



BELGIAN RESEARCH ACTION THROUGH INTERDISCIPLINARY NETWORKS

Deliverable D 2.3

Scenario 2: Worst-case

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BRAIN-TRAINS

Transversal assessment of new
intermodal strategies

WP2: Optimal corridor and hub development

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INTRODUCTION

WP2: Optimal corridor and hub development aims at providing tools from the operations research domain, in order to highlight the potential efficiency of intermodal rail transport in Belgium. The objective of this package is also to give more insight on the decision-making process of the different stakeholders in the intermodal transport chain. The methods are based on the area of expertise of optimization, which aims at translating a managerial problem into a mathematical model that should be optimized. The main components of the methodology consist in:

- 1) Identifying the managerial problem,
- 2) Modelling the problem using mathematical programming,
- 3) Computing the solutions, and
- 4) Translating the scenarios.

As previously defined in deliverable D1.3, the general goal of the scenarios, within the present research context, is to identify the impact of different plausible situations on the future development of intermodal rail transportation, principally in Belgium. The difference between offering insights into the future, the main scope of the developed scenarios, and attempting to forecast its exact nature is specially highlighted.

As far as WP2 is concerned, the aim is to provide guidelines and outlooks as to the effect of certain operational factors on the competitiveness and the future success of intermodal transport, measured in agreed upon and quantified terms. Indeed, in previous deliverables, the project proposed different important parameters to consider when dealing with intermodal and rail transport in Belgium. These parameters were retrieved out of a SWOT analysis, and selected based on their relevance and plausibility by a panel of experts, using the so-called Delphi method. Different values have been assigned to each parameter, according to the scenario that is used (best-case, worst-case, middle-case).

In a complementary way to deliverable D.2.2 (which focuses on best-case scenarios), this document concentrates on the test of our models according to the worst-case scenario values. The model is applied on the Belgian case study and allows identifying the flow behavior between road and intermodal transport, for the reference and for the worst-case scenarios. An economic perspective (minimization of operational costs) is compared to two environmental perspectives (minimization of CO₂ emissions and air pollution external costs). An intermediate policy which focuses on operational costs by including road taxes is also analyzed. In what follows, we elaborate on the elements considered for the scenario analysis, the models invoked, the compared results for the reference and worst-case scenarios and the foreseen perspectives of the research.

1. HYPOTHESES

1.1. Scenario parameters

Contrary to the best-case scenario, which is assumed to be in line with the goals set by the White Paper from the European Commission (2011), the worst-case scenario reflects the situation when the objectives of the White Paper are not taken into account. No shift from road to more environmentally-friendly modes is therefore aspired. In this scenario, policy makers do not support the 30% objective of the European Commission, and this goal is therefore not to be executed by the transport stakeholders. Based on the realized SWOT analysis for each WP, the results are translated into a selection of crucial scenario elements and corresponding parameters and values, validated by the panel of experts of the BRAIN-TRAINS project. Table 1 shows the considered inputs and outputs for WP2, among the total list of scenario parameters, together with the calculated reference- and worst-case values of the inputs. Values are given for road, rail and inland waterway (IWW) transport.

TABLE 1. INPUTS AND OUTPUTS FROM THE CONSIDERED SCENARIO PARAMETERS

Name	Inputs		Outputs
	Reference value	Worst-case value	
Operational costs – Road long-haul	0.070 - 0.020 EUR/tkm	0.063-0.018 EUR/tkm (-10%)	Modal split (% of tkm)
Operational costs – Road short-haul	0.100 - 0.040 EUR/tkm	0.090 - 0.036 EUR/tkm (-10%)	
Operational costs – Rail	0.025 - 0.019 EUR/tkm	0.030 - 0.023 EUR/tkm (+20%)	
Operational costs – IWW	0.0076 - 0.0381 EUR/tkm	0.00912 - 0.04572 EUR/tkm (+20%)	
CO₂ emissions – Road	72 g/tkm	43 g/tkm (-40%)	
CO₂ emissions – Rail (electric)	18 g/tkm	16 g/tkm (-10%)	
CO₂ emissions – Rail (diesel)	35 g/tkm	32 g/tkm (-10%)	
Road taxes	0.11-0.14 EUR/km	0.11-0.14 EUR/km (+0%)	

In the model, rail emissions of electric and diesel traction are aggregated in a single average value, using the diesel-electric traction ratio of 17%–83% (Eurostat, 2016). Rail unit CO₂ emissions are therefore assumed to be 21 g/tkm. (35*0.17+18*0.83). Average values of IWW costs of 0.02285 and 0.02742 EUR/ tkm are assumed respectively for the reference and the worst-case scenarios. Based on the current updated values of the Viapass tax in Belgium, a value of 0.14 EUR/km is selected to test the flow distribution of the Belgian case. This value corresponds to the average existing rates weighted by the number of vehicles in each category for 2014 (Emisia, 2015).

1.2. Other operational parameters

In addition to the above stated parameters, other elements are considered in order to evaluate the impact on modal split of economic and environmental policies.

The impact of transshipping goods from one mode to another when using intermodal transport is taken into account by considering the related emissions and costs that these operations generate. Transshipment operational costs originate from Janic (2007, 2008) whereas transshipment CO₂ emissions come from te Loo (2009). Unit values of CO₂ emissions of IWW are taken from EEA (2015).

This scenario analysis also provides information on flow distribution when the focus is on air pollution external costs. Additional parameters related to air pollution external costs (based on Ricardo-AEA, 2014) are therefore included compared to deliverable D1.3. The damage cost values of air pollutants for road and rail are based on the European New Energy Externalities Development for Sustainability (NEEDS) study (Preiss & Klotz, 2007). IWW values originate from CE Delft (2011) and Brons and Christidis (2013). Marginal external costs related to the transshipment of goods from one mode to another are small and negligible compared to other external costs of intermodal transport (Baccelli et al., 2001). They are therefore assumed equal to zero both for intermodal rail and IWW transport. As for the CO₂ emission values, the unit rail value for air pollution external costs is the result of the combined values for diesel and electric trains, using the 17%–83% ratio (Eurostat, 2016). Table 2 presents these additional parameters with their respective values for the reference and worst-case scenarios.

TABLE 2. ADDITIONAL OPERATIONAL INPUTS

Inputs	Reference Value	Worst-case value
Transshipment operational costs	2.8 EUR/t	3.36 EUR/t (+20%)
Transshipment CO₂ emissions	0.000167 t of CO ₂ /t	0.0001503 t of CO ₂ /t (-10%)
CO₂ emissions - IWW	61 g/tkm	55 g/tkm (-10%)
Air pollution external costs – Road long-haul	0.0032 EUR/tkm	0.00192 EUR/tkm (-40%)
Air pollution external costs – Road short-haul	0.0069 EUR/tkm	0.00414 EUR/tkm (-40%)
Air pollution external costs – rail	0.00202 EUR/tkm	0.001818 EUR/tkm (-10%)
Air pollution external costs - IWW	0.00229 EUR/tkm	0.002061 EUR/tkm (-10%)
Transshipment air pollution external costs	0 EUR/tkm	0 EUR/tkm (+0%)

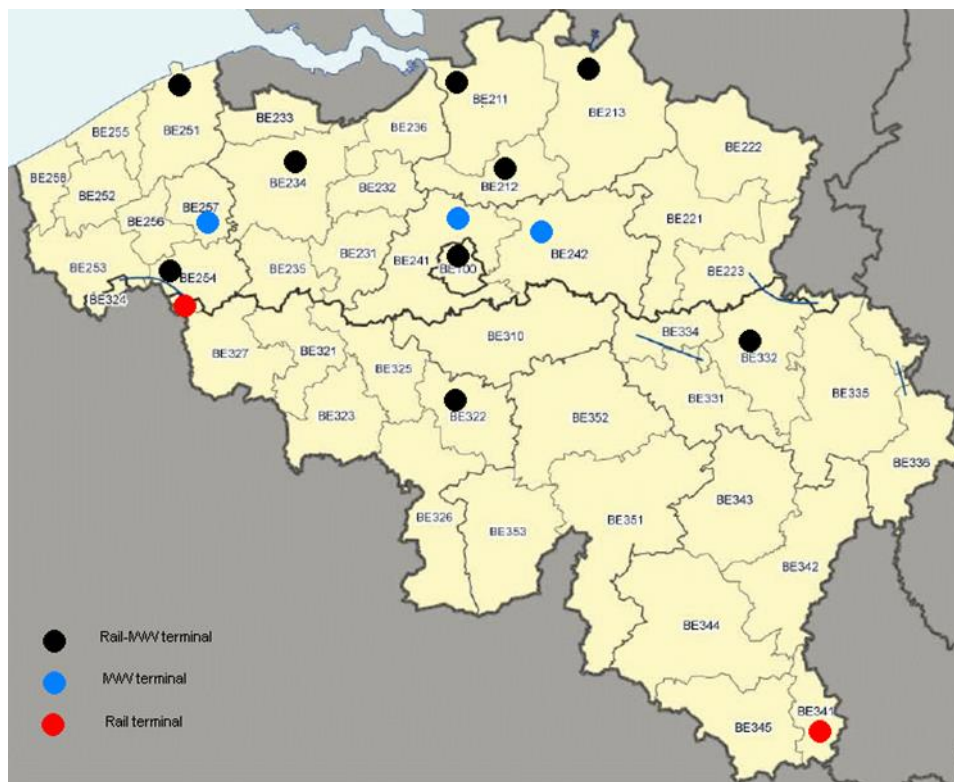
The model is applied on the Belgian case study. It takes into account the already existing configuration of terminals on the network and evaluates the optimal flow distribution under the policies which optimize the transport network

- i. operational costs
- ii. CO₂ emissions
- iii. air pollution external costs.

For these three policies, the results of the reference and worst-case scenarios are compared. Finally, the effect of including road taxes in a policy which focuses on operational cost minimization is also analyzed, both for the reference and worst-case scenarios.

Flow exchanges between Belgian regions and some regions of neighboring countries (the Netherlands, Germany, France and Luxembourg) at the third-level of Nomenclature of Territorial Units for Statistics (NUTS 3) are taken into account. Sea flows originating from or leaving the country at maritime ports are also considered. A map of the terminal implementation in Belgium is given by figure 1.

FIGURE 1: MAP OF THE RAIL-IWW, IWW AND RAIL TERMINALS IN BELGIUM



SOURCE: MOSTERT ET AL. (2017)

2. MODELLING APPROACH

Our methods are based on the area of expertise of *Mathematical Programming*, which aims at translating a managerial problem into a mathematical model, within an optimization framework. We address a strategic, long-term decision horizon, from an economic and from an environmental perspective. The model assumes a general view and aims at providing decision support for several transport stakeholders such as intermodal operators, public leaders, and terminal and infrastructure managers. These stakeholders can indeed gain insight from the impact on flows of different implemented policies. This section develops the methodological issues of the model. The results of the application of the model to the Belgian case study are then presented in section 3.

2.1. Intermodal network design

The model that is used in this document to evaluate the results of the reference and the worst-case scenarios is based on the theory of intermodal network design. Intermodal network design consists in modelling an intermodal network using a mathematical formulation and in solving this model by providing the answer to two main types of questions:

- Where should intermodal terminals be located inside a pre-determined geographical area?
- How should the flows distributed between the different available modes of transport?

The input values of the model consist in the origin-destination matrix of flows between several regions and the parameters of costs, emissions, and distances related to each mode of transport. The output of the model is the value attributed to the mathematical variables, i.e. the answer to the two previous questions: the terminal locations and the distribution of flows between the different modes of transport.

Intermodal network design models are very important at a strategic horizon since the location of intermodal terminals definitely influences the competitiveness of intermodal transport in relation to road (Mostert et al., 2016). Indeed, intermodal transport benefits from the long-haul travel performed by the more environmentally-friendly mode i.e. rail or IWW. If terminals are wrongly located, the pre- and post-haulage distances by truck may be increased in such a way that the long-haul travel cannot compensate anymore for the negative impacts of the pre- and post-haulage travels by truck.

Intermodal network design models are often referred to location-allocation models since they provide decision support on the location of the terminals and on the allocation of flows between the available modes of transport on the network.

2.2. Intermodal allocation model

In Belgium, intermodal terminals exist a priori and are therefore already located on the network. This means that there is no need to provide decision support regarding the location of intermodal terminals, except if new terminals are expected to be implemented. In this context, the previously developed intermodal network design models can be simplified into intermodal allocation models. The latter take into account the already existing terminals on the network (i.e. terminal locations become known parameters instead of variables) and determine the resulting optimal flow

distribution under different desired policies (e.g. optimization of operational costs, of environmental objectives, inclusion of additional taxes).

The formulation used in this document to test the reference and worst-case scenarios is based on the intermodal location-allocation and on the intermodal allocation model developed by Mostert et al. (2017a, 2017b). The focus is on containerized flows of transport between several origin-destination pairs. The model structure can be summarized as follows:

Minimize

Operational costs **OR** CO₂ emissions **OR** air pollution external costs

Subject to

The existing terminals should be open

Demand should be satisfied for each origin-destination pair

All the flows should leave their origin

Flows cannot go through a closed terminal

Flows should be conserved between the intermodal variables of a specific origin-destination pair

Flow variables should be nonnegative

The model minimizes the total costs or emissions of transport companies. These costs/emissions are divided into four main parts: (i) door-to-door road costs/emissions, (ii) transshipment costs/emissions between sea and road, (iii) rail-road intermodal costs/emissions and (iv) IWW-road intermodal costs/emissions. Rail-road and IWW-road costs/emissions are subdivided into

- pre-haulage costs/emissions by road
- transshipment costs/emissions at origin intermodal terminal
- long-haul travel costs/emissions by rail or IWW
- transshipment costs/emissions at the destination terminal
- post-haulage costs/emissions costs by road.

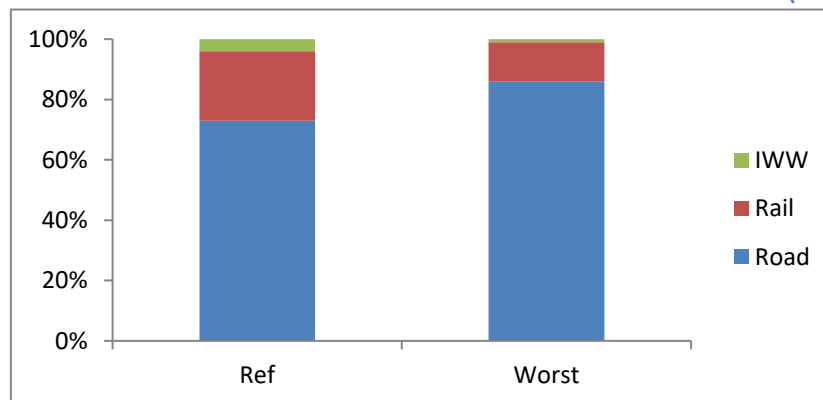
3. RESULTS AND DISCUSSION

This section analyzes the results of the application of the model to the Belgian case study. It compares the reference and worst-case scenarios in terms of flow distribution for an economic and for two environmental policies: optimization of operational costs, optimization of CO₂ emissions, and optimization of air pollution external costs. The resulting flow distribution of a policy which focuses on operational costs in which additional road taxes are included for considering the environmental impact is also evaluated.

3.1. Operational costs

This section identifies the effects on flow distribution between road, intermodal rail and intermodal IWW transport of the optimization of operational costs. This optimization policy aims at determining the optimal flow distribution on the network when an economic policy is followed. Figure 2 compares the flow distribution between the reference (Ref) and the worst-case (Worst) scenarios, under the optimization of operational costs.

FIGURE 2. FLOW DISTRIBUTION FOR THE OPTIMIZATION OF OPERATIONAL COSTS (IN TKM)



The results indicate that, in the reference case, the optimal solution in terms of flow distribution leads to 73% of flows for direct road transport, 23% for intermodal rail transport and 4% for intermodal IWW transport. In the worst-case scenario, i.e. if the objectives of shifting 30% of goods from road to more environmentally-friendly modes are not pursued, results indicate that even more road transport is used (market share of 86% - increase of 13%) and that the intermodal market share decreases (market share of 14% - decrease of 10% for rail and of 3% for IWW). This result is explained by the assumption that, in the worst-case scenario, road costs are expected to decrease, whereas rail and IWW costs are expected to increase. Since rail and IWW costs increase by the same percentage, they both suffer from a decrease of their market share.

In the worst-case scenario, the decrease of the intermodal market share is also related to the increase of the transshipment costs (in the same proportion as the increase of rail and IWW unit costs). Indeed, if politicians do not intend to put in place measures for achieving the 30%-shift objective, it may happen that no operational adjustment is done at the operational level. This leads to potentially even greater interoperability and connectivity issues, which may increase the transshipment costs.

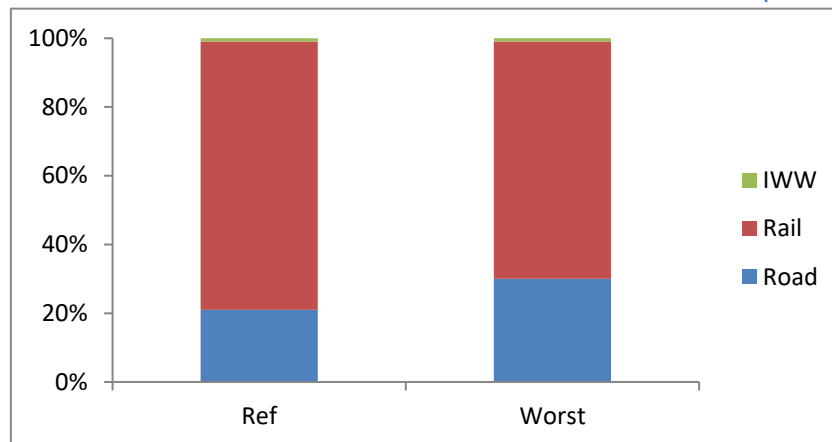
The impact of transshipment costs increase is nevertheless small. Indeed, if operational costs are optimized in the worst-case scenario assuming the same level of transshipment costs than in the reference scenario (+0% increase), road flows have a market share of 84% against 16% for intermodal flows. This means that the increase of 20% of the transshipment costs only leads to a decrease of 2% of the intermodal flows. Transshipment costs therefore have a lower impact on flow distribution than the respective mode unit operational costs.

Finally, in both reference and worst-case scenarios, intermodal rail transport remains a more interesting solution than intermodal IWW transport in terms of operational cost optimization.

3.2. CO₂ emissions

This section identifies the effects on flow distribution between road, intermodal rail and intermodal IWW transport of the optimization of CO₂ emissions. This optimization policy aims at determining the optimal flow distribution on the network when an environmental policy related to climate change is followed. CO₂ emissions are used as the proxy indicator for the impact on climate change since CO₂ is the most important greenhouse gas which contributes to climate change. Moreover, the limitation of CO₂ emissions of the transport sector is also part of the European Commission's priorities, since road transport is responsible for 25% of total transport CO₂ emissions in the European Union (European Commission, 2015). Figure 3 compares the flow distribution between the reference and the worst-case scenarios, under the optimization of CO₂ emissions.

FIGURE 3. FLOW DISTRIBUTION FOR THE OPTIMIZATION OF CO₂ EMISSIONS (IN TKM)



When the focus is on CO₂ emissions, the reference case identifies intermodal rail transport as the best opportunity in most of the flow exchanges. Indeed, the intermodal rail market share is 78% whereas direct road transport and intermodal IWW transport respectively have a market share of 21% and 1%. In this case, few flows are sent using the intermodal IWW combination. This result highlights the competition that may occur between intermodal rail and intermodal IWW transport. Indeed, since the intermodal paths have the same structure in terms of emissions (road emissions for pre- and post-haulage, transshipment emissions at the terminal, and rail or IWW emissions for the long-haul travel), rail and IWW may enter in competition. The advantage of rail compared to IWW is explained by its lower unit value of CO₂ emissions. Since most of the trains run with electricity, the emissions generated by the rail sector are very low compared to the ones of IWW. Since intermodal

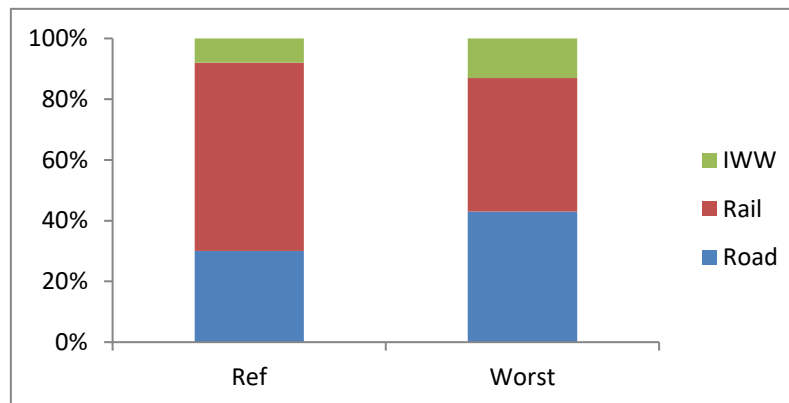
rail and intermodal IWW transport only differ by their unit values of rail and IWW emissions on the long-haul travel, the choice is made for the most attractive mode in terms of these emissions, i.e. rail.

As expected, the worst-case scenario leads to more road transport (market share of 30% - increase of 8%), whereas the intermodal market share decreases (market share of 70%). The market share of intermodal IWW transport remains stable compared to the reference scenario (market share of 1%) whereas the market share of intermodal rail transport decreases (market share of 69%). The worst-case scenario assumes that the road emissions decrease at a higher rate than the rail and IWW emissions. The increased market share of road transport is the expected consequence of this hypothesis. However, even in these worst conditions, intermodal rail transport remains the most attractive solution in terms of CO₂ emissions.

3.3. Air pollution external costs

This section identifies the effects on flow distribution between road, intermodal rail and intermodal IWW transport of the optimization of air pollution external costs. This optimization policy aims at determining the optimal flow distribution on the network when an environmental policy related to the improvement of air quality is followed. This objective is sustained by observations of the World Health Organization (WHO) which estimates that air pollution is now “the world's largest single environmental risk.” In 2012, one out of eight people who passed away died because of air pollution exposure (WHO, 2014). Figure 4 compares the flow distribution between the reference and the worst-case scenarios, under the optimization of air pollution external costs.

FIGURE 4. FLOW DISTRIBUTION FOR THE OPTIMIZATION OF AIR POLLUTION EXTERNAL COSTS (IN TKM)



Under the reference scenario which minimizes air pollution external costs, intermodal rail transport has the most important market share (62%). It is followed by road transport (30%) and by intermodal IWW transport (8%). As in the policy which optimizes CO₂ emissions, intermodal rail transport is the most used mode when air pollution external costs are optimized. From our results, intermodal rail transport is therefore the most interesting mode in terms of environmental objectives.

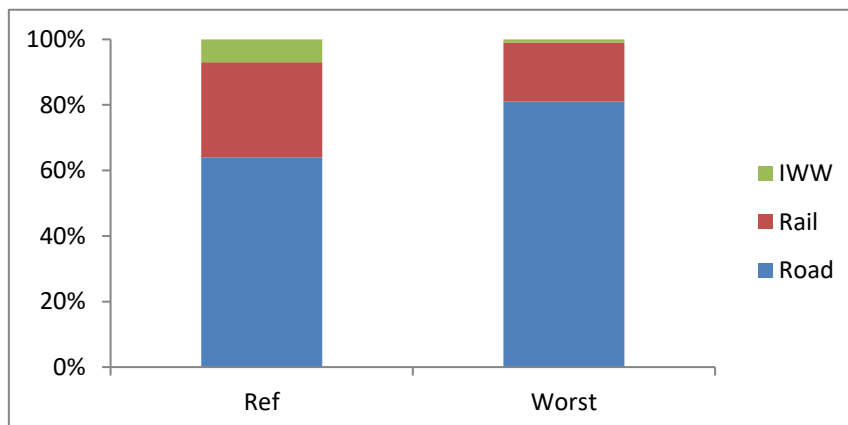
As for the two previously tested policies, the worst case scenario leads to an increase of the road market share (value of 43% - increase of 13%), to the detriment of intermodal transport (value of 57%). Intermodal rail flows (-18%) are transferred to road (+13%) and to intermodal IWW flows (+5%). Even if most of the flow transfer happens between road and intermodal rail transport, the results of this analysis also highlight the possibility of flow transfers between intermodal rail and

intermodal IWW. This phenomenon is explained by the relatively close unit values of rail and IWW transport in terms of air pollution external costs (contrary to CO₂ emissions). In the worst-case scenario, this behavior may be interesting for the intermodal transport sector, since not all the flows are transferred to road. However, when dealing with better conditions for intermodal transport (e.g. a decrease in the unit external costs of rail and IWW), there is a risk of flow transfers within intermodal transport, rather than between the road and the intermodal sectors.

3.4. Operational costs with road tax

This section identifies the effects on flow distribution between road, intermodal rail and intermodal IWW transport of the optimization of operational costs with the inclusion of road taxes on the network. This optimization policy aims at determining the optimal flow distribution on the network when an intermediate solution between economic and environmental optimization is followed. The objective is to identify how the introduction of road taxes may influence the flow distribution compared to purely economic or environmental optimization policies. This intermediate situation is to put in relation with the recent introduction of the Viapass tax in Belgium (April 2016) for motorways. This tax replaces the previous Eurovignette system and is a kilometer-based charge for trucks only. Figure 5 compares the flow distribution between the reference and the worst-case scenarios, under the optimization of operational costs with the introduction of the road tax.

FIGURE 5. FLOW DISTRIBUTION FOR THE OPTIMIZATION OF OPERATIONAL COSTS WITH ROAD TAX (IN TKM)



As for the single optimization of operational costs, the reference situation is characterized by the dominance of direct road transport (market share of 64%), followed by intermodal rail (market share of 29%) and by intermodal IWW (market share of 7%) transport.

Similarly to what has been observed in the three previous optimization policies, the worst-case scenario also leads to an increase of the road market share (value of 81% - increase of 17%) to the detriment of the intermodal market share (value of 19%). As for the single optimization of operational costs (without considering any road tax), a market share decrease is observed for both intermodal rail (value of 18% - decrease of 11%) and intermodal IWW (value of 1% - decrease of 6%) transport.

Table 3 provides a comparison of the flow distribution under the reference and worst-case scenarios for the optimization of operational costs, with and without the introduction of the additional road tax.

TABLE 3. FLOW DISTRIBUTION UNDER THE OPTIMIZATION OF OPERATIONAL COSTS, WITH AND WITHOUT ROAD TAX (IN TKM)

	OPERATIONAL COSTS WITHOUT ROAD TAX			OPERATIONAL COSTS WITH ROAD TAX		
Mode	Road	Rail	IWW	Road	Rail	IWW
Ref	73%	23%	4%	64%	29%	7%
Worst	86%	13%	1%	81%	18%	1%

For the reference scenario, the introduction of the road tax decreases the road market share by 9% compared to the single optimization of operational costs. For the worst-case scenario, the road market share is only decreased by 5% compared to the single optimization of operational costs. This means that if conditions go wrong for intermodal transport (increase of intermodal and transshipment costs, while decrease of road costs), as stated in the worst-case scenario, the introduction of the road tax in its current value would lead to a lower decrease of the road market share. This result is interesting since it highlights the need of adaptation of the policy tools to the underlying economic conditions. It suggest that the taxation policy should be carefully adapted based on the evolution of the particular conditions of the system in which it is applied.

TABLE 4. FLOW DISTRIBUTION UNDER THE OPTIMIZATION OF CO₂ EMISSIONS AND AIR POLLUTION EXTERNAL COSTS (IN TKM)

	CO ₂ EMISSIONS			AIR POLLUTION EXTERNAL COSTS		
Mode	Road	Rail	IWW	Road	Rail	IWW
Ref	21%	78%	1%	30%	62%	8%
Worst	30%	69%	1%	43%	44%	13%

Table 3 and Table 4 allow comparing the flow distribution of the environmental optimizations with the optimization of operational costs with road tax. The road market share under the optimization of operational costs with the road tax is always higher than the optimal road market share in terms of CO₂ emissions and air pollution external costs.

3.5. General insights

The results of the four policies which have been analyzed here above allow making general remarks regarding the competitiveness of the different modes of transport and the use of specific policy tools such as taxes.

It has been observed than different kinds of policies lead to different kinds of flow distributions. Indeed, the policy focusing on economic objective (optimization of operational costs) identifies road transport as the leader in terms of market share. On the contrary, intermodal transport is determined as the most used solution for optimizing environmental objectives related to CO₂ emissions and air pollution external costs. The choice of the policy to follow can therefore influence the attractiveness of intermodal transport over road transport.

It has been identified that the flow distribution between intermodal transport and road may vary in a different way when going from the reference to the worst-case scenario, depending on the policy

that is followed. Indeed, for CO₂ emissions and air pollution minimizations, the worst-case scenario leads to a stable or an increased market share for one particular intermodal solution (intermodal IWW transport in this case). On the contrary, a decrease of both intermodal solutions (rail and IWW) is observed when going from the reference to the worst-case scenario in the economic optimization. Under the environmental policies, going from the reference to the worst-case scenario leads to flow transfers within intermodal transport. Under the economic policy, the market shares of both intermodal rail and intermodal IWW transport decrease in the worst-case scenario. The flow transfer consequently happens between intermodal transport and road. This difference in flow transfers may in particular be explained by the assumptions of the scenarios. Indeed, the worst-case scenario for operational costs foresees an increase of rail and IWW operational costs, together with a decrease of the road operational costs. This favors road transport in the optimization of operational costs. On the contrary, the worst-case scenario for environmental parameters expects a decrease of the unit values for any kind of modes, with a higher decrease for road than for rail and IWW. This situation still leaves some opportunity for intermodal transport to be competitive on certain connections. The choice of the policy to follow is therefore important to take into account since, depending on the evolution of its parameters, it may influence the way in which flows are transferred on the network: either within intermodal transport itself (not wished by public authorities) or between intermodal transport and road transport.

The results have also shown that the economic context is important to take into account when evaluating the impact of a tax on the flow distribution. When applying the same level of tax to the reference and to the worst-case scenarios, results show that the effect on flow transfers in the reference case is larger than in the worst-case scenario. It is therefore important to use policy tools (such as taxes) that are evolve with time and with the economic conditions of the system under study.

Finally, it has been noticed that the introduction of a road tax could help reducing the amount of flows transported by road, to the benefit of intermodal transport. However, this modal shift is not enough to reach the intermodal market shares observed under the environmental optimizations focusing on climate change and on air pollution.

4. CONCLUSIONS AND PERSPECTIVES

This research tested the reference and worst-case scenarios identified in deliverable 1.3 of the project in terms of their impact on the flow distribution between intermodal and direct transport. The scenarios are defined by some of the important parameters identified in the previous SWOT analysis. In this context, an intermodal allocation model has been tested on an economic policy (optimization of operational costs) and on two environmental policies (optimization of CO₂ emissions and of air pollution external costs). An intermediate solution between the economic and the environmental policies has also been studied. This policy consists in optimizing the operational costs of transport in a system in which road taxes are implemented, for reflecting the impact of road transport on its environment. The model takes into account the already existing terminals on the network and identifies the optimal flow distribution of goods on the Belgian case study.

The application of the model to the different scenarios and to the various optimization policies leads to the following results:

- The followed policy (defined practically in the model by the objective function) influences the flow distribution between the different modes of transport. Going for economic objectives leads to more road transport. Focusing on environmental objectives emphasizes the use of intermodal transport.
- The worst-case scenario (i.e. no means are implemented to sustain the objectives of 30% of flow transfer from road to more environmentally-friendly modes) always favors the development of road transport, to the detriment of intermodal transport.
- The introduction of a road tax on the network, under a policy which focuses on optimizing costs, increases the market share of intermodal transport. However the resulting intermodal market share still remains lower than the one obtained under the optimization of environmental objectives related to CO₂ emissions and air pollution.
- The definition of the value of a tax as a policy tool should be done in a system in which the economic parameters are known as best as possible. Indeed, better understanding the environment allows better evaluating the impact of the tax on the flow distribution and on the flow transfer between modes.

This study compared the resulting flow distribution of purely economic and environmental views, as well as an intermediate policy which integrates both aspects. This research could be extended by evaluating the impact on flow distribution between road and intermodal transport of other kinds of policies. The latter could, for instance, relate to the evaluation of the impact of the introduction of subsidies for rail transport, of the optimization of other externalities of transport, or of the internalization of external costs of transport. The balance between economic and environmental objectives could also be evaluated using a bi-objective model which would identify a set of Pareto optimal solutions regarding two objectives, rather than a single optimal solution. A Pareto front could then be determined, constituted by solutions for which none of the objective functions could be improved without worsening the value of the other objective.

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