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MODAL CHOICE IN FREIGHT TRANSPORT: A COMBINED MCDA-GIS APPROACH

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ABSTRACT

In this paper, a modal choice decision support model for comparing intermodal options with unimodal road transport was developed. Since many, possibly conflicting, criteria exist as modal choice variables; we suggest a Multi-Criteria Decision Analysis (MCDA) approach. For two trajectories within Belgium, unimodal road -, intermodal barge/road- and intermodal rail/road transportation chains are compared. The MCDA method Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) is used to find the best trade-offs between the selected criteria and to select the most appropriate transport alternative. As input for the evaluation of the different alternatives on these criteria, output from a Geographic Information System (GIS)-based model, called LAMBIT (Location Analysis Model for Belgian Intermodal Terminals) is used. Two scenarios are analysed, with a focus on the possible role of transport externalities in modal choice.

Keywords: Intermodal Transport, Modal Choice, Multi-Criteria Decision Analysis, GIS

1. INTRODUCTION

The 2006 mid-term review of the European Commission's 2001 Transport White Paper, "Keep Europe Moving, Sustainable mobility for our continent", provided forecasts of a 50% growth in road freight traffic between 2005 and 2020 (European Commission, 2006) articulating the importance of a seamless and efficient transportation system. In the most recent White Paper, "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system", this (predicted) growth in freight transport is coupled with the ambitious goals of shifting road freight to rail and waterborne transport modes and reducing the greenhouse gas emissions in the transport sector by at least 60% in 2050, with respect to 1990 (European Commission, 2011). To achieve these goals, the European transport system needs to become greener. Therefore, one of the White Paper's objectives is achieving a modal shift of 50% of the road freight over 300 km to rail and waterborne transport by 2050.
To design a sustainable and competitive transport system, it is a key issue to understand the variables influencing the choice for a transport service. To test the feasibility of a modal shift

in Belgium, a link is made to different criteria that are considered when making a modal choice, i.e. the modal choice criteria. If one wants to influence the behaviour of actors in transport decisions, one needs to understand their behaviour first. This paper describes a model that allows the user to assess the importance of the criteria considered for a container transport between an origin and destination. Changes in the attitudes towards these variables can change their relative importance and enhance such a modal shift. The variables that are taken into account are transport price, time and reliability. Also external effects were included to simulate their (possible) importance in modal choice. A MCDA model built for this modal choice is connected to a GIS-based model, namely LAMBIT, which provides the necessary input for the first model.

This paper shows a way to take the modal choice behaviour into account, using a MCDA method. The paper shows how different attitudes towards modal choice variables can influence modal choice and enhance a modal shift. Two case studies for container transport within Belgium compare two different modal choice scenarios and show possibilities for intermodal transport when the focus on external effects in modal choice increases.

In section 2, modal choice and the external effects of freight transport are discussed. In the methodology section (3), the combination of the MCDA and the GIS model is explained and justified. Additionally, the alternatives considered and the values of their criteria are discussed in section 4. Section 5 shows the results by comparing the proposed alternatives for two origin-destinations combinations in Belgium. Section 6 concludes the article.

2. LITERATURE

2.1 Modal choice in container transport

We consider intermodal transport as the combination of at least two modes of transport in a single transport chain, without a change of container for the goods, with most of the route travelled by rail, inland waterway or ocean-going vessel and with the shortest possible initial and final journeys by road (Macharis and Bontekoning, 2004). In this paper we focus on maritime-based transport chains within Belgium, combining rail/road and barge/road, using containers as loading units. Different modal choice variables determine the shipper's mode and route choice. The majority of empirical studies to identify these attributes employ methods as focus groups, interviews, syntheses of previous studies or hypotheses of researchers (Cullinane and Toy, 2000). Cullinane and Toy (2000) applied a content analysis methodology to the freight mode choice literature. They provide an overview and ranking of the frequently used modal choice variables. The attributes ranked highest in their analyses are: cost/price/rate, speed, transit time (reliability), characteristics of the goods and service level. Flodén et al. (2010) provide a review of the literature on modal choice variables in freight transport in Europe. Their review finds that cost, transport time, reliability and transport quality are the key factors. They also refer to the multiplicity of actors in freight transport (shippers, forwarders, transport operators…) with different preferences. The interaction of these actors, based on the information available to them and their attitudes is the framework for transport choice. Vannieuwenhuyse et al. (2003) used a survey to determine the perception of Belgian logistics decision maker's concerning the transport modes and concluded that these decision makers allocate the highest weights to

transportation cost, reliability, flexibility, transportation time and safety. They also found that often bias exists towards the use of other modes, due to a lack of knowledge or experience. Market price is often considered as the main variable determining the choice between unimodal and intermodal transport (e.g. Frémont and Franc, 2010; Kreutzberger, 2008). For intermodal transport to be competitive, sufficient volumes and longer distances, positively affect the transport price per transported unit. The cost of intermodal transport basically depends on the network of intermodal terminals, the existing intermodal connections, the length of the main haul, the length of pre- and post-haulage and the balance of traffic (Niérat, 1997). Flodén et al. (2010) conclude that after ensuring that the basic quality requirements for transport are met, price is dominant in transport decisions.
Next to market price, transport time is often stated as a major modal choice variable. According to Danielis et al. (2005), the importance of time diminishes when longer transport times are expected. Transport time is a variable which is easily measurable and can be modelled by using a value of time (Pekin et al. 2013). Often also reliability is considered a part of the transport time, as on-time delivery (Flodén et al., 2010). Kreutzberger (2008) concludes that its ranking compared to other modal choice variables differs strongly and that also the valuation of time is characterized by some dispersion.
Next to studies identifying and ranking the most important modal choice variables, Meixell and Norbis (2008), in their review of transportation mode choice literature and carrier selection, mention studies on the mode choice and carrier selection decision processes. Some of these studies include the modelling of modal choice, simulating the decision process itself. A notably example are discrete choice models (e.g. de Jong and Ben-Akiva, 2007; Truschkin and Elbert, 2013).
The attributes mentioned above are the ones shippers might consider from an internal cost perspective. For reasons of data availability and time constraints, we only took into account transport cost, time and reliability. Besides, there are also societal consequences of this modal choice, which are commonly not accounted for. The next section focuses on these external effects of freight transport.

2.2 External effects of container transport

Currently, an extensive list of negative externalities is associated with freight transport activities. Maibach et al. (2008) mention the environmental damage costs caused by emissions (climate change and air pollution), accidents, noise, congestion, wear and tear of infrastructure and up and downstream external effects related to energy production. These negative effects became important in the transport industry, witnessing a multiplicity of sustainable transport awards and an abundance of related Corporate Social Responsibility (CSR) initiatives. However, these environmental variables are rarely included in modal choice literature. The few studies that include environmental impact as modal choice factor, mainly find their importance to be low (Flodén et al., 2010). For instance Lammgård's (2007) survey indicates a weight of 5% to environmental efficiency in transport decisions.
When calculating the impact of externalities generated by intermodal transport, a difficulty arises. Externalities of intermodal transport are more complex due to the use of different transport modes and additional transhipments. However, on average intermodal transport will generate lower externalities than unimodal road transport. This is due to the fact that the distance of the pre- and post-haulage by road is usually rather limited if intermodal transport

wants to be commercially attractive (Macharis and Van Mierlo, 2010). It should nevertheless be clear that this will depend on case specific parameters. Therefore, in practice, the different externalities on specific routes need to be observed in detail. This, to decide upon the total level of externalities of intermodal transport routes compared to those of unimodal road routes. Again, for reasons of data availability, a limited amount of external effects were taken into account for this analysis, i.e. the emission of CO_2-eq., the accident risk and noise. Average values (as described below) were used for the different routes.

3. METHODOLOGY

From literature overviews on the use of operational research in intermodal transport (Macharis and Bontekoning, 2004; Caris et al., 2008), can be concluded that most of the existing models are not taking the intermodal solutions into account, and they primarily look at transport cost as main modal and route choice variable. Modelling modal choice with MCDA allows the inclusion of the preferences, including qualitative criteria, of the decision maker (e.g. Qu and Chen, 2008). They take into account the total transportation time, the total cost and social benefits such as the decrease of congestion. In Sawadogo and Anciaux (2011) the ELECTRE method is used in order to consider several criteria such as time, cost, environmental impacts, accidents, transhipment time and damage. In Macharis et al. (2008), modal choice is modelled for a real case with the PROMETHEE method. This study allowed including the perception of the shippers on the evaluation of the different criteria.
In this paper, the AHP and PROMETHEE methodologies are combined with a GIS approach to solve the modal choice problem in freight transport. In this methodology section, the use of MCDA is applied to modal choice. In the first subsection, a combination of the Analytical Hierarchy Process (AHP) method for the determination of the weights and the PROMETHEE method for performing the overall MCDA is proposed. The second subsection focuses on the LAMBIT-model, which is used for the selection of alternatives and as input for the criteria scores. Subsection 3 describes how these methods are integrated.

3.1. Multi-Criteria Decision Analysis

MCDA allows evaluating alternatives on several quantitative or qualitative criteria (Vincke, 1992), in this case: the different modal choice criteria. MCDA is a decision making support tool that uses a structured approach to determine preferences among different alternatives.
Although there are different ways to conduct a MCDA, the same steps can be found in most methods. A MCDA is mostly built up out of two main phases: the construction - and the exploitation phase. Each phase consists of several steps that need to be carried out to complete the MCDA and provide a solution. Generally, six steps are identified, four belonging to the construction phase and two to the exploitation phase, which usually take place in a chronological order (De Brucker et al., 1998; Nijkamp et al., 1990).
Step 1: Analysis and definition of the problem. Experts and decision makers analyse the problem, which in this case is the modal choice problem.
Step 2: Generation of different alternatives. Several possible alternatives are listed. Here, these will be the different possibilities to go from point A to point B, resulting in three alternative routes: one road-only and two intermodal.

Step 3: Formulation of criteria, their weights and indicators. Here the different criteria are listed. This set comprises all the relevant elements needed to evaluate and compare the different alternatives in a certain situation. When a set of criteria is created, the indicators and the weights for every criterion need to be considered (Vertonghen, 1992). Every criterion consists of one or more indicators, used to evaluate them. It is the scale method that will be used for the evaluation of the alternatives. The indicators can be quantitative or qualitative, leaving a large potential for possible criteria. The weight of a criterion indicates its importance in the assessment of the alternatives. The higher the weight attached, the more the criterion will affect the outcome of the MCDA. To obtain the weights, the pairwise comparisons of the AHP method were used (Turcksin et al., 2011).
Step 4: Construction of the evaluation matrix. The decision matrix is constructed and the actual evaluation takes place. The matrix provides a structured overview of the strengths and weaknesses of every alternative. However, it is not possible to come to a final decision based on the matrix in its original form, since for instance a difference in transport cost cannot directly be compared to a difference in accident risk. A transformation or aggregation is required to allow experts to draw conclusions out of the decision matrix.
Step 5: Overall evaluation using an aggregation method. In this step, the difference between the various MCDA methods becomes most clear. The PROMETHEE method is applied to easily grasp the modal choice decision. Its D-Sight software further enabled the analysis. The results from this step can be used to come to a final conclusion. A preferred mode (combination) can be selected.
Step 6: Integration of MCDA results in decision making. All the output information of the MCDA should be incorporated in the ultimate decision making procedure. A sensitivity analysis can be performed to test the robustness of the solution towards changes in the weights of the modal choice variables.
Next, the choice for the AHP en PROMETHEE methods is briefly explained. AHP is developed by Saaty (1982, 1988, 1995). The method is based on three principles: (1) construction of a hierarchy, (2) priority setting and (3) logical consistency (Macharis et al., 2004). First, a hierarchy is used to decompose the complex system into its constituent elements. A hierarchy has at least three levels: the overall objective or focus at the top, the (sub-) objectives (criteria) at the intermediate levels and the considered alternatives at the bottom (Macharis et al., 2004; Dagdeviren, 2008). Second, the relative priorities of each element in the hierarchy are determined by comparing all the elements of the lower level against the criteria, with which a causal relationship exists. The multiple pairwise comparisons are based on a standardized comparison scale of 9 levels (Saaty, 2008). The result of the pairwise comparisons is summarized in a pairwise comparison matrix, where its standard element indicates the intensity of the preference of the row element over the column element in terms of their contribution to a specific criterion. Lastly, the consistency of decision-makers as well as the hierarchy can be evaluated by means of the consistency ratio (Wang and Yang, 2007). This procedure is explained in detail in Saaty (1988).The major reason why the AHP method is applied, is its ability to decompose a complex problem into its constituent parts and its simplicity in use (Macharis et al., 2004; Dagdeviren, 2008; Konidari and Mavrakis, 2007). In general, a major weakness of AHP is its complete aggregation of the criteria which might lead to important losses of information (e.g., in case where trade-offs between good and bad scores on criteria occur). Additionally, the amount of pairwise comparisons for the evaluation of the alternatives in terms of their contribution to the criteria

might become substantially high (Macharis et al., 2004). But in this case, for the determination of the weights of modal choice variables, the method works fine as the amount of variables is limited.
PROMETHEE belongs to the methods of partial aggregation (De Brucker et al., 2004). The decision matrix obtained in step 4, where the alternatives are evaluated on the different criteria, is the starting point of the PROMETHEE method. But, the PROMETHEE method requires additional information.
First, a preference function needs to be defined that translates the deviation between the evaluations of two alternatives on a particular criterion into a preference degree ranging from 0 to 1. This preference index is a non-decreasing function of the observed deviation between the scores of the alternatives on the considered criterion. Six possible shapes of preference functions are proposed to the decision-maker by Brans et al. (1986): usual shape, U-shape function, V-shape function, level function, linear function and Gaussian function.
Second, information on the relative importance of the weights of the criteria is required, which will be provided by the users of the decision module by using the pairwise comparisons of the AHP method. With this information, an overall preference index can be computed, taking all the criteria into account.

3.2. LAMBIT

LAMBIT, a GIS-based location analysis model, is developed to conduct ex-ante and ex-post analysis of policy measures related to intermodal transport (Macharis, 2000). The main aim of the model is to explore the relative attractiveness of each transport mode. In this case, LAMBIT is used to calculate optimal routes and the values of their respective modal choice variables and external effects. This is coupled with a Multi-Criteria Analysis model as proposed in this paper.
LAMBIT is built on three main inputs: transportation networks, container flows from the municipalities to and from the sea ports and transport prices. For the purpose of this paper, also other modal choice variables and externalities were added next to transport price. A GIS network was set up by including three different network layers: the road network, the rail network and the inland waterways network. The geographic locations of the intermodal terminals, the port of Antwerp and the port of Zeebrugge and the municipality centres are defined and connected to the different network layers.

3.3. General methodology

Figure 1 summarizes the general methodology used in this analysis, combining the AHP and PROMETHEE methods with the LAMBIT-model. The methodology involves eight steps:

1. Data collection. The LAMBIT model is used to determine the different mode-route alternatives.

2. LAMBIT calculates the route- and mode specific values of each variable for all criteria.

3. Proposing a decision hierarchy. Every criterion consists of a subset of indicators, accounting for the aggregate value of every criterion. For instance the criterion cost consists of different sub cost variables.

4. Assignment of weights to each criterion. This allows stressing the relative importance of each criterion compared to another. For these two steps, the AHP method is used. In the final stage, using the PROMETHEE method, the preferred modal choice is made.

5. Set-up of the decision matrix, including all alternative route-mode combinations and the corresponding values for all considered criteria.

6. Ranking of the alternatives.

7. Sensitivity analysis. This step allows conducting a sensitivity analysis to check for uncertainty related to the model inputs.

8. The favoured modal choice for every origin-destination couple is retrieved.

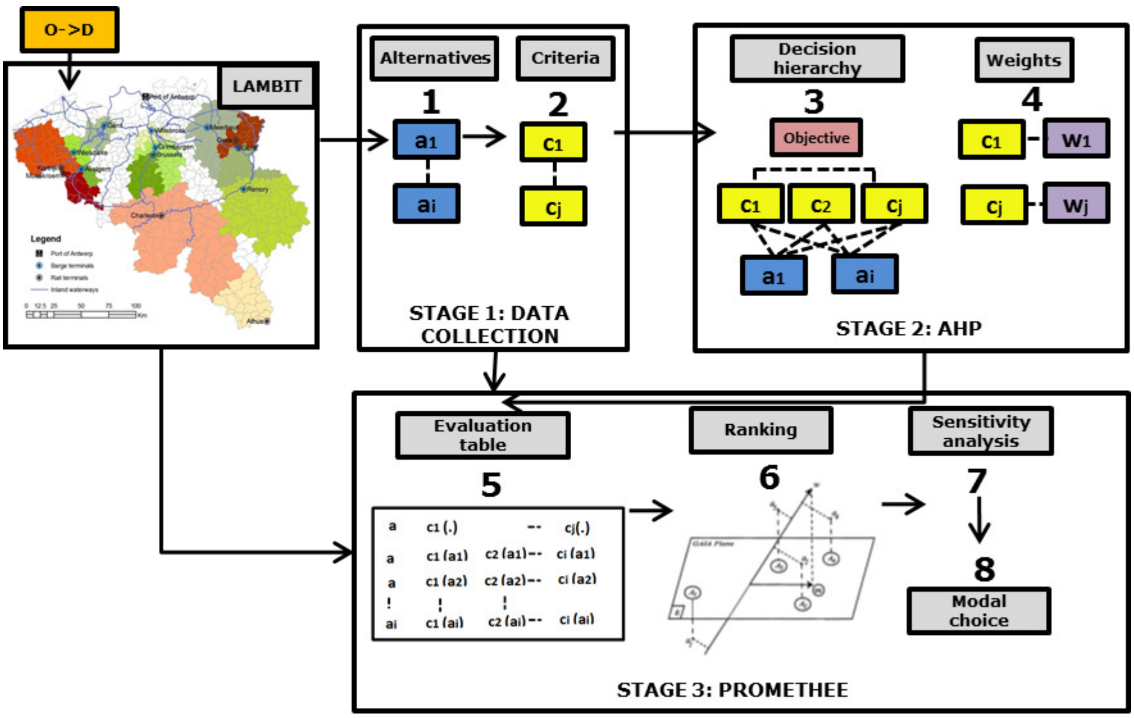

Figure 1 - Overview of the methodology

4. APPLICATION

As stated before, the LAMBIT model was used to determine the routes to be evaluated and compared. The methodology was tested for the possible routes between two origin-destination (OD) couples within Belgian. For the first route, crossing Belgium from north to south, as origin, the port of Antwerp was chosen, as this is the main sea port in Belgium, handling over 8.6 million TEU in 2011. As destination a Walloon municipality named Arlon was depicted. The yearly freight transport between Antwerp and Arlon is approximated around 4.240 TEU (ADSEI, 2010). The second route, going from the west to the east, goes from the sea port of Zeebrugge to the municipality of Geel. The yearly freight transport between Zeebrugge and Geel is approximated around 172 TEU (ADSEI, 2010), while the port of Zeebrugge yearly handles 2.2 million TEU.

4.1. The generation of alternatives

LAMBIT depicts three alternative mode combinations for both OD couples: road only transport and intermodal rail and barge transport with the post-haulage performed by truck. For the calculation of the optimal routes, a trade-off scenario was considered, between transport distance and transport time. For both OD-combinations, three alternative routes remain (Figure 2).

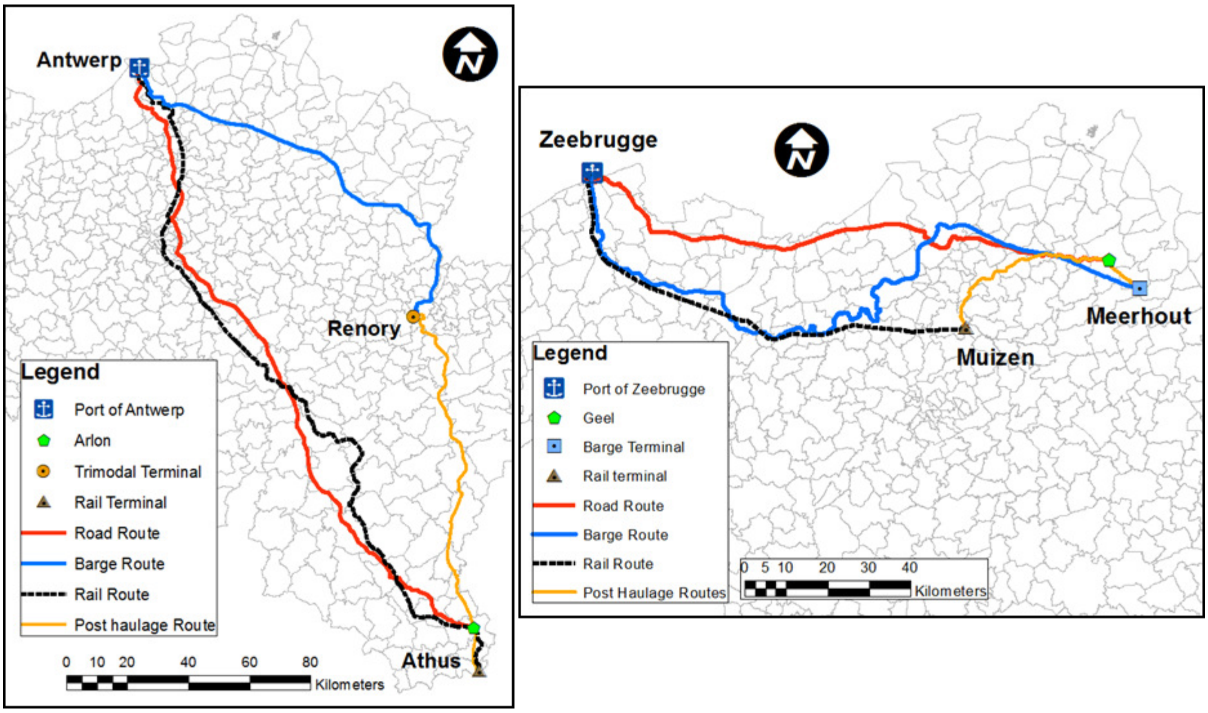

Figure 2 - Route alternatives for freight transport from Antwerp to Arlon (left) and from Zeebrugge to Geel (right)

4.2. Formulation of criteria, weights and indicators

Danielis (2002) states that freight transport is characterized by a strong heterogeneity in preferences. It was not the goal to include all variables which are described in section 2, but to select the most important modal choice variables (i.e. cost/price, transport time and reliability) and on the other hand include some of the most principal external effects of freight transport (global CO_2-emission effects, noise and accident risk). These variables were chosen based on previous research and data availability (see section 2). The criteria considered, combined with the indicators used, are structured in a criteria tree (Figure 3) and explained below.

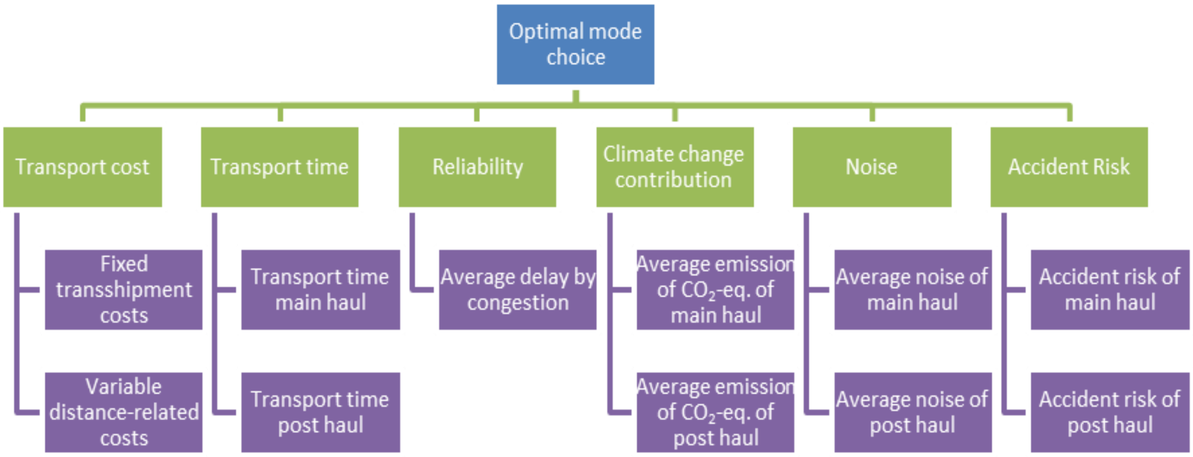

Figure 3 - Criteria tree, including the overall objective (top), considered variables (middle) and indicators (bottom)

4.2.1. Transport cost

Figure 4 presents the intermodal cost function. Since twice a maritime-based transport chain is considered, no pre-haulage costs are considered. The intermodal transport chains have larger fixed costs at the port due to higher transhipment costs. But due to the economies of scale that can be obtained by transporting large quantities at the same time, the indicator cost per tonne-km for the intermodal main haul cost function is lower than for the one of road-only transport. The extra cost of a second transhipment in the intermodal terminal and the steeper cost function of the post-haulage transport in comparison to the one of road-only transport, compensates for the scale advantages obtained during the main haul. It is obvious from the graph that shorter main-haulage distances and longer post-haulage distances in intermodal transport negatively influence its competitiveness. The total price of intermodal transport is calculated as the sum of (1) the transhipment cost in the sea port to a barge or a wagon, (2) the cost of the intermodal main haul, (3) the transhipment cost in the inland terminal to a truck and (4) the cost of the final haulage by truck.

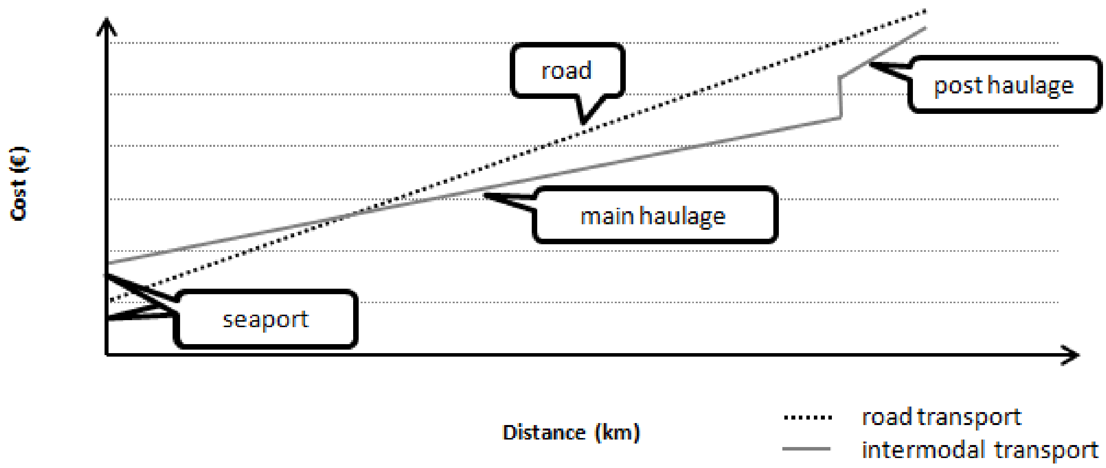

Figure 4 - Intermodal cost function (Source: Pekin et al., 2013)

The transport prices are calculated based on the real market price structures for each transport mode and they are linked to the network layers of the LAMBIT-model. The variable costs are attached to the network layers and the fixed costs to the nodes (e.g. transhipment costs are linked to intermodal terminals), which also indicate the origin and destination of each path. The same logic goes for the other modal choice variables and the externalities. For instance the accident risk on each link is attributed to that link, making the total accident risk of a route the sum of all individual accident risks of the links in a transport chain.

4.2.2 Transport time and reliability

Also for the calculation of the transport time and reliability, the LAMBIT model was used. The road network is based on data from TELE ATLAS, dating from 2005. This network allows calculating shortest path algorithms and transport times for a given trajectory in a GIS environment. Real world restrictions are taken into account such as restricted turns and one way streets. The transport time is calculated for an average morning situation. Real speed limits are used for trucks, while for inland waterways and rail, average speeds of 11 and 25 kilometres per hour respectively were adopted (ECMT, 2006; Janic, 2007).
To account for reliability, the possible delay time due to congestion was calculated. For these values of congestion time, data from the Traffic Centre Flanders (Verkeerscentrum Vlaanderen, 2012) were adopted. The reliability gives an indication of the possible delay due to severe morning congestion. Since the possible delay due to congestion is only a part of total transport reliability, this criterion was allocated a minor weight in comparison to transport cost.

4.2.3 External effects

For CO_2-eq. emissions contributing to climate change, values for a standard 20ft. container were calculated. CO_2-eq. stands for CO_2 equivalent and indicates that also other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) are included, recalculated to the same comparison base expressed in CO_2 through their global warming potential. CO_2-eq. emissions are calculated expressed in kg CO_2-eq. per 1 TEU-kilometre, resulting in "emissions per loading unit" multiplied by the distance for the different transport modes. The average CO_2-eq. emission factors used for calculations are based on the values published in the overview report on transport related carbon emissions published by McKinnon and Piecyk (2010). The carbon footprint on a particular intermodal or unimodal trajectory will however depend on a number of cost drivers, so that only an estimation of the CO_2-emissions based on averages is used.
The values on accidents were derived from a VITO (Flemish Institute for Technological Research) study (De Vlieger et al., 2004). Numbers per tonne-km for freight transport in Flanders were provided, allowing the calculation of average values for the given trajectories. These numbers vary strongly by the mode used, from 150 accidents per billion tonne-km for road transport, over 15 for rail transport and 7 for barge transport. The numbers for noise finally were adopted from a study from Kürer (1993), using estimated noise levels of 64 dB(A) per tonne for trucks and 63 dB(A) per tonne for trains, while the noise due to barge transport can be neglected.

4.3. Decision matrix

The weights can be given on a pairwise comparison basis on a 1 to 9 scale. Two scenarios were elaborated. Scenario 1 attaches a major weight to the modal choice attributes: transport cost, transport time and reliability and a minor weight to the external effects. This scenario is based on the estimate of Lammgård (2007), were in the current situation only approximately 5% of the importance is attached to environmental efficiency. Scenario 2 starts from the objective of the European Commission to lower the environmental impact of transport considerably and attains much higher weights to environmental variables in modal choice. The sources of the data at the bottom of the tables are described in the previous sections. These values are imported in the D-Sight software. Additionally, the preference functions were chosen (see Table 1 and 2) as described in section 3.1. These preference functions show the preference the decision-maker is attaching to a difference in the values on a specific criterion. For transport cost, a V-shaped function is chosen. This function can account for small deviations in prices. A full preference is given when an alternative is 30 €/TEU cheaper. For the transport time, a linear function with a total preference from threshold 3.0 and an indifference of 0.5 is selected, meaning that if two transport options have a difference of 3 hours, a full preference is given to the fastest one for that criterion. If the difference is less than half an hour, both alternatives will be ranked equally. Linear functions are used for quantitative data with an indifference value. For congestion time and emissions, Gaussian functions are used. These functions are an alternative for linear functions, but they have a smoother shape. Respective indifference values of 15 minutes and 50 kg/TEU are used. Usual functions are used for accident risk and noise. These functions are simple, the smaller value the better and no threshold values are included. In this case, a minimization of all the criteria is preferred.

Table 1 - Decision matrix for transport between Antwerp and Athus

	Intermodal terminal	**Transport Cost (€/TEU)**	**Transport Time (hour)**	**Congestion Time (min)**	**CO_2-eq. Emissions (kg/TEU)**	**Accident risk (accidents/ TEU)**	**Noise (dB (A)/Tonne))**
Weight scenario 1(%)		40	25	30	3	1	1
Weight scenario 2(%)		23	15	17	15	15	15
Function		V-Shape	Linear	Gaussian	Gaussian	Usual	Usual
Indifference		-	0.5	-	-	-	-
Preference		30,0	3.0	15.0	50,0	-	-
Mode Main haul							
Road	-	443	4.3	59.9	276	4.8E-04	64
Rail	Athus	436	11.3	1.3	86	8.5E-05	63
Barge	Renory	489	15.9	8.9	212	2.5E-04	neglegible

Table 2 - Decision matrix for transport between Zeebrugge and Geel

	Intermodal terminal	**Transport Cost (€/TEU)**	**Transport Time (hour)**	**Congestion Time (min)**	**CO_2-eq. Emissions (kg/TEU)**	**Accident risk (accidents/ TEU)**	**Noise (dB (A)/Tonne))**
Weight scenario 1(%)		40	25	30	3	1	1
Weight scenario 2(%)		23	15	17	15	15	15
Function		V-Shape	Linear	Gaussian	Gaussian	Usual	Usual
Indifference		-	0.5	-	-	-	-
Preference		30,0	3.0	15.0	50,0	-	-
Mode Main haul							
Road	-	334	2.0	27.3	166	2.9E-04	64
Rail	Muizen	369	5.7	5.0	101	1.5E-04	63
Barge	Meerhout	336	18.3	1.4	108	4.2E-05	neglegible

5. RESULTS

Two PROMETHEE tools are used to analyse the evaluation problem: the PROMETHEE II complete ranking and the Geometrical Analysis for Interactive Aid (GAIA) plane. PROMETHEE II provides a ranking of the alternatives, which is based on the net preference flow (Figure 5). This flow accounts for the strengths and the weaknesses of the alternative, in comparison to the other alternatives in one score. For the transport between Antwerp and Arlon, in both scenarios intermodal rail transport is preferred. In scenario 1, rail scores better on the important criteria of price and reliability, while road performs better on transport time (Table 1). The first scenario proves that even without an increased importance attached to transport externalities, intermodal transport can be favoured also for a transport distance below 300 km. Scenario 2 shows improved preference for the intermodal options as both intermodal rail and – barge score better on the externalities than road-only transport (Table 1).

For the transport between Zeebrugge and Geel in scenario 1, the road-only alternative is preferred above the intermodal barge option. In the second scenario, again we witness a stronger preference for the intermodal options, while road-only transport is less preferred. In the case of the second scenario, intermodal barge transport will be the preferred alternative. Both cases prove that when shippers allocate greater importance to transport externalities in modal choice, opportunities for intermodal transport are created. By reducing the weights attached to transport time and cost, intermodal transport gets more interesting in both cases. An application to more OD-couples could increase insight in this matter.

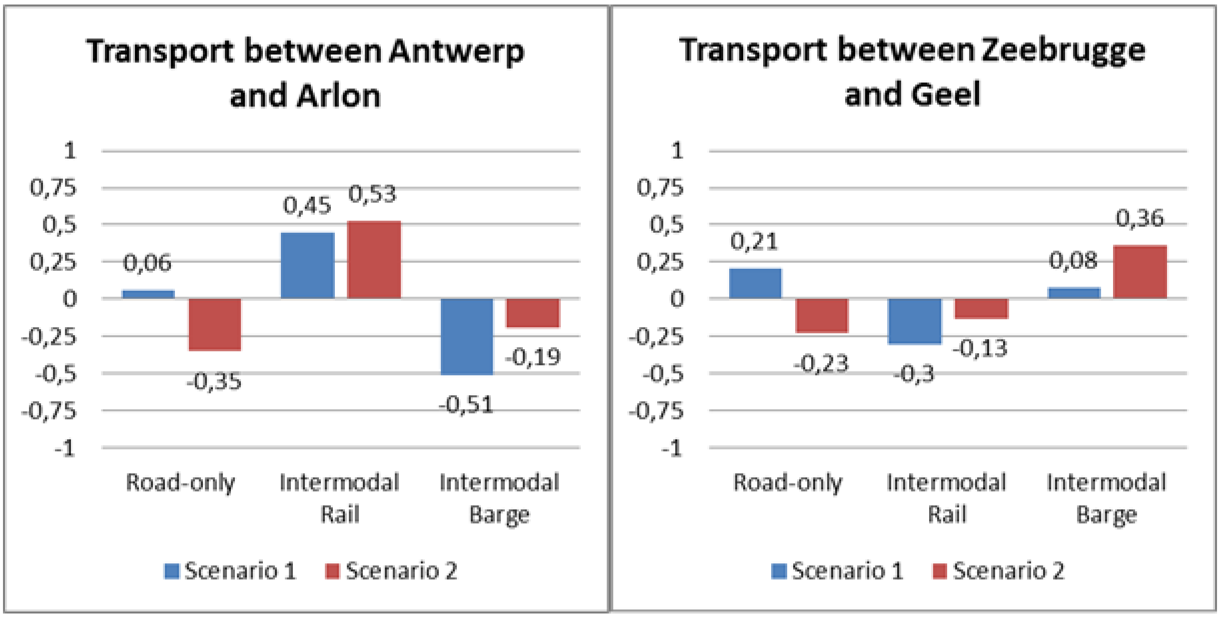

Figure 5 - PROMETHEE II Ranking (own set-up with D-Sight)

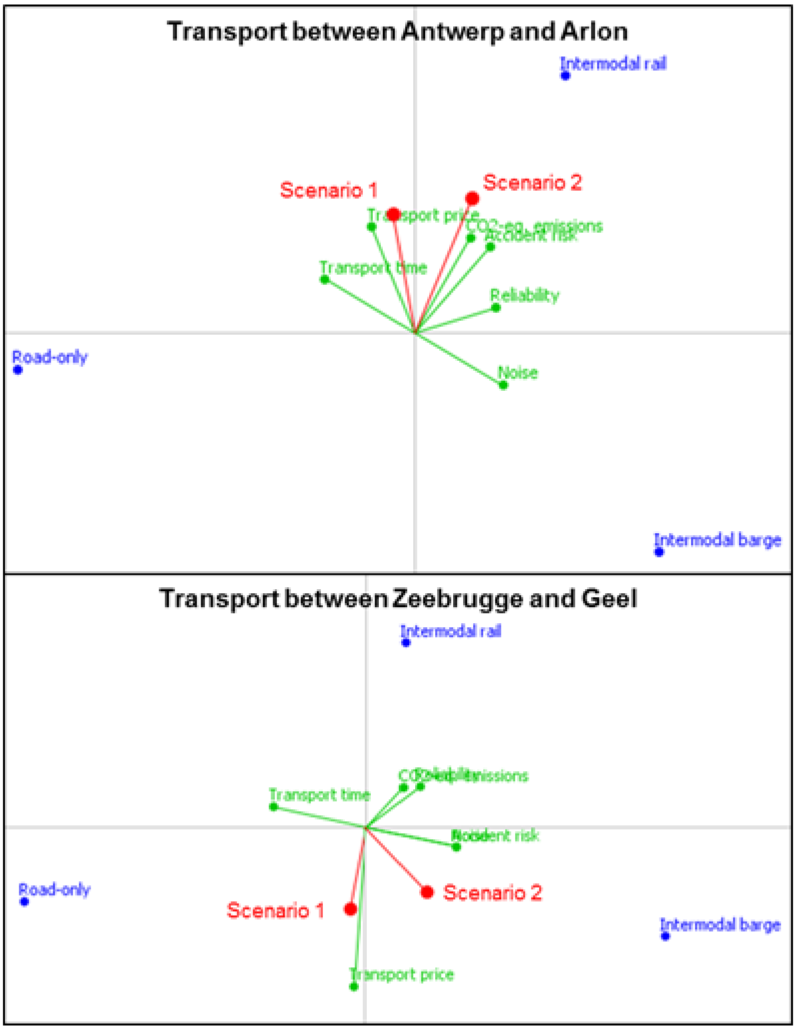

Figure 6 - GAIA Visual Stick Analysis (own set-up with D-Sight)

The GAIA plane (Figure 6) provides a graphical representation in which the alternatives and their contribution to the criteria are displayed. A decision stick can be used to further investigate the sensitivity of the results in function of weight changes (Brans and Mareschal, 1994). The decision problem is presented in two dimensions. This plane is obtained by applying a Principal Component Analysis (PCA) to the matrix of unicriterion net flows scores. Within the GAIA Visual Stick Analysis, a further analysis can be made of the positive and negative aspects of the different options. The GAIA Stick relies on the same principle as the GAIA plane; a projection of the initial decision problem in a two-dimensional plane. Nevertheless, the first dimension of the plane is defined by the GAIA Stick. Hence the projections of the actions on this axis are proportional to the net flow values and correspond to the PROMETHEE II ranking. The second (vertical) axis is orthogonal to the first one and is such that the GAIA Stick plane gathers as much information as possible from the decision problem. The figure clearly shows that the second scenario in both figures induces a shift away from road-only transport, favouring the intermodal options that perform better regarding the transport externalities (Figure 6).

6. CONCLUSIONS

By including external effects in the mode choice more sustainable transport decisions can be made. It is clear from both cases that the greater importance of externalities in modal choice favours the use of intermodal transport. Also on relatively short distances, intermodal transport can become an interesting alternative, when different modal choice and sustainability criteria are taken into account, instead of solely the total logistics cost. A more comprehensive analysis, including a wider set of modal choice and external effect variables, can increase insight in this matter.

The MCDA-GIS module developed in this paper can be used in several ways. First, it can be used in an interactive way by users (such as shippers, freight forwarders…) in combination with a website showing the different modal options. By providing this possibility, the users can actively analyse their decision behaviour and depending on the type of carriage, change the weights and even the preference functions. Secondly it can be used as a part of a transportation model, in which in the MCDA-GIS module helps in the assignment of the flows on the network. In this case a good understanding of the weights and preferences of the decision-makers in modal choice can be used as standard weight distribution and input for the preference functions. We foresee in the near future to collect data on a large scale to determine these values.

For the European Commission, to reach their goals of sustainable transport (European Commission, 2011) the current modal choice behaviour of shippers should be altered to enhance a shift towards rail and barge transport. Therefore a better insight is needed in this matter. Three possible options are available to make modal choice more sustainable. A first one is the lowering of the external effects of road transport. This can be achieved by using more environmentally friendly vehicles and through a more efficient use of the infrastructure and load capacity. A second option is an increased performance of intermodal transport regarding the traditional modal choice variables such as price, time and reliability, relative to road-only transport. Also the perception of intermodal transport can be improved. A third option is a better internalization of transport externalities in the modal choice. By the internalization of the external costs or the granting of subsidies, the modal choice can be substantially altered.

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