"protoPI" - Development of a prototypical Gateway to the Physical Internet

Dr. Bartosz Piekarz[1],
FH-Prof. DI Hans-Christian Graf[2], DI Florian Ehrentraut[3]

1. Johannes Kepler University Linz - Institute of Production and Logistics Management, Austria
2. University of Applied Sciences Upper Austria – Logistikum, Steyr, Austria
3. Graz University of Technology – Institute of Logistics Engineering, Graz, Austria

Corresponding author: Hans-Christian.Graf@fh-steyr.at

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Abstract

Within existing supply chains there is still a significant potential for the combination of part and single unit loads, but in many cases competing suppliers as well as fix contracted service providers hinder optimized truck fill rates and transport consolidation. To overcome these drawbacks, within the FFG-funded project "protoPI", a team of Austrian research and business partners developed a) an integrated conceptual framework and b) a web-based transportation management platform in order to show and evaluate the potential of the PI approach to real life applications. By digitalizing the transport management process as far as possible, pooling systems for further developed returnable transportation items (RTIs) are made possible and significant potential cost savings in the delivery process can be identified, resulting from the use of specialized transport service providers (TSP). This could be of particular relevance for small and medium-sized enterprises, which in many cases are dependent on global forwarding companies.

Introduction

The conceptual approach of the Physical Internet can undoubtedly be granted a tremendous charm in scientific terms, but the great leap from the digital concept world to the lowlands of physical logistics (still) does not succeed. Industrial and commercial companies cannot really approve of PI approaches because they often prefer their own (non-open) transport systems. Transport and logistics service providers often see the PI approach as a threat to their own core business.

The complexity of the project is reflected not least in the assessment of the European technology platform ALICE, which makes recommendations to the EU under Horizon2020 to propose the Physical Internet as a target for the year 2050 (ALICE 2015). Previous pilot projects clearly show the difficulties of such a project, which does not only have to solve technical problems but also organizational and legal difficulties. On the other hand, there are industrial pilot projects in which parts of the PI (such as the exchange of information and physical resources) are successfully deployed (Bohne/Ruesch 2013). A selection of practical applications from the areas of warehousing and transport are described in DHL/Cisco Trend Report, for example. Applications in incoming goods (acceptance of goods with RFID tags), better application possibilities in Track & Trace through higher visibility of the objects as well as information on the content of load carriers on the Last Mile and tools for monitoring the resilience of the supply chain (DHL/Cisco 2015) should be highlighted.

Project Goal

The aim of the protoPI project was to demonstrate the potential of a new PI business model to be conceived via Internet-based order platforms using a demonstration model corresponding to the visions of the physical Internet for the inter-company consolidation of transport orders. The chances, tasks and duties of the future PI system partners were assessed or mapped in a prototypical application model. In addition, the functional and technical requirements had to be developed based on the philosophy of the physical Internet and on state-of-the-art IT systems available on the market. Ultimately, these elements lead to a reference model, which serves as a basis for further work packages and developments.

Case study simulation and prototype design were chosen as the main methods, which, in the context of comparable PI publications (Sternberg/Norrman 2017), are among the most frequently applied research methods.

Survey on Transportation Management Systems

In the course of the project, transport-relevant software products were first examined, which are increasingly being used in German-speaking countries. Tour planning programs, freight exchanges and classic freight forwarding software packages were identified as the most frequently used ICT systems. Over the past two years, however, it has also been observed that more and more start-ups are entering the transport market internationally who want to change it disruptively. These therefore represent a further system group, as they enable new functionalities and cannot be assigned to an existing group. The start-ups push the direct contact between shipper and freighter or truck driver as a digital forwarding agency. From an operational point of view, this means that the system actively displays additional loads to the truck driver (alternatively also to freight forwarders or dispatchers) when free capacities are available, which he can also take with him and which are anyway on the route or represent a minor detour. This enables the hauliers to generate additional turnover, the transport operators to transport goods quickly and the overall transport distances to be shortened.

Modern transport management systems (TMS) are increasingly relying on the complete outsourcing of transports (to the detriment of the company's own fleet) and thus represent quasi-digital purchasing platforms. The main customer benefit resulting from the use of such systems is the management of the transport partners together with their freight offers and the IT-supported commissioning of individual transports according to certain criteria (e.g. the cheapest freight rate for a particular transport relation). A selection of well-known TMS in German-speaking countries can be seen in the fig.1 below: In addition to the market leader Transporeon and the "digital forwarding platform" Cargonexx, two Austrian solutions are also represented with Elogate (of the project partner SATIAMO) and Spot.

SATIAMO SAVES TIME AND MONEY / ELOGATE YOUR GATE TO E-LOGISTICS	Key Features: ▪ web-based transportation order allocation ▪ administration of service provider tariffs ▪ mobile feedback via app
SPOT / SPOT Supply Chain Visibility & Collaboration Platform	Key Features: ▪ digital platform for automating the procurement and delivery process ▪ transportation and freight price module
TRANSPOREON	Key Features: ▪ contracting platform for shippers ▪ connection to a large number of TSPs ▪ individual services available
CARGONEXX	Key Features: ▪ digital trading platform for FTL transports ▪ truck loads are priced and sold based on algorithms

Figure 1. Overview of Selected Transportation Management Systems

Integration of Transport Service Providers

A look at the structure of the Austrian transport industry (see fig.2) reveals the great benefits that transport management systems bring to loading industrial and trading companies: The freight transport sector with its more than 11,000 players and more than 1,600 freight forwarders reflects the highly fragmented market.

- 44.1billion **turnover**
- 213,224 annual average number of **employees**
- 11,082 **Enterprises** in the freight transport sector
- 1,645 **freight forwarders**
- 109 **railway operators**

Figure 2. Structural data of the Austrian transport industry with a focus on freight transport (WKO 2017)

The companies surveyed or examined in the course of the project use a different number of transport service providers depending on the size of the company. While small companies often only commission a single groupage freight forwarder and, depending on the consignment structure, also use parcel services and, in some cases, carriers for full loads, medium-sized and large companies use a significantly higher number of transport service providers (see fig.3). A distinction is made here not only according to the structure of the consignments (parcels, general cargo, partial loads, full loads, containers, etc.) but also according to the respective destination (usually as countries or regions).

	Small Enterprise	Medium-size Enterprise	Large Enterprise
parcel service	0-1	1-3	1-5
groupage freight forwarder	1-2	1-5	3-7
FTL carrier	0-3	1-10	5-25

Figure 3. Typical Structure of Used TSP depending on Company Size

In summary, it can therefore be said that the larger and more differentiated the shipment volume and the more standardized (digital, uniform) the process handling, the higher the number of transport service providers used. This means that the corresponding profiles, tariffs and performance and cost values must also be managed by an appropriate transport management platform.

As “post and search” coupled with “negotiation” is still the prevailing method of freight purchasing in practice (Lafkihi et al. 2019), a digital supplier management of transport service providers must be in the focus of a PI transportation management platform.

Effect Evaluation

In order to be able to quantitatively evaluate the concrete benefits of a PI-based transport management platform, the flows of goods between two strong economic regions in Austria, namely Upper Austria in the north and Styria in the south, were used as the background for the analysis and evaluation.

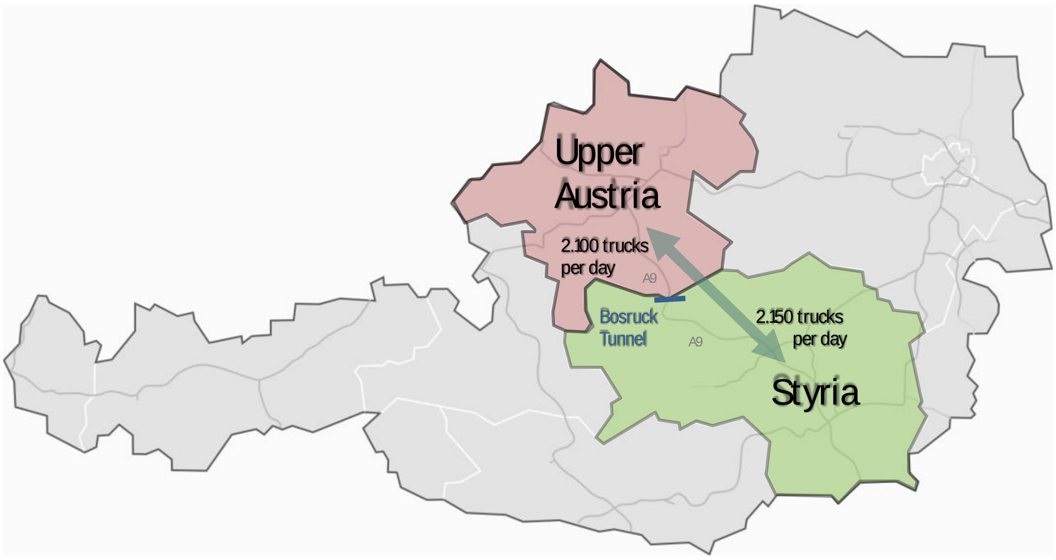

Figure 4. Considered Transport Relation on the Austrian A9 Motorway

Since the main connection between the two regions runs through a toll tunnel - the Bosruck Tunnel - on the A9 motorway, the corresponding counting point could serve as a quantitative starting point for the benefit assessment. The Austrian motorway operator ASFINAG records the traffic at the Bosrucktunnel toll station (see fig.4). The relevant data were therefore easily available online. On average, 2,150 trucks per day were travelling towards Styria and 2,100 towards Upper Austria at the Bosrucktunnel toll station on Mondays to Fridays. This results in a volume of about 300-400 trucks per working day and per direction on this route. Every year this is between 90,000 and 120,000 trucks.

In addition, relevant practical partners (freight forwarders, forwarding agents, industrial partners and software partners) were interviewed for an in-depth analysis of market conditions in order to draw conclusions about volume flows, consignment structure, order processing process and filling levels. In some cases, the project consortium was also provided with a shipment structure data set.

Conceptual Framework

What do a medicine, an X-ray machine, a frozen chicken and a doctor's coat, all of which are to be delivered to a hospital, have in common from a logistical point of view except for the same delivery address? From the point of view of the physical Internet metaphor, it would be efficient to pack these goods in standardized PI containers and deliver them together. In practice, however, this is difficult to impossible since

- There are bans on loading between certain goods (medicine/food);
- Different temperatures are required for transport (frozen goods);
- Larger appliances are usually supplied with a crew of 2 (appliances);
- Certain goods require a higher delivery service or shorter delivery times.

This simple example illustrates the current gap between an overall theoretical concept and actual logistics practice. Isolated PI prototypes cannot hide the fact that a general roll-out of the PI approach is problematic. Even the best documented case studies refer to one class of goods (see Hakimi et. 2012 and the example of the French Fast Moving Consumer Goods flows described there). Therefore, the application-oriented implementation of the concept should be based on the following premises:

(1) A larger number of different transport service providers must be integrated into an envisaged transport management platform;

(2) Their service offerings must be sensibly segmented according to certain criteria so that they also contribute to higher profitability through more adequate logistics structures;

(3) The role of the platform operator must be defined in such a way that it does not have a negative impact on the actors involved.

(4) Standardized returnable load carriers should be integrated into the concept.

System Architecture

The transport management systems used in practice (see fig.5) are all geared to individual shippers. The underlying service provider pool as well as the corresponding tariff structure are mostly static (determined by periodic tenders), the exchange of documents in the transport chain is limited (since usually only a one-step view is taken).

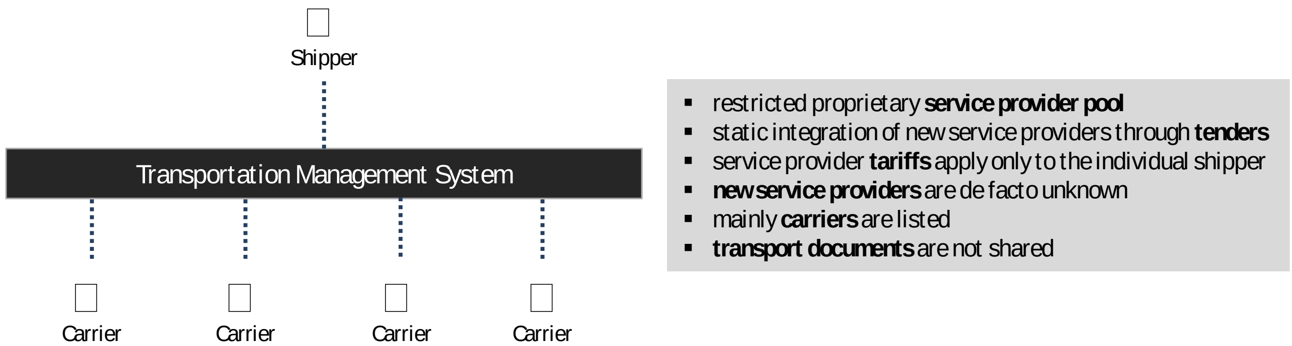

Figure 5. Traditional TMS Architecture

In opposite to that, the PI concept is based on the approach of an open transport platform, where the transport service providers (TSPs) used are shared between the shippers, thus creating a higher degree of bundling. In addition, logistics infrastructure and pool providers for returnable systems must also be integrated in order to be able to map new and multimodal transport routes (see fig.6).

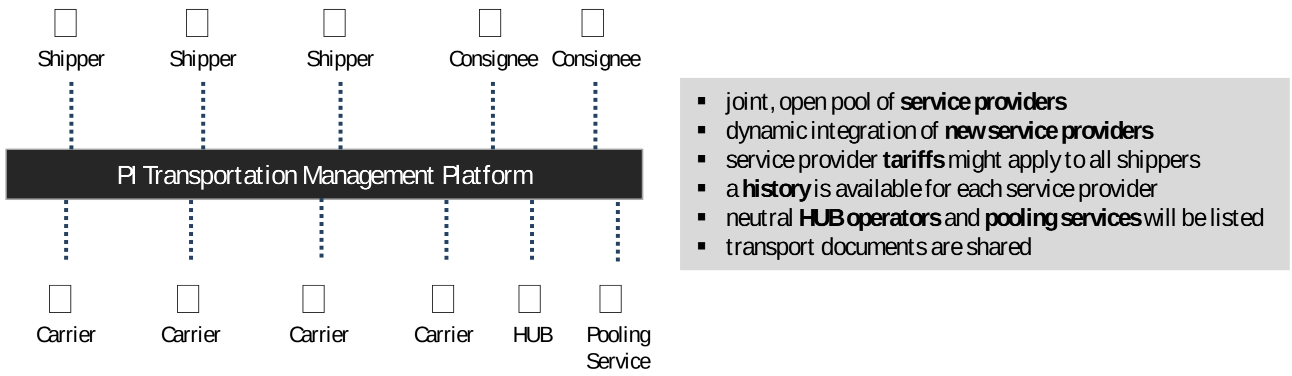

Figure 6. Open PI Transportation Management Platform Architecture

PI Channels

Starting from the almost universal idea of a physical Internet for all kinds of goods, the following realistic limitations were imposed due to the practical observation and evaluation of the logistic systems represented in the project:

- Due to product technical, legal and other aspects of the transported goods (e.g. temperature requirements, hazardous goods, bans on additional loading, choice of means of transport, ...), not all goods can be transported via a single, overall optimized system. Rather, it makes sense to define individual transport channels that are independent of each other but can also be used alternatively.
- This leads to the applied definition of PI channels with a bundling of mutually compatible goods via an adequate system configuration.

According to our understanding, the Physical Internet thus consists of a multitude of PI channels existing side by side, which have the following practical characteristics:

- **Industry-specific channels**, e.g. for temperature logistics, hazardous goods logistics.
- **Channels related to means of transport**, e.g. parcel service, sea and air freight.
- **Receiver-related channels**, e.g. cross docking systems for branch distribution (see Pan et. al 2013, where geographical and products' flows pooling was proposed, namely geographical consolidation among suppliers or retailers with similar flows).

On the one hand, each channel thus contains a concrete service description (e.g. temperature-controlled transport of standardized parcels and individual pallets within a country in the next-day logistics network with delivery van with lifting platform). Thus the parameters type of goods to be transported, relation, recipient segment, service definition, equipment used and freight price have to be defined. On the other hand, a PI Channel bundles comparable service offers of different transport service providers, so that corresponding selection decisions regarding price, service and/or quality can be made by the users of the PI transport management platform.

The logistical advantage of more specialized transport channels lies above all in a higher receiver-related bundling, which is ideally achieved via an appropriate hub, "open to any PI-certified users" (Pach et al. 2014) - without the need for intermediate outbound and inbound depots (see fig.7).

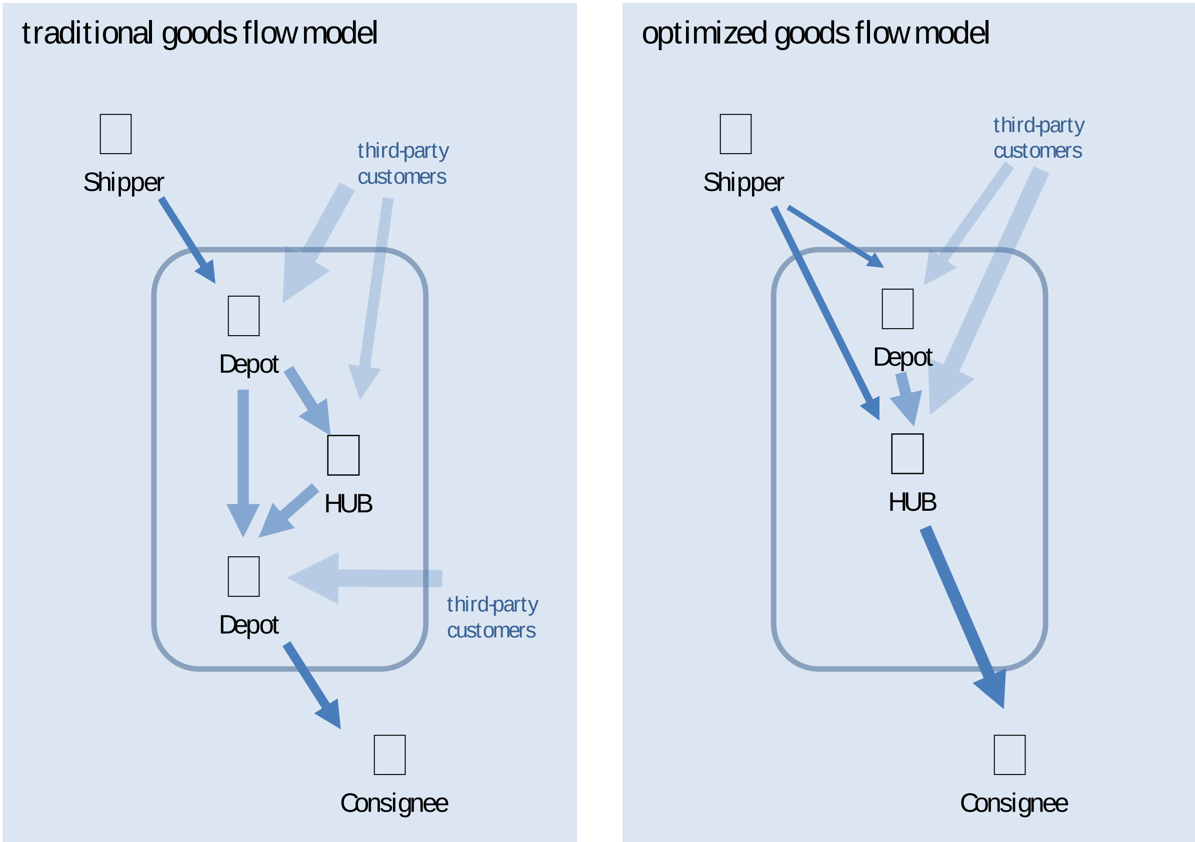

Figure 7. Traditional vs. Optimized Goods Flow through Groupage Cargo Systems

This also corresponds to the findings from the expert interviews carried out within the framework of the project, according to which the profitability of groupage systems depends to a very high degree on receiver-related consolidation - when several customers send their consignments to the same receiver independently of each other -, whereas trade logistics systems use precisely this effect to establish their own logistics systems.

Another new feature of the concept is that both users and transport service providers can introduce new PI channels to the transport management platform in order to map specialized service offerings accordingly. This also corresponds to the business orientation of highly specialized service providers who only focus on limited market segments (e.g. a freight forwarder that specializes in partial loads from Austria to Spain and Portugal and performs this as a subcontractor for many leading groupage freight forwarders). It is the responsibility of the platform operator to manage, set up, activate and combine the corresponding channels.

Business Model

The conceptual framework comprises the organizational, technical and legal framework for the operation of a corresponding business model. The role of the platform operator is of central importance here. In order to make the platform as attractive as possible for a large number of TSPs - and at the same time to offer the loading partners a broad spectrum of potential carriers - the actual task of the platform operator is limited to providing adequate transport channels in the form of so-called PI channels and arranging transport orders. In addition, the integration of RTIs as a practicable form of PI containers is made possible. PI channels map different service bundles for different goods with different requirements as higher-level clusters, for which specialized TSPs are listed by the platform operator. The listing process as such runs along the milestones identification - qualification - validation: The TSP interested in the cooperation is qualified for the channels relevant to him and all the transport services he provides flow into an integrated supplier evaluation system, which is made available to other interested clients in aggregated form. This is intended to make it easier to find new and efficient TSPs. The actual conclusion of the contract ultimately takes place between the shipper and the selected transport service provider, ideally on the basis of a tariff stored in the associated PI Channel - specifically for the shipper or in general. The platform operator's business model as a neutral freight broker is therefore primarily based on corresponding freight brokerage commissions.

From individual expert interviews with the transport and logistics service providers involved in the project, it became clear that a commission in the lower single-digit range would just be acceptable. As a way out with regard to the rigid determination of the amount of commission, targeted experimentation in a pilot phase of a real operation is a good option. In addition to the transaction volume - which as a rule will correlate strongly with the transport distance - the following factors are of particular relevance:

Relation: Journeys to areas with weak cargo technology are usually more expensive and less in demand than vice versa; attractive "return cargoes" therefore tolerate higher commissions.

Season: Especially in spring and autumn, prices rise significantly due to a greater shortage of truck capacity, while the price level from January to February or summer is usually lower (holiday season).

Equipment: Expensive special equipment is generally reflected in the transport price. Since this is often not easy to get, higher commissions would be possible.

Seen in this light, the commission model is related to the traditional business model of freight forwarders. The economic benefit of the platform is based on the reduction of freight forwarding margins through a largely digital process handling and targeted channel and transport service provider selection, which overall leads to more efficient process handling. This circumstance is supported by practical findings from the analysis phase of the project, according to which part loads of the shippers are predominantly assigned to large forwarding companies, which in turn - after deduction of their margin - use specialized carriers. The latter would have been the more economical alternative from the outset if a) these are known to the shipper and b) are digitally linked to the process flow. It is precisely these two points where the PI transport management platform comes into play.

PI Container

The most common standard load carrier in (European) practice is the Euro pallet. The protoPI project therefore discussed the further development of a collapsible box pallet based on a Euro pallet into a variant of a **PI container**. This would not only be Euro-compatible, but also stackable, foldable, lockable, upgradeable with RFID tags and other sensor technology and ultimately suitable for use in an open transport pool (see table 1; for a generic set of requirements for PI containers see Landschuetzer et al. 2015). The platform operator thus also has the task of mapping the exchange processes of the PI containers between the individual players.

Standard steel box pallet	**PI-Container**
standard height (2.5m) of a truck fully usable	flexible size due to modular design
stackable	stackable
non foldable	foldable for space-saving storage and transportation of empty containers
box with grids on the sides	lockable
compatible with euro pallets	compatibility with truck load space
space for RFID tags in the stand blocks	integrated RFID tag for identification
space for further sensors in the stand blocks	integrated sensor technology for measuring environmental influences
space for tracking system in the stand blocks	integrated tracking system
easy assembly/disassembly by one person	easy assembly/disassembly by one person
cost-effective production	cost-effective production
boxes are stacked and secured against lateral slippage	integration of several containers to a single shipping unit
handling with conventional equipment (forklift, etc.) possible	handling with conventional equipment (forklift, etc.) possible

Table 1. Comparison of the requirements for a further developed PI container based on steel box

Based on the properties of the PI container specified in this way, a simulation model for the analysis of the loading and distribution processes was created on the basis of the transport and shipment data of a practical partner, with which the utilization of the transport capacity could be evaluated against the actual state. In addition, requirements were placed on a cross-loader load carrier pool in order to ensure the provision of returnable load carriers without the need for a closed distribution system.

Prototypical Realization

The vision underlying the prototypical implementation can be described as follows: Imagine an open portal called "YouFreight" (name invented!), which offers different service bundles in the form of so-called "channels" for different goods with different requirements. Shippers can allocate their transport volumes to the different channels, while transport service providers can easily sign up for existing channels ("reinstall their content"). Through the channel system, services are sensibly segmented; the trust aspects ("which provider is behind it") are covered by evaluable performance histories. Finally, additional services can be added to the platform.

Development

Based on the reference model developed in the analysis phase, the requirements for the PI transport management platform for bundling transports were developed. Based on this, a demonstration prototype was created, with which the basic processes of the PI platform - from the point of view of the respective actors - could be simulated. Step by step, it became apparent at which points a corresponding interaction on the part of the shipper / the TSP / the platform operator became necessary and accordingly, the demonstration prototype was conceptually extended or interactively rebuilt step by step. At the end of this process, a conclusive process could be defined with which the required functionalities could be integrated in a target-oriented way.

The project addresses not only the technological implementation of a PI transportation management platform as an experimental prototype at TRL-5 level, but also takes into account the associated services around the data platform, which are supposed to solve meaningful tasks from the existing data base (see fig.8).

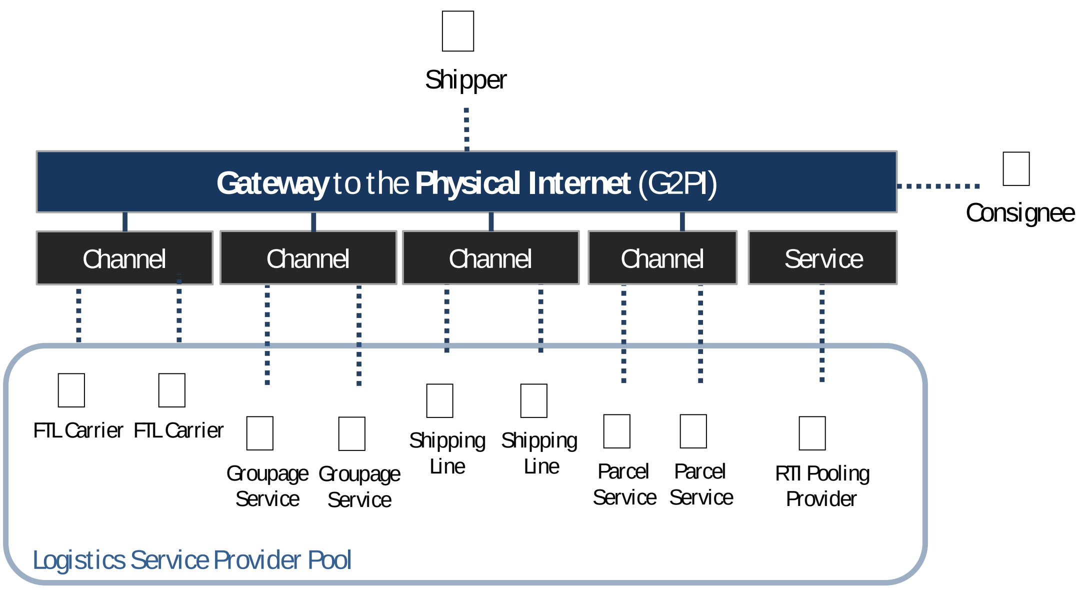

Figure 8. G2PI-System Architecture

The demonstration prototype was realized iteratively in several loops with an adequate prototyping tool within the scope of an explorative prototyping. Thus, the "product" went through several life cycles, as the requirements changed in part over the course of the project. In addition, several parallel views - those of the client, the transport service provider and the platform operator - had to be arranged in a logical sequence in order to be able to run through the entire process. Decisive for the final design of the demonstration prototype was the introduction of the channel term in order to be able to group similar transport offers in a clear and structured way. In addition, novel processes had to be completely redesigned, namely the channel setup, the inclusion of a transport service provider in a channel as well as the channel selection. The prototype, which was completed at the end of each development cycle, was logistically tested both within the project and with selected practical partners and thus validated for consistency and functional fulfillment. At this point, the use of prototyping as a project tool proved to be particularly effective, as the cycle times (also in view of the given project duration) were relatively short.

The PI transport management platform as a **digital gateway to the physical internet** (G2PI) has three main tasks: To connect the participating shippers to the PI system, to enable cross-company consolidation of freight and to measure the performance of the TSPs involved.

Connecting to the PI: A shipper docks to the PI system via a digital business platform, which we call the Gateway to the Physical Internet - G2PI. After an appropriate registration process, the shipper gains access to the available PI channels and can request the TSPs listed there with regard to transport offers. In this respect, quotations are always prepared only by the TSP itself for a specific customer. Building on this, the TSP can then be commissioned accordingly via the PI platform.

Enabling Consolidation: The actual added value of the transport platform results from a primarily receiver-oriented channel definition of the platform operator. For example, channels such as "partial consignments in the deep-freeze segment to southern Spain" or "delivery to C&C-markets in Austria" are possible. The assignment of a shipment to a channel therefore depends not only on the dimensions of its load carriers (parcel, pallet, etc.) and the framework parameters (temperature, equipment,..), but also on the specific recipient address. A corresponding assignment algorithm proceeds in such a way that a specialized channel is always displayed before a general channel as a default decision for the shipment assignment. Beyond that, specialized TSPs can offer their range of services directly to interested shippers - without the involvement of intermediate freight forwarders.

Measuring Performance: Since a large number of transport service providers use valid qualification ("Is the German minimum wage law observed?)" or meaningful evaluation ("How is delivery reliability to Poland?") associated with high effort, this task is performed by the PI transportation platform across all clients. For each transport carried out, the service provided is evaluated in terms of time and quality parameters and displayed on the platform in aggregated form. In individual cases, the TSP is given the opportunity to object to the evaluation of a client in order to prevent misuse. In such cases, the platform operator must intervene as a neutral "arbitrator".

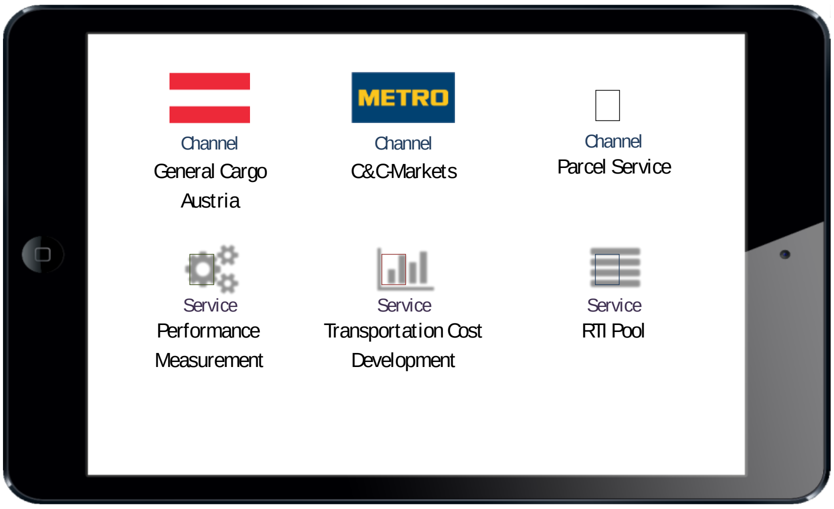

Figure 9. Demonstration Prototype of the G2PI Platform

The corresponding **functionality of the PI gateway** was experimentally programmed in Java by the project partner SATIAMO in the form of a web-based transportation management platform with integrated mobile apps and was evaluated in the course of the research project (see figure).

In addition, various service offers (services) can be docked to the platform, such as analysis tools to better support selection decisions (e.g. in the form of the question "Which transport partner has performed best in the last 12 months in the distribution of food in Poland?") as well as reusable load carrier functionalities (inventory management, repeat orders).

Benefit Evaluation

In the protoPI project, the benefits of the PI framework and the transportation management platform were examined through use cases of the companies involved in the project.

Reduction of transport costs

By using specialized TSPs in specifically defined PI Channels, transport costs can be on average reduced by up to 20%. This is usually due to the fact that the TSP concerned has a bundling option in delivery and can therefore distribute one-off stop costs across several customers (see the process costs example per pallet place on HUB Bundling in comparison to the Traditional Groupage System in table 2), as his total shipment usually consists of several individual shipments belonging to different shippers. Typically, a direct HUB delivery is more profitable than a groupage system if the total number of pallet places is 3 or more considering the transportation route in Fig. 4.

Traditional Groupage System	per pallet
Main run Upper Austria-Styria	€ 12,50
Depot handling	€ 2,00
Last Mile Delivery	€ 17,50
Total Cost per pallet	**€ 32,00**

Direct Delivery from HUB	3 pallets	4 pallets	5 pallets
Main run (as direct run)	€ 12,50	€ 12,50	€ 12,50
Direct stop costs (€ 50,-/ stop)	€ 16,67	€ 12,50	€ 10,00
Total Cost per pallet	**€ 29,17**	**€ 25,00**	**€ 22,50**
	-9%	-22%	-30%

Table 2. Comparison of Process Costs between Traditional Groupage System and HUB Bundling

Since a typical shipper employs in practice between 10-15 transport service providers - from parcel services to general cargo - the PI channel approach appears to be extremely promising and practicable - also in view of the current significantly higher freight prices on the market. A monetary savings potential for the channel provider arises from the possible automation of scheduling tasks, as the transport orders are automatically passed on to the relevant transport service providers.

On the other hand, by creating a specific channel on the platform, the transport service provider has the advantage that he receives exactly those additional orders with which he has the greatest potential for consolidation and which thus offer him the greatest potential for optimization. This also allows him to offer a lower price. The fact that the platform is only an intermediary and not a self-employed freight forwarder means that the competitive thinking of freight forwarders to place orders on the platform is partly eliminated. This is facilitated by a neutral platform. Overall, the platform must be able to offer a nationwide service, but will be able to offer a lower price than conventional channels, especially in those relations where a specific channel exists (comparison of potential transportation tariffs in the "Channel Austria" vs. "Channel C&C markets").

Bundling in delivery

An additional traffic-minimizing savings potential of the PI channel platform results from the possibility of consolidating small items according to delivery addresses: Particularly in general cargo, there are often small consignments. If many small consignments can be consolidated to individual delivery addresses, these can be consolidated to fewer load carriers (e.g. not 2 Euro pallets with 4 cartons each, but 1 Euro pallet with 8 cartons) and thus the load in the truck can be increased, since another load carrier could be loaded.

Overall, the delivery consolidation significantly reduces the total kilometers driven and the delivery vehicle concerned can deliver a higher volume of consignments in the remaining time. Especially in the context of hyper-connected city logistics, the benefits resulting from bundling can be very high (Nayeon et al. 2018).

Savings in loading space due to the use of PI containers

With regard to the use of PI loading units, corresponding advantages and potentials of the developed PI-capable containers were shown by simulation calculations and comparison with the actual situation on the basis of the investigated application case of retail logistics in the area of store distribution. The space utilization advantage resulting from the improved stackability of the PI grid boxes is about 10-20%. With a functioning pooling model, entire return load transports could be omitted in individual cases. A modified grid box was used as a prototype of a PI container. With this, above all core functions such as stackability and the possibility of folding empty PI grid boxes could be implemented. Due to the same basic dimensions as with Euro pallets, the loading areas of conventional trucks can be used as well as with conventional pallets with this PI grid box. Due to the stackability or two different heights of the PI box, the full height of a truck can also be used (see fig. 10). With the historical data on the delivery rounds of the practice partner, the savings in parking spaces were determined by using PI boxes. If the boxes also have to be returned, the savings of over 80% are already very significant due to the foldability (based on a freight ratio of 5:1 for the return transport of the foldable PI grid boxes).

Figure 10. Improved stackability of foldable PI grid boxes

The results of the simulation model make it clear that a PI-capable, optimized transportation items can make the use of existing loading volumes much more efficient, especially with low pallet heights. However, due to the high investment costs for new RTIs, such measures are hardly profitable for transport service providers. From a practical point of view, such solutions must therefore be offered by specialized RTI pool providers (e.g. CHEP, Container Centralen, IPP, etc.).

Digitization of the transport order process

A further added value of the platform lies in the avoidance of manual scheduling/execution tasks. Thus, the platform is able to receive transport orders directly from industry and trade, to bundle these transport orders with others if possible and to automatically forward them to qualified carriers. The platform receives part of the savings for the brokerage function, the other part is passed on to the client through lower prices.

Overall results with regard to the "counting point" valuation model

Based on the Bosruck Tunnel reference point on the A9 motorway established in the project, around 800 trucks are travelling daily between the two regions of Upper Austria and Styria, based on the practice partners investigated. The average fill level of these vehicles was about 90% according to surveys carried out in the course of the project. Based on the bundling effects described above, the capacity utilisation of these vehicles could be increased to about 96%. This corresponds to a potential reduction of about 50 trucks per day. In addition, the savings potential calculated quantitatively in this way for the transalpine transports under consideration was evaluated and confirmed by quantitative interviews with 12 leading companies in the regional transport industry.

Research Agenda

Based on the results obtained in the demonstration and evaluation phase and further expert interviews with the project partners involved, a number of further research questions could be identified and divided into the following topic areas:

Information Technology: How to define physical standards and interfaces and prepare for integration into a global PI network? What measures can be taken to minimize the risks of such integration? How can existing concepts of intelligent load carriers be further developed to support the use of PI?

Organization and Business Models: How can existing networks be integrated or linked into a future PI platform? What new business models in logistics are created by PI? How can a PI business model best combine economic, social and ecological benefits? What critical masses must be reached in order to ensure the economic viability of PI hubs and PI services?

Logistics Processes and Business Models: How can logistics processes in the various branches of industry be sustainably improved and optimized by PI? Which PI penetration rate must be achieved in the logistics sector in order to be able to pursue a sustainable change towards PI? How do transport networks and PI services have to be designed in order to successfully implement the PI vision?

All in all, it can be said that the prototyping-oriented approach helps the PI metaphor to further conceptual development - and also meets with a high level of acceptance in practice.

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