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A combined AHP-PROMETHEE approach for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet

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Abstract

The aim of this paper is to recommend a multi-instrumentality policy package to the Belgian government in its objective to reduce environmental externalities by encouraging people to make a more sustainable vehicle choice. As there are many policy instruments available (regulatory, economic, transport supply instruments), which may have several important effects referring to economic, environmental, technical and social aspects, selecting the most appropriate policy scenario is a multi-criteria decision making problem. This paper proposes an integrated approach for the decision-making problem that combines the Analytical Hierarchy Process (AHP) and the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE). The combination of both approaches enables a careful evaluation of the identified policy scenarios in which their strong and weak points are detected and a ranking is provided which facilitates the final selection for the decision-maker.

Keywords: Multi-Criteria analysis, AHP, PROMETHEE, policy scenarios, clean vehicle fleet

1. Introduction

The growth in road transport imposes an increasing environmental burden on society. In Europe, road transport generates about one fifth of total carbon dioxide (CO_2) emissions, and releases other pollutant emissions such as particulate matter (PM), nitrogen oxides (NO_x) and hydrocarbons (NMHC) that cause harmful effects on human health and ecosystems (EC, 2009). These negative externalities are often under-priced or not internalised in the current transportation system. As a consequence, transport users are not aware of the environmental external costs of their activities and they do not factor this into their purchase patterns or behavioural decisions (Browne and Ryan, 2010). Without policy intervention, the market is incapable to reach an efficient equilibrium. The take up of low emission vehicles or alternative fuels (liquefied petroleum gas, compressed natural gas, biofuels) and drivetrains (battery electric, hybrid electric vehicles) on the market is likely to be the single most important intervention to address emissions from the vehicle fleet (Hickman et al., 2010). Nevertheless, in a complex system such as transportation, many trade-offs or unexpected side-effects may occur from isolated measures (Vieira et al., 2007).

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A combined approach of policy instruments might potentially be better to accommodate increasing transport demand and enhance the adoption of cleaner vehicles (Hickman et al., 2010; Vieira et al., 2007; Santos et al., 2010).

To address the problem of externalities, governments have the disposal of economic instruments, regulatory instruments and transport supply instruments (Viegas, 2003). Economic instruments use market-based approaches (e.g. taxes, charges) to guide consumer behaviour in more favourable directions. This includes taxes and charges related to the ownership and usage of the vehicle. Regulatory instruments refer to legal instruments (restrictions, standards and controls) to induce an adjustment of market participant's behaviour. The main regulatory instruments used in practice are fuel economy standards (e.g., CAFE standards in the US), vehicle emission standards (e.g., Euro emission limits), fuel quality standards (e.g., EU Fuel Quality Directive 2003/17/EC), and restrictions including restricted access to a specific zone (e.g., limited traffic zones in Italy), parking restrictions, vehicle ownership restrictions (e.g., Singapore) and vehicle circulation restrictions (e.g., odd and even number plate circulation allowance in Greece) (Timilsina and Dulal, 2009; Vieira et al., 2007; Koopman, 1995; Santos et al., 2010). Transport supply instruments include measures to enlarge the supply and quality of available vehicles, fuels and infrastructure. This includes amongst others incentives for public transportation, stimulation of R&D, educational and information measures, public-private partnerships, etc. (Schwaab and Thielmann, 2001; Vieira et al., 2007).

Governments might be particularly interested in finding groups of policy measures that reinforce each other to achieve changes in the transportation system (May et al., 2006). The aim of this paper is to recommend a multi-instrumentality package to the Belgian government in its objective to reduce environmental externalities by encouraging people to make a more sustainable vehicle choice. This raises a complex decision making process, as many potential policy instruments are available, which may have several important effects referring to economic, environmental, technical and social aspects. Today, the multi-criteria decision analysis (MCDA) is increasingly used in environmental policy evaluation as (1) it offers the possibility to deal with complex issues, (2) it incorporates criteria that are difficult to monetise, (3) it represents a holistic view incorporating tangible as well as intangible (or 'fuzzier') aspects, often neglected by other evaluation methods, such as the cost-effectiveness analysis (CEA) or cost-benefit analysis (CBA), which also require a full monetisation of all aspects and (4) it enables the inclusion of stakeholders in the decision-making process (Macharis and Geudens, 2009; Browne and Ryan, 2010; Munda, 2004; Gamper and Turcanu, 2007; De Brucker et al., 2004).

There exist various techniques to conduct a MCDA. Among the methods, the most popular ones used in the field of transport are multi-attribute theory variants (AHP, MAUT, MAVT, SMART, SMARTER, VISA), outranking methods (PROMETHEE, ELECTRE) and regime analysis (Macharis and Geudens, 2009). In this paper, an integrated approach is used that combines the Analytic Hierarchy Process (AHP) and the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE). AHP is used to structure the decision problem and to attribute weights to the criteria, whereas PROMETHEE is used to obtain a final ranking of the proposed alternatives and to perform sensitivity analyses by changing the weights. Section 2 introduces AHP, PROMETHEE and the integrated AHP-PROMETHEE approach, and section 3 applies the steps of the combined approach to rank the multi-instrumentality packages to stimulate a clean vehicle fleet. Conclusions and policy recommendations are formulated in section 4.

2. The AHP-PROMETHEE methodology

2.1. AHP

AHP is developed by Saaty (1982, 1988, 1995). It belongs to the multi-attribute theory (MAUT) variants, where the criteria are completely aggregated in a single utility function that takes the preferences of the decision-maker into account (De Brucker et al., 2004). The AHP 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 standardised comparison scale of 9 levels, see Table 1 (Saaty, 2008). The result of the pairwise comparisons is summarised in the pairwise comparison matrix (see

Table 2), where its standard element $Pc(a_i,a_l)$ indicates the intensity of the preference of the row element (a_i) over the column element (a_l) in terms of their contribution to a specific criterion C. 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).

Table 1: The Saaty scale for pairwise comparison (Saaty, 2008)

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Higher importance
7	Much higher importance
9	Complete dominance
2, 4, 6, 8	Intermediate values
1/2, 1/3, 3/4, … 1/9	Reciprocals

Table 2: Pairwise comparison of elements in AHP

C	a_1	…	a_l	…	a_n
a_1	1				
…		[1]			
a_i			$P_c(a_i,a_l)$		
…				[1]	
a_n					1

AHP is a probably the most widely applied MCA for the evaluation of various transport projects related to organisational, technological, environmental and infrastructural decision subjects (see Ferreira, 2002; Tudela et al., 2006; Sharifi et al., 2006; Janic, 2003; Tzeng et al., 2005, and so on). AHP is especially advantageous with respect to 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). On the other hand, AHP is often criticised with respect to the 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).

2.2. PROMETHEE

PROMETHEE is developed by Brans (1982) and further extended by Brans and Vincke (1985) and Brans and Mareschal (1994). It belongs to the methods of partial aggregation, or also called outranking methods, and was partly designed as a reaction to the complete aggregation (MAUT) methods (De Brucker et al., 2004). The evaluation table, where the alternatives are evaluated on the different criteria, is the starting point of the PROMETHEE method. The use of the PROMETHEE method requires additional information.

First, a specific preference function needs to be defined ($P_j(a,b)$) that translates the deviation between the evaluations of two alternatives (a and b) on a particular criterion (g_j) into a preference degree ranging from 0 to 1. This preference index is a non-decreasing function of the observed deviation (d) between the scores of the alternatives on the considered criterion ($f_j(a)$-$f_j(b)$), as shown in Formula 1. In order to facilitate the selection of a specific preference function, 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).

$$P_j(a,b) = G_j\left\{f_j(a) - f_j(b)\right\} \tag{1}$$

Second, information on the relative importance of the criteria (weights) is required. PROMETHEE does not yet provide any formal guidelines on how weights can be elicitated. It assumes that the decision-maker is able to weigh the criteria appropriately, at least when the number of criteria is not too large. For large amounts of criteria, Macharis et al. (2004) advise to determine weights according to several methods: direct rating, point allocation, trade-off, pairwise comparisons, and so on. In this case, the latter method (AHP) is used to determine the weight of each criterion (w_j). With this information, an overall preference index $\pi(a,b)$ can be computed, taking all the criteria into account (see Formula 2). This preference index is based on the positive $\varphi^+(a)$ and negative $\varphi^-(a)$ preference flows for each alternative, which measures how an alternative (a) is outranking (see Formula 3) or outranked (see Formula 4) by the other alternatives. The difference between these preference flows is represented as the net preference flow $\varphi(a)$ (see Formula 5), which is a value function whereby a higher value reflects a higher attractiveness of alternative a.

$$\pi(a,b) = \sum_{j=1}^{k} w_j \, P_j(a,b) \tag{2}$$

$$\varphi^+(a) = \frac{1}{n-1} \sum_b \pi(a,b) \tag{3}$$

$$\varphi^-(a) = \frac{1}{n-1} \sum_b \pi(b,a) \tag{4}$$

$$\varphi(a) = \varphi^+(a) - \varphi^-(a) \tag{5}$$

Three main PROMETHEE tools can be used to analyse the evaluation problem: (1) PROMETHEE I partial ranking, (2) PROMETHEE II complete ranking and (3) the GAIA plane. In PROMETHEE I, the partial ranking is obtained from the positive and negative outranking flows (see Formulas 3 and 4). In this respect, alternative (a) is preferred to alternative (b) if it has a high positive flow and a low negative flow. In some cases, the ranking of alternatives may be incomplete as PROMETHEE I allows indifference (both positive and negative flows are equal) and incomparability (alternative (a) scores high on a set of criteria on which (b) is weak and vice versa) situations. PROMETHEE II provides a complete ranking of the alternatives from the best to the worst one, which is based on the net preference flow (see Formula 5). The Geometrical Analysis for Interactive Aid (GAIA) plane provides a graphical representation in which the alternatives and their contributions to the criteria are displayed. Additionally, a decision stick can be used to further investigate the sensitivity of the results in function of weight changes (Brans and Mareschal, 1994).

The PROMETHEE methodology and outranking methods in general have several advantages over the MAUT approach (see Macharis et al., 2004). First of all, the PROMETHEE I method avoids trade-offs between scores on criteria, which is likely to happen in AHP. However, when the partial ranking is forced into a complete ranking of the alternatives (PROMETHEE II), detailed information might also get lost. Secondly, PROMETHEE achieves a synthesis indirectly and only requires evaluations to be performed of each alternative on each criterion. Conversely, in AHP, the synthesis builds directly on the information included in the evaluation matrix which might lead to a substantial amount of pairwise comparisons to be completed (De Brucker et al., 2004). Finally, outranking methods like PROMETHEE are better suited to perform extensive sensitivity analyses. On the other hand, PROMETHEE does not provide the possibility for constructing a ‘classical’ decision tree (yet only a ‘criteria hierarchy’ is possible), or specific guidelines to determine the weights.

As a result of the advantages and disadvantages of both methods, this study will apply AHP to structure the decision-making problem and to determine the weights. For the aggregation of the criteria, the ranking of the alternatives and sensitivity analyses, PROMETHEE will be used. Next section introduces the proposed AHP-PROMETHEE approach.

2.3. AHP-PROMETHEE

The proposed AHP-PROMETHEE approach (see Figure 1) consists of three main stages: (1) Data collection, (2) AHP and (3) PROMETHEE. In the first stage, the alternatives submitted for evaluation are identified **(step 1).** In **step 2**, the key objectives of the decision-makers are identified and translated into criteria on which the alternatives will be evaluated. The information gathered in steps 1 and 2 is then used in the second stage to set-up a hierarchical decision tree **(step 3).** In order to express a preference for the different criteria, weights are allocated in **step 4.** For this purpose, the decision making software Expert Choice, based on Saaty's AHP is used. In the third stage, preference functions and parameter values are determined to enable the measurement of the contribution of the alternatives to the criteria. With this information, the evaluation table is constructed in **step 5.** Afterwards, the alternatives are evaluated and ranked by means of partial ranking with PROMETHEE I and complete ranking with PROMETHEE II and the GAIA plane **(step 6).** Here, the PROMETHEE decision making software D-SIGHT is used. Special features of the software include the 'walking weights' or the construction of 'stability intervals' that allow to perform sensitivity analyses and to confirm the robustness of the results (**step 7).** Based on the information from PROMETHEE I, II, GAIA and the sensitivity analyses, recommendations towards the best compromise can be formulated **(step 8).**

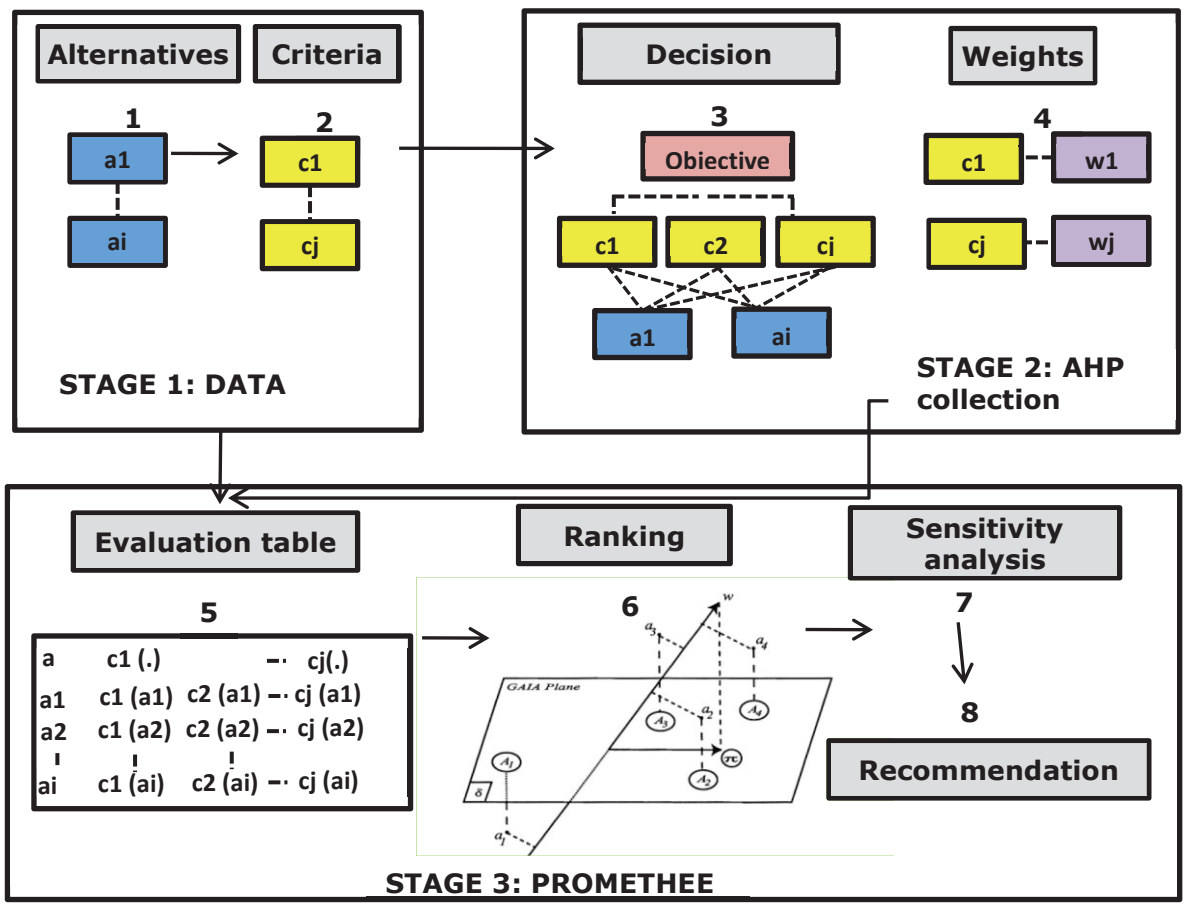


Figure 1: The proposed AHP-PROMETHEE approach

3. Application of the proposed methodology

The proposed methodology is applied in order to select the most appropriate multi-instrumentality package for the Belgian government in order to reduce environmental externalities by encouraging people to make a more sustainable vehicle choice. The MCA will be structured in three main stages: data collection, AHP and PROMETHEE.

3.1. Data collection

First, the possible alternatives submitted for evaluated are identified (**Step 1**). Here, an early involvement of stakeholders might not only stimulate discussions and help decision-makers to understand the problem, the priorities of themselves and of the involved stakeholders, but it will also considerably help to enhance the acceptance of the final result (Banville et al., 1998; French et al., 1993; Geldermann et al., 2005). In line with other studies (Bana E Costa, 2001; Scannella and Beuthe, 2003), stakeholder discussions have been organised to set up the framework. The stakeholder meetings gathered representatives from the supply side (e.g., car manufacturers, fuel industry), NGOs, consumer organisations, automobile clubs and policy makers. At the end of each reunion, a short questionnaire was administered to all representatives. A total of 40 participants evaluated a list of policy measures (drawn from an extensive literature review) regarding their perceived effectiveness (with respect to the stimulation of clean vehicles), feasibility (with respect to implementation) and priority (urgency of the measure) on a 3-point rating scale. The sample consisted of 19 members of the car manufacturing industry, 9 members from user-organisations and 12 policy makers. Responses were weighted according to the distribution of the different stakeholder groups. Based on the mean scores attributed to 'effectiveness', 'feasibility' and 'priority', three scenarios were conceived: a baseline, realistic and progressive scenario (see Table 3 for an overview). The 'baseline scenario' is defined as the situation with no additional measures taken on top of the currently existing and planned legislation. In the 'realistic scenario', the baseline scenario is supplemented with a number of new measures which were averagely perceived as being both very effective and feasible, and to which most of the stakeholders attributed a certain level of priority. In the 'progressive scenario', measures are mainly selected upon their perceived effectiveness, and less upon their feasibility and priority.

The next step includes the identification of the evaluation criteria (**Step 2**). The criteria and subcriteria were identified within the evaluator's team and validated by representatives of the Belgian government. The definition of the (sub)criteria is listed below.

Environmental effectiveness is defined as the effectiveness of the considered scenario to improve the environmental performance of the transportation system. The assessment under this criterion is based upon its ability to reduce CO_2, NO_x and PM emissions *(fleet emissions)* and to improve the global environmental performance of the Belgian vehicle fleet *(average Ecoscore)*.

Impact on mobility refers to the impact that the considered scenario may have on car use. The assessment of the scenarios under this criterion happens along two sub-criteria. The *amount of km driven* determines the extent in which a scenario might reduce the amount of kilometres driven, whereas *modal choice* investigates how it might positively affect the use of other transportation modes, such as public transport.

Feasibility is defined as the aggregate applicability of the scenarios in terms of their *financial feasibility, technical feasibility and socio-political acceptance. Financial feasibility* refers to the economic efficiency of the scenario in terms of overall implementation costs, *technical feasibility* determines the technical complexity regarding the need for additional infrastructure and changes on the administrative level and *socio-political acceptance* refers to the distributional consequences that may arise in the implementation phase of the scenario.

Table 3: Overview of the policy packages

Baseline scenario
Euro emission standards (e.g. Euro 5 and Euro 6)
Maximum average CO_2 treshold for car manufacturers by 2015 (e.g. 130 g CO_2/km)
Mandatory introduction of biofuels as from 2013 (5% biodiesel and 5% ethanol)
Gradual introduction of CO_2 as coolant in mobile air conditioning systems as from 2011 (Dir. 2006/40/EC)
Mandatory quota for green public fleets
Realistic scenario
Vehicle taxation system based on CO_2 and Euro standard instead of power (kW) and cylinder capacity (CC)
Advantages for early-complying-Euro 6 vehicles
Clean fuel standardization and availability (e.g. CNG, E85)
Change in excise duties (equal excise duties for diesel and petrol cars, exemption of excises for clean fuels)
Subsidies for retrofitting old (Euro 3 and Euro 4) diesel vehicles with particulate filters
Subsidies for converting vehicles to cleaner fuel systems (LPG and CNG)
Progressive scenario
Vehicle taxation system based on the Ecoscore† and no longer on the combination CO_2/Euro standard
Abolishment of circulation tax in favour of a time-, place- and Ecoscore dependent kilometre charge
Limited access to environmental zones in large Belgian cities (> 70.000 inhabitants), dependent on the Ecoscore
Mandatory green private fleet quota: 40% of company car purchases needs to reach a minimal Ecoscore
Scrappage scheme: premium rewarded for a switch to a vehicle with a higher Ecoscore

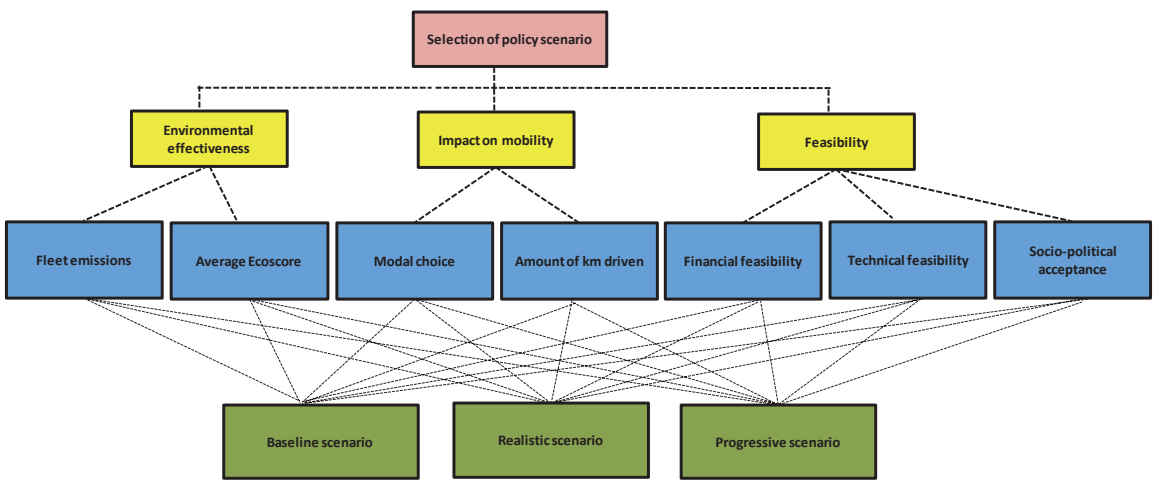


Figure 2: Hierarchical decision tree

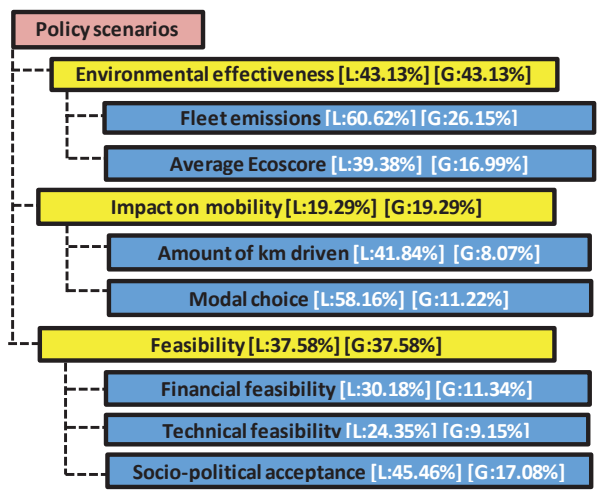
† The Ecoscore is an environmental rating tool, based on a well-to-wheel framework, that allows the evaluation of the environmental impact of road vehicles with different drive trains and using different fuels. The Ecoscore makes it possible to calculate an environmental score for each vehicle ranging from 0 to 100. The higher the score, the more environmental friendly the vehicle is. This methodology has been developed by Vrije Universiteit Brussel (ETEC), VITO and Université Libre de Bruxelles (Timmermans et al., 2006).

3.2. AHP

Based on the information gathered from the first stage, the hierarchical decision tree (Figure 2) is constructed that highlights the multiple criteria and subcriteria on which the baseline, realistic and progressive scenario will be evaluated (**step 3).**

In **step 4**, the criteria are assigned weights, based on the AHP procedure (see Table 4). For this purpose, the decision making software Expert Choice based on Saaty's AHP method was used. This gave the opportunity to the involved stakeholders to indicate their preference intensity for a specific pair of criteria. Table 4 gives the results obtained from the weight distribution. As different members within a stakeholder group were consulted, the geometric mean is calculated to bring the evaluations together (suggestion of Saaty (1995)). Overall, environmental effectiveness gets the highest preference (43%), followed by feasibility (38%) and impact on mobility (19%).

Table 4: Weight distribution. *Note: "L" denotes the local priorities calculated for a single level of objectives or sub-objectives that are situated directly below an objective or sub-objective in the hierarchy. "G" denotes the global priorities which refer to the priority with respect to the entire hierarchy. Source: Comparion TM Suite*



3.3. PROMETHEE

In this stage, the three scenarios (baseline, realistic, progressive) are evaluated in terms of their contribution to the criteria. With this information, the evaluation matrix is constructed (**step 5**, see Table 5). The valuation of the 'feasibility' criteria and 'impact on modal choice' is difficult to quantify and their valuations are based upon literature reviews and brainstorm sessions within the evaluators' team. For this purpose, a 5-point qualitative scale ranging from 1 (very low impact) to 5 (very high impact) has been applied. For other criteria ('fleet emissions', 'average Ecoscore', 'amount of km driven'), the valuation of the alternatives was obtained quantitatively, using the E-motion road model, developed at VITO (VITO, 2010). This model was used to make predictions on the fleet composition (number of cars), vehicle use (number of kilometres) and environmental impact (emissions and Ecoscores) for a short (2020) and medium (2030) timeframe.

Subsequently, for each criterion, a specific preference function is selected and parameter values (Min./Max., see Table 5) are defined to compute the degree of preference associated to the best alternative in the pairwise comparison process (Brans and Mareschal, 1994). For quantitative assessments, the PROMETHEE guidelines advise to apply a linear preference function. For qualitative assessments, the Usual shape or the Level type can be selected. In this context, the Usual shape has been applied as it is the preferred choice in case of a small number of levels on the criteria scale (up to 5 point scale).

After the determination of the evaluation matrix and the preference functions, the scenarios are evaluated and ranked by means of the PROMETHEE decision making software, D-SIGHT **(step 6)**. The positive (φ^+) and negative

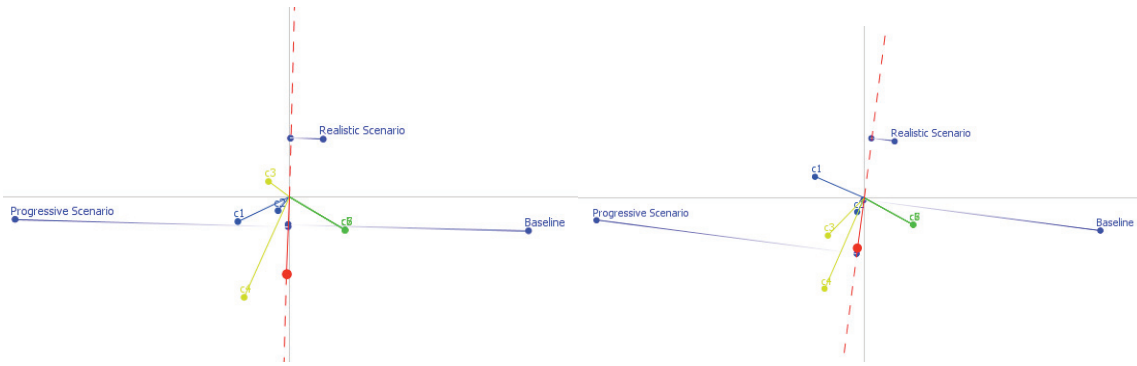
(φ^-) flows (PROMETHEE I) and the net flow (φ) values (PROMETHEE II) obtained from this evaluation are displayed in Table 6. The PROMETHEE II ranking, based on the net preference flow of the analysed alternatives shows that for both reference years (2020 and 2030), the progressive scenario outranks the baseline and the realistic scenario. Additionally, the decision problem is visualised in the GAIA plane (Figures 3 and 4), in which the 7-dimensional space of criteria is projected on a 2-dimensional plane by means of principal component analysis (PCA). In this plane, scenarios are represented by points and criteria by vectors. As a result, scenarios scoring high on a particular criterion are represented by points located in the direction of the corresponding criterion axis (Brans and Mareschal, 1994). The length of the criterion vector is a measure of its power to differentiate the different scenarios (Dagdeviren, 2008). The projection of the weights vector in the GAIA plane corresponds to another axis, i.e., the decision stick (red line), which provides an indication of the direction of the best scenario, given the weights allocated to the criteria (D-Sight manual, 2010).

Table 5: Evaluation matrix. Note: "B" = Baseline scenario; "R" = Realistic scenario and "P" = Progressive scenario

		Alternatives						
		Reference year 2020			**Reference year 2030**			
	Unit	**B**	**R**	**P**	**B**	**R**	**P**	**Max/Min**
Criteria								
Environmental Effectiveness								
Fleet emissions	%	100	94,37	81,2	100	90,57	69,22	Min.
Average Ecoscore	Ecoscore	69,16	69,59	71,65	73,73	73,77	75,43	Max.
Impact on Mobility								
Amount of km driven	%	100	97,46	95,13	100	97,88	90,62	Min.
Modal Choice	Qualitative	1	1	3	1	1	4	Max.
Feasibility								
Financial feasibility	Qualitative	5	3	1	5	3	2	Max.
Technical feasibility	Qualitative	5	4	2	5	4	3	Max.
Socio-political acceptance	Qualitative	5	4	2	5	4	3	Max.

Table 6: PROMETHEE I/II scores

Alternatives	Year	φ^+	φ^-	φ	Rank
Baseline	2020	0.376	0.315	0.061	2
Realistic	2020	0.275	0.402	-0.126	3
Progressive	2020	0.441	0.376	0.066	1
Baseline	2030	0.376	0.371	0.004	2
Realistic	2030	0.320	0.418	-0.098	3
Progressive	2030	0.469	0.376	0.094	1



Figures 3 and 4: GAIA plane for reference years 2020 and 2030. Notes: c1 = Fleet emissions, c2 = Average Ecoscore, c3 = Amount of km driven, c4 = Modal choice, c5 = Financial feasibility, c6 = Technical feasibility and c7 = Socio-political acceptance. The delta-value for both visualizations is 100%, which means that no information got lost by the projection

Stability level : 1

Criteria	Min Weight	Value	Max Weight
Fleet emission (CO2eq/NOx/PM)	25,9%	26,1%	100,0%
Average Ecoscore	15,9%	17,0%	100,0%
Amount of km driven	7,4%	8,1%	100,0%
Modal Choice	10,9%	11,2%	100,0%
Budgetary Impact	0,0%	11,3%	11,6%
Technical Feasibility	0,0%	17,1%	17,3%
Socio-political Acceptance	0,0%	9,2%	9,4%

Stability level : 1

Criteria	Min Weight	Value	Max Weight
Fleet emission (CO2eq/NOx/PM)	22,7%	26,1%	100,0%
Average Ecoscore	0,0%	17,0%	100,0%
Amount of km driven	1,9%	8,1%	100,0%
Modal Choice	5,6%	11,2%	100,0%
Budgetary Impact	0,0%	11,3%	15,1%
Technical Feasibility	0,0%	17,1%	20,6%
Socio-political Acceptance	0,0%	9,2%	13,0%

Figures 5 and 6: Stability intervals for reference years 2020 and 2030, respectively. Note: The stability level of 1 denotes that the first scenario (progressive scenario) is considered.

Out of Figures 3 and 4, it is observed that "impact on modal choice" has a high differentiating power and represents indifferent preferences as compared to the other criteria. Moreover, the environmental effectiveness criteria clearly conflict with the feasibility criteria. A scenario that performs well with respect to "fleet emissions" and "average Ecoscore", will perform worse with respect to financial, technical and socio-political feasibility and vice versa (in case of the progressive and baseline scenario). The decision axis reveals that for 2030, the progressive scenario is clearly the best compromise, followed by the baseline and realistic scenario. However, for 2020, both the progressive and baseline scenario appear to be good solutions according to the attributed weights. Given these results, it is of particular interest to perform sensitivity analyses (**step 7**). When the decision-maker is not able or willing to allocate precise weights to the criteria, "stability intervals" can provide an indication of the range in which the criteria weights can be varied without affecting the PROMETHEE II complete ranking. Figures 5 and 6 display the lower bound, current value and the upper bound of the criterions' weights for the reference years 2020 and 2030. The green colours, attributed to the "environmental effectiveness" and "mobility" criteria, indicate that the weights can be modified over a large interval (up to 100%), without altering the absolute outranking performance of the progressive scenario. The orange colours, attributed to the "feasibility" criteria indicate that weights can almost not (for 2020) or slightly (for 2030) increase, if the outranking performance of the progressive scenario should be preserved. In other words, if the decision-maker attributes a higher importance to "feasibility" (from 49% onwards), the baseline scenario might become the most preferred scenario for 2030. These sensitivities should be taken into consideration when deciding on which scenario to implement (**step 8**).

4. Conclusions

The aim of this paper is to formulate recommendations towards decision-makers in order to select the most appropriate multi-instrumentality policy package to stimulate a clean vehicle fleet. For this purpose, an integrated approach of AHP and PROMETHEE has been proposed, in which the strengths of both methodologies are combined in a single MCA tool. AHP has been used to set up the hierarchical decision tree and to determine criterion weights and hence represent trade-offs between criteria in PROMETHEE, which did not provide any formal guidelines for weighing up to now. On the other hand, PROMETHEE enriches AHP by associating a preference function to each criterion. Moreover, for analysing the decision problem, several PROMETHEE tools can be used. PROMETHEE I is based on partial ranking and avoids potential trade-offs between good and bad scores on criteria, which often occur in complete aggregation methods such as AHP. In some cases, the partial preorder of the alternatives may be incomplete due to indifference or incomparability issues and further evaluation efforts are required. PROMETHEE II provides a complete ranking of the alternatives from the best to the worst one. The GAIA plane enables a graphical representation of the alternatives and criteria and helps to explore the weak and strong points of the different policy options. Additional tools such as the decision axis or stability intervals can be used to extensively evaluate the direction of the best compromise in function of weight changes.

In the application under consideration, three policy scenarios, namely baseline, realistic and progressive are evaluated on three criteria groups: environmental effectiveness, feasibility and impact on mobility. The integrated AHP-PROMETHEE approach revealed that “environmental effectiveness” and “feasibility” appear to be conflicting criteria. The baseline scenario, which performs well with respect to enhancing the financial, technical and socio-political feasibility, will perform worse with respect to minimising fleet emissions and increasing the environmental performance (Ecoscore) of the vehicle fleet. The opposite is true for the progressive scenario. Given the attributed weights (environmental effectiveness: 43%, feasibility: 38%, impact on mobility: 19%), both the baseline and progressive scenario appear to be good compromises for 2020. For 2030, the progressive scenario is clearly the best solution to stimulate a clean vehicle fleet. However, when feasibility becomes more important to the decision-makers (from 49% onwards), the baseline scenario will be the most preferred scenario for 2030. The sensitivity possibilities of PROMETHEE should be carefully considered when deciding on which scenario to implement.

This paper examined the long-term impact of several policy scenarios in a static way. In further research, strategies towards long-term goals should be identified based on their contribution to control the very dynamic behaviour of the complex socio-economic system. For this purpose, the principles of System Dynamics, Control theory and the proposed AHP-PROMETHEE approach can be combined (see also Brans et al., 1998).

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