"From Horizontal Collaboration to the Physical Internet: Quantifying the Effects on Sustainability and Profits When Shifting to Interconnected Logistics Systems" Final Research Report of the CELDi Physical Internet Project, Phase I

Research Project Leaders and Lead Authors[1]:
Russell D. Meller, Ph.D.
University of Arkansas, Fayetteville, AR 72701 USA
e-mail: rmeller@uark.edu

Kimberly P. Ellis, Ph.D.
Virginia Tech, Blacksburg, VA 24061 USA
e-mail: kpellis@vt.edu

Contributing Author:
Bill Loftis
Tompkins International
e-mail: wloftis@tompkinsinc.com

24 September 2012

Abstract

The Physical Internet (PI) is envisioned as a new paradigm for interconnected logistics systems, building on the recent success of horizontal collaboration projects. As part of a two-year research project funded by the U.S. National Science Foundation and eighteen thought leader organizations, we have developed models to quantify the effects on sustainability and profits as organizations shift to interconnected logistics systems. Our results indicate that the PI represents a "win-win-win" virtuous cycle with the business models of shippers, receivers and transportation service providers all benefiting from the PI in terms of increased profit margins and smaller environmental footprints. In addition, the transportation network that is anticipated to emerge would lead to strategic impacts on network design, customer service and the ability to significantly reduce the perennial driver shortage issue through reduced driver turnover. In addition to presenting business briefs for the principal PI participants, we also present possible paths forward, including a call for action in terms of focused pilot studies co-funded by shippers, receivers, and providers.

[1] The research team also included Lisa Thomas, Yen-Hung Lin, and Barb Lombardi (University of Arkansas) and Steven Roesch, and Leily Farrokhvar (Virginia Tech).

Executive Summary
"From Horizontal Collaboration to the Physical Internet: Quantifying the Effects on Sustainability and Profits When Shifting to Interconnected Logistics Systems"
Final Research Report of the CELDi Physical Internet Project, Phase I

Logistics systems, which drive the prosperity and quality of life in the U.S., epitomize current economic, environmental and social contradictions in our society. The economic value of logistics enterprises reaches the trillions of dollars annually, but there is significant waste and inefficiency. Roads are built to minimize their environmental impact, but transportation is the second-leading producer of greenhouse gas emissions. Our interstate system enables our prosperity and social connections, and provides millions of jobs to our citizens, but also leads to countless hours spent in congested traffic and an industry with one of the highest turnover rates in the country. Addressing these contradictions is an integral part of the **Global Logistics Sustainability Grand Challenge** [1].

In 2007, road-based freight transportation modes consumed nearly 30 billion (B) gallons of fuel [2]. Further, from 1990-2008, the CO_2 emissions associated with road-based freight increased by 14.9% to 517 trillion grams (Tg) [3], despite significant social pressure to curb such emissions growth. The transportation industry is largely segmented with over three-quarters of freight being carried using dedicated resources. Dedication is not inherently bad, but when carrying an average load, truck trailers are, according to government statistics, less than 60% full and 20-30% of all trips are empty [4-5], resulting in an overall utilization of 43%. And although the statistics collected as part of our project are more positive, with an estimate of overall utilization of trailers today of approximately 50%, a tremendous opportunity exists for improvement.

We ask: Why not transform our transportation system to allow us to fully utilize our logistics resources? Such a system would have significant economic, environmental and social implications.

Our vision for addressing the Global Logistics Sustainability Grand Challenge is to fully interconnect our logistics systems through shared resources. The sharing of resources, through a practice known as horizontal logistics collaboration, has been implemented today, but on a very limited basis due to a myriad of obstacles. A newer way of collaboration proposes to use a framework of logistics where goods are handled, stored and transported in a shared network. Such a framework would be enabled by an open, global intermodal logistics system that utilizes standard, modular and re-usable containers, real-time identification, and routing through logistics facilities [6]. This framework is referred to as the Physical Internet (PI). The PI employs a metaphor taken from the Digital Internet, which is based on the co-utilization of computer servers, all transmitting information under a standard TCP-IP protocol. A simplified mental image of our vision for interconnected logistics is to imagine an eBay-like freight transportation "auction" that handles "black box" modular containers through an open and shared intermodal logistics network with a vast community of users that utilize supplier ratings to drive logistics performance. We believe the annual impact of the PI, even when serving only a subset of the principal freight flows in the U.S. (say, 25% of all freight flows in the U.S.), would be \$100B, 200 Tg of CO_2 emissions, and a reduced turnover rate of long-haul truck drivers (up to a 75% reduction).

Such system impacts are impressive, but what would this mean to various supply chain stakeholders? We focus on principal potential participants like consumer packaged goods (CPGs) manufacturers, retailers, diversified manufacturers/shippers, and transportation service providers. We use our modeling results to predict the impact the PI would have on their respective key performance indicators (KPIs) to motivate organizations to consider what it would take to move towards the PI.

Our modeling and analysis indicates a surprising consequence of moving into a shared system that was not originally anticipated beyond increased trailer fullness and fewer empty miles: we conclude that for many industries the underlying network strategy will evolve to more inventory holding points located closer to customers than in conventional dedicated networks. For example, we believe that many manufacturers will see a shift from today's configuration of a limited number of regional distribution centers to many shared distribution centers. The shared network eliminates two major cost and service constraints of the conventional dedicated network:

- A full truckload economic order quantity (EOQ) for low-margin commodity industries will shift towards a full-pallet equivalent EOQ.
- Long-haul trucking for customer delivery will shift to more predictable short-haul shuttle runs as inventory moves closer to customers.

Other unintended outcomes also improve the sustainability of freight transportation. This strategic network shift suggests intermodal utilization will expand, as locating inventory closer to the customer with more frequent deliveries takes days out of the supply chain, allowing for the use of less

time-reliable intermodal transportation from manufacturing plants to the shared inventory centers. And finally, we believe there will be a shift to more of a relay network approach to transportation (versus the point-to-point or hub-and-spoke designs of today), which will achieve the goal of getting drivers home more frequently and should reduce driver turnover and lessen the strain on driver availability.

These strategic outcomes suggest the evolution of a virtuous win-win-win logistics cycle for logistics service providers, shippers, and retailers, such that:

- Logistics service providers create a new multi-shipper shared logistics relay network flow path with higher asset utilization that offers higher profits, better customer service, lower rates, and reduced driver turnover;
- Shippers are able to change EOQs from full truckloads to smaller units, ship across a broader network, locate inventory closer to customers, travel fewer highway miles, provide better service at lower rates, and realize higher profits; and
- Retailers seeing more frequent deliveries will see their safety stocks decrease while simultaneously increasing in-stock levels; these factors allow retailers to both increase profit margins and offer lower prices to the consumer through this leaner logistics system.

We provide business briefs for these supply chain stakeholders that illustrate the new logistics dynamics as well as higher profit margins for each stakeholder.

We believe the strategic benefits of this virtuous cycle represent a more significant and compelling strategic benefit of the PI not commonly associated horizontal collaboration. Perhaps these quantified benefits may finally launch these concepts forward. A defining characteristic of the difference between the PI and traditional horizontal collaboration concepts is the ability to support both cost and service improvements in a shared system, eliminating conventional constraints of dedicated networks.

How will such a virtuous cycle begin and what is required for all of this to happen? We present a number of potential paths forward for the PI. In general, the possible paths fall into three categories: (1) a bottom-up initiative; (2) a top-down initiative; or (3) a 3PL initiative. In all paths, we believe that once the momentum of the PI is initiated, other efficiencies will be realized, allowing the "network effect" to propel the system forward. We believe that *pilot efforts* designed to address remaining questions about the PI are needed. All parties in this win/win/win cycle should invest in these efforts. It is our hope that this research provides a story sufficiently compelling to support this evolution.

Like the PI itself, the PI Initiative is an open one, with participation from a wide variety of organizations as PI Thought Leaders (see below). This report represents the culmination of a two-year project. We are embarking on Phase II of the project in the fall of 2012 and welcome new participants.

For more information on the CELDi Physical Internet Project, please see: http://faculty.ineg.uark.edu/rmeller/web/CELDi-PI/index-PI.html.

Contact:

Russell D. Meller, CELDi Physical Internet Project, Center for Excellence in Logistics and Distribution, the University of Arkansas, rmeller@uark.edu

This material is based upon work supported by the National Science Foundation (NSF) under Grant Nos. (IIP-1032062 and IIP-1031956) through the NSF Industry-University Cooperative Research Center for Excellence in Logistics and Distribution (CELDi) and the associated CELDi Physical Internet Thought Leaders. Russell D. Meller and Kimberly P. Ellis authored this report in conjunction with Thought Leader, Bill Loftis from Tompkins International, as well as the other CELDi Physical Internet Thought Leaders. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation, CELDi, or the CELDi PI Thought Leaders.

"From Horizontal Collaboration to the Physical Internet: Quantifying the Effects on Sustainability and Profits When Shifting to Interconnected Logistics Systems"
Final Research Report of the CELDi Physical Internet Project, Phase I[2]

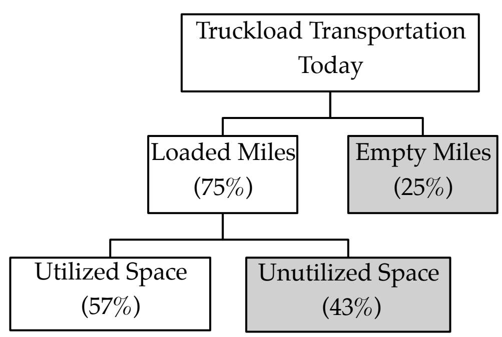
1.0 The Global Logistics Sustainability Grand Challenge

As stated by the U.S. National Science Foundation, "a sustainable world is one in which human needs are met equitably without harm to the environment, and without sacrificing the ability of future generations to meet their needs." And one of the greatest threats to a "sustainable world" is the growth of U.S. (and worldwide) greenhouse gas emissions (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6), with CO_2 being the largest current concern (85.4% of the total GHG emissions in the U.S.) [3]. Thus, innovative solutions for reducing CO_2 emissions promise the realization of a "sustainable world."

Based on the latest data available from 2007 [3], at a high level, fossil fuel combustion is the largest component of CO_2 emissions, accounting for 94% of the total 6,103.4 trillion grams (Tg) of emitted CO_2 (1 Tg = 1M metric tonnes). And transportation is second (1,877.4 Tg) only to electricity generation (2,397.2 Tg) in terms of its contribution to total fossil fuel combustion. Therefore, the efficiency of our transportation sector, which represents 30.9% of total CO_2 emissions, is a significant target for reductions. Even when limited to the freight transportation sector (which is defined as trucks, ships, and trains used to deliver freight) with annual CO_2 emissions at 517 Tg per year [7] (9.2% of the total U.S. economy), that is still more than five times greater than the 2nd-leading emitter, China (under 100 Tg per year). There are substantial opportunities to improve today's freight distribution, as we detail below.

Let us consider transporting freight by truck in the U.S. (based on the latest data available, 2007). Three primary logistics modes are employed today: (1) private fleets that deliver loads and then generally return empty; (2) contracting with a full truckload carrier who tries to construct routes that link loads and often dispatches drivers for weeks at a time; or (3) contracting with a less-than-truckload (LTL) carrier who ships over their private hub-and-spoke network. For all modes combined, a total of 8.96B tons of freight was transported by truck [8] over a total of 145B miles in the U.S. in 2008 [2]. And given an average of 5.1 miles to the gallon [2], this accounted for 28.7B gallons of diesel fuel. At today's prices for diesel fuel (approximately $4/gallon), this represents an annual expenditure of $114B.

Unfortunately, freight distribution is not efficient, in general, and transporting freight by truck (71.5% of the total value freight is transported by trucks [2]) is especially inefficient. Consider the most-recent U.S. government data related to empty miles, fullness of trailers when traveling with a load, and thus, the blended fullness for the three truck-based logistics modes. That is, the average fullness of a truck's trailer (measured in terms of the percent of its maximum weight load) was 43% in 2007 [8], which can be broken down as 20-30% of the time completely or nearly empty [4-5] and for the remaining 75% of the time, the trailers were only 57% full. Thus, we see two basic inefficiencies (shadowed boxes, at right): trailers travel with a load only ¾ of the time and they are not full when they are traveling loaded.



Social sustainability is another significant aspect to the sustainability challenge for logistics systems. The job of a truck driver places many challenges on those drivers and their families. Many are away from home for more than two weeks at a time, most suffer from poor diet and sleep patterns, and these combine for a high degree of risk associated with the job, with the NTSB finding that 58% of all accidents associated with truck drivers were deemed to be fatigue and sleep-deprivation related [1]. According to Ray LaHood, the U.S. Secretary of Transportation (2010), North American male truck drivers have a reduced life expectancy of 16 years [9]. These factors lead to an industry with an incredibly high turnover rate (some years more

[2] This material is based upon work supported by the National Science Foundation (NSF) under Grant Nos. (IIP-1032062 and IIP-1031956) through the NSF Industry-University Cooperative Research Center for Excellence in Logistics and Distribution (CELDi) and the associated CELDi Physical Internet Thought Leaders. Russell D. Meller and Kimberly P. Ellis authored this report in conjunction with Thought Leader, Bill Loftis from Tompkins International, as well as the other CELDi Physical Internet Thought Leaders. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation, CELDi, or the CELDi PI Thought Leaders.

than 200% annually) and the America Trucking Association predicts a shortage of 111,000 jobs by 2014 [1].

What is the impact of these inefficiencies for you and me? We pay more for products than we need to, the greenhouse gas (GHG) emissions of our societies are unnecessarily high, and many of us are excessively delayed in congested traffic, decreasing our quality of life. Thus, the inefficiencies of freight logistics via truck, train and intermodal platforms must be addressed to significantly affect environmental sustainability and to improve the lives of drivers and the vast majority of Americans that use the roads, while not threatening economic sustainability. We refer to this as the Global Logistics Sustainability Grand Challenge [1].

Our motivation is to help address the Global Logistics Sustainability Grand Challenge. *If the only effect of addressing the challenge was filling truck trailers*, annual CO_2 emissions would be reduced by 233.8 Tg (4.2% of the total CO_2 emissions for the entire U.S. economy, or approximately 50% of Canada's or Mexico's entire output), the annual miles driven by trucks reduced by 83.2B, the annual gallons of diesel fuel used reduced by 16.5B, and the annual dollars expended on diesel fuel reduced by $65.8B. Moreover, addressing the Challenge would also cover rail and intermodal transportation, the logistics facilities, along with the containers used for the freight and, thus, addressing the Challenge would impact more than just truck trailer fullness. Therefore, we believe addressing the Challenge is integral to realizing a "sustainable world."

The foundation of our approach for increasing the efficiency of our freight logistics system is *interconnected logistics*. That is, the development of an intermodal logistics system that allows massive and seamless collaboration of the logistics enterprise so that we can, simply stated, fill trucks, ships, trains, and distribution centers via a digital exchange similar in spirit to eBay and other online auction sites. Companies recognize the value in transportation collaboration; 88% of companies believe that collaborating with carriers, suppliers, and customers will lead to more economical supply chain processes [10]. Implementations of collaborative logistics systems support this belief – most companies who are using some form of collaborative logistics have seen significant cost reductions, often on the order of 8% to 20% [10-12]. However, although horizontal collaboration has been referred to as the "missing link" in the supply chain [13] and "too dangerous to ignore" [14], only 10-30% of companies collaborate in their supply chain in *any form* [15].

So, although "filling trucks" and "getting drivers home each night" are simply stated goals, they are not simple to realize due to the complexity of the underlying transportation system and will require a significant effort. We provide some insight and motivation into that effort. First, we discuss our vision for interconnected logistics that would reinvent the logistics system (Section 2), including a collaborative logistics example that clearly illustrates the potential of our vision. We then present the results of various modeling initiatives related to our vision for interconnected logistics (Section 3). These results form the backbone for representative organization "business briefs" to quantify the benefits of a fully interconnected logistics system for stakeholders like CPG and other manufacturers, retailers and transportation service providers, using KPIs defined by these groups (Section 4). We conclude with challenges to our vision (Section 5), possible paths forward (Section 6) and an invitation to join the initiative (Section 7).

2.0 Vision to Address the Global Logistics Sustainability Grand Challenge: The Physical Internet

Core to meeting this challenge is the sharing of logistics resources like the vehicles used to transport freight in our supply chain and the facilities used to coordinate that transportation. A system that achieves this sharing of resources would be, in our definition, "interconnected." Our vision to achieve an interconnected logistics system is called the Physical Internet (PI) – an open global intermodal logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols [6]. The PI enables an efficient and sustainable logistics web that is both adaptable and resilient. The starting point of an interconnected logistics system is horizontal collaborative logistics.

2.1 Horizontal Collaborative Logistics

The term "collaborative logistics" refers to the practice of two or more organizations collaborating to reduce the logistics costs (or some other relevant measure) of each organization. This is a broad term that can encompass practices like retailers finding backhauls to offset costs for the private fleet to two shippers working with a 3PL to lower costs. When the word "horizontal" is added to the term, the implication is that the organizations share the same role in the supply chain. For example, two CPG manufacturers sharing a truck's capacity into a retailer's distribution center, or even a 3PL's distribution center.

The economic goal of collaborative logistics is to receive the convenience of shipping only the amount needed to be shipped when it needs to be shipped (like with LTL today) at the unit cost achieved with a truckload shipment. We refer later in the report to the "economic order quantity," or EOQ, of a shipment. Today's logistics systems push organizations towards an EOQ that equals a complete truckload because it is cheaper to contract a truckload carrier for a load that only requires 60% of a trailer's capacity than to send that same shipment over an less-than-truckload (LTL) network (and the goods will typical arrive faster with the truckload carrier). Collaborative logistics allows a shipper to change the EOQ to a pallet.

Horizontal collaboration has been gaining traction in the last few years [6] as a cost-cutting measure, but the participating organizations have been noting other benefits; namely, reduced carbon footprint, better service, and reduced inventories. This last benefit, reduced inventories, is something that we emphasize later when we study the PI in more detail.

A recent player in this sector is the Belgium-based company, TRI-VIZOR. The mission of TRI-VIZOR is to "offer specialized knowledge and solutions to create, support and orchestrate flow bundling and horizontal partnerships in transport and logistics" [17]. TRI-VIZOR uses a database of flows, looks for opportunities with data mining techniques, and then forms legal partnerships to share the gains of a horizontal partnership. TRI-VIZOR cites statistics related to miles and CO_2 emissions reduced due to the partnerships that they have orchestrated. As of 9 July 2012, these savings are proclaimed to be 8.9% and 31.3%, respectively (all details are deemed confidential by TRI-VIZOR) [18].

2.2 The Physical Internet

The term, PI, employs a metaphor taken from the Digital Internet, which is based on the co-utilization of computer servers, all transmitting standard packets of data under a standard TCP-IP protocol. We believe the PI will address the conflict between economic growth and environmental and social sustainability.

The enabling technologies to make the PI a reality include the encapsulation of goods in modular, re-usable and smart containers. This will make it possible for any company to handle any company's products because they will not be handling *products* per se. Instead they will be handling standardized modular containers (just as the Digital Internet transmits data packets rather than information/files).

Another enabling technology is a standard set of collaborative and routing protocols. Modularized product is easier to route through intermodal transport networks as individual "black box" loads instead of heterogeneous loads of different-sized cases and pallets. But the efficient routing of modular containers over a collaborative intermodal network can only be realized if there is a standard set of routing and digital protocols, as well as business rules that apply across a vast community of users.

And of course, handling and digital interfaces are needed to ensure reliability, security, and transparency as well as that the quality of the product being handled is not compromised through its movements. These interfaces cannot be proscribed, but the functional requirements need to support the development of innovative interfaces.

A simplified mental image of our vision for interconnected logistics is an eBay-like freight transportation "auction" that handles "black box" modular containers through an open and shared intermodal network with a vast community of users that utilize supplier ratings to drive logistics performance. This creates a multi-scale process where at the lowest level we have individual containers while at the highest level we have an international network of transportation resources. With this vision, we set the following system-level KPIs, one for each facet of sustainability:

1. **Economic** – Total transportation miles for goods from point of product realization to the customer;
2. **Environmental** – Total CO_2 transport emissions from point of product realization to the customer;
3. **Social** – Average long-haul truckload driver turnover.

2.3 An Illustrative Horizontal Collaborative Example

To set the stage for our PI business briefs, we present a horizontal collaboration example. The example illustrates some of the main network dynamics that result with horizontal collaboration – dynamics that will be exploited fully in the PI: network reconfiguration for service and asset utilization implications.

This example uses specific data based on actual observations. The next section develops generalized models that are used in our larger study.

We evaluate horizontal collaboration from a strategic, rather than tactical perspective, by examining horizontal network solutions as an alternative to the traditional dedicated network. The reason for taking a strategic perspective is that logisticians tend to view horizontal collaboration primarily from the transportation perspective. The discussion often focuses on reducing empty miles, lowering costs and improving utilization. Rather focusing on trucking resource utilization, we felt there may be more compelling advantages from a network strategy perspective. The rationale for this thinking is that dedicated networks – the default standard in North America – are inherently challenged because it is nearly impossible to optimize both cost and service.

That is, there is an inherent tradeoff between cost and service. A cost-based objective function will minimize the number of facilities within a desired level of service. However, fewer facilities reduce service potential due to increased distance (and time) to the customer. Therefore, service could be enhanced with increased shipment frequency, however in a single-company network this reduces load size and increases cost. In fact, this usually does not occur and as a result the default economic order size in the CPG industry is typically a truckload. Moreover, limiting the EOQ to truckloads inevitably creates item level stockout issues, as inventory managers are frequently challenged with the question of how long to hold an order to balance individual item fill rate objectives versus maintaining full truckload shipment sizes to optimize transportation costs. This is a classic tradeoff, an inherent problem with dedicated networks.

Our hypothesis is that horizontal networks will "change the game." We believe that combining multi-shipper density in small market areas will change the results of strategic network design objective function, such that the optimal number of facilities in a national network will increase substantially, resulting in both cost and service improvements versus dedicated networks.

We start by developing a framework for the horizontal network within the overall context of a CPG manufacturer. As shown in Figure 1, the key elements of this framework are:

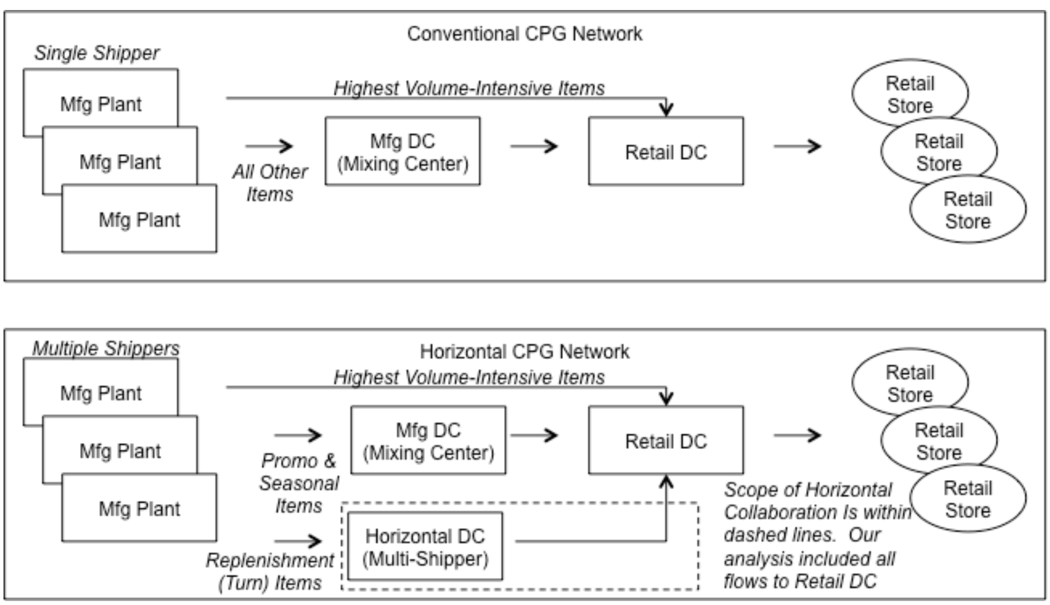


Figure 1: Conventional and Horizontal CPG Networks

- The horizontal network is the designated flow path for retail replenishment flow. Promotional items, new product launches, and seasonal builds are designated for the dedicated network. The reason for this is that demand for the replenishment flow path is more consistent and stable, and less susceptible to the spikes often seen with artificial influences.
- The horizontal flow path would be similar to most CPG flows, that is, from manufacturing plant to a DC (in this case a horizontal DC (HDC) shared by multiple shippers), then flowing from the horizontal DC to a retail DC.

- We assume that flows direct to store are not be considered at this time. Direct-to-store flows are assumed to be overly complex to consider as a "next step" improvement at this time, but clearly could be an option for improvement at a later stage of advancement.
- In this example, the material handling unit is a pallet. The assumption is that manufacturers would flow full truckloads into the HDC. Truckloads out of the HDC would be multiple pallet loads of items from the variety of shippers utilizing the facility, and result in relatively full, although not completely fully utilized truckloads, due to the strong desire to replenish on a daily basis.

- A second qualification is that the horizontal flow is destined for VMI customers. Although retailers have held various positions on acceptance of VMI supply relationships over the last several decades, it has become a conventional method, and eliminates order quantity constraints on a manufacturer's supply chain, provided the manufacturer achieves the inventory service agreements defined by the arrangement. Although VMI is not necessarily required for the solution, the removal of order quantity constraints is an important element in maintaining effective cube utilization of truckloads flowing from the HDC to the Retail DC, as there will be multiple manufacturers product on the load.

The data for this study was compiled from a wide variety of CPG companies. We looked at a cross-section of manufacturing plants and DC locations, and created a hypothetical "CPG supply chain network" that included 21 plants located across the nation and six regional DCs located in high-density DC markets as one would typically expect for a CPG manufacturer. Assumptions used for the model:

- Location and flow assumptions were made from a wide variety of CPG companies.
- Candidate HDC locations were identified at 26 possible locations throughout the country, all close to intermodal hubs to take advantage of the potential for intermodal utilization for inbound loads.
- Demand locations were identified from a prior study with a number of CPG shippers who had common customers across a number of high volume retail accounts. This data identified 150 high-volume retail DCs located throughout the country, from destinations to which any large CPG manufacturer would likely be shipping products. This data amounted to 55,000 truckloads and allowed us to develop confidence in assumptions about the volume of multiple shippers comingling on delivery flowing into the same locations.
- In this "hypothetical" network, we assumed that all flows (manufacturing plant to shipper's DC, and shipper's DC to retail DC) would flow on the shortest possible flow path. This is a significant simplifying assumption because CPG companies frequently do not manufacture all products from any facility, and also do not have the flexibility to flow to the nearest point due to manufacturing constraints or supply/demand inventory imbalance issues. In reality, shippers often ship longer distances from plant to DC, which creates a wider path from source to ultimate destination than the straighter paths assumed in this model. Hence, we believe that actual flows would indicate more miles than assumed, and the mileage variance between dedicated and HDC networks may actually be greater (and more favorable) than the model output showing 30% reduced miles, because an HDC will always produce a straighter path with less miles due to the close proximity between HDC and customer destinations.
- In-bound intermodal assumptions were 75% of inbound loads for the dedicated model and 90% of loads in the HDC model. These assumptions were applied to inbound distances greater than 500 miles. The 75% is reflective of inbound CPG transportation data we typically see. The HDC solution assumes intermodal service should be expected to increase due to the more consistent demand of replenishment products.
- On-time service assumptions were obtained from various sources, and reflect service that would be expected in two different delivery environments and applying those assumptions in the model based on distance to customer. The HDC solution assumes that distances less than 150 miles would be serviced with shuttle delivery service, reflecting regular scheduled service, more permanent driver pool, and assumes on-time delivery of 99% which we often see for 1st-stop retail deliveries. The other delivery environment assumes conventional long-haul trucking, more common in the conventional CPG environment. Service assumption for long-haul delivery assumes 94% on-time performance, the result of a recent customer service study, and applies to all deliveries for the dedicated model and all deliveries in the HDC model greater than 150 miles.

- DC costs were assumed to be $17 per pallet shipped. This was applied to both models. Both the dedicated model and collaborative model assume pallet picking to service customers.
- Outbound delivery cost assumed delivering from HDCs to be less efficient than from conventional DCs as it pertains to load factor and cost per mile.
  - Trucks delivering from HDCs were less fully utilized (30,000 lbs assumed) than if delivered from a conventional DC (40,000 lbs assumed) due to daily frequency requirement.
  - Trucks delivering from HDC assumed $1.92/mile (these averaged 112 miles and $215 per load; delivery from a conventional DC assumed $1.60/mile (these averaged 370 miles and $593 per load).
- Fuel costs were not included in the analysis; if done so it would favor the HDC model due to less highway miles and higher intermodal usage.

Our modeling results support the hypothesis in terms of customer service, sustainability, and costs improvements:

- For sales and customer service:
  - On-shelf fill rate improves with lower order minimums (1 pallet vs. full TL) and daily deliveries
  - On-time delivery improves from 94% to 97%
  - Deliveries are changed from ad hoc to predictable, scheduled daily drops
  - Logistics issues and exceptions are eliminated with the scheduled delivery service
- For sustainability:
  - Highway miles traveled are reduced 29%
  - Total miles traveled are reduced 8%
- For costs:
  - Manufacturer's network costs are reduced by approximately 5%
  - Retailer's safety stock is reduced 35% - 50%
  - Smoother flows reduce DC congestion, off-site storage and trailer detention costs

The rationale for horizontal network delivering better performance:

- Aggregated volumes of multiple companies in a horizontal network completely changes the optimal network solution:
  - TL volume to demand points increases approximately 5 times (from 3 to 16 TLs per week).
  - This results in more DCs, placed closer to the customer with less total miles between the original manufacturing point and the demand point.
  - The "optimal" network shifts from 6 to 17 locations, the distance from DC to customer drops from 329 to 143 miles, and net total miles from plant to demand point drops 8%.
- Aggregated volumes allow smaller order sizes with daily deliveries to customers, dramatically reducing customer safety stock levels and improving fill rate:
  - The new minimum order size of 1 pallet reduces retail inventory. Although this was not modeled, similar industry studies converting to daily deliveries suggest retail inventories can be reduced 35% to 50%.
  - Daily deliveries improve fill rate.
- With DCs located closer to customers, the delivery method changes, from traditional long haul trucking to a shuttle delivery method, more like a retail DC to store run instead of a long haul trucking move.
  - Shuttle service provides superior on-time service, our analysis estimates an improvement from 94% on-time with long haul trucking to 97% with horizontal (a combination of shuttle and some long haul deliveries for lanes greater than 150 miles).
  - Scheduled shuttle service is more predictable and less complex than long haul trucking; the on-time statistics alone do not indicate the total impact of this change. Strategically, long haul trucking is arguably the most unpredictable function in the supply chain due to the fragmented supply base and the volatility of fuel prices. Conversion to a shuttle service creates a stable, stay at home driver pool and unprecedented improvements in reliability as opposed to long haul trucking.

- Aligning the horizontal network to the more consistent demand patterns of replenishment product is estimated to increase the use of intermodal on the inbound transit by 90%.
  - A more consistent demand stream of replenishment products allows more accuracy in forecasting, with a greater chance of committing in-transit inventory to service.
  - The separate flow paths to the customer (replenishment flowing via the horizontal network, and other more volatile order streams flowing on the dedicated network) creates a more uniform flow of product that supports conversion to intermodal service. This is similar to commodity flows, for which rail is the normal mode of service. Managing all product flows through a single dedicated network inevitably results in products of different volatility being co-mingled on the same loads, and usually service trumps cost in today's supply chain, resulting in use of trucks instead of intermodal. The horizontal solution eliminates this co-mingling effect and creates a simpler solution for managing intermodal shipment.
  - Another critical aspect of the horizontal solution is the ability to manage supply to an inventory level (VMI) rather than to an order quantity. We believe this is an impactful part of the solution that allows for a dramatic increase in intermodal, resulting in a 29% reduction of total highway miles in the horizontal solution.

From this example, we form a number of conclusions. First, the study supports the hypothesis that strategic advantages from horizontal solutions are real, and arguably far superior to the more tactical transportation cost and utilization improvement. Second, we believe the most impactful results come from improved customer service and sustainability instead of reduced cost. It is our opinion that companies choosing to differentiate themselves on service and sustainability would be the most eager to pursue this as a strategic initiative. Given that the initiative also lowers costs would seem to make it additionally compelling. Third, interestingly, the biggest winner in this effort may be the retailer customer. Retailers will experience step-change improvements by streamlining their inbound logistics, the ability to add backhaul freight to their own fleet networks (this was not modeled but seen as an additional retail opportunity), reductions of 35 – 50% safety stocks (for items in the program), and vastly improved fill rates gained from pallet ordering quantities and daily service. This suggests that efforts to pilot these efforts should reach out to retailers, requesting them to require this type of service from their suppliers. Finally, another potential big winner is the logistics service provider, although this is also a point of risk and a big change for most logistics providers.

The above example is a powerful illustration of the impact of collaboration on a relatively limited scale. Our research project involved using these fundamental insights to build models that would scale the impacts when collaboration increases in the PI. As these impacts grow in a non-linear fashion, the models were critical to our understanding. The next section presents summaries of our models and how we use the results from them to build our business briefs.

3.0 Modeling the Impact of the Physical Internet

This section reports our research project results that inform our view of the impact the PI will have on various facets of the supply chain. At this time, the results are limited to trucking as we have not modeled intermodal systems. In most cases this leads to conservative estimates of impact. The first three studies are generally viewed as "positive" developments of the PI. The next two studies are generally viewed as potential "negative" aspects of a PI. However, the impacts were not always negative, and in some cases provided positive benefits as well. We then move to summarizing the impact on a number of factors, some of which were measured through benchmark studies.

3.1 Load Planning Study

One of the central questions we study is how adoption of the PI will change the average fullness of trailers, the average percentage of empty miles, and the resulting CO_2 emissions associated with freight distribution. We conducted a study [19] using data from various sources in the U.S. to represent regional and national transportation systems. We also consulted a study in France [20] that used as its premise that the two largest retailers and their top-100 suppliers would all collaboratively distribute freight in France. In the France-based study, 100% adoption (and 100% visibility) was assumed for the partners in the limited network. In the U.S.-based study, different levels of PI adoption and visibility into the freight available for shipping were varied (from as low as 5% to as high as 100%). The results for a regional model are provided below in Figure 2.

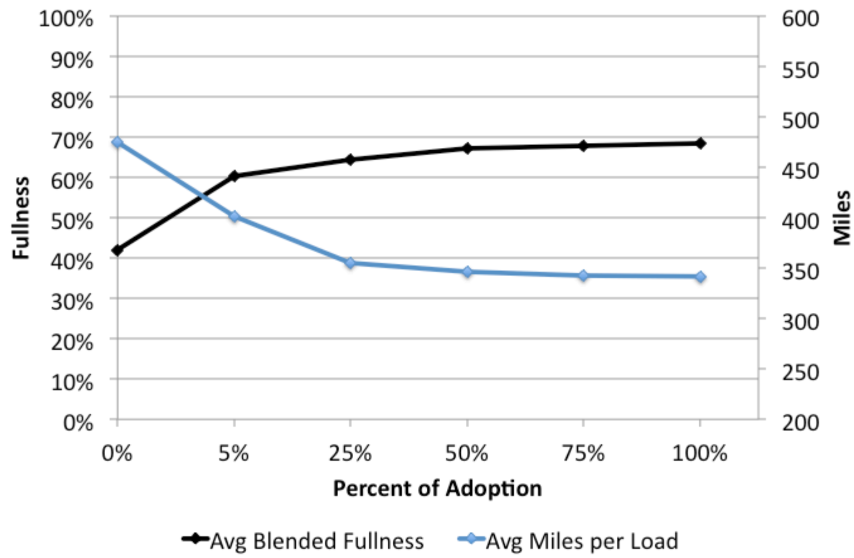


Figure 2: Average Trailer Fullness Values and Average Miles per Load (Loaded and Unloaded Miles) as a Function of Percent PI Adoption

Even with different assumptions, both the U.S.-based and France-based studies arrived at a similar conclusion: one-third to two-thirds of the emptiness could be filled, half or more of the empty miles could be reduced, and reductions in CO_2 emissions follow accordingly. For the U.S. study, the improvements shown were exhibited even with adoption levels as low as 25%.

Summary conclusion: We use these results in various ways in our business briefs, but in general, we assume 60% of the emptiness is filled in long-haul and short-haul fleets (less in private fleets) and empty miles are reduced by 50%.

3.2 Relay Networks and "Getting Drivers Home"

Thus far, we have not discussed s the important social aspect of "getting drivers home" so as to increase their quality of life, which we will measure in terms of driver turnover. One would assume that if long-haul drivers were to return home every day as LTL and private fleet drivers do in many cases today, we would see their turnover rates (currently and historically much over 100%) approach that of the other types of drivers (less than 10% for private fleet and less than 15% for LTL). Our modeling estimates that with the current dedicated networks to return drivers to domicile daily would increase the cost per load by as much as 60% [19].

We believe the PI offers the opportunity to reduce time away from domicile and we devised a study to test this. We used our above load planning models to measure the impact of the driver's time away from domicile on the fullness and average miles traveled by a load (including deadhead empty miles) [19, 21]. We then incorporated the cost of driver turnover into the equation to ensure that planning with longer times away from domicile resulted in larger driver turnover costs (to do so we looked at low, average and high turnover event costs, as reported in the literature [22]). Figure 3 illustrates the tradeoff for transportation service providers (using the high driver turnover event cost).

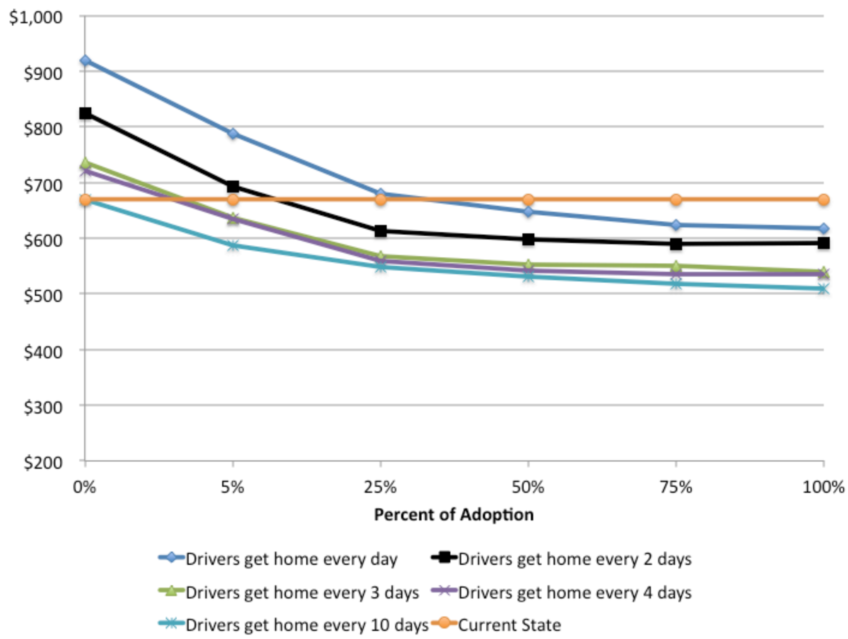


Figure 3: The Impact of Driver Time Away from Domicile on the Cost per Load (High Turnover Event Cost)

We make two points after examining Figure 3. The first is that even with high driver turnover event costs in a shared network, it is still preferable for transportation service providers to construct 10-day tours for their driver (this is the lowest point on the graph in Figure 3 at 25% adoption). However, the second point is that the penalty, in terms of cost per load, between 10-day tours and 4-day tours is less than 2% (at 25% PI adoption).

In this study we did not enforce a relay network structure, which greatly facilitates reducing tour lengths, as was originally hypothesized in the original paper on the PI. It remains to be seen if such a relay network would naturally emerge from a larger transportation system. If a relay type network does emerge, there is also the potential to substantially increase the speed by which freight can move over long distances. For example, using today's current HOS rules and a one-driver, one-trailer model, a shipment from Quebec to Los Angeles will take over 120 hours while a relay network will decrease that time to 76 hours. We conducted a study [21] where we looked at a representative set of nationwide flows and found that the average transit time decreased from 26.5 hours to 16.5 hours (a 38% decrease) and the CO_2 emissions reduced by 22% (the largest impact on the latter was due to the elimination of sleeper cabs and the associated overnight idling [23]). In this study we relied on the results from a study to design PI facilities [24]. That study showed that the average time in a PI transit point was likely to be approximately 30 minutes.

Therefore, we can see that a transportation service provider has a tradeoff to make. Keeping drivers out as they do currently may minimize shipment costs, but will continue to result in high turnover. However, the combination of a relay network structure and the PI may allow for transportation service providers to reduce the time away from domicile from 10-15 days to 3-4 days, with turnover estimated to decrease from over 100% to 24%.

Summary conclusion: We use the above results in two ways: (1) to estimate our overall driver turnover KPI; (2) to influence the cost reductions in our business briefs; namely, a reduction in empty miles, an increase in trailer fullness, and a reduction in transit time down from an average of two days to one day.

3.3 Average Distance Model

One of the advantages of distributing products through a more comprehensive network is that total miles may decrease. Although this was illustrated through the horizontal collaboration example, we needed a way to generalize this result. Therefore, we developed a model to estimate the distance through the a traditional supply chain based on the number of manufacturer DCs, number of customer DCs, and the number of customer demand points [25]. These average distances then can be compared with our estimate of distance through a PI supply chain based on the number of manufacturer DCs, number of PI DCs shipped through, and the number of demand points. Table 1 illustrates the model's results for a retail supply chain where the number of DCs in the supply chain increases from 5 to 18 and this reduces the distance to the store by 50% and reduces total miles by 24%.

Table 1: The Impact on Distances from a Traditional to the PI Supply Chain

	Traditional Supply Chain	**PI Supply Chain**
	2 Mfg DC 5 Retail DCs 500 Stores	2 Mfg DC 18 PI DCs 500 Stores
Distance (Mfg DC to Retailer DC)	532	479
Distance (Retailer or PI DC to Store)	336	177
Total Distance	868	656
		24% Reduction

Summary Conclusion: We use this model to measure the impact on the reduction in miles through alternative views of a supply chain.

3.4 Inventory Models

A potentially "negative" issue to address relative to a PI network is what is the impact on the inventory in the supply chain as the PI is adopted. As illustrated in the horizontal collaboration example, on the one hand, CPGs may chose to pre-position their inventory closer to the retailer stores by storing their inventory in more locations than they would today. Traditional inventory models imply that the safety stock inventory of CPGs would then increase using the well known "square root rule." However, a move from full truckload "economic order quantities" to "pallet-by-pallet" replenishment offers the promise to decrease variability in the ordering patterns, a change that traditional inventory models suggest would decrease the safety stock inventory of the CPGs. In either case, note that the impact on retailers will be positive; i.e., the retailers will experience less total inventory in their system.

We attempted to address this question with some basic modeling [25] and present our results in Table 2. We assume the average order quantity changed from 7 days of inventory to 2 days of inventory and the time for shipping decreased from 2.5 days to 1 day. In all cases we assumed that safety stock equaled 50% of the order quantity (i.e., even when orders arrive weekly, as they due in the current case, the lowest inventory point is assumed to be 3.5 days). With these small changes, CPG inventory is reduced by 73% at each DC in the network. However, as the number of PI DCs grows, the net CPG inventory change can switch from a reduction to an increase. For example, if we assume that the CPG currently ships out of two nationwide DCs (say, co-located with two plants) to four retailer DCs (on the path to 500 stores) and in a PI will ship to 20 PI DCs, the total inventory for the CPG (assuming it owns the inventory in both systems until shipped to the store) would increase by 36%. However, if the CPG is currently shipping to six retailer DCs and switches to shipping to 18 PI DCs, the total inventory for the CPG would decrease by 20%.

Table 2: The Impact on Inventory in a PI Network

Number of Retailer DCs	Number of PI DCs	CPG Inventory Change at Each DC	Net CPG Inventory Change	Retailer Inventory Change
N	$2N$	-73%	-46%	-33%
N	$3N$	-73%	-20%	-33%
N	$4N$	-73%	+8%	-33%
N	$5N$	-73%	+36%	-33%

Using a similar inventory model [25], for both cases, retailer backroom inventory is estimated to decrease by 33%. Here, order quantities are assumed to be taken from 2 days to 1 with no change in the inventory in transit. Again, safety stock levels are assumed to be one half the order quantity size.

Summary conclusion: We use the inventory model to estimate changes in turns rates and average inventory levels in the supply chain. We adopt a "CPG neutral" approach in that we assume that the CPG will balance the tradeoff between cost and service by choosing the number of PI DCs to ship through that keeps inventory costs the same while increasing service level (for example from 5 retailer DCs to 18 PI DCs, inventory remains relatively unchanged). We assume that retailer inventory decreases by 33%.

3.5 Packaging Study

One of the first questions we attempted to answer in our research project was the impact of standardized modular container sizes on the amount of product shipped. Organizations today carefully size their cartons so as to minimize the amount of air in the packaging. They do so for at least two reasons: (1) to minimize the amount of air that they are paying to ship and (2) to protect the product, because in many cases the product itself provides the structural integrity of the loaded carton. So, having a carton that is too large works against these goals. And we have data that support this thought: for one CPG, their products were represented by 40 distinct packaging dimensions and the CPG used 45 different case sizes; for another CPG, their products were represented by 268 distinct packaging dimensions and the CPG used 258 different case sizes, and finally, for a retailer, there were 1715 products received, representing 850 distinct packaging dimensions and 1057 distinct cases sizes. Clearly, limiting the number of modular containers has the potential to increase the amount of air shipped. But, by how much?

The results of our study [26] show that the answer to the above question depends on your assumptions. We assumed that the amount in the modular container could be within -/+10% of the amount of items in the original case. This is because retailers like to receive their items in cases that correspond to a specific amount of demand or shelf space (e.g., 1 week or 1.5 shelf modules). Because the demand and layout vary by store, this is an approximation to allow some limited flexibility. The other assumption we made is that in some cases the shelf dimension of some of the products could be adjusted (in those instances where the product was a small portion of the shelf dimension). So, with these assumptions the results are very interesting and compelling, as shown in Table 3. For the above-referenced retailer data set, for example, the items filled 85.2% of the case's volume today and by placing those same items in one of 30 modular container choices (less than 3% of the number of choices today!), the items filled 78.1% of the case's volume. However, the original cases only filled 77.6% of the pallet's volume whereas the modular containers filled 100% of the pallet's volume. Thus, while there is a slight increase in the amount of air shipped when just considering this problem at the case level (like in a floor-loaded practice), when the product is shipped on pallets, there is actually a 20% **decrease** in the shipped volume per product.

Table 3: Percent Utilization of Case or Pallet Volume in Current or Modular Setting

	Current			Modular		
Limits	Item In Case	Case on Pallet	Item on Pallet	Item In Case	Case on Pallet	Item on Pallet
-/+ 10%				80.2%	100%	80.2%
-/+ 25%	85.2%	77.6%	66.1%	82.9%	100%	82.9%
-/+ 50%				85.9%	100%	85.9%

The other aspect of this problem is that the amount of product on, say, a trailer, depends on whether the trailer weighs out or cubes out. When the trailer weights out, there will be virtually no impact on the amount of product in a trailer. When the trailer cubes out, if the product is shipped without pallets, then there will be a slight increase in the amount of trailers needed to ship a given quantity of product, whereas if the product is shipped on pallets, there will be a slight decrease in the amount of trailers needed to ship a given quantity of product.

Summary conclusion: We use these results in various ways in our business briefs. For example, we assume CPGs ship product on pallets and therefore the total volume shipped potentially decreases slightly (10%) and retailers ship product in cases and therefore total volume potentially

increases slightly (5%); we assume half the trailers weigh out (no impact) and half of the trailers cube out (with the above volume impacts).

3.6 Benchmarking Studies

Our modeling results measure of the impact of the PI on some, but not all, stakeholder KPIs. So, we use various benchmarking studies from WERC, Chainalytics, Supply Chain Forum (run by Tompkins International), and input from our TLs to establish representative KPI values today and then to project what they might be in the future. When we had little information, we used the KPI value represented by "average" performance today and then used "best in class" (BIC) performance in the future to represent the PI KPI value.

3.7 The PI's Impact on Fullness and Empty Miles

Realizing there are many assumptions embedded in the below, we still believed it was of value to summarize the impact on fullness and empty miles that PI adoption may have. Recall that the latest set of full data from government sources (1997) indicated that on average 25% of all miles are empty and, when loaded, trailers were, on average, 57% full. Unfortunately, these statistics are not separated by the three types of truck-based transportation modes and there isn't a consistent basis over which to represent the market share of each mode. Nonetheless, the values in Table 4 are internally consistent with data that we do have available from publications.

Table 4: Summary Statistics Consistent with U.S. Government Data

Metrics	Private Fleet	FTL	LTL	Composite
% **Full**	55%	65%	35%	57%
% **Empty Miles**	35%	15%	15%	25%
Blended Fullness	36%	55%	30%	43%
Market Share	50%	40%	10%	

The problem with these statistics is that organizations are not willing to accept that the values presented in Table 4, which indicate poor performance of the industry overall, are valid. Therefore, if we use these statistics as our reference point, we may overstate the potential improvements in the PI. Therefore, we pulled together estimates of these key metrics from our TLs and other organizations that were willing to share their view of the industry (see Table 5). Although the values in Table 5 may not gain universal acceptance, we believe they are more accurate than the government statistics and therefore, a more conservative starting point for our study. Despite these conservative starting values, there is still much room for improvement with an overall average composite fullness of 55%.

Table 5: Summary Statistics from Consensus Thought Leader Perspective

Metrics	Private Fleet	FTL	LTL	Composite
% **Full**	75%	80%	45%	74%
% **Empty Miles**	35%	15%	18%	25%
Blended Fullness	49%	68%	37%	55%
Market Share	50%	42%	8%	

Based on the studies presented earlier in this section, we expect that up to 60% of the emptiness of a trailer can be filled through a collaborative shipping network and that empty miles can be reduced to half their current values.

We assume there will be little difference between a full truckload carrier and an LTL carrier in the future; the difference will be in whether the load is long-haul or a short-haul. We believe that short-haul freight will slightly be more prevalent than long-haul freight. We also assume that the prevalence of private fleet networks will be cut in half and that the relative impact of the PI on their fleets will be about half of what it is for the long-haul and short-haul modes. Thus, we assume the summary statistics as shown in Table 6.

Table 6: Summary Statistics from PI Modeling

Metrics	Private Fleet	Long Haul	Short Haul	Composite
% **Full**	85%	93%	91%	90%
% **Empty Miles**	20%	10%	12%	13%
Blended Fullness	68%	84%	80%	78%
Market Share	25%	35%	40%	

3.8 The PI's Impact on the Initiative KPIs

Although difficult to measure the overall impact of the PI Initiative, we estimate the system in the U.S. would realize something on the following order of magnitude:

1. **Economic Impact – Total truck miles driven** (a necessary ingredient for measuring the total miles on a per product basis). We estimate that this reduction would be approximately 29.4%, which given that there were 145B total truck miles driven in 2007, represents a net reduction of 43B miles and the associated diesel fuel, truck purchasing and maintenance costs, etc. This impact is likely to reach $100B annually.
2. **Environmental Impact – Total CO_2 emissions due to truck operation** (a necessary ingredient for measuring the total CO_2 emissions from source to consumption). We estimate that this reduction would be approximately 32% due to 29% less miles driven and a CO_2 output efficiency due to operating a relay network and greatly reducing the number of sleeper cabs. Given that the CO_2 emissions due to truck operation were estimated to be 465 Tg (90% of all freight-related CO_2 output), this represents a net reduction of 150 Tg.
3. **Social Impact – Long-haul truck driver turnover rate** (a necessary ingredient for measuring the overall truck driver turnover rate): We estimate that long-haul truck driver turnover would reduce from well over 100% in most years to a value that is less than two times the current rate of 15% in the LTL sector; therefore, less than 30%. This reduces the retention costs in the industry (which range from $2,243 to $20,729 per driver [22]) and provides a mechanism for reducing the gap in life expectancy for these citizens.

In calculating the above we have purposely avoided just rolling up all these impacts to one final cost number. However, it is clear that this overall number would reach into the hundreds of billions of dollars annually, and this is accomplished by only concentrating on the trucking industry.

4.0 Business Briefs for PI Stakeholders

The motivation of this section is to take the macro-level view of Sections 1 and 2 down to the individual organization level. The intent is to provide a "business brief" for principal potential PI stakeholders.

The methodology that we employ here is to start with various KPIs used by the PI stakeholders and estimate the impact of the PI on the KPIs. In doing so, we pull from the results of our research project, other research projects, and a database of KPIs maintained by one of our project thought leaders (Tompkins International). We will now explain the results in more detail below. Note that the results are limited to trucking as we have not studied intermodal systems in detail. Thus, there are even larger gains available as we expand to consider other modes.

4.1 Stakeholders

There are many stakeholders in the logistics system that we are considering: shippers (manufacturers), receivers, transportation service providers (rail, truckload, less-than-truckload, parcel, etc.), and supporting services (like logistics software providers and non-asset-based 3PLs). The stakeholders could also include government entities (i.e., cities that want to improve the quality of life of its citizens by improving city (otherwise known as, final-mile) logistics, material handling and logistics equipment manufacturers (including packaging suppliers), and facility designers.

In the following analysis we focus on the following stakeholders:

- CPG manufacturers
- Retailers
- Truckload and less-than-truckload transportation service providers
- Diversified manufacturers/shippers

This group of stakeholders was chosen for two reasons: 1) these stakeholders will realize a large majority of the costs and impacts, and 2) we have better access to KPI value data for these stakeholders.

4.2 Business Briefs for Transportation Service Providers, Manufacturers and Retailers

For each stakeholder group below we present a few high-level figures to characterize the stakeholder (e.g., for a CPG manufacturer, its total annual sales, transportation costs as a percentage of sale dollars, etc.). We then present KPIs that our stakeholder is likely to track. We present current and possible future KPI values, and in each case provide our rationale for the change. We summarize with potential high-level impacts on the stakeholder.

4.2.1 A transportation service provider's business brief

For this business brief we make some basic assumptions about a representative transportation service provider (TSP) to allow us to make some calculations later. This TSP currently operates as a truckload carrier, utilizing its equipment 2,000 miles per week, which results in an operating cost of $1.50/mile. We also assume the following:

- Total Revenue = $2B
- Fuel Costs as a % of Revenue = 30%
- Driver costs as a % of Revenue = 35%
- Equipment costs as a % of Revenue = 15%
- Overhead costs as a % of Revenue = 15%
- Profit Margin as a % of Revenue = 5%

With these values, the total annual fuel costs are equal to $600M, total annual driver costs are $700M, total annual equipment costs are $300M, and total annual overhead costs are $300M. The current annual profit is then $100M.

Before we proceed further, a bit about a TSP business model from a truckload perspective. With the current operating strategy of sending drivers out on two-week tours, the equipment is utilized about 2,000 miles per week (maintenance and HOS-required rest times are not included in this total). This leads to an approximate operating cost of $1.50/mile. Given that currently truckload operators average 15% empty miles, the operator needs to bill out at about $1.76 to break even; and if making a 5% profit margin, the rate it charges will be approximately $1.85.

Two things change with the PI. First, due to the extensive use of relay networks, equipment utilization can, conservatively, increase to 3,500 miles per week (if not go as high as 4,000 or 4,500 miles per week). Because equipment costs comprise 15% of the total, this allows for up to a 7.5% decrease in the total costs to operate. Second, because of a larger collaborative network, the percentage of empty miles can effectively decrease from 15% to 5%, which allows the TSP to avoid deadhead miles that contribute nothing to the bottom line. Thus, if the entire savings of these two affects were applied to the bottom line of the TSP, the profit margin would rise considerably. However, we assume there would be market pressure to pass along the majority of these savings to the shippers and thus, only 20% of the cost reductions would go to the bottom line in our analysis below.

The KPIs we consider are outlined in Table 7. We have separated the KPIs into "primary" and "secondary" based on the statements from the industry that if a TSP is not competitive on the primary KPIs they will not be in business and the secondary KPIs allow a TSP to increase its profit margin. The intent is not that the KPI values correspond to any organization today, but rather that the KPI values are *reasonable* for our *representative* TSP.

We also present an assumed value of the KPI in a future state, assuming the PI exists at a matured state with an approximately 25% level of adoption. The future values are determined by examining best practices today (BIC values), the results of the modeling that we conducted as part of this project (Section 3), and discussions with our CELDi PI Thought Leaders. Again, the exact value is not as important as the direction and magnitude of the improvement that we believe will be realized. The other columns of the table present the impact of the changed KPI values when possible to calculate.

Table 7: Current and Future KPI Values for Transportation Service Provider

KPI		Current	Future	Improvement
Primary	Empty Miles	15%	11%	26% reduction in empty miles by participating in a collaborative network
	Equipment utilization (miles/tractor/week)	2,000	3,500	Nearly a 100% increase due to the use of relay networks that gets drivers home without idling equipment overnight
	Operating cost per mile (basis: total miles)	$1.50	$1.37	9% decrease due to utilizing equipment at a higher rate
	Revenue per mile (basis: billed miles)	$1.85	$1.62	This 12% reduction will be explained further below
Secondary	Driver Turnover	100%	27%	Reduction due to getting drivers home more often in a relay network
	Service (OTD)	95%	98%	Increase to BIC value
	Safety (collisions/1M miles)	2	2	There are advantages and disadvantages to driving in a PI network; a relay network structure may imply more regular work house, which may decrease the collision rate

With the above, the new cost totals and profit based on the same business are shown below:

- Total Fuel Costs = $576.4M (4% decrease)
- Total Driver Costs = $587.3M (16% decrease)
- Total Equipment Costs = $171.4M (43% decrease)
- Total Overhead Costs = $300M (unchanged)
- Total Profit = $119M (19% increase)
- Profit Margin = 7% (2% absolute increase)

Thus, due to the change in cost structure (reduced empty miles, increased equipment utilization, and reduced driver turnover), the TSP can simultaneously realize a 19% increase in profits while providing a 12% reduction in the rate it charges its customers and also provide a higher level of service. This is a classic win-win outcome. This rate reduction will show up in the next business brief for CPG manufacturers.

4.2.2 A CPG manufacturer's business brief

For this business brief we make some basic assumptions about a representative CPG manufacturer to allow us later to make some calculations. The CPG manufacturer has two plants in the U.S. that distribute to, on average, five DCs per each retailer customer. We also assume the following:

- Total Annual Sales = $10B
- Raw Materials, Manufacturing, and Non-Logistics Costs as a % of Sales = 83.8%
- Transportation Costs as a % of Sales = 2.5%
- Warehouse Costs as a % of Sales = 1.5%
- Inventory Unit Costs as a % of value (based on Sales) of units in inventory = 10%; and due to a current turn rate of 6, this constitutes 1.67% of the total annual sales

- Damage/Spoilage Costs as a % of Sales = 0.5%
- Profit Margin as a % of Sales = 10%

With these values, the raw materials, manufacturing and non-logistics costs are $8.3B, transportation costs are $250M, warehouse costs are $150M, inventory costs are $167M, and damage costs are $50M. The current annual profit is then $1B.

Before we proceed further, a bit about a CPG supply chain today and how we envision it in the future. As was illustrated in the horizontal collaboration example (refer back to Figure 1 in Section 2.3), today CPGs ship to relatively few retailer DCs (we assume five per retail customer) and the economics are such that truckload quantities are preferred. However, in the PI, the CPG will have the potential to ship to many more PI DCs (we assume eighteen for this CPG), which allows the CPG to both reduce the total distance traveled from their DC to the retailer store, but also reduce shipment sizes dramatically. This reduction in shipment size (with a corresponding increase in shipment frequency) will mean that service to the retailer will improve, likely beyond even the best-in-class values that we cite below.

We estimate that for our CPG the average outbound distance (from their DC) will decrease from 530 miles (shipping to five retailer DCs) to 477 miles (shipping to eighteen PI DCs) and that the inbound distance to the retail store will decrease from 335 (from five retailer DCs) to 177 (from 18 PI DCs). The other dynamic at work is that although positioning inventory in more locations provides greater service benefits to the retailer, it comes at the cost of a reduced safety stock pooling effect. That is, although there is less inventory in each of the eighteen PI DCs for this CPG's products (than in the current system with five retailer DCs), the total inventory can grow due to a lack of pooling. Therefore we chose the 18 PI DCs on the basis of holding total inventory constant in our models. That is, if the CPG would choose to use more PI DCs, then CPG inventory would increase (although service to the retailer would increase); likewise, if the CPG would choose to use less PI DCs, total inventory would decrease (but service to the retailer would also not improve as much).

So, the combined effect of a lower rate and less miles means that the CPG will reduce its costs. And like with the TSP brief business model, we assume there would be market pressure to pass along the some of these savings to the retailers and thus, only 50% of the cost reductions would go to the bottom line in our analysis below.

The KPIs we consider are outlined in Table 8. We have separated the KPIs into three categories: customer view (how retailers view the CPG), transportation and warehousing. For each KPI we present a current value and a future value using the methodology and process described earlier. The intent is not that the KPI values correspond to any organization today or in the future, but rather that the KPI values are *reasonable* for our *representative* CPG and our assumptions about the PI moving forward.

Table 8: Current and Future KPI Values for CPG

	KPI	Current	Future	Improvement
Customer View	Lead time	2.5 days	1 day	Reduction to minimum due to proximity to retailer; 1.5 days saved for a 60% reduction
	On time delivery	92%	98%	Increase to BIC value (6% increase) due to proximity to retailer and less truck downtime in relay network
	Fill rate [outbound]	94%	99%	Increase to BIC value (5% increase) due to proximity to retailer and less truck downtime in relay network
	Damage or spoilage	0.5%	0.25%	Reduction to BIC value (50% of the damage removed) due to PI containers
Transportation	Average miles per shipment	531	478	Reduction (10%) due to shipping to more PI DCs, which are located closer to major markets
	Average truck fullness	80%	92%	Models indicate that 60% of emptiness filled due to a collaborative platform
	Average costs per mile	$1.85	$1.62	The TSP brief business model indicates that 12.3% rate reductions would be seen by shippers
	Average cost per pound	$0.05	$0.037	Models indicate a 24% reduction from less miles lower rates
Warehouse Measures	Inventory turn rate	6	6	More, frequent shipments, but to more locations means that there will either a positive or negative impact on CPG inventories
	Average days on hand of inventory [finished goods]	60	60	More, frequent shipments, but to more locations means that there will either a positive or negative impact on CPG inventories
	Average cost to handle a pallet	$17	$10	Decreased by 40% due to operating warehouses with less inventory and equipment optimized for the PI ($7 saved per pallet)
	Average cost to handle a case [Distribution cost per unit shipped]	$1	$0.60	Decreased by 40% due to operating warehouses with less inventory and equipment optimized for the PI ($0.40 saved per case)

With the above, the new cost totals and profit for the same product volume are shown below:

- Total Annual Raw Materials, Manufacturing, and Non-Logistics Costs = $8.3B (unchanged)
- Total Annual Transportation Costs = $197M (21% decrease)
- Total Annual Warehouse Costs = $90M (40% decrease)
- Total Annual Inventory Costs = $163M (2.4% decrease)
- Total Annual Damage Costs = $25M (50% decrease)
- Total Profit = $1.1B (7% increase)
- Profit Margin = 11% (1% absolute increase)

Thus, due the change in cost structure in the TSP community and the ability to ship through a large, collaborative network of DCs (that are operating at lower cost and with less damage due to the use of standardized modular containers), the CPG can simultaneously realize a 7% increase in profits while providing a 0.7% reduction in the rate it charges its retail customers and also provide a higher level of service to those retailers through more frequent shipments. This is a classic win-win outcome. This rate reduction will show up in the next business brief on retailers. In addition, CO_2 emissions would reduce 24.3% due to this change, shrinking the carbon footprint of the CPG manufacturer as well.

4.2.3 A retailer's business brief

For this business brief, we make some basic assumptions about a representative retailer to allow us later to make some calculations. We assume that the retailer has 1,000 stores that are currently being served by five regional DCs. We assume that the retailer mostly sells CPG products and we do not consider perishables. We also assume the following:

- Total Annual Sales = $10B
- Annual Receipt Costs from CPGs as a % of Sales = 66%
- Labor Costs as a % of Sales = 10%
- Effective Outbound Transportation Costs (accounting for backhaul revenue) as a % of Sales = 2.5%
- Distribution Center Costs as a % of Sales = 1.5%
- Inventory Costs as a % of value (based on Sales) of units in inventory = 13%
- Infrastructure and Overhead Costs as a % of Sales = 16.3%
- Profit Margin as a % of Sales = 3.0%

With these values, the annual receipt costs would equal $6.6B, labor costs would be $1B, effective transportation costs would be $250M ($300M for outbound and $50M in backhaul revenue), distribution center costs are $150M, inventory costs are $55.6M (based on a current industry average of 18 turns per year), and the infrastructure and overhead costs are $1.3B. The current annual profit is then $300M.

Before we proceed further, a bit about the impacts that we have seen so far. First, we know that the total annual receipt costs will be reduced by 0.7% due to savings passed on from the CPGs. Also note that due to an increased CPG shipment frequency the inventory levels for the retailer will reduce by an estimated 33%. Second, by entering the PI, the retailer, if they chose to still operate their private fleet, they will see increases in backhaul revenue (from 30% of paid backhauls to 60% paid backhauls). We assume that they maintain their private fleet even though larger savings would be available by switching to a PI TSP. And finally, as noted earlier, the average distance from the PI DC to the retailer store will be reduced from 337 miles to 178 miles (47% decrease), which further will reduce outbound transportation costs. Other savings will result from DCs that are operated at higher levels of efficiency due to modular containers. We assume that due to competitive pressures only 20% of the savings will be applied to the bottom line of the retailer (i.e., 80% of the savings will be passed along to the consumer).

The KPIs we consider are outlined in Table 9. We have separated the KPIs into three categories: Supplier view (these are repeated from the CPG business brief), Distribution Center, and Retail Store. For each KPI we present a current value and a future value using the methodology and process described earlier. The intent is not that the KPI values correspond to any organization today or in the future, but rather that the KPI values are *reasonable* for our *representative* retailer and our assumptions about the PI moving forward.

Table 9: Current and Future KPI Values for Retailer

	KPI	Current	Future	Improvement
Supplier View	Lead time	2.5 days	1 day	Reduction to minimum due to proximity to retailer; 1.5 days saved for a 60% reduction
	On time delivery	92%	98%	Increase to BIC value (6% increase) due to proximity to retailer and less truck downtime in relay network
	Fill rate [outbound]	94%	99%	Increase to BIC value (5% increase) due to proximity to retailer and less truck downtime in relay network
	Damage or spoilage	0.5%	0.25%	Reduction to BIC value (50% of the damage/spoilage removed) due to PI containers
Distribution Center	Average days on hand of inventory	20	13	33% reduction due to more frequent, smaller shipments
	Inventory turn rate	18	27	50% increase due to more frequent, smaller shipments
	Cartons per trailer Items per trailer	1,600 32,000	 30,400	Packaging results indicate that there may be a slight decrease (10%) in items per trailer if floor-loaded cartons AND trailers that cube out (if trailers weigh out there is no impact, and if cartons are loaded onto pallets, there would be an <u>increase</u> in the items per trailer); potentially raises per item transportation cost by 6%
	Handling cost per carton	$0.80	$0.48	Decreased by 40% due to operating warehouses with less inventory and equipment optimized for the PI ($0.32 saved per case)
	Average distance from DC to store	337 miles	178 miles	Decreased by 47% by shipping through 18 PI DCs versus 5 RDCs
	Percentage of revenue-generating backhauls	30%	60%	A substantial increase in backhaul opportunities in collaborative network
	Effective transportation cost/mile to stores	$2.31	$1.97	Due to increase in backhaul opportunities; above potential decreases in items per trailer are paid for by these increases

Retail Store	Percent delivered on-time to stores	93.5%	95%	Increase to BIC value (1.5% increase) due to proximity to retailer and less truck downtime in relay network
	Time to unload trailer with team	90 minutes	90 minutes	There are advantages and disadvantages to handling modular PI containers at the store; not enough information to indicate how this KPI would be affected

With the above, the new cost totals and profit for the same sales volume are shown below:

- Total Annual Receipt Costs = $6.55B (0.7% decrease)
- Total Annual Labor Costs = $1.0B (unchanged)
- Total Annual Outbound Transportation Costs = $158M (47% decrease)
- Total Annual Backhaul Revenue = $70M (41% increase)
- Total Annual Effective Transportation Costs = $87M (65% decrease)
- Total Annual Warehouse Costs = $90M (40% decrease)
- Total Annual Inventory Costs = $37M (33% decrease)
- Total Annual Infrastructure and Overhead Costs = $1.3B (unchanged)
- Total Profit = $412B (37% increase)
- Profit Margin = 4.3% (1.3% absolute increase)

Thus, due to the change in cost structure for CPGs, due to changes in the cost structure in the TSP community, and the reduction in transportation distances and the ability to compete for backhaul loads in a large market, the retailer can simultaneously realize an $112B increase in profit (a 1.3% net increase) while still reducing prices for the consumer by 2.1% and providing better service with higher fill rates. This is a classic win-win outcome. In addition, CO_2 emissions would reduce 47% for the inbound-to-store loads due to the change in the network, thus shrinking the carbon footprint of the retailer as well.

4.2.4 A diversified manufacturer's/shipper's business brief

A diversified manufacturer/shipper is our term for manufacturers that are not CPG manufacturers. We purposely added the label of "diversified" because this group represents small, medium and large manufacturers based on annual shipment volume, but also based on the size of the items shipped, the frequency of shipments, etc. Thus, of all the business briefs, we realize this one is less likely to speak to a majority of companies represented by this category. Nonetheless, as a diversified manufacturer is most likely to be using an LTL transportation service provider (either for inbound, outbound, or both), we thought it was important to include this business brief.

For this business brief, we assume that the diversified manufacturer is responsible for paying (either directly or indirectly) for inbound and outbound transportation. Inbound transportation is handled by an LTL carrier and outbound transportation, due to the need for specialized handling equipment and to minimize the number of touches and to increase the security of the shipping process, is handled by a truckload carrier. The diversified manufacturer has multiple plants in the U.S. that distribute to the DCs of the wholesaler that they work through to bring their products to market. We also assume the following:

- Total Annual Sales = $1B
- Raw Materials, Manufacturing, and Non-Logistics Costs as a % of Sales = 66.5%
- Inbound Transportation Costs as a % of Sales = 2.0%
- Outbound Transportation Costs as a % of Sales = 3.0%
- Inventory Unit Costs as a % of value (based on Sales) of units in inventory = 10%; and due to a current turn rate of 4, this constitutes 2.5% of the total annual sales
- Damage Costs as a % of Sales = 1.0%

- Depreciation and Overhead Costs as a % of Sales = 10%
- Profit Margin as a % of Sales = 15%

With these values, the raw materials, manufacturing, and non-logistics costs are $665M, inbound transportation costs are $20M, outbound transportation costs are $30M, inventory costs are $25M, damage costs are $10M, and depreciation and overhead costs are $100M. The current annual profit is then $150M.

The diversified manufacturer will benefit from the PI in the following foreseeable ways. Inbound transportation rates will be lowered as LTL carriers are able to fill trailers more full. Outbound transportation rates will be lowered as TL carriers reduce the amount of empty miles in their network. And due to this, lead time will decrease, which will lower inventory and increase inventory turn rates. Finally, with effective use of modular PI containers, product damage should decrease substantially. So, the combined effects will reduce the cost structure and the diversified manufacturer will reduce the cost it charges to it distributors. As with the CPG manufacturer's brief business model, we assume only 50% of the cost reductions would go to the bottom line in our analysis below.

The KPIs we considered are presented in Table 10. For each KPI we present a current value and a future value using the methodology and process described earlier. The intent is not that the KPI values correspond to any organization today or in the future, but rather that the KPI values are *reasonable* for our *representative* manufacturer and our assumptions about the PI moving forward.

Table 10: Current and Future KPI Values for Diversified Manufacturer

KPI	Current	Future	Improvement
Lead Time (days)	14	5	Reduced due to operating in a collaborative network
On-Time Delivery	92%	98%	Increase to BIC value (6% increase) due less truck downtime in relay network
Fill rate (outbound)	94%	99%	Increase to BIC value (5% increase) due to less truck downtime in relay network
Damage	2.5%	0.25%	Reduction to BIC value (90% of the damage removed) due to PI containers
Average cost per pound (inbound)	$0.10	$0.079	Transportation service provider business brief result (21% reduction in LTL rates possible)
Average cost per mile (outbound)	$2.00	$1.75	Transportation service provider business brief result (12.3% reduction in TL rates possible)
Average days inventory in the system	90	81	Direct result of reducing pipeline inventory by 9 days
Inventory turn rate	4.0	4.4	Direct result of reducing pipeline inventory by 9 days

With the above, the new cost totals and profit for the same product volume are shown below:

- Total Annual Raw Materials, Manufacturing, and Non-Logistics Costs = $665M (unchanged)
- Total Annual Inbound Transportation Costs = $15.8M (21% decrease)
- Total Annual Outbound Transportation Costs = $26.3M (12.3% decrease)
- Total Annual Inventory Costs = $22.5M (10% decrease)
- Total Annual Damage Costs = $1M (90% decrease)
- Total Annual Depreciation and Overhead Costs = $100M (unchanged)
- Total Profit = $160M (6.7% increase)
- Profit Margin = 16% (1% absolute increase)

Thus, due the change in cost structure in the TSP community and the ability to ship through a large, collaborative network, the diversified manufacturer can simultaneously realize a $10M (7%) increase in profits while providing a 1.0% reduction in the rate it charges its distributors and also provide a higher level of service to those distributors through more frequent shipments. This is a classic win-win outcome. In addition, CO_2 emissions would reduce 17.3% due to this change, shrinking the carbon footprint of the diversified manufacturer as well.

5.0 Challenges Ahead

The physical internet (PI) provides a vision for interconnected logistics that has the potential to turn the promise of today's horizontal collaboration projects into an open global intermodal logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols. Our research, which was directed by PI Thought Leaders from leading organizations worldwide, indicates that there are operational and strategic benefits from engagement in the PI. In particular, we presented business briefs that illustrate the business dynamics of the new logistics system that results, including increased profit margins for the supply chain partners and lower costs for the consumer. In sum, the impacts of the PI on economic, environmental and social sustainability are significant, with estimated annual savings of $100B, 150 Tg of CO_2 emissions, and reducing the turnover rate of long-haul truck drivers (up to a 75% reduction).

However, there are physical, digital and operational obstacles to realizing our vision for interconnected logistics.

On the physical side, the various dimensions, as well as the useful weight of the key components such as pallet, trailer truck, train car, and maritime shipping container, present issues of compatibility leading to waste of capacity and extra handling. A closely related issue is the functional design of the modular containers. Designing the modular containers to protect the product so that the product or its secondary packaging does not have to provide the structural integrity is an important issue. Another physical issue is the design of the facilities used to transfer and store loads throughout the logistics network. With loads that arrive with a specified ship date and consist of standardized modular containers, the facilities to handle the products should be designed much differently than they are today; as today, facilities must accommodate a very wide range of pallet, case and carton dimensions and most warehouses are designed under the assumption that product is to be stored for "eventual" shipment.

The second set of obstacles to the realization of an interconnected logistics system is digital. In the PI, container tracking is extremely important, but is not, by itself, sufficient. In addition, users will need to *communicate* with containers. This communication will need to take place irrespective of which operator is providing the transportation and storage resource through the supply chain, which presents a significant challenge in terms of problem scale. Past solutions provide a starting point. However, as none were conceptualized or designed for containers operating in an open environment (they are based on proprietary platforms, membership fees, etc.), modifications will be necessary to be used in the PI.

The third set of obstacles to the realization of an interconnected logistics system is operational. A recent survey by EyeForTransport [16] reveals that the key drivers for collaboration in the supply chain are reduced distribution costs, enhanced customer service, and increased efficiency. The PI promises gains in each of these areas, but users need to be confident that their shipments will not be stuck in a queue in the supply chain, the goods are secure, the goods will be delivered on-time and in the correct condition, etc. The transportation provider would be very interested to know how long their drivers are on the road and how to appropriately bid freight services, and of which mode. The logistics community would be very interested to know how this affects the number of trucks on the road. And the government would be interested to know the impact on road and rail traffic. Further, given a switch in emphasis from complete orders to modular containers, many of the stakeholders would be interested in the emergent behavior resulting from the independent (from a transportation perspective) movement of those containers. All stakeholders in the supply chain have to be part of an economically sustainable business environment.

That said, many of these obstacles are only obstacles in the long term. As we highlight in the next section, the PI can start today on a smaller scale, with limited use of modular containers, in a system that is only open to the partners that invest (much like the digital Internet started).

6.0 Possible Paths Forward for the PI

The purpose of this discussion is to describe how the PI *might* unfold from a high-level perspective (clearly, we do not *know* which path or paths will emerge for the PI to begin). That is, how will the virtuous cycle begin and what is required for all of this to happen? As part of our vision we present a number of possible paths forward for the PI. To aid in this discussion, note that we use the term "industry" to refer to a collection of shippers and receivers of products that share high-level characteristics (e.g., retail, grocery, military supplies, automotive, etc.) and we use the term "sector" to refer to subsets of an industry (e.g., the fast-moving consumer goods sector of the retail industry, the perishable foods sector of the grocery industry, etc.). We also use the terms "top-down" and "bottom-up" to refer from where the motivation comes. That is, in a top-down initiative, the "customer" (in this case the receiver, like the retailer, the military, or the automotive manufacturing plants) will mandate the change, whereas in a bottom-up initiative, competitive pressures that result when shippers observe opportunities for improvement, will encourage the change. And finally, as observed earlier, the distinctions between transportation service providers will continue on their current path of being less rigid. Therefore, in the below we refer to all transportation service providers in the more general term of a 3PL.

In general, the possible paths fall into three categories: (1) a bottom-up initiative; (2) a top-down initiative; and (3) a 3PL initiative. We present the initiatives in this order because we, in general, believe that bottom-up initiatives are more effective, when started; however, we recognize that it is sometimes necessary to start an initiative from the top. And although we believe that a 3PL initiative, with the right shared risk-reward structure is a promising point from which to begin, we acknowledge that the current 3PL community, by and large, does not appear interested in taking the lead to advance large scale horizontal collaboration partnerships.

One example of a bottom-up initiative is one that we call "the slow-moving CPG initiative." In this initiative, a significant group of CPGs that supply slow-moving products in the retail industry realize the cost and service benefits from horizontal collaboration and form an association with increased horizontal collaboration as its goal. To allow for broad participation across the CPGs in the association, an investment is systems is made that allow the CPGs to collaborate in a safe and secure manner. The CPGs start the initiative with traditional pallets and cases as most of the benefits of the PI are available through such a system. As trailers approach higher levels of fullness, the CPGs realize that further benefits will be realized through the use of modular containers, which they implement when TSPs realize the efficiency benefit of using these containers.

There are many possible variations to the slow-moving CPG initiative. For example, the perishable foods sector of the grocery industry is plagued by product damage, spoilage and reduced food quality due to these factors. The perishable food providers realize there is the possibility of all providers doing better if they utilized shared assets and form an association to put in the systems to achieve this goal. The perishable food sector views this as a physical platform to complement the Foodlink.net digital platform used for POs in much of the industry (which was started to combat the issue of PO reconciliation because POs changed, on average, 4.5 times from issue to delivery).

One example of a top-down initiative is one that we call "the grocer initiative." In this initiative, the grocers do not wait for the perishable food distributors to form an association. Instead, the grocers form the association whose goal is to facilitate horizontal collaboration amongst the perishable food suppliers. Once formed, the grocers mandate participation by its partnering food distributors, including a shift to standardized modular containers at a point in the future. The grocers see significant advantages in terms of less product damage, higher product quality, and less wasted produce. These advantages drive their investment in the initiative.

There are many possible variations on the grocer initiative. For example, retailers could create a CPG PI association and then mandate participation in it from their CPGs. Or, the military, recognizing the speed and efficiency advantages of handling standardized modular containers, could create a mechanism for PI collaboration and then mandate participation. This variation is made more plausible by the recognition that the military is used to experimenting with new systems and has a more centralized command structure than most commercial organizations. And because of the military's concerns about safety and security, an initial initiative in the military would likely reap benefits for other industries and sectors that follow. Likewise, the military has the wherewithal to invest in new facilities that take advantage of handling standardized, modular containers, which would also benefit the commercial sector down the road.

And finally, the last initiative example that we provide is in the category of a 3PL initiative. We refer to this as the "private 3PL northeast initiative." In this initiative, a private 3PL, with a long-term growth vision that recognizes the opportunity in the PI, begins a partnership based on a dense-market business model. The 3PL identifies a sector in an industry in the northeastern U.S. where the density is appropriate to realizing 80% of the PIs benefits with minimal changes and disruptions to the current system (e.g., using current pallets and cases, able to meet current receiver requirements for shipment operations, etc.). The 3PL gains a commitment from the shippers and receivers and invests in newer, efficient infrastructure in a localized network. They use this dense market to improve its facilities, systems, and protocols, which ultimately allows it to expand into other less-densely-populated markets as well as allowing the participation of organizations not part of the original partnership.

There are variations to the private 3PL northeast initiative. For example, a publicly held company that has a long-term growth strategy may be able to justify the initial effort and capital investment in the network reorganization. Likewise, the dense market may be defined on a smaller scale (e.g., the NY/NJ transportation corridor, the Los Angeles import base, etc.).

In all paths, we believe that once the momentum of the PI is initiated, allowing the "network effect" to propel the system forward, other efficiencies will be realized. The first steps on these paths occur when stakeholders recognize the potential benefit in terms of their own organization, invest in actions that will be necessary to answer unanswered questions, and design and execute *pilot efforts* with their partners to address these questions. It is our hope that this research provides a story sufficiently compelling to allow this to happen.

7.0 Conclusions

This report represents the conclusion of Phase I of the CELDi Physical Internet Project. Phase II of the project will focus on answering the key questions related to physical and operational interconnectivity for industry-based pilot studies and supporting the collection of data related to these pilots.

Like the PI itself, the PI Initiative is an open one, with participation from a wide variety of organizations, as our title page suggests. This report represents the culmination of a two-year project. We are embarking on Phase II of the project in the fall of 2012 and welcome new participants.

For more information on the CELDi Physical Internet Project, please see: http://faculty.ineg.uark.edu/rmeller/web/CELDi-PI/index-PI.html.

Contact:

Russell D. Meller, CELDi Physical Internet Project, Center for Excellence in Logistics and Distribution, the University of Arkansas, rmeller@uark.edu

Bibliography

[1] B. Montreuil, "Toward a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge," *Logistics Research*, **3**(2-3), 71-87, 2011.

[2] "Highway Statistics, Annual Issues, 1995-2008," Federal Highway Administration, U.S. Department of Transportation, 2009.

[3] "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007," U.S. Environmental Protection Agency, 2009.

[4] Online Resource for Studies on Empty Trailers in Freight Distribution, http://answers.google.com/answers/threadview?id=164154, 2003.

[5] A. McKinnon, "European Freight Transport Statistics: Limitations, Misinterpretations and Aspirations," 15th ACEA Scientific Advisory Group Meeting, Brussels, Belgium, 2010.

[6] Physical Internet Initiative Website, www./physicalinternetinitiative.org, 2011.

[7] "U.S. Life Cycle Inventory Database Roadmap," U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, August 2009.

[8] "Commodity Flow Survey," Bureau of Transportation and Statistics, Research and Innovation Technology Administration, U.S. Department of Transportation, 2009.

[9] R. LaHood, *Fastlane*, 2010. [Online]. http://fastlane.dot.gov/2010/09/healthy-trucker-movement-an-important-development-in-an-important-industry

[10] J. Sutherland, "Collaborative Transportation Management: A Solution to the Current Transportation Crisis," Technical Report, Lehigh University, 2006.

[11] M. Frisk, M. Gothe-Lundgren, K. Jornsten, and M. Ronnqvist, "Cost Allocation in Collaborative Forest Transportation," *European Journal of Operations Research*, **205**(2), 448-458, 2010.

[12] T. Esper and L. Williams, "The Value of Collaborative Transportation Management (CTM): Its Relationship to Collaborative Planning," *Transportation Journal*, **42**(4), 55-65, 2003.

[13] J. Sutherland, "Collaborative Transportation Management-Creating Value Through Increased Transportation Efficiencies," Technical Report, Lehigh University, 2003.

[14] L. Tesseras, "Dangerous to Ignore it," *Supply Chain Standard*, 10-11, October 2011.

[15] J.T. Mentzer, J.H. Foggin, and C.L. Golicic, "Collaboration: The Enablers, Impediments, and Benefits," *Supply Chain Management Review*, September/October 2000.

[16] EyeForTransport, "North American Horizontal Collaboration in the Supply Chain Report," EyeForTransport Survey, 2011.

[17] TRI-VIZOR, "TRI-VIZOR Company Flyer," 2011.

[18] TRI-VIZOR Website, "TRI-VIZOR: The World's First Cross Supply Chain Orchestrator," http://trivizor.com.apache10.hostbasket.com/, 2012.

[19] K.P. Ellis, S. Roesch, and R.D. Meller, "Collaborative Freight Transportation in the Physical Internet: A Result of the CELDi Physical Internet Project," Center for Excellence in Logistics and Distribution, University of Arkansas, 2012.

[20] E. Ballot, R. Sarrah, and S. Pan, "Potential of Routing Protocols for Freight in Open Logistics Networks: The Case of FMCPG in France," *Proceedings of ILS 2012*, 1-10, 2012.

[21] B. Lombardi, R.D. Meller, K.P. Ellis, and L.M. Thomas, "The Impact of a Relay Network Transportation System: A Result of the CELDi Physical Internet Project," Center for Excellence in Logistics and Distribution, University of Arkansas, 2012.

[22] J. Rodriguez, M. Kosir, B. Lantz, and G.J. Griffen, "The Costs of Truckload Driver Turnover," Upper Great Plains Transportation Institute, North Dakota University, 2000.

[23] B. Lombardi, R.D. Meller, K.P. Ellis, and L.M. Thomas, "The Impact of Removing Sleeper Cabs: A Result of the CELDi Physical Internet Project," Center for Excellence in Logistics and Distribution, University of Arkansas, 2012.

[24] B. Montreuil and R.D. Meller, "Designing Material Handling Systems and Facilities for the Physical Internet," Material Handling Industry of America, July 2010 - July 2012.

[25] R.D Meller and K.P. Ellis, "Distances Reduce and Inventory Levels Change in a Physical Internet Network: A Result of the Physical Internet Project," Center for Excellence in Logistics and Distribution, University of Arkansas, 2012.

[26] R.D. Meller, Y.H. Lin, K.P. Ellis, and L.M. Thomas, "Standardizing Container Sizes Saves Space in the Trailer: A Result of the CELDi Physical Internet Project," Center for Excellence in Logistics and Distribution, University of Arkansas, 2012.