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PHYSICAL INTERNET CONCEPT FOR DESIGNING THE RAIL FREIGHT INTERCHANGE OF THE FUTURE

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Abstract

Freight logistics suffers from the lack of coordination of the stakeholders whereas have different objectives and point of views about an efficient system delivery. The rail freight interchanges, as strategic infrastructure, play a critical role in enabling economic growth and development of an efficient logistic. Recent developments in Physical Internet concept have highlighted the need for introducing new logistic innovations and reliable tools to design multimodal facilities. However, most of the previously published studies are limited to operator point of view. This paper analyses the impact of multiple stakeholders (public authorities, freight operators, consumers, infrastructure operators) for designing the interchange for the rail of the future.

1. Introduction

Multimodal Transport Network is a key factor in the performance of European supply chain. The development of rail freight corridors integrated to efficient last mile transport might minimise environmental impacts and also reduce the logistic costs. The Physical Internet (Pi) concept has shown great promise in complex logistic scenarios. The logistic interconnection between operators with shared resources proposed on this approach uses encapsulation, interfaces and protocols for multimodal logistics services allowing multiple shippers to merge freight flows improving logistic efficiency. Compared to non-encapsulated cargo the Pi modularized containers are easier to route through transport system over a collaborative network (Ballout et al. 2012). And Pi containers also could increase the average combined cubic footprint of the shipped cargo by 12% resulting in less truckload (Meller & Ellis, 2012). A persuasive argument for the concept was put forward by Montreuil (2011) looking the evolution on CO2 emissions in France where the freight transport, which is responsible for 14% of the greenhouse emissions, having grown at an annual rate of +23% from 1990 to 2006. The Physical Internet is potentially capable of providing real sustainable solutions reducing significantly the carbon emissions. Another advantage alleged for the Pi concept is the integration of new and advanced technologies into innovative rail services, promoting the co-modality and helping the transport system to meet the changing EU need to promote environmentally friendly transport. However to handle Pi containers it is required a new set of facility types to operate (Pi nodes) which will vary in terms of capabilities and capacities.

Ballot at al (2012) provides a first functional prof-of-the-concept of a Pi road-rail interchange to enable the transfer of the Pi containers from their inbound to outbound destinations considering customer and operator perspective. On this layout, the train arrives at the Pi rail gate and the modularized containers are loaded/unloaded from the Conveyor using special handling equipment Figure 1. The containers sizes can be combined in integer multiples to fill volumes that are 1.2m length (x-axis). Using small Pi container sizes is expected a reduction on empty miles, actually responsible for 25% of the miles and an a substantial increase in unutilized space, nowadays in 43% (Meller & Ellis, 2012)

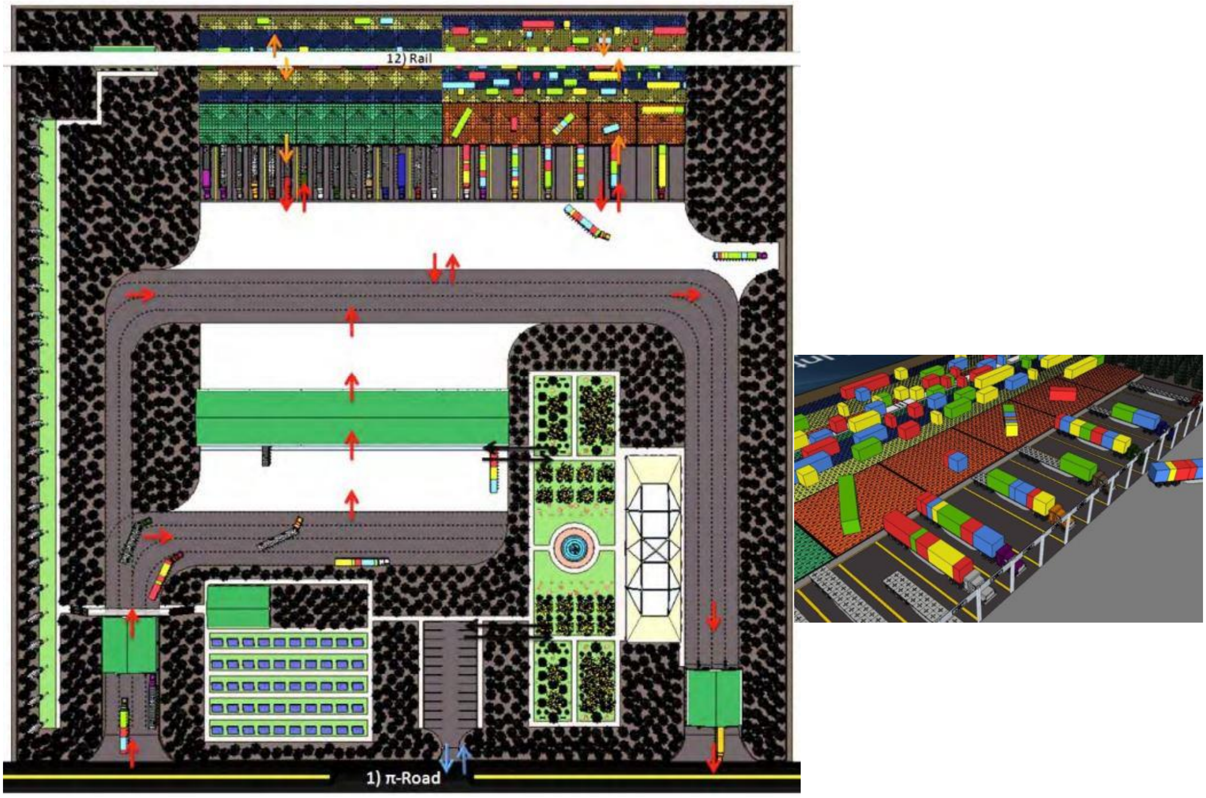

Fig 1. Pi rail-road terminal

Differently than the operation in traditional marshalling yards with several lines where the train are decomposed in the new configuration, the goal in Pi terminal is to handle only the containers, avoiding safety constraints on the train formation and reducing the time spent in the terminal to enable short lead-times. As described by Ballot at al. (2012) the goal of his first layout propose for road-rail interchange is to create a seminal design to promote the Pi concept encouraging further researches on the development of new concepts and optimization tools to an evolving structure. This article analyses the main KPIs adopted by Ballot team on the interchange conception and introduces an expert system based on the modelling tool to evaluate alternatives design interchanges based on a number of user-defined technical parameters and equipment selections in order to compare alternatives designs using multiple stakeholders decision drivers. The aim is to introduce new software resources to help design the new terminal concepts analysing not only the technical aspect but also economic feasibility for rail network considering multiple stakeholders

2. KPIs and conceptual design

Traditionally to planning the development of a reliable terminal design is expected consider multiple tradeoffs between the stakeholders involved in the whole logistic chain. For instance the typical tradeoff between capacity and costs, in order to reduce the processing times the operators could have more handling equipment and a more terminal area which will increase the operational costs. The seminal Pi hub conceptual design proposed by Ballout team focus on KPIs related to the capacity described in table 1 resulting in 75 cargo handlers to process up to 20 trains of 30 rail wagons per 7 days a week. Although the use of the KPIs with the focus on capacity present a significant contribution to terminal planning the overall cost of these facilities focusing on capacity could represent a serious barrier to the development of the Pi concept. As can be seen from Table 1 the time spent on the terminal and the capacity of handle multiples trains make the logistic operation a reliable technical solution.

Table 1: KPIs for Pi Terminal

Customer	
Processing Time	25 min
Arrival of trucks per hour	6.25
Average trains in connections	4
Maximum connecting time between road and rail	2h24min
Maximum connecting time between trains	4h48min
Operator	
Area of road-rail hub	12.000m3
Number of wagons processed in parallel	10
Number of rows of Pi conveyors from road to rail	4
Number of rows of Pi conveyors from a train to another train	4
Number of containers processed in parallel per wagon	15
Number of road gates (in)	4
Number of road gates (out)	4
Number of bridge Bays	24

In recent years the industry in order to consider the economic feasibility of the new terminals and the entire rail network consider also other decision drivers. At same time alternatives layout and different equipment evaluation are necessary to meet the objectives of the shippers, operators and society.For example the absence of construction costs and operational costs on the Pi terminal proposed might impact directly onf the feasibility of the concept. Traditionally the intermodal transport costs have to be lower then the road transport to mitigate the weaker time performance and the transshipment costs.

Moghadam and Noori (2011) have analysed the costs for semi-automated cranes and finding that an single equipment could cost between £232.450,00 (Straddle Carrier) to £667.140,00 (Automated Rail Mounted Gantry). This costs evaluation suggests that the according with the transshipment technology chosed for the Pi terminal the total investiments required to setup a Pi terminal for 15 containeres processed in parallel could be a barrier to further deleopment of the concept.

The literature suggests that transshipment costs are relevant in order to analyse the terminal performance and the commercial attractiviness of the rail. Numerous authors have been identified the relationship between production and cost for terminal design. Ballis and Golias (2002) analysis of the technical and logistics developments of rail–road transport terminals have identified a number of cost versus volume curves for various terminal equipment and configurations (Fig. 2)

1. Half Module - 2 Reach Stackers operating at 15 ITUs / h - truck pattern adjusted to train arrival
2. Full Module - 2 Reach Stackers operating at 15 ITUs / h - truck pattern adjusted to train arrival (upper) and to ITU availability (lower)
3. Half Module -1 Gantry Crane operating at 22 ITUs / h - truck pattern adjusted to train arrival
4. Full Module - 1 Gantry Crane operating at 22 ITUs / h - truck pattern adjusted to train arrival
5. Full Module - Moving train technique -1 crane - Single Area Variant - truck pattern adjusted to train arrival
6. Full Module - 2 Gantry Cranes operating at 24 ITUs / h - truck pattern adjusted to train arrival
7. Full Module - Moving train technique —1 crane — Basic Variant - truck pattern adjusted to ITU availability
8. Full Module - 3 Gantry Cranes operating at 24 ITUs/h - truck pattern adjusted to train arrival
9. Full Module - 3 Gantry Cranes operating at 28 ITUs/h - truck pattern adjusted to train arrival (upper) and to ITU availabiity power)
10. Full Module - Moving train technique - 2 cranes - Single Area Variant — adjusted to train arrival truck pattern
11. Two Full Modules X 2 Reach Stackers operating at 15 ITUs / h - truck pattern adjusted to train arrival
12. Two Full Modules X 2 Gantry Cranes operating at 24 ITUs/h - truck pattern adjusted to train arrival
13. Half Module - 2 Gantry Cranes operating at 24 ITUs / h - truck pattern adjusted to train arrival
14. Full Module - Moving train technique — 2 cranes - Basic Variant - truck pattern adjusted to ITU availability
15. Two Full Modules X 3 Gantry Cranes operating at 24 ITUs/h - truck pattern adjusted to train arrival (upper) and to ITU availability (lower
16. Unidirectional bridges design (the design requires new wagon types and special ITU corner casting attachments)
17. Bi-directional rolling gantry crane (the design requires new wagon types and special ITU corner casting attachments)

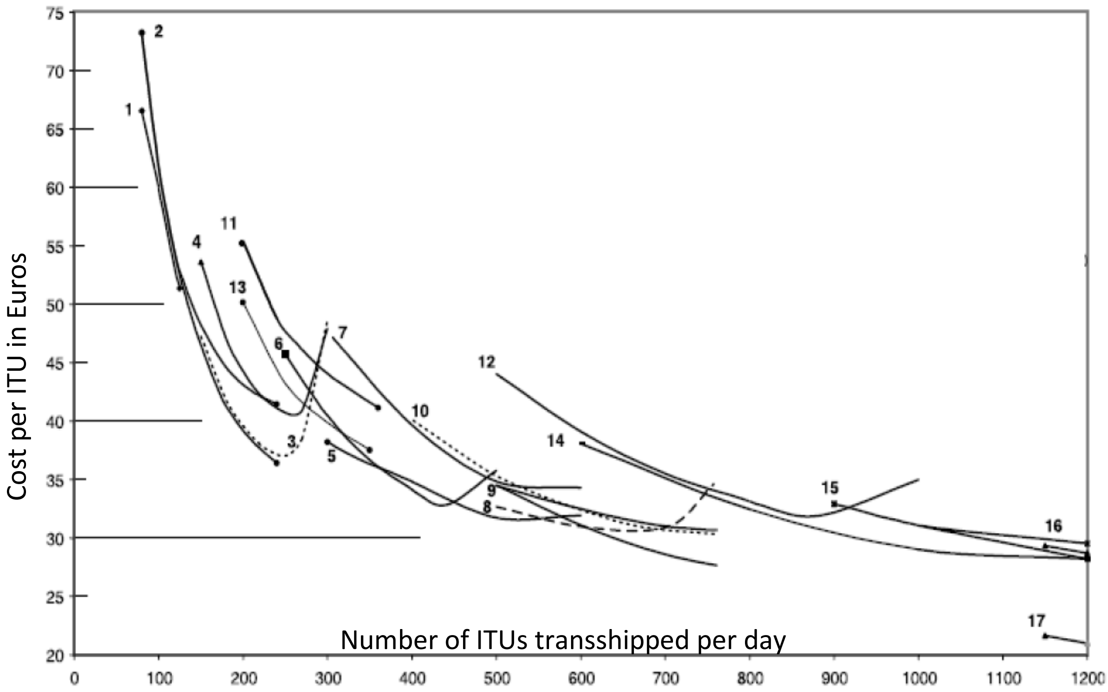

Fig 2. Comparative cost analysis for alternative terminal designs (includes infrastructure, personnel and truck times (Ballis & Golias).

As can be seen on the curves based on the number of the freight handled on a daily basis the equipment required on conventional terminals present a significant different operational costs. Therefore the equipment selection and the terminal design are an important decision process. Fig 3 show an innovative road-rail terminal design with 4 lines for transhipment using automatic operation (IMPULSE-2000). Similarly, than PI terminal concept In these new facilities the freight are checked by electronic sensors in the preliminary zone amended where necessary and the appropriate instructions scheduled for the equipment located further down the line

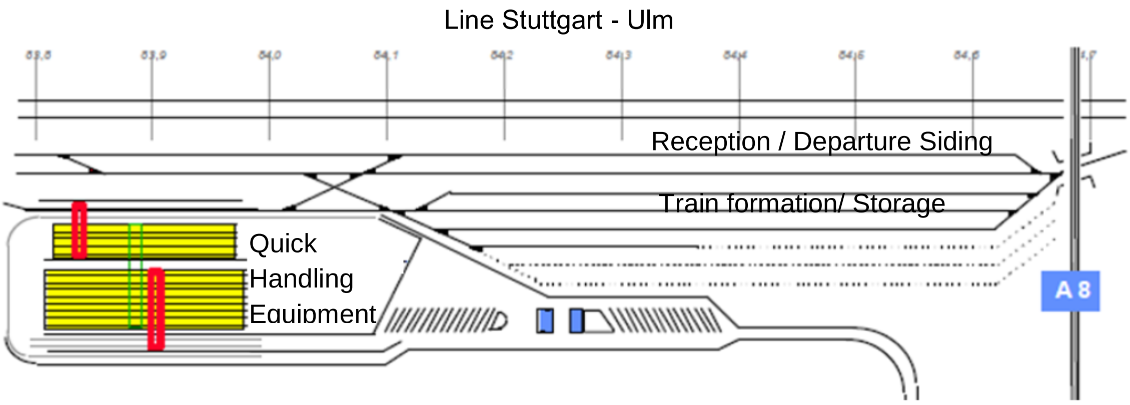

Fig. 3 Layout of Krupp Fast Handling System (Impulse 2000)

Comparable to Pi terminal the Krupp's Fast Handling System is characterised by automated and fast transhipment . The essential difference is that this technology can load and unload during the train slowly pass the terminal through the quick handling system. The containers, swap bodies or trailers are first checked electronically using detectors in a strategic location and based on the carrier wagons distance the envelope is prepared. In the main hall the handling equipment summarise the transshipments.

As can be seen on Fig.3 the terminal area also includes the rail transfer area, the rail intermediate area, the receiving and departure lines, cargo storage area and road traffic area (parking spaces and waiting areas, turning area and turning around area), buildings and technical installations.

3. Software development under Multiple stakeholders analysis

The conflicting nature of the objectives to maximize for the different stakeholders perspective could lead to different designs layouts, for example for cost objectives could present a reduced terminal area, demand-oriented objectives could present a large queuing area, profit objectives will look at maximizing the return on the investment, environmental objectives will aim to minimize carbon emissions. To modelling multiple decision drivers an Analytic Hierarchy Process (AHP) algorithm have been introduced in the software package in order to identify the user intentions on the interchange design.

The Analytic Hierarchy Process (AHP) for organising and analysing complex decisions helps decision makers find one that best suits their goal and their understanding of the problem with multiple criteria scaling elements in a hierarchy structure with mutually independent elements in each level, or in a network (Saaty, 1992). Traditionally used to compare alternatives from several options and selection criteria the AHP starts with the importance of the criteria for the evaluator

Our goal is to develop tools and approaches to enable the evaluation of the impacts of new interchanges and required equipment considering 4 main stakeholders with different and sometimes conflicting decision drivers and objectives comparing the priority of each decision drivers. Table 2 illustrate the main decision drivers

Stakeholder/ Input	Decision drivers	Objective function
User / Final client (Performance)	Transport price	**minimize**
	Inventory cost /transit time	**minimize**
	Handling price	**minimize**
	Reliability	**maximize**
Multimodal logistic operator (Operational cost)	Transport cost	**minimize**
	Transit time	**minimize**
	Queuing on terminal	**minimize**
	Train size	**maximize**
Terminal Operator (Aquisition cost)	Handling cost/ investment	**minimize**
	Land use	**minimize**
	Frquency	**maximize**
	Train size	**minimize**
Society (Envoirnmental)	Co2 Emissions	**minimize**
	Employment generation	**maximize**
	Traffic	**minimize**
	Accidents	**minimize**

Using the data for each infrastructure element and widget based on the priority assigned by the user the simulation tool are able to define a value for each decision driver for each infrastructure element and the interchange evaluation package that return the total objective function and the performance of the design on economic point of view (user), operational (operator) acquisition cost (terminal) and environmental (society). However user inputs and preferences are required in order to simulate the performances. The Fig.4 illustrate the user inputs system

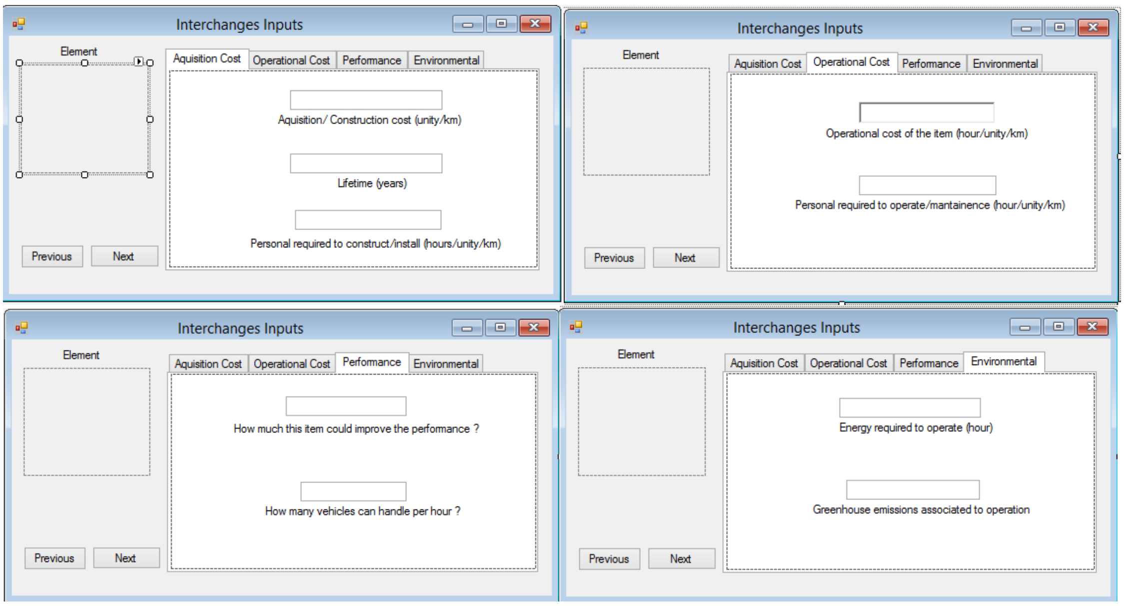

Fig 4. User Interface for interchanges inputs

4. Conclusion

The rail system is an important element in the logistic supporting the development of an attractive, sustainable society. Furthermore, the innovations towards the development and provision of new market services and adequate transport infrastructure require solutions affordable, cost effective and which have a quick market uptake in order to meet the key challenges on the freight sector. Our research is principled aiming to analyse in what way the customers and the society are affected by the rail freight and how particular innovation on the interchanges can contribute to an attractive rail system. Considering the early methodology by Ballout et al (2012), Montreuil (2011), and Meller et al (2012) for the Pi concepts and for the hub development; our model is able to simulate Pi concept in order to create the hub elements, but introducing new variables to support the software package development. In our model we consider an application consisting of 4 main stakeholders point of view to be pairwise in order to generate a comparison matrix.

Academic literature recently has intensely devoted attention to modelling intermodal terminal operation, usually making assumptions about rail freight demands and load factors. The interchanges simulation tool support decisions based on multiple scenarios, with different demands helping to understand the competitiveness of the rail freight for the future market.

One potentially drawback of our methodology is that the software package requires user data and user preferences to simulate scenarios; we plan to address this in future work analyzing real case terminal implementation, such as Krupp Fast Handling System using as default parameters. The analysis presents an opportunity for future research on software development focusing on examining the potential of different innovation on interchanges and infrastructure facilities.

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