country, for up to multiple drives and/or fulfillers per city, and for up to multiple smart locker sets per neighborhood.

In the subsequently described case, the term fulfiller is used to distinguish smaller larger scale fulfillment centers from larger ones. Such smaller scale fulfillers are deployed in localities to preposition items forecasted to be ordered soon locally, and to pick, pack and ship the instantiated orders to drives, smart lockers or homes. Fulfillers are not expected to have in stock all items ordered by a consumer, but rather the highly popular ones that consumers expect to receive fast or, even better, the ones expected to be ordered soon by local consumers based on predictive analytics. Fulfillers may be part of the solution for deliver reliably and efficiently on a large scale offers in the spirit of Amazon Prime Now (primenow.amazon.com).

Smart lockers are currently used mostly for order delivery by the e-commerce delivery providers and for order pickup by the consumers. They can also be used to pre-position items in neighborhoods, specially for items known with high probability to be needed nearby soon and for which immediate rapid accessibility is widely appreciated by consumers.

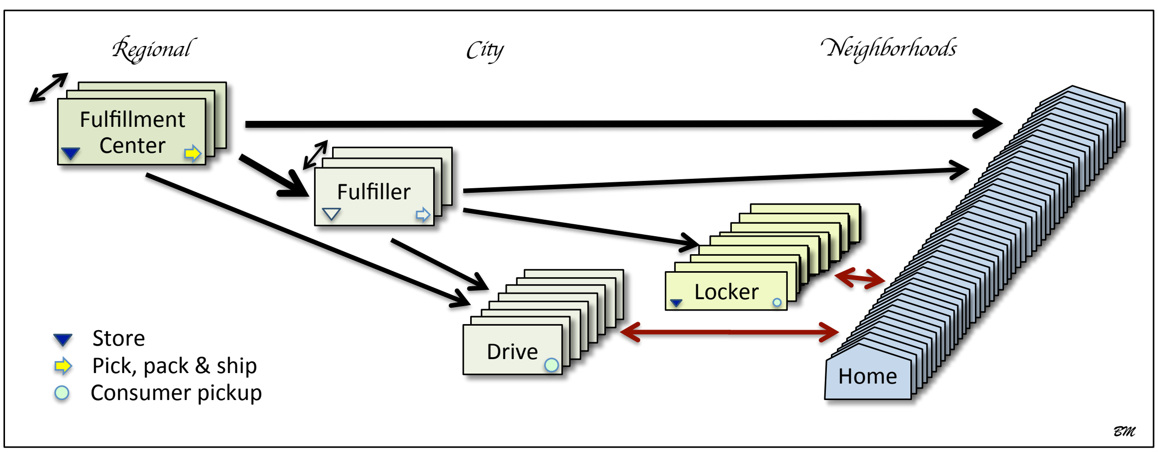

Figure 7. Flow diagram of the downstream part of an omnichannel B2C supply chain

Consider a store-less e-commerce business aiming to deploy its products through a combination of fulfillment centers, fulfillers drives and lockers, feeding its options of drive pickup, locker pickup and home delivery offered to consumers. The logic of this specific business can be illustrated by the flow diagram of Figure 7 and summarized as follows:

- Home delivery orders are fulfilled from the nearest urban fulfiller whenever possible, complemented or replaced by the regional fulfillment center when time constraints are loose and/or ordered goods are slower movers not available at the fulfiller;
- Pickup at a neighborhood locker is offered to consumers as a cheaper alternative to home delivery;
- Fed from urban fulfillers, lockers are also exploited to deploy in neighborhoods some popular fast-response products;
- Pickup at a nearby urban drive is the cheapest offer to consumers;
- Drives are fed from the fulfillment center whenever quantities and delays permit, otherwise they are fed from fulfillers;
    - On one extreme the very fast moving high-quantity products can be shipped to drives daily from the fulfillment center;
    - On another extreme, a consumer order of very slow moving products can also be shipped from the nearest fulfillment center;
    - The rest is fed from a convenient fulfiller located nearby that also feeds other drives within the city.
- Lateral product deployment is allowed among nearby fulfillment centers, as well as among nearby fulfillers;
- A fulfiller can be collocated with a drive.

Thus in this case, the business deals with four types of downstream logistics facilities, each with its own specific role in the business's supply chain: fulfillment centers, fulfillers, drives and lockers. Furthermore, consider that the business operates in a country where it serves consumers in three regions, each region including four cities, each with local neighborhoods.

A set of interconnection options for B2C product deployment, pickup and delivery is hereafter described for this case.

Figure 8 depicts the first option where the business relies on an internal network of facilities. In this case, the business ends up building and operating 3 regional fulfillment centers, 12 urban fulfillers, 24 drives and 96 lockers.

For the business, the main advantage of this option is:

- It has entire control over facilities, flows and operations over the entire network.

The main disadvantage for the business is:

It is asset intensive, indeed beyond the financial capabilities of most businesses.

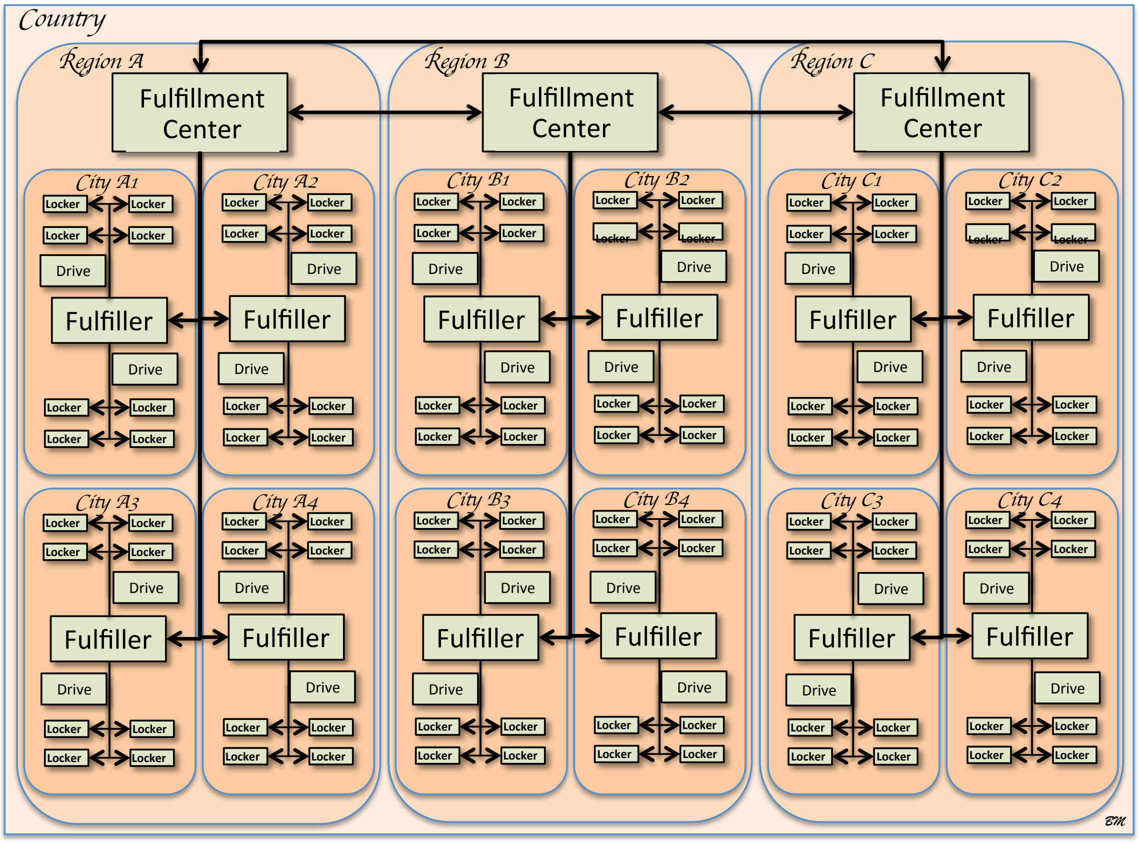

Figure 8. Interconnecting product deployment, pickup and delivery through an internal network of fulfillment centers, fulfillers and lockers

Taking a holistic point-of-view over the territory, there is an atrocious facet that appears when considering what happens when many businesses decide to use such an option. Indeed, when duplicated over multiple businesses, it creates a territorial invasion of business specific fulfillers, drives and lockers across cities and neighborhoods. It can be illustrated by stating that Figure 8 has to be duplicated for every business exploiting the internal network option.

From an urban planning perspective, this is undesirable, notably in terms of aesthetic, convenience and space usage. From a business perspective, it induces a stiff competition for best locations, inflating site prices, with a complete lack of asset sharing and flow consolidation between businesses serving the same overall population, and resulting in potentially low utilization rates of the facilities and vehicles operated by a specific business.

A second option is for the business not to own or operate any of the facilities, indeed not touching the products, rather relying on strategic logistics partners to do so. Such an option is depicted in Figure 9, where facilities are colored according to the partner's network it belongs. A simple variant of this option is for the business to deal with a single strategic logistics partner.

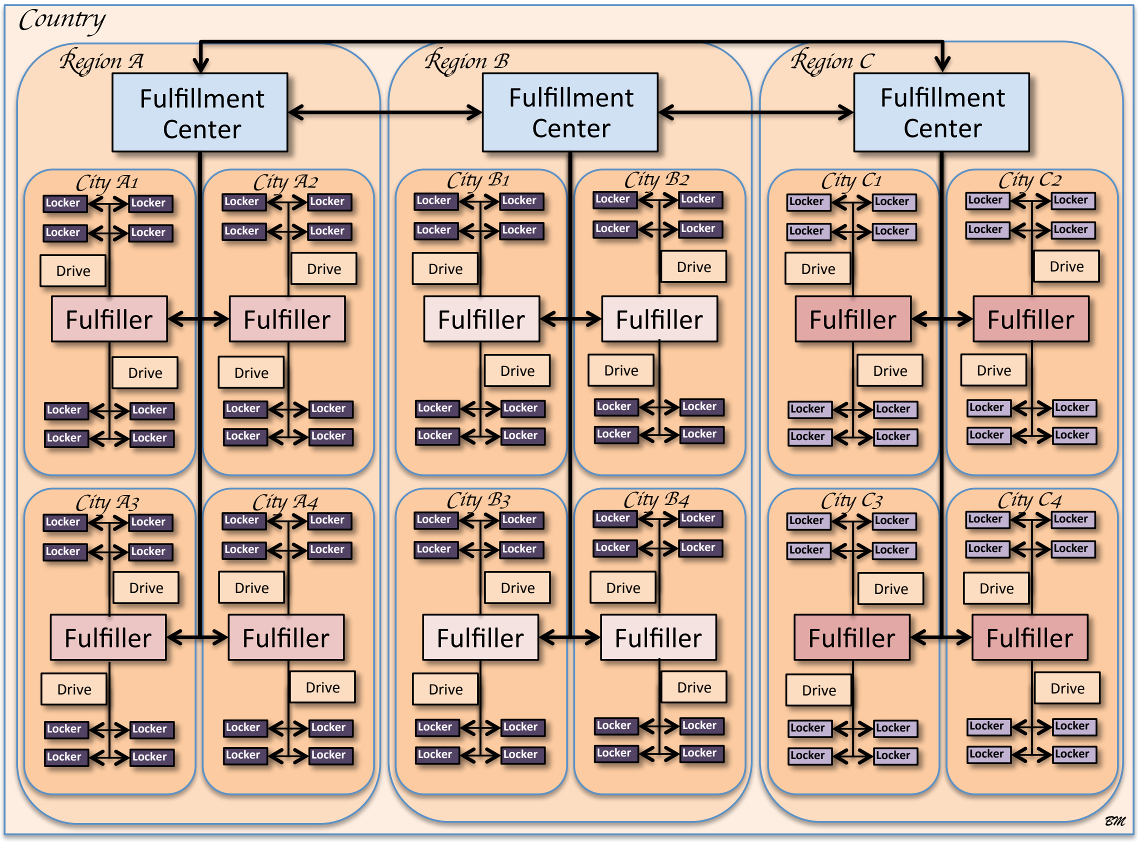

Figure 9. Interconnecting product deployment, pickup and delivery exploiting multi-client networks of fulfillment service, drive service and smart locker service providers

In this case, the business imparts all its fulfillment center operations to a fulfillment service provider (FSP). This FSP has fulfillment centers spread over the regions served by the business. Each fulfillment center of the FSP performs storage, picking, packing and shipping operations for multiple clients, and the business being one of them. In each city, the business does the same at a lower level, dealing with a local FSP that operates multiple fulfillers within this city.

Also, the business deals with a single national-wide drive service provider (DSP) with drives implemented in each city. Finally, it deals with two locker service providers (LSPs). The first covers all served neighborhoods of the served cities in regions A and B while the second does the same for region C.

The business has the choice between keeping the responsibility of deciding which product to keep in which quantity at what time in each facility of each of the interconnected logistics partners, or to let them deploy the products intelligently within their networks based on forecasts and signals it provides them with.

It is important to highlight that Figure 9 only shows the facilities of the partners selected by the business, and that according to this option there would normally be a number of alternative service providers, each with its own network of facilities. The networks of competing service providers would be disconnected from each other, not accessible to the business once it has signed with its partners.

The main advantages of this second option are:

- It is physical asset free from the business perspective;
- It exploits the networks of facilities of respected strategic partners well implemented in the type of facilities and in the territories it serves;
- It benefits from its partners exploiting multi-client asset sharing within their network;
- It may exploit flow consolidation with other clients of the partner if facilitated by the partner;
- It gains pricing savings from medium to long-term sole-provider contracts.

The main disadvantages are:

- It is engaging the business in medium to long term strategic partnerships and/or contracts with the selected third-party service providers;
- It requires seamless interconnection between the multiple networks: physically, digitally, operationally, as well as in terms of transactions and liability protection;
- It lacks the potential to interconnect with other facilities within the territory that are not part of the partners' networks, inducing inefficient product deployment, pickup and delivery compromises.

Taking a holistic territorial perspective, this second option contributes less to the multiplication of potentially lowly utilized logistics facilities in the served regions, cities and neighborhoods. Yet this option still induces extraneous duplication of resources. Instead of duplication of networks of logistics facilities dedicated to a specific retail/manufacturing business, there is duplication of networks of logistics facilities dedicated to a specific service provider, serving a given set of retail/manufacturing businesses. This limits the potential for asset sharing and flow consolidation. It also clutters cities and their neighborhoods with up to N^T times too many logistics facilities of a type T, where N^T is the number of competing logistics service providers exploiting facilities of type T.

Figure 10 depicts the playground for two further options, involving more intense interconnectivity in the spirit of the Physical Internet. The main differences between Figure 10 and the previous Figures 8 and 9 are:

1. All facilities have been colored in green to express their open nature, serving within their capabilities and capacity any client respecting required protocols and accepting their contractual agreements. They may be independent businesses by themselves or be part of a multi-facility network operated by some business;
2. Many more facilities have been depicted, as there exist many businesses exploiting open facilities across the territory.

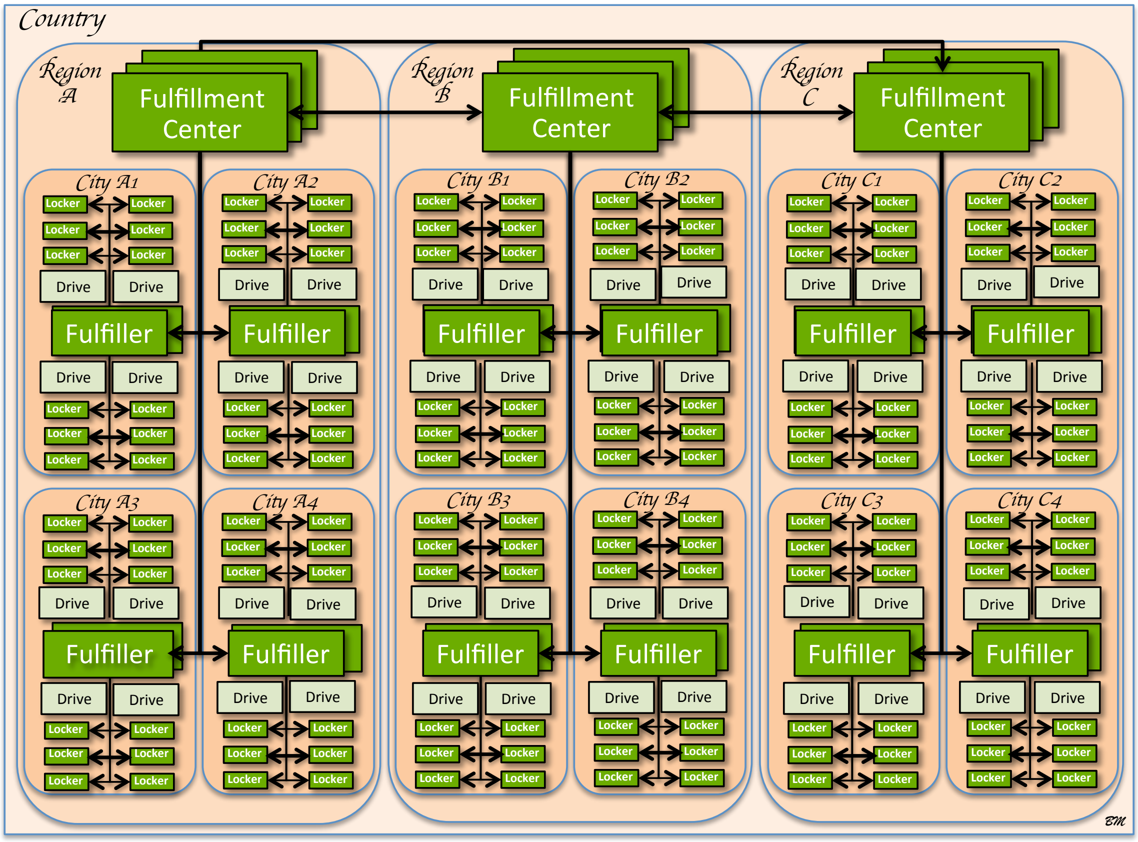

Figure 10. Interconnecting product deployment, pickup and delivery across a web of open fulfillment centers, fulfillers, drives and lockers, directly or through a virtual fulfillment service provider

In the third option, the business interconnects directly with the overall web of open fulfillment centers, fulfillers, drives and lockers operated by various businesses. Based on demand forecasts, consumer orders, current product deployment state, as well as services and prices offered by each open facility or network of facilities, the business decides:

- Which product to keep in which quantity at what time in each open facility;
- Which product to transfers in which quantity at what time to other open facilities;
- Which facility(ies) from which to ship a consumer order to his home or to have him pick it up.

For the business, the main advantages of this option are:

- It has access to a much larger solution space in terms of product deployment, pickup and delivery decisions, with the wider pool of open facilities;
- It controls all the key product deployment, pickup and delivery decisions;
- It does not have to sign strategic agreements with the open facility owners/operators, as it may pay for spot usage as needed, yet it may sign such

facility or network centric agreements whenever pertinent to gain economies-of-scale;
- It has the potential to induce significant cost reductions and environmental footprint from system-wide economies of scales induced by the open pooling and flow consolidation.

The main disadvantages for the business are:

- It requires more decision making and asset/product tracking effort;
- It dynamically involves many more players getting in and out of the network, requiring to respect effective protocols and interfaces;
- It has the potential to lose contract-specific economies associated with long-term single-provider partnerships.

For a holistic territorial perspective, this third option enables regions, cities and neighborhoods to forbid or limit duplication of logistics facilities of any type through regulations. In such a setting, even without such regulations, the quest for competitiveness may lead fulfillment and locker service providers to seek territorial synergies and complementarities when deciding where to invest in setting up their logistics facilities, indeed minimizing wasteful duplication of assets.

Option 4 differs from option 3 by the decision of the business to exploit the services of a fulfillment orchestrator (FO) that does not own any physical asset, rather being an expert in serving its clients through the exploitation of the web of open facilities depicted in Figure 10. In the spirit of a current fourth-party logistics service provider (4PL), it takes over from the business the burden of dealing with all these open facilities while taking advantage of its privileged position as a heavy multi-client player having access to prices and services potentially inaccessible to the business by itself.

The business has the choice between keeping the responsibility of deciding which product to keep in which quantity at what time in each targeted open facility, or to let the FO deploy the products smartly within the open fulfillment web across the territory based on forecasts and signals it provides to the FO.

As compared to the third option, the main advantages of this fourth option are:

- It simplifies drastically the complexity and efforts associated with exploiting dynamically the web of open fulfillment facilities;
- It has the potential to gain from economies of scale induced by the multi-client nature of the fulfillment orchestrator.

Its main disadvantages are:

- The extra cost charged by the fulfillment orchestrator, which may be partially or completely compensated by the leaner internal resource requirements for supporting product deployment;
- The reliance on one fulfillment orchestrator that may cause strategic issues over the long run as the business may get dependent on it.

The above four options are illustrative of the panorama of deployment, pickup and delivery interconnection options available to businesses depending on the interconnectivity of the underlying logistics system. They uncover a wide spectrum of option variants for tackling these activities, ranging from current and near future ways in industry to highly sophisticated next generation hyperconnected ways enabled by the Physical Internet. Depending on its own capabilities, capacities, targeted markets and strategic intents, the viable possibilities that are available to a multichannel-engaged consumer-centric retail or manufacturing business depend on factors such as those hereafter highlighted:

- Logistics facilities:
  - Where are they located?
  - What are their capabilities, capacity, services, costs and prices?
  - Are they dedicated to a specific user (manufacturer, retailer, etc.) or to a specific fulfillment or locker service provider and its clients, or are they open facilities widely offering their services?
- Fulfillment & locker service providers:
  - What territories do they cover, what services do they offer, at what cost and price?
  - What are their market shares in their served territories?
  - Are they limiting their offers and operations to the network of facilities that are dedicated to them (owned or leased)?
  - Are they willing and geared to interconnect with the networks of other service providers, or with open facilities?
- Fulfillment orchestrators:
  - What territories do they cover, what services do they offer, at what cost and price?
  - What are their market shares in their served territories?
  - With which fulfillment and locker service providers, as well as open facilities, are they interconnected?

At the core of enabling ever more hyperconnected omnichannel logistics lays the advent of open logistics facilities, notably fulfillment centers, fulfillers, drivers and lockers designed, engineered and implemented from the ground up to enable seamless, fast, cheap, safe, reliable, distributed, open product storage and deployment service to numerous parties using Physical Internet principles and constituents, as was mentioned in the previous section for hyperconnected B2C transportation focused facilities. Notably, these are to deal with ever more standardized smart modular packaging, handling and/or transport containers facilitating the open shared storage and consumer order consolidation, with products from numerous parties that may be competitors (see Montreuil et al. 2010 for basics). Ultimately, this is bound to induce such facilities not having to know explicitly what is encapsulated within these containers, as long as unique identification, tracking, monitoring, traceability, compatibility and security capabilities are insured.

6. Interconnecting omnichannel B2C production

Whereas transportation and distribution have been prominent in omnichannel business-to-consumer logistics capability development, production is also very important. If products can be made fast and on demand near point of delivery or pickup, then delivery speed over long distances becomes much less critical. The same goes with advance deployment of already made products across the territory near expected demand locations. Hence, as omnichannel B2C logistics matures, there will exist an ever-evolving equilibrium act in interconnecting transportation, distribution and production.

Consequently, production itself has to evolve in face of these new challenges and the new technological breakthroughs. As discussed in section 2, modular production, additive manufacturing (3D printing), postponement and personalized manufacturing are illustrative of the changes to occur.

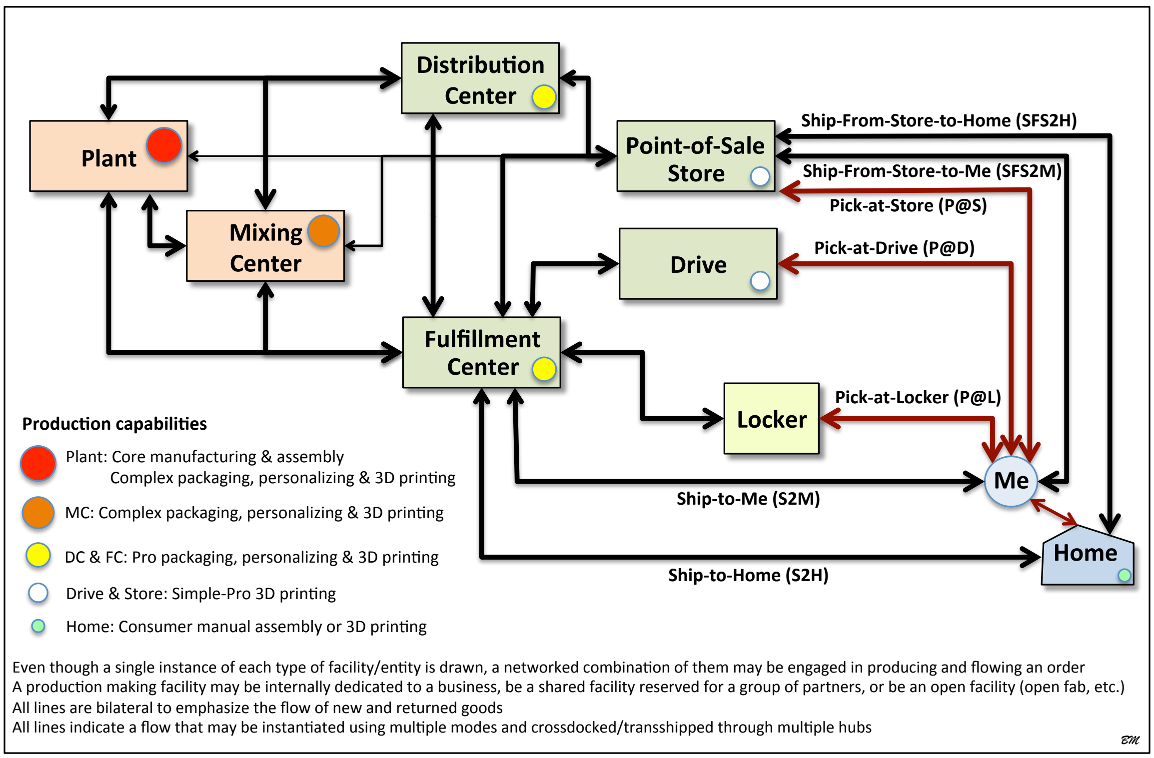

Figure 11. Hyperconnected production options for a B2C omnichannel supply chain

Figure 11 illustrates a set of hyperconnected production options for the omnichannel B2C supply chain of Figure 1. Whereas Figure 11 depicts a single box for each type of facility, there may be numerous facilities of each type exploited by the business. As it was the case for transportation and distribution, each producing facility can be internally dedicated to the business, shared among a closed group of partnering businesses, or even open for exploitation by any certified business or individual.

In fact, Figure 11 considers every facility in the supply chain to be a potential production site. It segregates five levels of production capabilities for specific sites:

a. Manual assembly or 3D printing of ordered products, performed by the consumer at home (office, etc.);
b. Simple professional (Simple-Pro) 3D printing, performed at a store or a drive;
c. Professional packaging, personalizing and 3D printing, performed at a distribution or fulfillment center;
d. Complex packaging, personalizing and 3D printing, performed at a mixing center or a plant;
e. Core manufacturing and assembly, performed at a plant.

This five-level characterization is not meant to be generic to all cases, but rather well fitting for this illustrative case.

In most current cases, production is performed in a factory of the product manufacturer or in a factory of the business' third-party contract manufacturer. The main advantages of this approach for the business are:

- Economies of scale;
- Simplicity of operations, control and management;
- Protection of intellectual property and confidentiality.

Its main disadvantages are:

- Distance from ordering consumers and their preferred pickup or delivery location, limiting fast delivery or pickup capabilities without relying on extensive inventory and/or express delivery services;
- Capacity limitations to deal with distributed consumer demand randomness, seasonality and growth-decline variations.

Allowing shifting production downstream to more capillary facilities has both advantages and disadvantages as compared to the above. The key relative advantages for the business are:

- Reduced distance from ordering consumers and their preferred pickup or delivery location, reducing reliance on extensive inventory and/or express delivery services for fast product access by consumers;
- Reduced overall finished goods transportation and distribution costs;
- Added capability to adjust production to local expectations and seasonality, subject to local production capacity.

The main relative disadvantages are

- Loss of economies of scale that achieved through centralized production;
- More complex network-wide production operations, control and management;
- Increased reliance on once retail-focused facilities to perform sensitive production operations;
- Increased inbound materials and components flows downstream to more capillary facilities;

- When some production activities are shifted to consumers, then added pressure on ease and duration of production (e.g. assembling furniture from kits);
- Increased complexity of intellectual property and confidentiality protection due to multiplicity of engaged production sites and actors.

Even though the downstream production shifting advantages are important, its perceived disadvantages are often showstoppers for businesses. This is where Physical Internet induced open interconnection, with production allowed to be made in open facilities using standardized protocols, interfaces, digital platforms, modular production units and modular containers, becomes a game changer. Its key advantages stem from improving the downstream production shifting advantages and attenuating most of the disadvantages:

- Greater capability to reduce distance from ordering consumers and their preferred pickup or delivery location due to access to numerous open production-capable facilities, reducing even further the reliance on extensive inventory and/or express delivery services for fast product access by consumers;
- More reduction of overall finished goods transportation and distribution costs due to closer-to-consumer production capability;
- Greater capability to adjust production to local expectations and seasonality, as well as local growth and decline, not bounded by the sole business dedicated capacity, but rather by the overall capacity near to consumers;
- Regained economies of scale by exploiting the production services, capabilities and capacity of open facilities exploited by multiple businesses;
- Reduced complexity of open network-wide production operations, control and management due to exploitation of standardized protocols, interfaces, digital platforms, modular production units and modular containers;
- Reduced issues relative to reliance on once retail-focused facilities to perform sensitive production operations, as exploited facilities are re-designed and managed for facilitating open interconnectivity when they offer open production services;
- Facilitated inbound materials and components flows downstream to more capillary facilities through hyperconnected transportation and distribution;
- Reduced pressure to rely on home based consumer production activities as nearby well equipped open facilities offer services and/or resources for doing so (e.g. paper copy shops vs. at-home printers);
- Added protection for intellectual property and confidentiality protection given multiplicity of engaged certified production sites and production/logistics actors exploiting standardized protocols, interfaces and modular containers.

The main disadvantages are similar to those expressed for similar shifts in hyperconnected transportation and distribution, with more direct emphasis on the following due to the production context:

- Need for critical mass of available open production services and fabs across market territories to efficiently cover on-demand production requirements in the face of distributed market peculiarities, randomness, seasonality and growth-decline phases;

- Need to insure that the profit margins taken by open agents do not become an impediment in offering good prices to consumers;
- Need to insure that production specifications for products are inducing efficient production in open facilities;
- Need to insure capability of differentiating products from competitors potentially using some of the same open production facilities;
- Need to insure that open production facilities are capable to support the shift of product mix and production processes associated to fast-paced innovation.

This said, the concurrent evolution of product design and engineering, production technologies and capabilities, and supply chain technologies and capabilities is bound to facilitate a shift of production responsibilities from dedicated, central, large and monolithic facilities to open, distributed, small and modular facilities, ultimately to the consumer homes.

From a grand scale perspective, the shift toward exploiting hyperconnected production in omnichannel B2C supply chains has the potential to completely transform the overall worldwide production landscape. Indeed it opens avenues for shifting production nearer to consumers, thus affecting production to be realized in specific countries, regions and localities. For example, it may result for some businesses to shift from offshoring their finished goods production to offshoring the production of key modules that are then put together on demand to shape finished goods nearer to markets. Also, exploiting hyperconnected production in omnichannel B2C supply chains has the potential for better matching demand and production capacity, notably avoiding production overcapacity due to disconnected manufacturers requiring the same processes, equipment and technologies, yet not sharing any of them even though serving the same territories.

7. Interconnecting omnichannel B2C logistics with city logistics

Hyperconnected omnichannel B2C logistics is tightly linked to the concept of city logistics, as cities are the locus of last-mile delivery challenges (Ducret, 2014; Savelsbergh & Van Woensel, 2016). As reported in Crainic and Montreuil (2016), the city logistics concept has been introduced to address the challenge of the sustainable cohabitation and development of freight transportation and the city. City logistics proposes new organizational and business models for urban freight transportation to reduce its negative impacts, while continuing to support the social and economic development of the city. The fundamental idea is to consider urban freight transport stakeholders, material elements and activities not individually but rather as components of an integrated logistics system (Crainic and Montreuil, 2016). Hyperconnected city logistics exploits the concepts of the Physical Internet to extend and reinforce the city logistics concept.

It is out of scope for this paper to encompass the conceptual framework for hyperconnected city logistics. Yet Figure 12 from Crainic and Montreuil (2016) provides a conceptual overview of a concentric city having adopted its underlying principles, and helps to make the link with omnichannel B2C logistics.

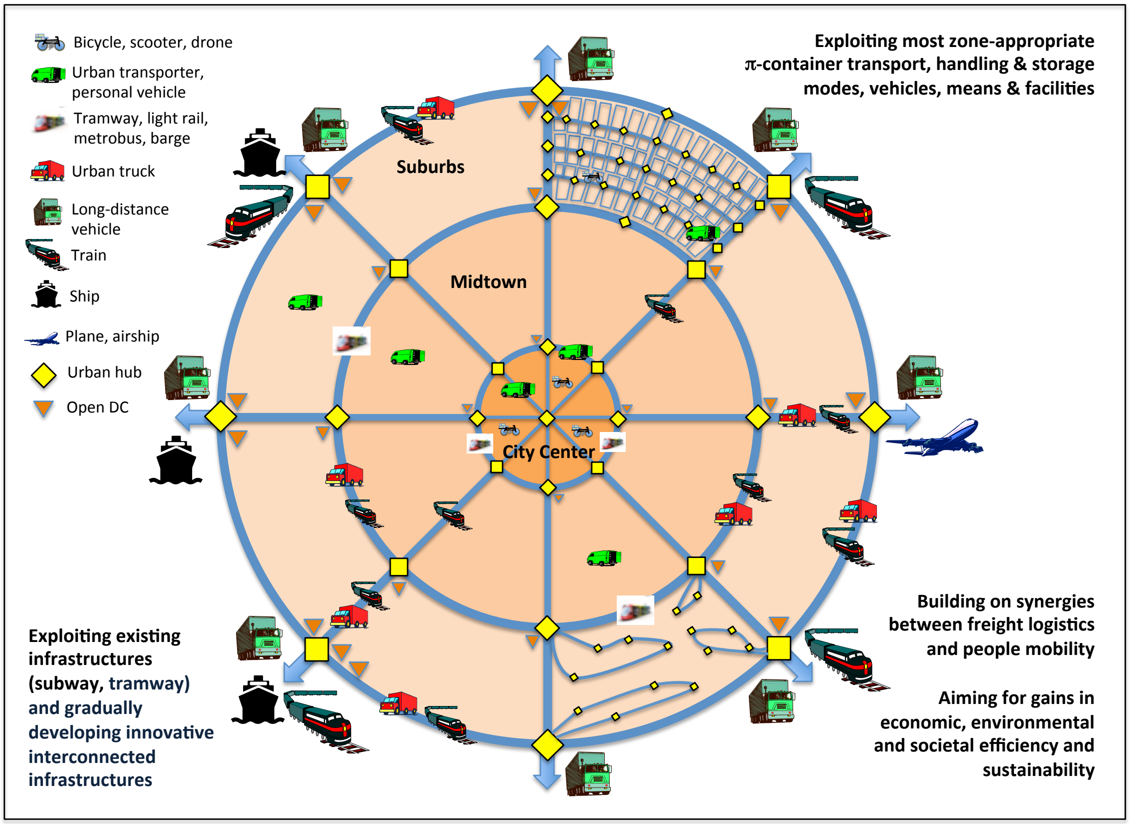

Figure 12: Illustrating Hyperconnected City Logistics instantiated in a concentric city (Source: Crainic and Montreuil, 2016)

The depicted city exploits three logistics rings and eight radial flow corridors, interconnected by urban hub zones. The outer ring hosts a set of urban multimodal gateway hubs that are located at strategic positions such as highway crossings, nearby airports and seaports, rail yards and so on. These urban gateway hubs openly receive, sort, transship, consolidate and ship both city inbound and outbound flows of goods encapsulated in modular containers. Nearby the outer ring and its gateway hubs are located sets of open peri-urban distribution and fulfillment centers (DCs), buffering the city with sufficient inventory to deliver rapidly on demand their urban customers. The urban gateway hubs and the open peri-urban DCs are interconnected by a transportation ring facilitating multimodal flow along the outer circumference (Crainic and Montreuil 2016).

Along the inner rings and radii, the transportation modes are increasingly involving smaller land, air or water based vehicles. Vehicles and carriers used in the more central areas, and in the residential areas in the suburbs and midtown zones, are generally smaller and ecofriendly, propelled using electricity, natural gas or active human effort. Flows within zones of the city can be logistically structured in the hyperconnected way, illustrated in Figure 12 through the exploitation of small neighborhood hubs in a single suburb, where such hubs can be as simple as smart locker clusters (Crainic and Montreuil 2016).

Hyperconnected City Logistics exploits existing urban train, light train, subway and tramway infrastructures. It also exploits any logistics center made open by its owner, respecting the Physical Internet interfaces and protocols, and designed to handle and store modular containers. Finally, it inherently builds on synergy between freight and people mobility, smartly interconnecting their usage of public infrastructures, public transport such as buses, as well as individual vehicles (Crainic and Montreuil 2016).

Achieving efficient and sustainable omnichannel B2C logistics in a city having implemented hyperconnected city logistics is much easier than in typical contemporary cities. Therefore there is much to be gained in building synergy between industry lead omnichannel B2C logistics initiatives and city lead hyperconnected city logistics initiatives.

8. Conclusion

Taking a Physical Internet inspired hyperconnected logistics perspective, this paper contributes to omnichannel business-to-consumers logistics and supply chain network and facilities design by introducing and contrasting sets of design options for efficiently and sustainably dealing with transportation, distribution and production in such a context.

The options range from current practice to those fully applicable in a mature widespread implementation of the Physical Internet, yet many options can be readily implemented fully in the short term while several others can also be implemented to a partial degree in the short term. They can form the basis of strategic reflections and visions on the evolution and transformation of supply chains and logistics systems in general, and more specifically of transportation, distribution and production facilities. Other options can be added to the provided set using the same overall philosophy, yet adapted to other contexts than the illustrative cases used through the paper.

Overall, the paper depicts an expanded solution space for omnichannel B2C supply chain and logistics networks and facilities. Overall patterns emerge from these options in terms of expanding horizons:

- Getting away from taking a single business perspective when designing omnichannel B2C supply chains and logistics systems, toward acknowledging that greater efficiency and sustainability can be achieving by exploiting the fact that numerous businesses aim to serve the same set of consumers in each city and region around the world;
- Getting away from exploiting facilities dedicated to a single company or a limited group of partners, toward exploiting openly shared facilities interconnected

through standard protocols, interfaces, business models and encapsulation into modular containers;

- Getting away from exploiting a small stable network of dedicated, centralized, large, monolithic, single-purpose facilities toward exploiting a wide dynamic network of open, distributed, small, modular, multi-purpose facilities, encompassing consumer homes.

Overall, four main challenges need to be addressed for widespread implementation and exploitation of hyperconnected networks and facilities for omnichannel B2C logistics, here labeled as efficiency, encapsulation, protocolization and trustworthiness.

- Efficiency: Demonstration should be made that openly shared logistics networks and facilities can offer and deliver the omnichannel logistics services to be expected by consumers in a way that is significantly easier, cheaper, faster, more reliable and less constraining than what can be achieved by currently practiced dedicated and collaborative networks, through pilot studies as well as analytical, optimization and simulation based assessments such as those of Meller et al. (2012), Ballot et al. (2014), Hakimi et al. (2015) and Sohrabi et al. (2016 a and b) done for different contexts;
- Encapsulation: As in hyperconnected logistics, products are to be transported, handled and stored by multiple parties across multiples modes and facilities, often with products from competitors, they are to be encapsulated in smart modular containers that are to (1) protect products physically and virtually; (2) standardize and ease their flow across networks and within both manual and automated facilities, (3) allow logistics service providers to deal mostly at the container level with minimal informational requirements on the flowed products, (4) and facilitate real-time tracking and monitoring of encapsulated goods (Montreuil et al. 2016).
- Protocolization: As businesses are to interconnect with many open logistics facilities, they are to expect that all actors and systems are to operate using the same of set of industry-standard, ideally world-standard, protocols for operational, communicational, informational and transactional purposes (see Montreuil et al. 2012, Ballot et al. 2014), in a spirit similar to protocoled international postal logistics where every postal facility in the world deals with international mailings using the same protocoled transfer rules regulated the Universal Postal Union (UPU, 2016);
- Trustworthiness: Businesses have to be fully convinced that open networks and facilities are to take care of their product integrity, working according to high quality standards; to perform reliably according to their promised response time and availability; to insure the physical and informational security of their products and orders, void of thefts, frauds, leaks and so on.

Each challenge above brings its own set of research opportunities. Their combination also opens a wealth of research opportunities. Some of these focus on designing the facilities and handling systems at the core of hyperconnected omnichannel logistics, with various levels of automation, robotics and human operations. These are to build on pioneering works on Physical Internet facilities and handling systems such as Montreuil et al. (2010), Ballot et al. (2014b), Meller et al. (2014) and Montreuil et al. (2014), in tight relationships with works on designing smart modular containers (Landschützer et al. 2015; Montreuil et al. 2016; Sallez et al. 2016). Beyond the individual facilities level, there are research opportunities on designing hyperconnected omnichannel supply chains and logistics networks, exploiting the options developed in this paper. There is also need for extending research on information and communications technology infrastructure for specific omnichannel businesses (e.g. Angeles, 2016) so as to be capable of sustaining on a large scale the hyperconnected omnichannel logistics design options elaborated in this paper. Several threads of research are possible, such as analytical modeling, exact and heuristic optimization, simulation-based assessment, systems design, case studies, pilot studies and living labs.

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