Operational assessment of intermodality future in Belgium: Best-case scenario

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Abstract: *From the perspective of stimulating intermodal transport as an ecological and economically promising freight transport scheme in the EU, this paper is devoted to assess its future position with respect to crucial and plausible operational factors that were selected a priori. The study is conducted in the context of a best-case scenario development, within a rational and optimal decision making framework. We address this goal by designing a realistic medium-term network design and pricing model, from the economic perspective of a typical intermodal operator, fitted to the sequential mathematical structure of bilevel programming. Based on real-life sized data, in and through Belgium, the results underline the costly position of rail transport and a clear correlation between the competitiveness of intermodal transport on one side, and the market size and the trucking competition's price on the other. It is additionally suggested that intermodal transport can benefit from small rail subsidies in the early market covering stages.*

Keywords*:* intermodal transport, scenario analysis, bilevel programming, Stackelberg games, joint design and pricing.

1. **Introduction and research questions**

The European conference of ministers of transport (1997) defined *intermodal transport* as the movement of goods, in one and the same loading unit (or vehicle), by successive modes of transport without handling the goods themselves when changing modes. Generally, rail or inland waterways (IWW) are used for most of the traveled route, known as the *main haulage*, and road for the shortest possible initial and final parts of the transport chain, known as the *pre- and post-haulage (pph)* or *drayage operations*.

In recent years, intermodal freight transport has claimed a rightful position among policy makers and researchers as a sustainable and ecological alternative in most cases (Kreutzberger et al., 2003; Mostert and Limbourg, 2016). Furthermore, when broadly adopted, it provides significant opportunities to generate economies of scale through freight consolidation and higher load factors (Kreutzberger, 2003; Mostert et al., 2017). These two previous reasons have hitherto fueled a wide interest to enhance the position of intermodal transport in the EU market and divert freight flows to its favor. This is greatly in line with the roadmap set by the European Commission's White Paper (2011) to shift 30% of road freight over 300 km to less environmentally harmful modes by the year 2030 and more than 50% by 2050.

Nevertheless, the above figures remain highly ambitious goals as intermodal transport has so far failed to attract the desired customer levels on most freight corridors in Europe when compared with its main competitor: all-road transport. This is clearly manifested in the current great imbalance in modal split on land with 71,3% of the EU freight transport still taking place via road (European Commission, 2016). Indeed, this relatively weak position of intermodality represents the main starting point of the research project BRAIN-TRAINS (2014), to which this paper belongs. The main goal of the project is to develop a blue print, outlining the necessary criteria and conditions for developing an innovative intermodal network, in and through Belgium, as part of the Trans-European Transport Network (TEN-T)

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and the European single transport area, with a particular focus on rail freight transport. Building upon existing knowledge, the problem is approached from an interdisciplinary perspective, concentrated around five main streams: the optimal corridor and hub development, the macro-economic impact, the sustainability impact, the effective market regulation and the corresponding governance and organization.

Based on existing literature and published studies, a profound analysis of the current strengths and weaknesses is documented, together with potential trends and barriers in the future development of intermodal transport, in the framework of a SWOT analysis (Troch el al., 2015). An exhaustive list of elements has been identified, analyzed and, lastly, translated into a number of quantifiable scenarios, containing the most plausible future events affecting the development of intermodal transport, particularly in Belgium. The analysis is performed according to three levels: best-, worst- and middle-case scenario (Vanelslander et al., 2015). The notion of *scenario* is used throughout the research with the interpretation of offering insights into the future, without attempting to forecast its exact nature.

As contributors to this wide scope, within the optimal corridor and hub development perspective, we aim through this study to provide guidelines and outlooks as to the effect of a number of operational factors, namely: costs of running freight services, growth of freight demands and setting taxes or subsidies, on the competitiveness and the future success of intermodal transport in the EU, according a special attention to the role of Belgium. We discuss in this research work the results with respect to the best-case scenario. A reference point of comparison is taken to be the present day situation. The paper is organized as follows: section 2 is devoted to explaining the adopted methodologies and mathematical framework. Section 3 outlines the scenario's description and its corresponding translation in the context of the devised models. The obtained results are analyzed in section 4 and the discussion is finally concluded in section 5 with the most notable takeaways and the potential work extension.

2. Methodology

2.1. Background

The complex nature and interleaved procedures along the intermodal transport chains provided interesting topics of research and investigation to the field of Operations Research, whose techniques we deploy in our study. The first developed multi-modal network models that were able to handle intermodal flows appeared in the early 1990s (Caris et al., 2013). The most notable considered decision problems are terminals location-allocation, internalizing external costs, consolidation strategies and service network design.

A particular aspect that closely affects intermodal transport competitiveness, and that is yet under-investigated in the corresponding literature, is the determination of the right service tariffs, known as the *pricing strategy* (Bontekoning et al., 2004). Generally speaking, pricing strategies are distinguishable in the way they handle the interplay between profitability and competitiveness. A service price has to be high enough to cover its costs, and hence generate a profit, and low enough to remain attractive to the target customers. Bontekoning et al. (2004) identify two levels, at which the pricing strategy operates. First, at the level of the individual actor in the intermodal chain, previous studies were mainly concerned with calculating opportunity costs and providing educated pricing guidelines, mostly from the perspective of the network (mainhaul) and the drayage operators. Second, at the whole door-to-door level, service pricing decisions are taken from the perspective of the service providers (carriers), while accounting for the potential competition and the target customers' (shippers') choices. As pointed out by the literature review in Tawfik and Limbourg (2015), there is a peculiar gap in the literature of solid optimization approaches tackling intermodal pricing

problems that belong to the latter category. Nevertheless, their relative importance and relevance to the competitiveness of intermodal transport is acknowledged through the conducted SWOT analysis within the BRAIN-TRAINS project (Troch el al., 2015).
Additionally, these types of decisions are closely entwined with the related services' operating costs, also ranked on top of the operational elements in the SWOT analysis and resulting from the service design decisions. We opt through our analysis to highlight the non-trivial tradeoff between these two parallel problem streams: pricing intermodal services as received by the target clients and designing the corresponding service network.

2.2. Modelling approach

Our methods stem from the concepts of *Mathematical Programming*, which aim at translating a managerial problem into a mathematical model, within an optimization framework. We address a tactical, medium-term decision horizon, from an economic perspective. The decision maker is namely an intermodal transport operator/service provider. To approach the problem in a robust manner, the model is developed and results are analysed over two subsequent stages: *Service Network Design* and *Joint Design and Pricing* models. In what follows, we elaborate on the adopted modelling framework in each of them.

2.2.1. Service network design

In order to gain insights about the costs influence on the partition of the flows over the modes of transportation in the network, we start by considering a tactical intermodal service network design problem, from the perspective of a transport service provider operating on a road-rail-IWW network. The decisions to be taken are two-fold: (1) the frequencies of the services over a certain period of time, typically a week; (2) optimal demands' routing over the service network. A static case is assumed, where the demands are *fixed*, as well as the underlying physical network, including the terminals' locations, throughout the decision process. The following constraints are particularly taken into account:

- The total container freight demands should be delivered.
- The services' capacities are not to be exceeded by the transported volumes.
- Round long-haul services (>300 km) are enforced, for resource balancing purposes.
- An itinerary is not to be used, unless a certain fraction of the demand is sent over it (i.e.: ensuring a minimum utilization).

At a pre-processing stage, a recursive algorithm is designed with the purpose of generating, for each Origin-Destination (O-D) pair, representing a freight demand, a set of feasible itineraries formed of defined intermodal services. Feasibility is meant in the context of geographical feasibility, mode succession and total length with respect to all-road paths. Mathematically, the model follows the original path-based service network design formulation by Crainic (2000), with an adaptation to the intermodal application context.

2.2.2. Joint design and pricing

At a second stage, we build upon the previous model by jointly considering intermodal service prices as explicit decision variables. A key issue in modelling such a decision framework is how to represent the target shippers' reasoning, and consequently, the demand volumes of the intermodal services in question. Unlike the previous case of fixed demands, we utilize the innate hierarchy in the problem's definition, where demands are dependent on the decisions taken by the service providers, to better depict reality. Without loss of generality, we consider a market situation consisting of small shipping companies that want to benefit from freight consolidation. The following sequence can therefore be envisaged; first the intermodal operator chooses his services' pricing and design strategy, whereas, afterwards, the target shippers optimally react to those decisions by choosing (or not) the offered services.

In that sense, a certain optimization framework was proven adequate for similar hierarchical and non-cooperative decision schemes, yet largely overlooked in intermodal transport planning problems, namely: *bilevel programming*. The concept is principally adapted from game theory, known under the name of *Stackelberg games* (Stackelberg, 1952). It denotes a game that involves two sequential layers of players: a leader and one or more follower(s). By definition, the leader has the privilege of making the first move in the game, while being able to anticipate the optimal reaction of the follower(s) to his chosen strategy. The leader's solution (or chosen strategy) is decided upon by working backwards the one maximizing his payoff; the game is thus played from the point view of the leader. Stackelberg games are first introduced into mathematical programming under the self-explanatory name of *mathematical programs with optimization problems in the constraints*, later known as *bilevel programs*.

The joint intermodal service pricing and design problem is constructed following a bilevel structure as follows:

Table 1: Bilevel structure of the joint design and pricing model

Upper level (leader)	**Lower level (followers)**
Decision maker: Intermodal operator/service provider.	Decision maker: Shipping firms.
Decisions: • Services' prices. • Services' frequencies.	Decisions: • Demand volumes on intermodal itineraries. • Demand volumes on trucking itineraries.
Objective: Profit maximization.	Objective: Costs minimization.
Constraints: • Services' capacities are not to be exceeded. • Round long-haul services are enforced.	Constraints: • All demands' are delivered. • Demands can only be sent on offered/open intermodal services.

The model follows the main bilevel joint pricing and design structure as originally presented by Brotcorne et al. (2008). The costs from the followers/shippers' perspective are primarily represented in the prices they are charged for the acquired transport services. An assumption that should remain unchanged throughout the model development is the ability for the competition, represented in trucking services, to accommodate all the demands of every shipper firm. It is thus ensured that the leader/intermodal operator is prevented from setting infinite tariff schedules on his services. It is equally important to assume that the competition shows no price or service quality change throughout the process.

3. Scenario translation

The main idea of the scenario translation is to invoke parametric analyses and practically probe the impact of the different changes in policies and operational circumstances on the future success of intermodal transport, taking the above designed mathematical models as rational reasoning layouts. We essentially adopt two main market views in our experiments: a domestic scale, where only national flows within Belgium are considered, and European scale, where Belgium is regarded as a main start/end point of the flows. Both real and fictitious freight demands (in tonnes) inspired by real life are considered, the details of which will be outlined with each experiment in the next section. In what follows, we elaborate on the different operational elements considered for the scenario analysis.

3.1. SWOT parameters

In accordance to the goals set by the White Paper from the European Commission (2011), the best-case scenario is designed to be in line with the first desired 30% shift by the year 2030, carried by both the government and the transport sector. Based on the realized SWOT analysis, the results are translated into a selection of crucial scenario elements and their corresponding parameters and values. The validation was performed by the panel of experts of the BRAIN-TRAINS project according to a so-called Delphi technique, often used to acquire consensus within a heterogeneous panel of experts as explained in Vanelslander et al. (2015). Table 2 shows the considered scenario inputs and outputs from the operational perspective, among the total list of scenario parameters, together with the calculated reference- and best-case values of the inputs. The transport modes considered for this analysis are road, rail and IWW.

Table 2: Inputs and outputs among the scenario parameters

Inputs			**Outouts**
Name	**Reference value**	**Best-case value**	**Name**
Infrastructure and maintenance costs - Road	0,00545 EUR/tkm	0,00486 EUR/tkm	Modal split (% of tkm)
Infrastructure and maintenance costs - Rail	0,0698 EUR/tkm	0,0555 EUR/tkm	
Infrastructure and maintenance costs - IWW	0,0219 EUR/tkm	0,0198 EUR/tkm	
Road taxes	0,15 EUR/km	0,18 EUR/km	
Freight demands	_______	+15%	

The infrastructure and maintenance costs, as stated in CE Delft (2010) comprise: the construction costs, the maintenance and operational costs and the land use costs. The study further provides a fixed and variable parts division of the costs.

3.2. Additional operational parameters

In addition to the above stated parameters, other elements are considered as well to establish necessary operational hypotheses and inputs throughout the model runs. The computed values are based on the norms applied in real life situations according to the collected industry information. The list of the additional inputs is composed of:

- All-road/trucking service price (in EUR/tkm).
- Terminals' physical locations.
- Transport modes' capacities (in tonnes).
- Transport modes' average operating speeds (in km/h).

We consider two cases for the terminals' locations parameter. First, at the domestic Belgian level, the locations are aggregated to the NUTS 3 territorial division level, based on the setup by Macharis et al. (2009). Second, at the whole European level, we refer to the Agora Europe Database (2017) and select 13 terminals across the continent. As for the transport modes' speeds, we choose to assume average cases for simplification purposes, while acknowledging the existing speed variances in terms of the chosen connections and travelled regions. This is especially valid for the rail freight transport; for instance, on the Scandinavian-Mediterranean rail corridor, a requirement is set to attain an operating speed of 100 km/h. However, some sections in Austria only allow 80 km/h due to mountain rail operations. Other speed restrictions for wider bundle of sections are experienced in Italy as well (European Commission, 2014).

4. Results and discussion

In this section, we concentrate on showing the results for every stage of the modelling. The effects of certain parameters' changes on the intermodal market share, and consequent modal split, are discussed, according to the reference- and best-case scenario developments.

4.1. Service network design

The freight demand data regarded for this experiment were obtained from Carreira et al. (2012) at the level 3 of the Nomenclature of Territorial Units for Statistics (NUTS) within Belgium, based on the accessible Worldnet database (Newton, 2009). An O-D matrix is considered comprising 302 commodities/shipping demands, where all-road paths are enabled for each O-D pair. The demands should be satisfied by the intermodal operator's or the all-road itineraries, or a combination of both. Scenario elements are changed to their best-case values in order to draw conclusions on the flows partition on the different transport modes, if the costs of operating services become the only considered choice criterion. The first row in table 3 shows the result when all the parameters are tuned to the reference scenario. In the subsequent rows, we refer to the parameter whose value is changed to the best-case scenario values, in order to test the effect and significance of each parameter separately until we arrive, at the last row, where all parameters' values follow those defined in the best-case scenario.

Table 3: Influence of the best-case parameter values on a costs-driven intermodal shares

Modified parameter	% of freight on intermodal paths	% of freight on all-road paths	Modal split (% of tkm)		
			Road	Rail	IWW
None (reference)	15,2	84,8	98,74	0	1,26
Road costs	16,58	83,42	98,63	0	1,37
Rail costs	15,2	84,8	98,74	0	1,26
IWW costs	16,57	83,43	98,63	0	1,37
Road taxes	16,57	83,43	98,63	0	1,37
Freight demands	15,62	84,38	98,7	0	1,3
All (best-case)	2,4	97,6	99,8	0	0,2

It is understandable that intermodal transport becomes highly dominated by all-road transport due to the fact that we only consider here flows within Belgium (<300 km); a breakeven distance for intermodality's favour is not reached considering our hypothesis. A general remark on the above results is that even in the case that intermodal transport is attracting some flows; rail still does not get any shares despite the best-case scenario changes. The obvious interpretation for this can be the relatively high fixed costs for rail (0,0541 EUR/tkm), in comparison to those of IWW (0,0205 EUR/tkm), which makes it hard to compensate the operation of a new rail service. Among all the considered parameters, it is evident that the best-case values of the road costs, IWW costs and road taxes have the highest influence. Despite the previous remark, when all values are changed collectively to the best-case scenario, a negative impact is observed on the intermodal share and modal split (last row). This shows that, in the case of increasing shipping demands, the slight decrease in all-road costs attracts most flows, even when combined with a greater decrease in the remaining rail and IWW costs. It equally suggests that the increasing road taxes, due to their presence in the *pph* parts in the intermodal transport chain, deter more flows from intermodal paths than it does from all-road paths.

Using the same model, the costs' scope is generalized to account for service quality aspects, namely, transit time, which will potentially become pronounced on large corridors. The longer-than-necessary delivery times are penalized in the objective function by a changing value, alongside the costs minimization. The shipping demands are extended to long-distance O-D pairs across Europe having 73 commodities, inspired by the announced service connections of a certain intermodal operator. Driven by the data availability at the European level, only road-rail connections are considered for intermodal paths. In order to render the model computationally tractable, rail distances are calculated based on average increases from the equivalent road distances. No all-road paths are enabled, and tests are conducted by altering the transit time penalty value and observing the change in modal split for road (in *pph*) and rail (in long-haulage). The reference values of the remaining parameters are considered.

Table 4: Influence of generalized costs on modal split in road-rail paths

Penalty value (EUR per hour)	**No. of rail services**	**Exceeded delivery times (in hours)**	**Modal split (% of tkm)**	
			Road	**Rail**
0	26 (6 relations)	756	42,71	57,29
2500	26 (7 relations)	220	42,71	57,29
7500	26 (7 relations)	182	37,13	62,87
50000	28 (10 relations)	106	28,38	77,62

As shown by table 4, the higher the weight is put on the service performance, described in duration, the more the rail service lines, and the less the transport chain parts carried by road. This may seem counter-intuitive at the outset, as the traditional picture of intermodal transport casts an impression of complicated operations and long transit and transfer times. Even though the speed of a freight train can equal that of a conventional passenger train, the numerous stops imposed on freight trains, as well as the experienced arrival delays, often reduce their commercial door-to-door speed, resulting in supply chain disruptions further down the line. This is, in part, true as the considered model does not fully express the waiting times at the terminals due to delays and consequent missed connections, which are repeatedly reported by the involved actors. However, at an ideal situation, which everyone opts to achieve, the model shows that it is more beneficial, from the service quality point of view, to increase the rail, terminal-to-terminal fast service lines for long distances. This implies a better connected rail network for continental shipping demands, hence, a minimization of the road parts in intermodal itineraries, and ultimately a minimization of transfers along the transport chain.

4.2. Joint design and pricing

At this second stage, we intend to show the results for the more realistic case, when the demands are no longer fixed and assigned to intermodal paths. Instead, we consider a market where shippers have the choice to send their demands between two available options: an all-road itinerary with a fixed price and intermodal itineraries belonging to a single service provider. A combination of both, or of more intermodal itineraries, is possible. As previously explained, the problem is depicted as a hierarchical game, played from the perspective of the intermodal service provider, deciding on the design the services, as well as their assigned prices. The same O-D matrix as in the previous European case study is considered, as well as the same infrastructure at the level of the road and rail physical networks. We begin by showing in figure 1, for the reference case scenario, the effect of increasing the all-road prices and the market size, represented in the number of commodities, on the resulting intermodal market share.

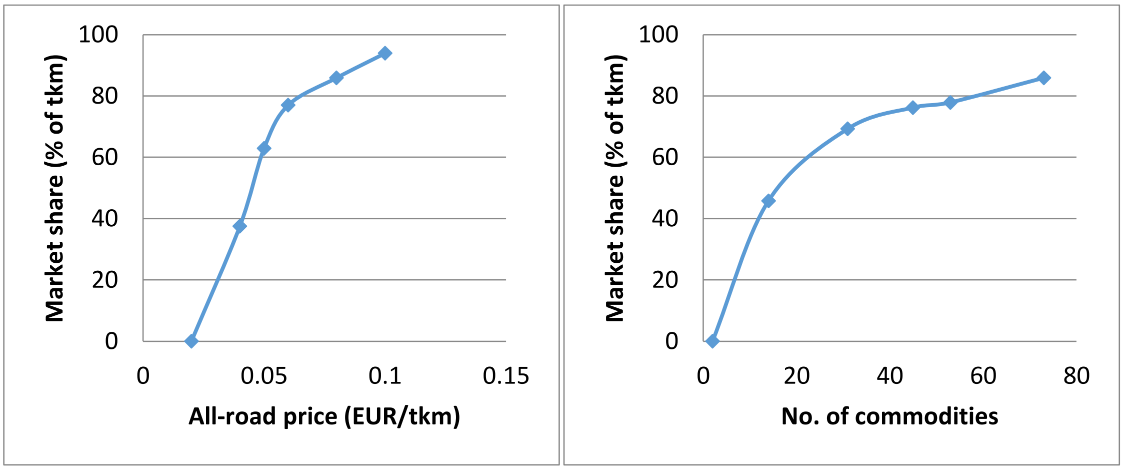

Figure 1: Effect of all-road/trucking prices and market size on the intermodal market share

It is evident from the graphs that intermodal transport would benefit from increasing competition's trucking price as well as from increasing the market size constituted of potential shippers. Indeed, a higher competition's market price implies a higher ceiling for the intermodal services' prices as well, giving intermodal service providers a bigger room, from the business point of view, to make up for the money invested in operating the services, hence, justify offering more services and attract a larger market. Likewise, an increasing market size offers more opportunities for bundling flows and achieving higher load factors without a big cost increase.

In what follows, we proceed by showing, in table 5, the effect of the change in parameter values, from the reference to the best-case scenario, on the intermodal market share, modal split, as well as the profit margin. The all-road/trucking price is fixed to be 0,08 EUR/tkm throughout the tests; a value decided upon according to market price investigations. A total demand of 73 commodities is considered, as well as a rail service unit constituted of 2 trains (3000 tonnes). Note that, due to the unavailability of actual demand data at the European level, a hypothetical case is examined for comparison purposes, inspired by typical intermodal operators' announced relations, where the tests do not impose any maximum bound on the *pph* distances within the road-rail intermodal connections.

Table 5: Influence of the best-case parameter values on profitability-driven intermodal shares

Modified parameter	**Intermodal market share (% of tkm)**	**Trucking market share (% of tkm)**	**Modal split (% of tkm)**			**Profit margin**
			Road (total path)	**Road (*pph*)**	**Rail**	
None (reference)	87,33	12,67	12,67	41,93	45,4	41%
Road costs	87,41	12,59	12,59	42,94	45,36	41.5%
Rail costs	87,39	12,61	12,61	41,95	45,44	51.6%
Road taxes	87,39	12,61	12,61	41,95	45,44	40%
Freight demands	84,77	15,23	15,23	41,77	43	42%
All (best-case)	93,64	6,36	6,36	40,43	53,21	47.2%

The above results are obtained with an acceptable optimality gap of 1-2%. They obviously show that the most significant of all instruments, in terms of profit margin advantage, are the rail costs. Although the increasing O-D flow matrix has, in fact, a negative effect on the intermodal market share, it does not harm the profit margin. It is equally noticeable that the collective application of all the parameter values of the best-case scenario drives the highest improvement on the intermodal market share and a sufficiently better profit margin. In order to get closer to the real-life intermodal transport chains, we impose an upper bound parameter on the total distance run by road in an intermodal itinerary. The corresponding change in intermodal market share, as well as the profit margin is plotted in figures 2 and 3 against the different values of road distance limit.

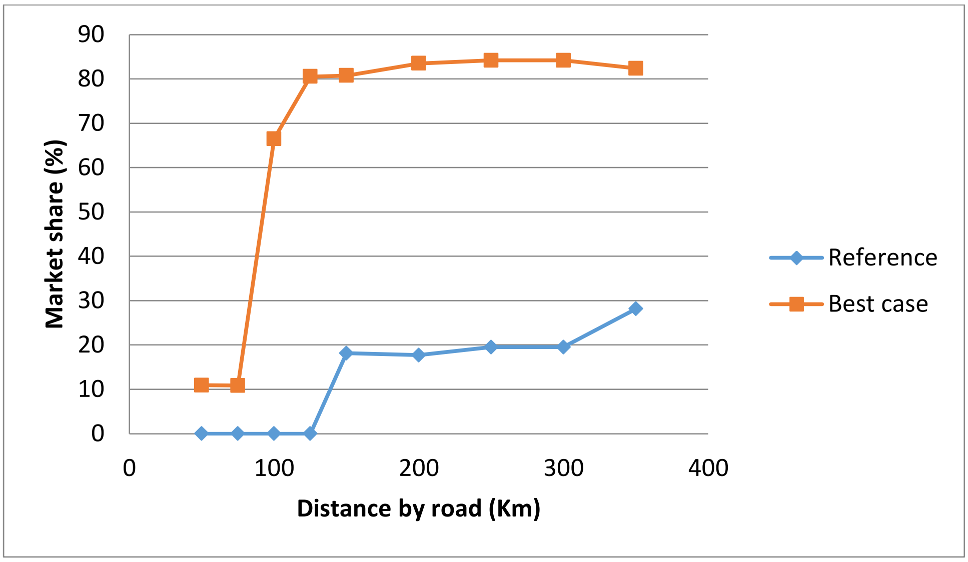

Figure 2: Impact of the road-borne distance on the intermodal market share

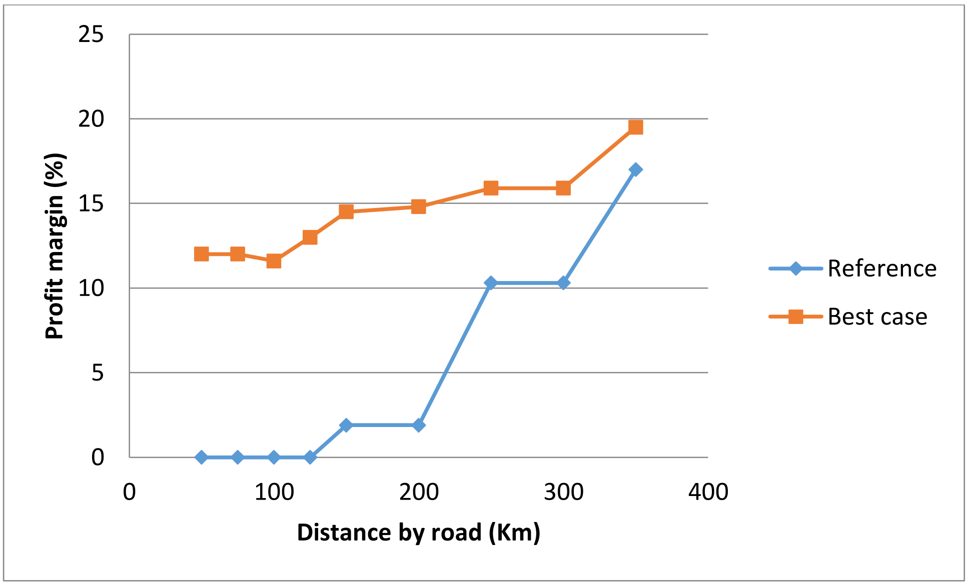

Figure 3: Impact of the road-borne distance on the intermodal profit margin

Obviously, the best-case scenario dominates the reference scenario for all considered road distances, in terms of both the market share and the profit margin. As shown in figure 2, the market share in both scenarios undergoes a sharp change, with visible varying severity, at approximately the same road distance (>100 km), after which, it stabilizes around the same values. In figure 3, however, the profit margin in the best-case scenario is stabilized throughout a road distance variation of 300 km, while that of the reference scenario demonstrates a continuous increase, starting from 200 km, until it eventually converges with the best-case result. The above apparently suggests the sensitivity of the conditions imposed on the intermodal paths' formation, especially in terms of the road parts' distances, on the competitiveness and profitability of intermodal freight services in a market of scattered demands. As the conditions become looser, the ability of intermodal operators to better tailor their services' according to the market structure and demands' locations tends to acquire more flexibility.

Finally, it is often argued about the significance of the rail subsidies on the success of the intermodal transport as a lucrative business, especially in the first stages. Table 6 shows the effect of this parameter, in both the reference and best-case scenario, on the rate of success and market competitiveness of intermodal transport. We consider a moderate limit of 250 km on the distance of the road parts in all intermodal transport itineraries, as well as a rail service unit constituted of a single train (1500 tonnes). To decide on the relevant subsidy levels to be experimented, we analyse the profit margin structure of the intermodal service provider (leader).

$$Profit\ margin = \frac{Revenues - Costs}{Revenues}$$

$$= \frac{Collected\ tariffs + Subsidies\ per\ distance - Fixed\ costs - Variable\ costs}{Collected\ tariffs + Subsidies\ per\ distance}$$

$$= \frac{(Prices \times Demands) + (Subsidies\ \times Frequency\ ) - (Fixed\ costs\ \times Frequency) - (Variable\ costs \times Demands)}{(Prices \times Demands) + (Subsidies\ \times Frequency\ )}$$

We observe from the above formulas that, for a certain service frequency level, an increase in subsidies would imply a proportional increase in the consequent profit and profit margin. This increase would continue until a subsidy level is reached that justifies the offering of new services (increase in frequency) and make up for the related costs, in particular, the fixed components. Therefore, we choose the tested subsidy levels, with respect to the considered costs in each scenario (table 1).

Table 6: Impact of rail subsidies on the success of intermodal transport (reference scenario)

Subsidy level (EUR/km)	Intermodal market share (% of tkm)	Profit margin (%)	No. of rail services	Average load factor (%)
0	66,19	6,8	14	99,2
5	71,79	10,1	16	99,3
10	71,79	13,71	16	99,3
20	71,79	20,2	16	99,3
25	81,32	20,4	20	94
30	81,32	23,3	20	94
35	81,32	26	20	94
40	92,39	24	24	86,7

Table 7: Impact of rail subsidies on the success of intermodal transport (best-case scenario)

Subsidy level (EUR/km)	**Intermodal market share (% of tkm)**	**Profit margin (%)**	**No. of rail services**	**Average load factor (%)**
0	74,56	24,11	20	98,5
2	83,05	22,74	22	96,2
5	88,78	23,15	24	94,2
7	88,78	24,54	24	94,2
10	93,62	24,98	26	91,9
12	93,62	26,31	26	91,9
15	96,45	27,3	28	89,9
25	96,45	33,15	30	83,9

Both tables 6 and 7 show the general positive impact of applying subsidies on the competitiveness and profitability of intermodal transport, though with different intensities and consequences. For instance, we notice that the market share, as well as the load factor, is more sensitive to the small changes in the subsidy levels in the best-case scenario, than it is in the reference scenario, especially at the first stages (0-10 EUR/km). This can be partially attributed to the difference in costs to be compensated between the scenarios. On the other hand, the profit margin shows a continuous and faster increase in the reference scenario, when compared to the steadier behaviour in the best-case scenario, for the same subsidy levels (0-25 EUR/km). A possible interpretation of this previous observation in the best-case scenario can be the already advantageous position it is starting from and the greater ability for the subsidies to help offer more services, hence more costs and a slower increase of profit, rather than a direct resonance in costs-free revenues. Furthermore, as opposed to the reference scenario, market position stagnation is reached in the best-case scenario with relatively high levels of subsidies (>10 EUR/km).

5. <u>Conclusions and perspectives</u>

In the context of testing the impact of certain instrumental changes on the intermodal freight transport and drawing insights about its potential future, we model a medium-term planning problem from the perspective of a typical intermodal operator. The decisions are two-fold: the prices of the offered freight services and the design the service network, in terms of the frequencies and demand routing. The model follows the structure of a bilevel joint design and pricing model. The problem is addressed in two stages. First, a case of fixed demands is considered, where the pricing decisions are omitted and conclusions are made with respect to the operating costs. Second, demands are explicitly modelled as subject to the services' prices and design decisions, by expressing the rational behaviour of the target shipper customers within a hierarchical Stackelberg game model. A competition, represented in trucking services, is always assumed to be available.

Based on the experiments and obtained results in each case study, we summarize the most notable conclusions in the following points:

- From a pure costs perspective, the collective application of the best-case scenario parameters (i.e., modes operating costs, road taxes, demand volumes, etc.) suggests an overall more costly future position of intermodal transport. A clear favoring of IWW over rail is noticed, potentially attributed to the high fixed costs of the latter.
- A directly proportional relation exists between the intermodal market share, on one hand, and the market size and the corresponding competition's trucking price, on the other.

- Both the competitiveness and profitability of intermodal transport are found sensitive to the intermodal paths' structure, namely, in terms of the distance limits imposed on the road parts.
- In what concerns the rail subsidies, rail-based intermodal transport, in the future best-case scenario, can benefit from relatively small subsidies to rapidly cover more market, up until a certain level. Afterwards, more subsidies imply a profit increase, though less load factors.

In order for a clear advantage of intermodality over traditional transport schemes to materialize, we underline the importance of the synchronized application of instrumental changes, with more weight accorded to the most significant ones. Furthermore, similar models, studying human behaviors in freight mode choices and their conceivable randomness, could become more relevant to real-life situations by integrating discrete choice methods in their approaches, as previously discussed by Ben-Akiva et al. (2013). Indeed, a typical methodological extension could enrich the discussion in the course of the next scenarios' analysis, namely: middle- and worst-case scenarios.

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