CLEVER
Clean Vehicle Research

WP7

Multi-Criteria Analysis

CLEVER
Clean Vehicle Research

Multi Criteria analysis: method, analysis and results
Task 7.1

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Table of contents

Figures

Tables

1 Introduction

The purpose of this task is to perform an evaluation of the different scenarios that have been set up through tasks 5.2 and 5.3. : the baseline, realistic and progressive scenario. By means of a multi criteria analysis (MCA), these scenarios will be evaluated on several criteria for which input has been gathered throughout the other tasks of the CLEVER project. For this purpose, a combination of the PROMETHEE GAIA methodology and the Analytic Hierarchy Process (AHP) is used. The overall aim is not to categorize the single best scenario, but to formulate suitable policy recommendations to the decision makers. Section 2 introduces the applied methodology for the evaluation task, section 3 presents the stepwise procedure of the MCA and section 4 concludes.

2 Methodology

MCA techniques can be used to identify a single most preferred option, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities. The main role of these techniques is to deal with the difficulties that human decision-makers have in handling large amounts of complex information in a consistent way. Typically, most decision problems have a multi criteria nature and refer to several concerns at the same time: technological, economical, environmental, social etc. As there is no alternative optimizing all the criteria at the same time, a compromise solution should be selected. In this task, the MCA Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) has been used, which has been developed by Brans (1982) and by Macharis, Brans and Marechal (1998). The PROMETHEE method has been applied successfully in several domains covering topics such as environment, hydrology and water management, business and financial management, chemistry, logistics and transportation, energy management etc. (Behzadian et al., 2009).

A typical MCA procedure consists of several steps:

1. Identification of the problem and selection of the alternatives **(STEP 1)**
2. Translation of the objectives (concerns) into several criteria **(STEP 2)**
3. Quantification of the relative importance of each criterion (weights) **(STEP 3)**
4. Assessment of the performance of each alternative to the identified criteria **(STEP 4)**
5. Categorization of the alternatives based on their performance contribution to the criteria (**STEP 5**). Table 1 presents the overall performance matrix, where the aggregation of each alternative contribution to the objectives is shown. a_1 to a_n represent the potential alternatives submitted for evaluation. g_1 to g_k are the evaluation criteria.
6. Sensitivity analysis **(STEP 6)**

Table 1: The PROMETHEE performance matrix (Brans and Marechal, 1994)

a	$g_1(\cdot)$	$g_2(\cdot)$	$\cdots$	$g_j(\cdot)$	$\cdots$	$g_k(\cdot)$
a_1	$g_1(a_1)$	$g_2(a_1)$	$\cdots$	$g_j(a_1)$	$\cdots$	$g_k(a_1)$
a_2	$g_1(a_2)$	$g_2(a_2)$	$\cdots$	$g_j(a_2)$	$\cdots$	$g_k(a_2)$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$
a_i	$g_1(a_i)$	$g_2(a_i)$	$\cdots$	$g_j(a_i)$	$\cdots$	$g_k(a_i)$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$
a_n	$g_1(a_n)$	$g_2(a_n)$	$\cdots$	$g_j(a_n)$	$\cdots$	$g_k(a_n)$

The advantage of using PROMETHEE here with respect to other MCA methods is that in the end it provides an overall ranking of the different alternatives with respectively positive and negative outranking flows expressing how an alternative is outranking or outranked by the other alternatives submitted for evaluation. With regard to the representation of the latter, several variations of the PROMETHEE method exist: (1) PROMETHEE I partial ranking, where both the positive and negative outranking flows are presented; (2) PROMETHEE II complete ranking, where a net outranking flow is presented based on the balance between the positive and negative outranking flows and (3) the Geometrical Analysis for Interactive Aid (GAIA) plane, that provides a graphical representation of the position of the alternatives relative to the various criteria. A disadvantage of using PROMETHEE is that it does not provide a specific method according to which the weights are to be determined (Macharis et al., 2004a). There exist several methods for determining the weights: direct rating, point allocation, trade-off, pairwise comparisons etc. The latter procedure, developed by Saaty (1980), proves to be very interesting in this case. 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. That is why in this task the PROMETHEE method will be combined with the decision making software Expert Choice, based on Saaty's analytical hierarchy process (AHP). For the PROMETHEE method, the decision support software D-SIGHT is used.

3. MCA procedure

Step 1: Defining the problem and the alternatives

The first stage consists of identifying the possible alternatives submitted for evaluation. In this case, the alternatives to be evaluated are the scenarios that have been set up in task 5.3 of the CLEVER project and consist of a baseline, realistic and progressive scenario. The description of these scenarios is listed herein.

- **Baseline scenario**

    - **EURO 5 and EURO 6 for passenger cars.** These emission limits come respectively into force in September 2009 and September 2014 for new type approval for passenger cars. They are introduced in January 2011 and September 2015 for the first registration of previously type-approved vehicle models.

    - **CO_2 legislation for new passenger cars.** By 2015, car manufacturers will have to reduce the CO_2 emissions of passenger cars to 130 g/km, with an additional 10 g/km coming from additional measures such as biofuels (CO_2 reduction of 5%), driving behaviour (CO_2 reduction of 1%) and environmentally friendly tires (CO_2 reduction of 1,7%).

    - **Biofuels.** From 2013, a volume percentage of 5% biodiesel and 5% ethanol is taken into account (gradual introduction).

    - **European directive 2006/40/EC** prohibits the use of HFC-134a as coolant in mobile air conditioning systems from 2011 for new type approvals and from 2017 for all new vehicles. The alternative R744 system with CO_2 as coolant is taken into account in this scenario for all new vehicles from 2011.

    - **Mandatory green public fleet quota.** Several governmental levels have already implemented green public fleet quota. In case of the Brussels Capital Region, the Flemish Region and the Federal Government, the environmental performance is defined based on the Ecoscore.

- **Realistic mid-term scenario (**= based on baseline scenario + extra measures):

    - **Definition of a clean vehicle:** based on CO_2 emissions and EURO standard.

    - **Tax system based on CO_2 and EURO standard.** A reformation of the registration tax (RT) and annual circulation tax (ACT). It is assumed that (1) vehicles emitting less than 105 g CO_2/km and using alternative fuels or propulsion technologies (category A) will face a minimum RT and ACT of 50 Euro (2) vehicles emitting less than 105 g CO_2/km and using conventional fuels (category B) will also face an RT and ACT of 50 Euro (3) vehicles emitting 105-115 g CO_2/km (category C) will face a RT and ACT of 500 Euro and (4) vehicles emitting > 115 g CO_2/km (category D) will face a RT and ACT of 1000 Euro. These tax levels are assumed to come into force in 2015, remaining constant for at least 15 years.

- **Advantages for EURO 6 vehicles.** To stimulate the replacement of older vehicles, an advantage of 200 Euro will be given in the period 2010-2014 for the purchase of new vehicles complying with the EURO 6 standard.

- **Clean fuels and standardization.** A standardization of clean fuels, such as E85 is foreseen.

- **Change in excise duties.** Starting from 2015, excise duties of diesel will rise up to the amount of excises to be paid for petrol fuel (61,36 Eurocent/L). As a result, the diesel price will rise up to 1,50 Euro/L. Excises on cleaner fuels (E85, other biofuels, CNG, LPG, electricity) are assumed to be 0.

- **Subsidies for retrofitting diesels with PM-filters.** The subsidy will be limited to 500 Euro and considered for 5 years (2011-2015).

- **Subsidies for retrofitting petrol cars with LPG systems.** This subsidy will be limited to 500 Euro and considered for 5 years (2011-2015).

* **Progressive long-term scenario** (= based on realistic scenario + extra measures):

  - **Definition of a clean vehicle**: based on the Ecoscore

  - **Tax system based on Ecoscore.** A reformed RT, based on the Ecoscore. It is assumed that (1) vehicles emitting less than 105 g CO_2/km and using alternative fuels or propulsion technologies (category A) will correspond to vehicles with Ecoscores > 75. As a result, these vehicles will be exempted from paying a RT, (2) vehicles emitting less than 105 g CO_2/km and using conventional fuels (category B) correspond to vehicles with an Ecoscore between 73 and 75. As a result, they get a minimum RT of 50 Euro, (3) vehicles emitting 105-115 g CO_2/km (category C) correspond to vehicles with an Ecoscore between 70 and 72. As a result, they will be faced with a RT of 500 Euro and (4) vehicles emitting > 115 g CO_2/km (category D) correspond to vehicles with an Ecoscore lower than 70. As a result, they will be faced with a RT of 1000 Euro. This reformed tax system is assumed to be introduced in 2015.

  - **Kilometre charge.** Besides a reformed RT, an abolishment of the ACT will happen in favour of a kilometre charge, dependent on location, time and individual Ecoscore. Table 2 gives an overview of the assumed kilometre charging levels (on a yearly basis) for the different vehicle categories, which each correspond to the Ecoscores as specified above.

Average annual km charge (€)	ecoscore category			
Year	A	B	C	D
2010	268	268	268	268
2015	200	200	400	400
2020	200	200	400	400
2025	200	400	600	600
2030	200	400	600	600

Table 2. **Simulated kilometre charge on a yearly basis (**source: CLEVER task 5.3).
Note: vehicle category A corresponds to vehicles emitting less than 105 g CO_2/km and using alternative fuels or propulsion technologies, vehicle category B corresponds to vehicles emitting less than 105 g CO_2/km and using conventional fuels, vehicle category C corresponds to vehicles emitting 105-115 g CO_2/km and vehicle category D corresponds to vehicles emitting > 115 g CO_2/km. These vehicle categories have been initiated in the CLEVER survey, elaborated in task 3.2 (2) to measure the shift of consumers to environmentally friendlier vehicles as a result of several pricing measures.

- **Limited access zone.** A limited access zone will be established in Belgian cities with more than 70,000 inhabitants. It is assumed that from 2015, vehicles with Ecoscore < 70 (category D) will be banned from city centers. From 2020, vehicles with Ecoscores 70-72 (category C) will be banned and from 2030, vehicles with Ecoscore 73-75 (category B) will be prohibited to enter the limited access zone. Here, a toll level of 30 Euro/entrance is considered as a ban.

- **Mandatory green private fleet quota.** It is assumed that at least 40% of the newly purchased company cars need to have a minimum Ecoscore as mentioned in table 3 below.

Year	Minimal ecoscore for 40% of company car fleet
2015-2019	70
2020-2029	74
2030	80

Table 3: Mandatory green private fleet quota based on Ecoscore

- **Scrappage scheme.** For switches from vehicles with Ecoscore 73-75 (category B), Ecoscores 70-72 (category C) and Ecoscore < 70 (category D) to vehicles with Ecoscores > 75 (category A), a premium of 2000 Euro will be given in the period 2015-2019.

Step 2: Defining criteria

The choice and definition of the criteria (and sub-criteria) is primarily based on expert meetings with the CLEVER consortium. Out of previous tasks of the CLEVER project, it is clear that the stimulation of cleaner vehicles into the end-user market by means of several policy measures is related to many concerns: environmental (see task 2: LCA and task 4.1: External costs), budgetary (see task 3: LCC) and feasibility concerns (see task 4.2: social barriers and task 5.2 stakeholder support). That is why it is important to integrate these aspects in the evaluation process of the several scenarios listed above. Overall, the scenarios will be evaluated based on environmental effectiveness, impact on mobility and feasibility, each having their own subcriteria:

1. **Environmental effectiveness** (= environmental performance of the scenarios)

    a. **Fleet emissions (CO_2 eq./NO_x/PM):** the scenarios will be evaluated based on their efficiency in reducing the CO_2/NO_x/PM emissions of the Belgian vehicle fleet.

    b. **Average Ecoscore:** the scenarios will be evaluated based on the positive impact that they might have on the average Ecoscore of the Belgian vehicle fleet through time.

2. **Impact on mobility** (= impact of the scenarios on car use)

    a. **Amount of kms driven:** the scenarios will be evaluated based on the extent in which they may reduce the amount of kilometres driven by the Belgian vehicle fleet.

    b. **Modal choice:** the scenarios will be evaluated based on the extent in which they might positively affect the use of other transportation modes, such as public transport.

3. **Feasibility** (= technical, financial and socio-political feasibility of the proposed scenarios)

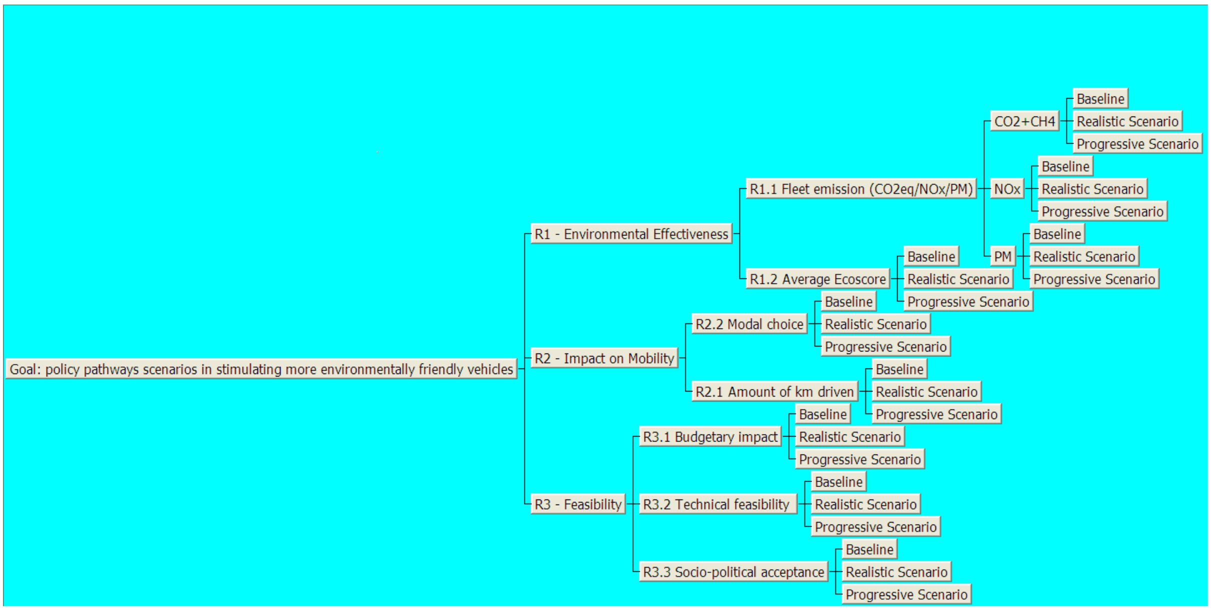
    a. **Budgetary impact:** the scenarios will be evaluated based on the initial costs related to the implementation of the whole package.

    b. **Technical feasibility:** the scenarios will be evaluated based on their technical complexity with respect to the need of additional infrastructure, changes on the administrative level etc.

    c. **Socio-political acceptance:** the scenarios will be evaluated based on their acceptance and support by the public.

With this information, an hierarchical decision three can be set up (see Figure 1) in which the multiple criteria and subcriteria are highlighted on which the baseline, realistic and progressive scenario will be evaluated.

Figure 1: Final decision three



Step 3: Allocation of weights to the criteria

In order to express preferences for the different criteria, weights are allocated. For this purpose, the decision making software Expert Choice based on Saaty's analytical hierarchy process (AHP) was used. Figure 2 shows a screenshot of the online survey, in which the CLEVER consortium as well as members of the CLEVER follow-up committee had the opportunity to indicate their preference intensity for a specific pair of criteria in a user friendly environment. By means of the rectangular bars, one could attach different gradations of importance to the criteria, ranging from extremely more important to extremely less important. Overall, 20 respondents provided weights (5 from the CLEVER consortium and 15 from the CLEVER stakeholders).

Figure 2: Screenshot of Expert Choice software based on Saaty' s AHP.

Note: Here, as an example, it was asked to attribute an importance with respect to the subcriteria fleet emissions and average Ecoscore which are part of the higher-level criteria group: environmental effectiveness

Figure 3 gives the overall results of the weight distribution for the different (sub) criteria. As different people (CLEVER consortium + CLEVER stakeholders) were consulted, the geometric mean is calculated to bring the evaluations together (suggestion of Saaty (1995)).

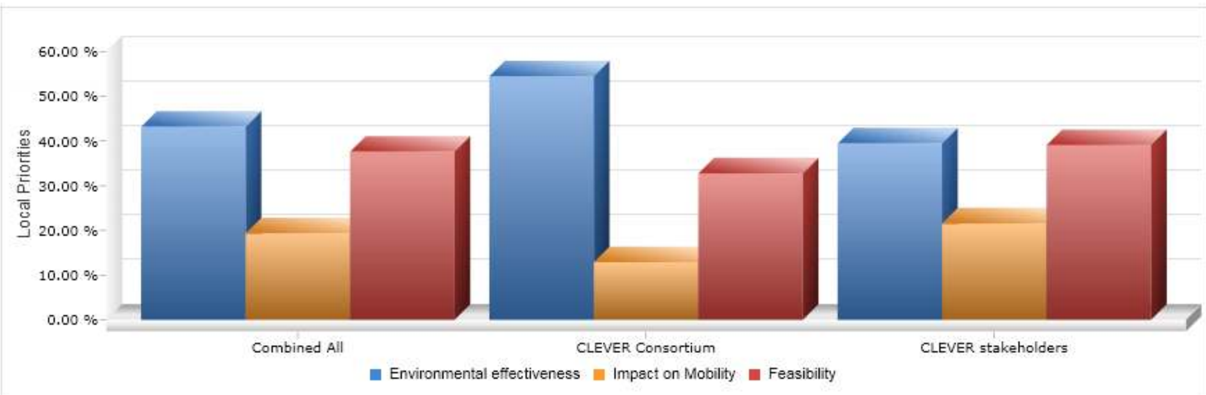
Figure 3: Weight distribution.

Note: "L" refers to local priorities which refer to the 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" refers to global priorities refer to the priority with respect to the entire hierarchy.

- **Policy pathways scenarios in stimulating more environmentally friendly vehicles**
  - Environmental effectiveness [L:43.13 %][G:43.13 %]
    - Fleet emission (CO2eq/NOx/PM) [L:60.62 %][G:26.15 %]
    - Average Ecoscore [L:39.38 %][G:16.99 %]
  - Impact on Mobility [L:19.29 %][G:19.29 %]
    - Amount of km driven [L:41.84 %][G:8.07 %]
    - Modal Choice [L:58.16 %][G:11.22 %]
  - Feasibility [L:37.58 %][G:37.58 %]
    - Budgetary impact [L:30.18 %][G:11.34 %]
    - Technical feasibility [L:24.35 %][G:9.15 %]
    - Socio-political acceptance [L:45.46 %][G:17.08 %]

Overall, it is shown that environmental effectiveness get the highest preference (43%), followed by feasibility (38%) and impact on mobility (19%). A deeper insight in the weight contribution by the different groups (CLEVER consortium & CLEVER stakeholders) is provided by Figure 4. It demonstrated that both groups have the same absolute ranking of the criteria, but environmental effectiveness clearly gets a higher weight by the CLEVER consortium than by the CLEVER stakeholders, for which feasibility is almost equally important.

Figure 4: Local priorities by the different consulted groups

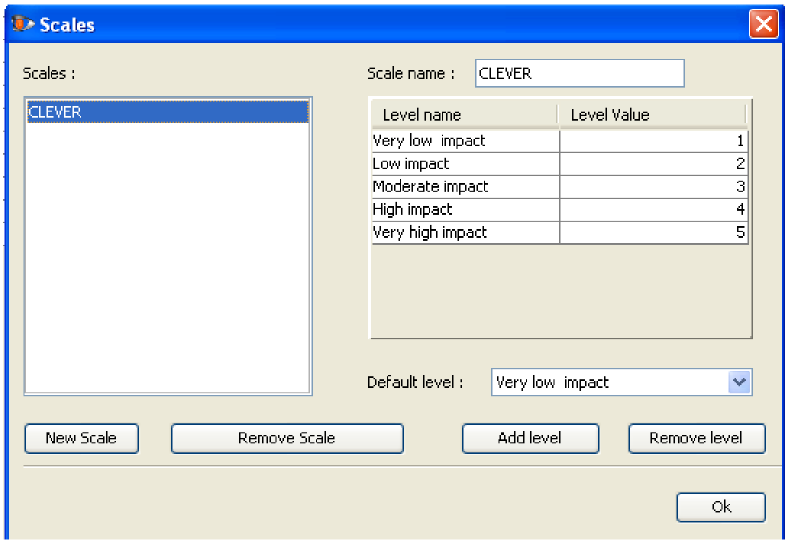


Step 4: Performance assessment

In this step, the previously identified criteria are "operationalized" by constructing indicators that can be used to measure whether, or to what extent, each alternative contributes to each individual criterion. Indicators can be quantitative as well as qualitative. In this analysis, the performance assessments have been made by the CLEVER project team (Vrije Universiteit Brussel, VITO and ULB). By letting expert assign the performance values, a scientific and solid foundation in the evaluation process of the alternatives (here: scenarios) is provided. In accordance with task 6: fleet analysis, the different scenarios will be compared for the years 2020 and 2030.

The following tables show an overview of the subcriteria, the indicators that have been built, the measurement method that has been chosen to measure the performance of each alternative with respect to the individual subcriterion (qualitative or quantitative) and the performance calculations. In case of qualitative performance assessments, the following scale has been used (see Figure 5)

Figure 5: Qualitative CLEVER scale in D-sight



Note that high scores are given when the respective scenario scores the best with respect to a specific criterion. If, for example, the aim is to have low initial implementation costs (budgetary impact), than a high qualitative score means that the potential implementation costs will be rather low. In reverse, if the aim is to stimulate the use of other transportation modes (modal choice), a high score indicates that the respective scenario contributes the best to evoking a shift in transportation towards other modes.

1.a Fleet emission (CO_2 eq/NO_x/PM)

Indicator: Compound emission indicator (€)
Measurement method: Quantitative
Reference: CLEVER task 6: fleet analysis, De Vlieger et al. (2011)
Performance measurement: The contribution of the scenarios (baseline, realistic and progressive) to the fleet emissions is first based upon their contribution to the TTW emissions of respectively CO_2 eq (see Figure 6), PM2,5 (see Figure 7) and NO_x (see Figure 8), expressed in kg. Then, the 3 pollutants are weighted by their external cost per kg (in €/kg) in order to construct the compound emission indicator, expressed in Euro (see Table 4).

Figure 6: TTW emissions CO_2 eq

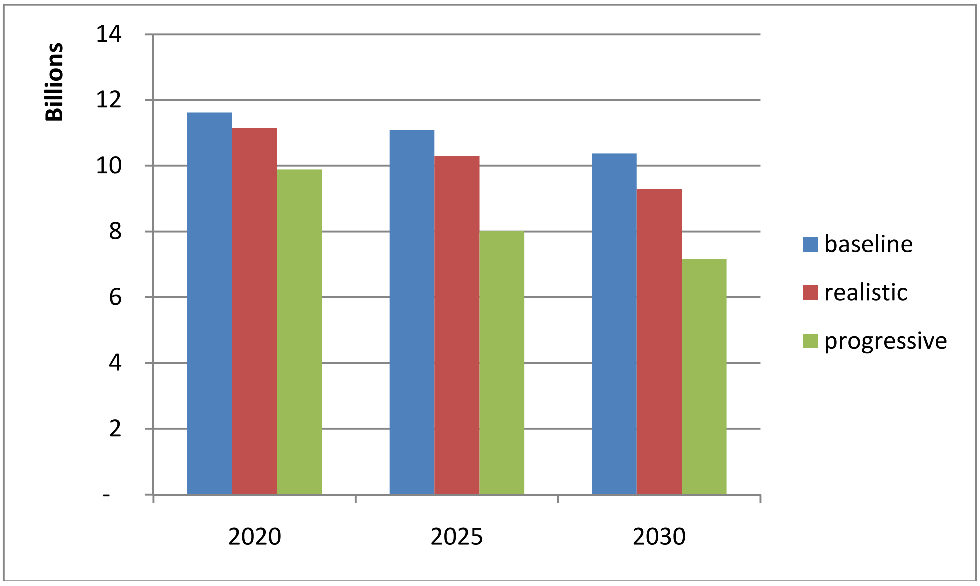


Figure 7:TTW emissions of PM 2,5

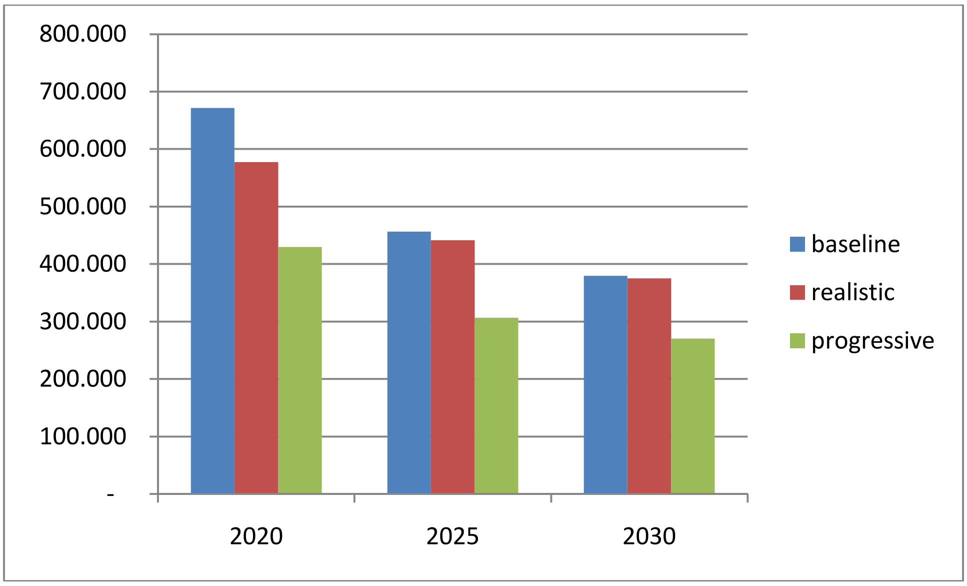
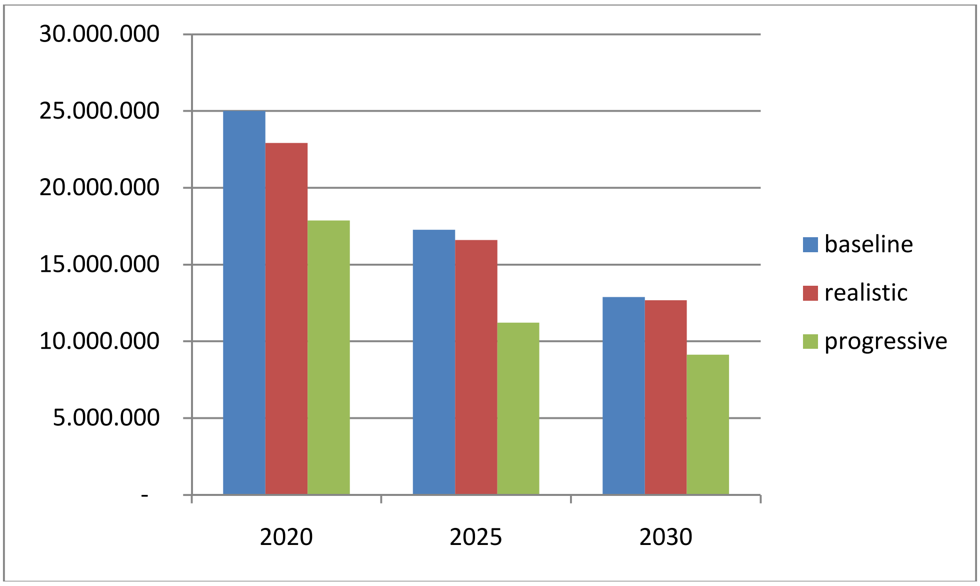


Figure 8: TTW emissions of NO_x



Out of Figures 6 to 8, it is clear that the progressive scenario contributes the most to the reduction of the TTW emissions of CO_2 eq, $PM_{2,5}$ and NO_x. Besides the absolute release of these emissions, it is important to take their respective relevance to the external costs caused by transport into account. For this purpose, an external cost of 111,9 Euro/kg is considered for $PM_{2,5}$; 2,5 Euro/kg for NO_x and 0,042 Euro/kg for CO_2 eq. These are the external cost predictions for 2020, to be found in Annex 2 of the final report of the BELSPO project Limobel (De Vlieger et al., 2011). Based on the TTW emissions (kg) * external costs (Euro/kg), the compound external cost indicator (Euro) is constructed, see table 4 below.

Table 4: Compound emission indicator (in Euro)

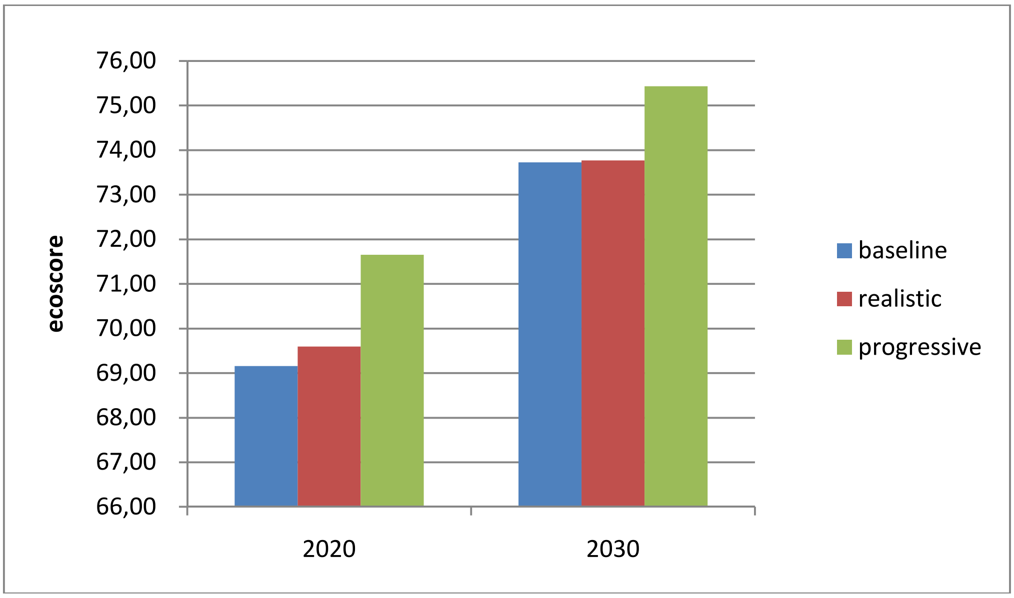
Timeframe	Baseline	Realistic	Progressive
2020	624.884.832	589.720.168	507.436.088
	100%	**94,37%**	**81,20%**
2030	663.162.976	600.641.503	459.066.993
	100%	**90,57%**	**69,22%**

Based this table, one can see that the progressive scenario is expected to deliver the greatest reductions in fleet emissions with respect to the other scenarios. These reductions even become bigger in 2030.

1.b Average Ecoscore

Indicator: Average weighted Ecoscore. The Ecoscore for each car is weighted by the (predicted) number of kilometres driven. This indicator gives a better idea of the overall performance of Belgian passenger cars.
Measurement method: Quantitative
Reference: CLEVER task 6: fleet analysis
Performance measurement: see Figure 9

Figure 9: Average Ecoscore of the Belgian vehicle fleet

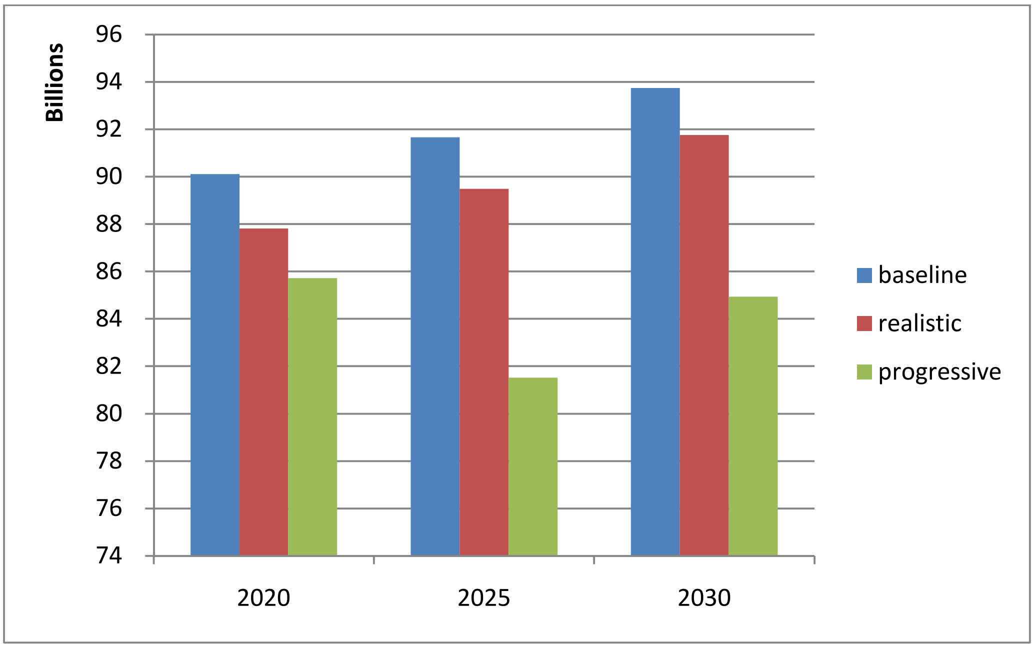


From Figure 9, it is clear that the progressive scenario provides a substantial benefit as compared to the baseline and realistic scenario (71,65 versus 69,16 and 69,59 in 2020 and 75,43 versus 73,73 and 73,77 in 2030) with respect to its contribution to a better average Ecoscore of the Belgian vehicle fleet.

2.a Amount of kilometres driven

Indicator: Kilometres driven
Measurement method: Quantitative
Reference: CLEVER task 6: fleet analysis
Performance measurement: see Figure 10

Figure 10: Kilometres driven in Belgium



Out of Figure 10, it is seen that the total number of kilometres driven in Belgium is expected to rise under the baseline and realistic scenario over the period 2020-2030. On the other hand, the total number of kilometres under the progressive scenario is declining over this period. Compared to the baseline scenario (set at 100%), the progressive scenario performs thus better in minimizing the amount of kilometres driven in Belgium (95,13% in 2020; 90,62% in 2030) than the realistic scenario (97,46% in 2020; 97,88% in 2030).

2.b Modal choice

Indicator: Use of other transportation modes
Measurement method: Qualitative
Reference: Expert judgments (VITO, MOSI), CLEVER task 5.3
Performance measurement: see Table 5

Table 5: Impact on modal choice

Scenario	Explanation	Score 2020	Score 2030
Baseline	**Limited impact on modal choice.** The current policy measures are not intended to impact modal choice.	**1**	**1**
Realistic	**Limited impact on modal choice.** Reformed taxation rather effects car ownership than car use. The same is true for subsidies. Only the change in excise duties might affect vehicle use of diesel drivers, but will not necessarily steer consumers towards the use of public transport.	**1**	**1**
Progressive	**Higher impact on modal choice.** Limited access zones will prohibit the entrance of polluting vehicles and only allow clean vehicles in urban cities. So other transportation modes will be used to enter the city. Kilometre charges might affect vehicle use too and will reduce the number of trips by car in favour of trips by other transportation modes. On the longer term, this affect might even become bigger.	**3**	**4**

3.a. Budgetary impact

Indicator: Implementation cost
Measurement method: Qualitative
Reference: CLEVER task 3.1, CLEVER task 5.3, Timmermans et al., 2005, expert judgments (MOSI, VITO)
Performance measurement: see Table 6

Table 6: Implementation cost

Scenario	Explanation	Score 2020	Score 2030
Baseline	**No additional implementation cost**	**5**	**5**
Realistic	**Higher implementation cost related to** - Subsidies for LPG & PM - Exemption excises for clean fuels - (Reformed RT & ACT can be designed budgetary-neutral) - (Mandatory quota can be gradually introduced with the renewal rate of the vehicle fleet)	**3**	**3**
Progressive	**Substantial implementation cost related to** - Km charge: infrastructure & enforcement costs - Limited access zone: infrastructure & enforcement costs - Uncertainty about fiscal income in initial stage - (Reformed RT & ACT can be designed budgetary-neutral) - Impact is more moderate in 2030 compared to 2020 thanks to the experience in the field of implementing these measures.	**1**	**2**

3.b. Technical feasibility

Indicator: Changes with respect to infrastructure and administrative issues
Measurement method: Qualitative
Reference: Expert judgments (VITO)
Performance measurement: see Table 7

Table 7: Technical feasibility

Scenario	Explanation	Score 2020	Score 2030
Baseline	**No fundamental changes** These policy measures are actually administered at Belgian level	**5**	**5**
Realistic	**Only small changes with respect to administrative issues**	**4**	**4**
Progressive	**Large changes** Infrastructure, enforcement, administrative issues mainly for the kilometre charge. Impact is expected to be more moderate in 2030 as by then experience has been built up in these fields (also in other countries)	**2**	**3**

3.c. Socio-political acceptance

Indicator: Socio-political acceptance
Measurement method: Qualitative
Reference: CLEVER report task 4.2, Expert judgments (ULB)
Performance measurement: see Table 8

Table 8: Socio-political acceptance

Scenario	Explanation	Score 2020	Score 2030
Baseline	**No acceptance problems** These policy measures are actually administered at Belgian level and imply no fundamental or sharp changes in habits or infrastructures used. Will be well accepted by the population and consequently by politicians.	**5**	**5**
Realistic	**Small acceptance problems** Acceptance of reformed RT & ACT will mainly depend on distributional issues that may arise (social equity). Mandatory quota for public fleets might give a good example ("leadership by example") and will induce infrastructure developments.	**4**	**4**
Progressive	**Larger acceptance problems** Kilometre charge is not a popular measure, as it might arise distributional issues and might be perceived as "unfair" as people living far away from their job might be severely punished. Moreover, limited access zones are perceived as an antisocial measure. Lastly, taxation based on Ecoscore might be less popular than based on another environmental indicator as it is not yet known. Again, socio-political opposition might be lower in 2030 as one gets more used to these innovative concepts and indicators.	**2**	**3**

Step 5: Categorization of alternatives

Table 9 first displays the PROMETHEE performance matrix in which all qualitative and quantitative assessments of the scenarios with respect to the criteria are summarized. One can see that the progressive scenario scores the best with respect to the criteria "environmental effectiveness" and "impact on mobility". It is best suited to minimize "fleet emissions" and "amounts of kilometres driven" and to maximise the "average Ecoscore" of the Belgian vehicle fleet and the encouragement towards other modes of transportation ("modal choice"). The progressive scenario is also found to be more optimal in the reference year 2030, than in 2020. It however scores less regarding its "feasibility". With respect to this criterion, the baseline scenario gets the highest overall score, followed by the realistic scenario.

		Alternatives						
		Scenarios-Reference year 2020			Scenarios-Reference year 2030			
	Unit	**Baseline**	**Realistic**	**Progressive**	**Baseline**	**Realistic**	**Progressive**	**Parameters**
Criteria								
Environmental Effectiveness								
Fleet emission (CO_2eq/NOx/PM)	%	100	94,37	81,2	100	90,57	69,22	Minimise
Average Ecoscore	Ecoscore	69,16	69,59	71,65	73,73	73,77	75,43	Maximise
Impact on Mobility								
Amount of km driven	%	100	97,46	95,13	100	97,88	90,62	Minimise
Modal Choice	Qualitative	1	1	3	1	1	4	Maximise
Feasibility								
Budgetary Impact	Qualitative	5	3	1	5	3	2	Maximise
Technical feasibility	Qualitative	5	4	2	5	4	3	Maximise
Socio-political acceptance	Qualitative	5	4	2	5	4	3	Maximise

Table 9: Overview of the quantitative and qualitative assessments.
Note: the numerical and qualitative scores refer to the performance assessments made in step 4 (see above).

For the overall assessment and ranking of the scenarios, the PROMETHEE decision making software, D-SIGHT, has been used. This software will combine the weight allocation, performed by the CLEVER consortium and CLEVER stakeholders (see step 3) with the performance valuation of the alternatives, assigned by the experts (see step 4). A complete ranking of the scenarios is shown in Figures 11 (for reference year 2020) and 12 (for reference year 2030), which is based on the net outranking flow (= balance between the positive and negative outranking flows in D-SIGHT).

Figure 11: PROMETHEE ranking results for 2020

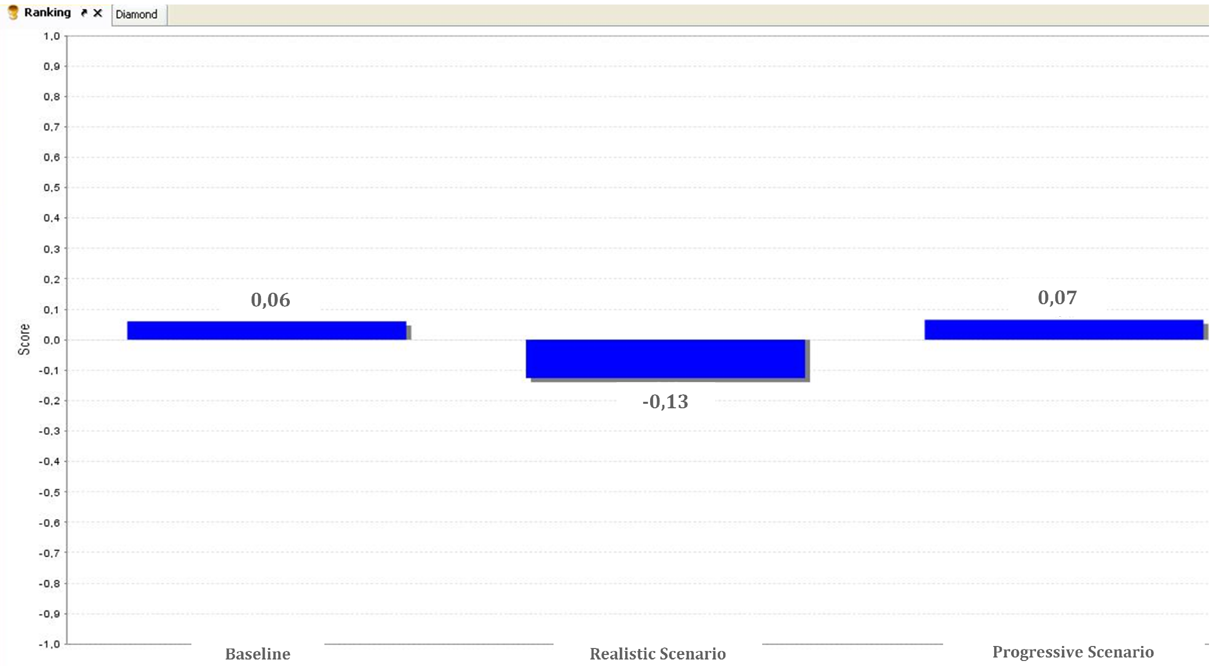
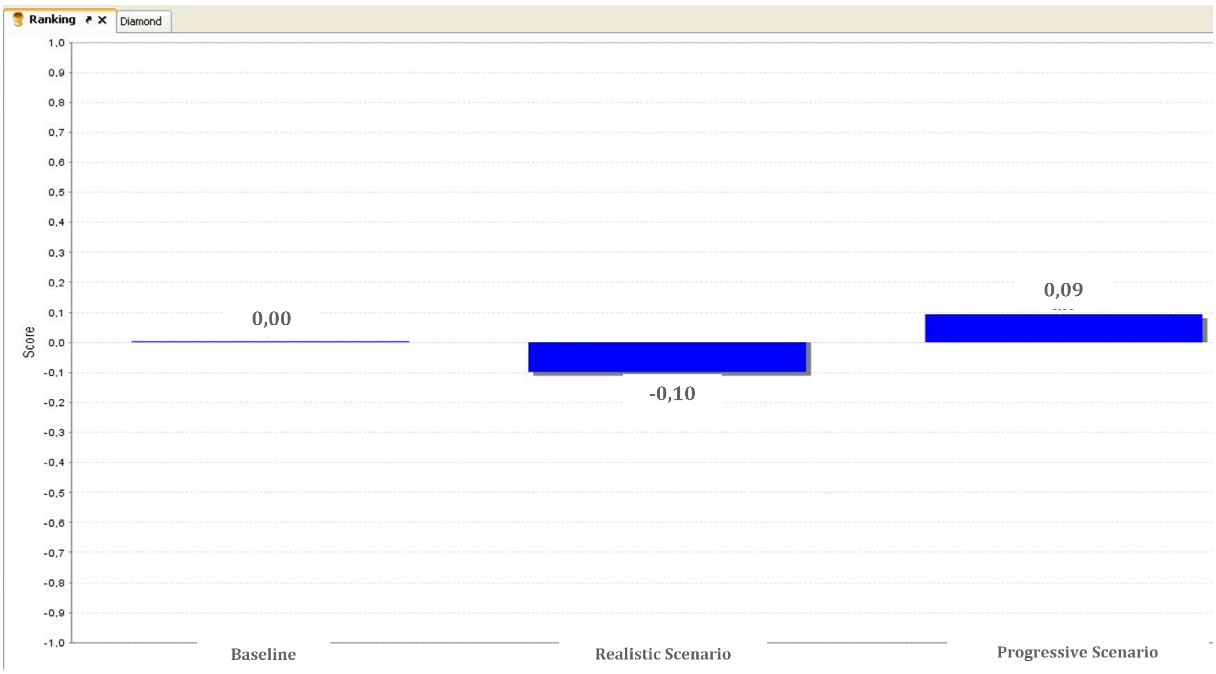


Figure 12: PROMETHEE ranking results for 2030



The net flow as presented in the figures indicates the difference between the positive flows (F+) and the negative flows (F-) into a single rating in the [-1, + 1] interval. Positive flows (F+) measure the extent in which an alternative is preferred to another one in the [0,1] interval. A value of 0 indicates that the alternative is not preferred to another one, while a value of 1 indicates that an alternative is totally preferred to another one. The inverse is true for the negative flow (F-).

Based on these net outranking flows, one can thus see that for the reference year 2020, the progressive scenario is ranked the highest, followed by the baseline scenario and the realistic scenario. The same is true for the reference year 2030, where the distance between the first (progressive) and second ranked (baseline) scenario even gets bigger. The high ranking of the progressive scenario in 2020 and 2030 is mainly attributable to its high performance on the "environmental effectiveness" criterion, and the fact that this criterion also got the highest importance out of the weight allocation. It also shows the best performance with respect to "impact on mobility". However, this scenario will also be the most difficult one to implement and will get less support by all involved actors ("feasibility"). More important than the absolute ranking of the scenarios, is thus the fact that an insight is provided in the strong and weak points of the considered scenarios.

These weak and strong points are also visualized in Figures 13 (reference year 2020) and 14 (reference year 2030) by means of the PROMETHEE GAIA plane. In this plane, the scenarios are represented as points. As the number of criteria is larger than two, it is impossible to get a clear view of the relative position of the points with regard to the criteria. That is why the information is projected in a 3-dimensional plane, where the points represents the alternatives and the axes represent the criteria. Alternatives scoring high on a particular criterion are represented by points located in the direction of the corresponding criterion axis (Brans and Marechal, 1994). For example, it is shown that the progressive scenario is located in the direction of "environmental effectiveness" and "impact on mobility", as this scenario performs well with respect to these criteria. Additionally, a kind of decision stick is introduced (represented by the red line), which is the weighted resultant of all the criterion axes. By means of this decision stick, the relative position of the alternatives in terms of contributions to the various criteria can be demonstrated. Out of Figure 13, the progressive as well as the baseline scenario are closely located in the direction of the decision axis, whilst the difference between these two alternatives becomes more clear in Figure 14.

Figure 13: PROMETHEE GAIA plane for reference year 2020

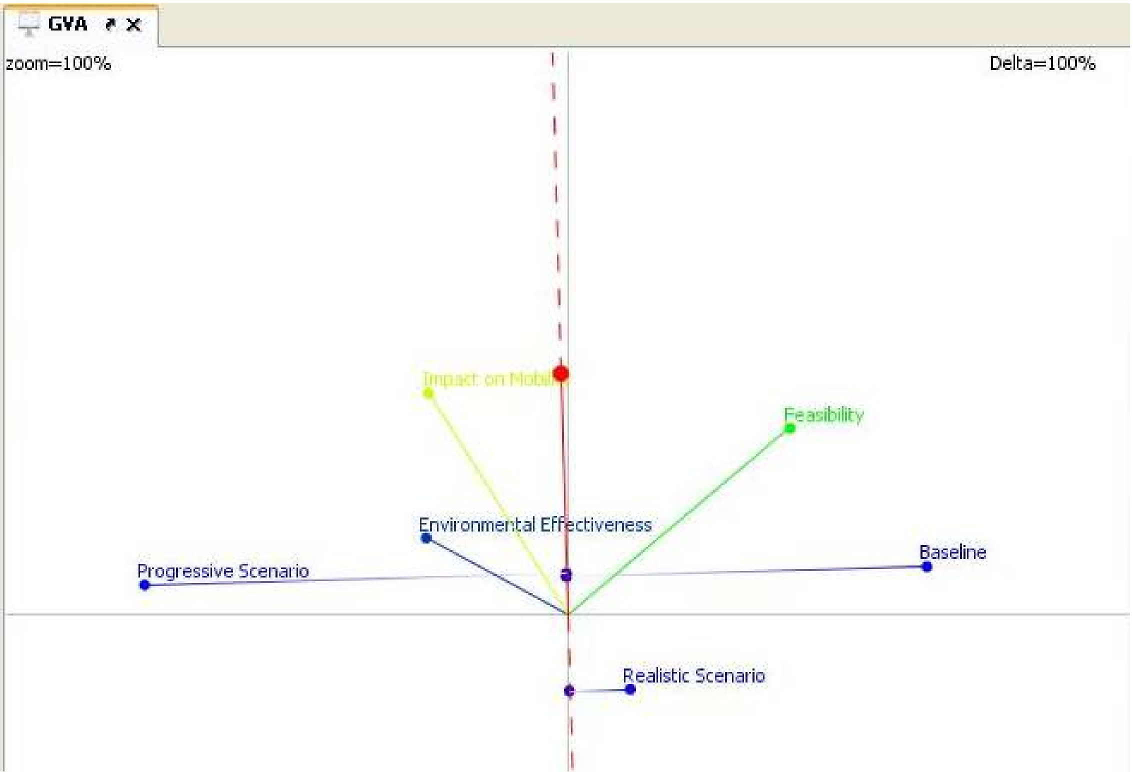
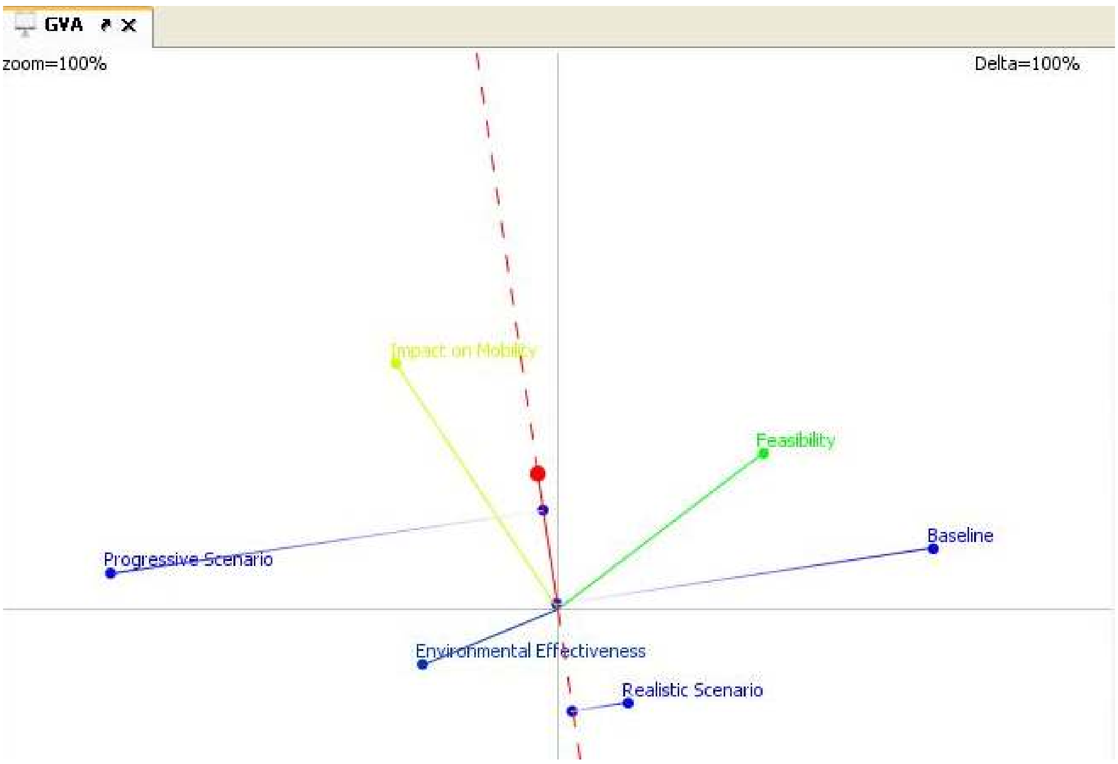


Figure 14: PROMETHEE GAIA plane for the reference year 2030



Step 6: Sensitivity analysis

The overall ranking of the scenarios, elaborated in step 5, is noticeably influenced by the established weights attributed to the criteria groups and the subcriteria. Before finalizing a decision, it is recommended to simulate different weight distributions to assess the robustness of the results when the weights are modified (Brans and Marechal, 1994). For this purpose, PROMETHEE provides additional tools such as the "walking weights" to further analyse the sensitivity of the results in function of weight changes (Macharis et al., 2004b). Figures 15 and 16 show the ranking results when the weight of the "feasibility" criterion is increased from 38% (initial weight) up to 50% (new weight). From this figures, it is clear that if "feasibility" is of mayor importance to the decision-makers, the progressive scenario will be outranked by the baseline and the realistic scenario.

Figure 15:PROMETHEE ranking before sensitivity analysis (feasibility = 38%)

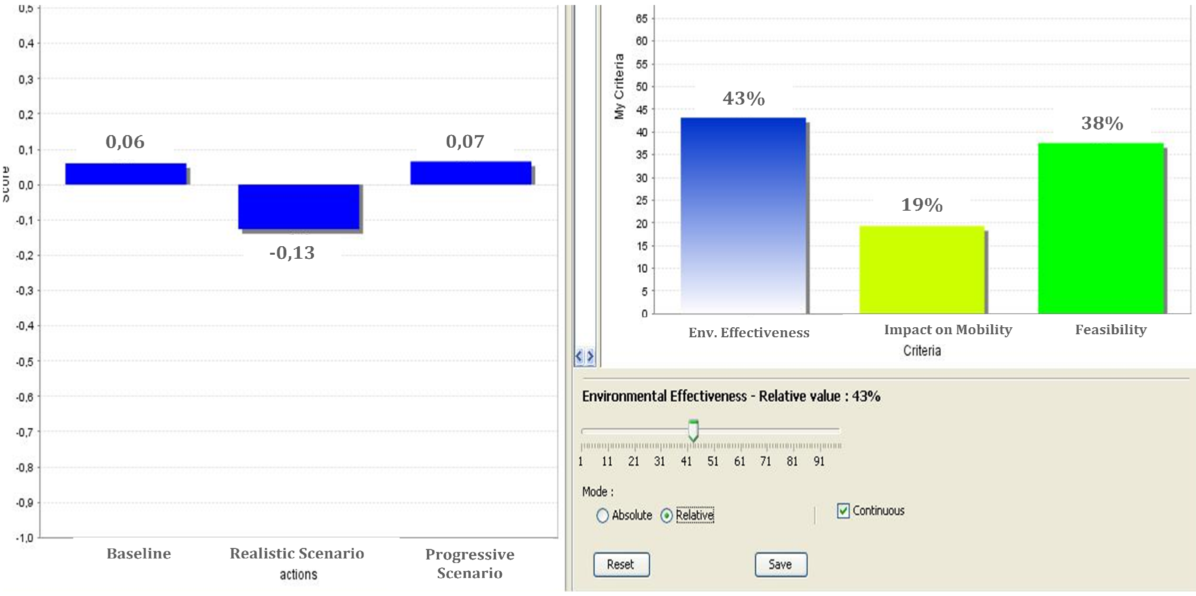
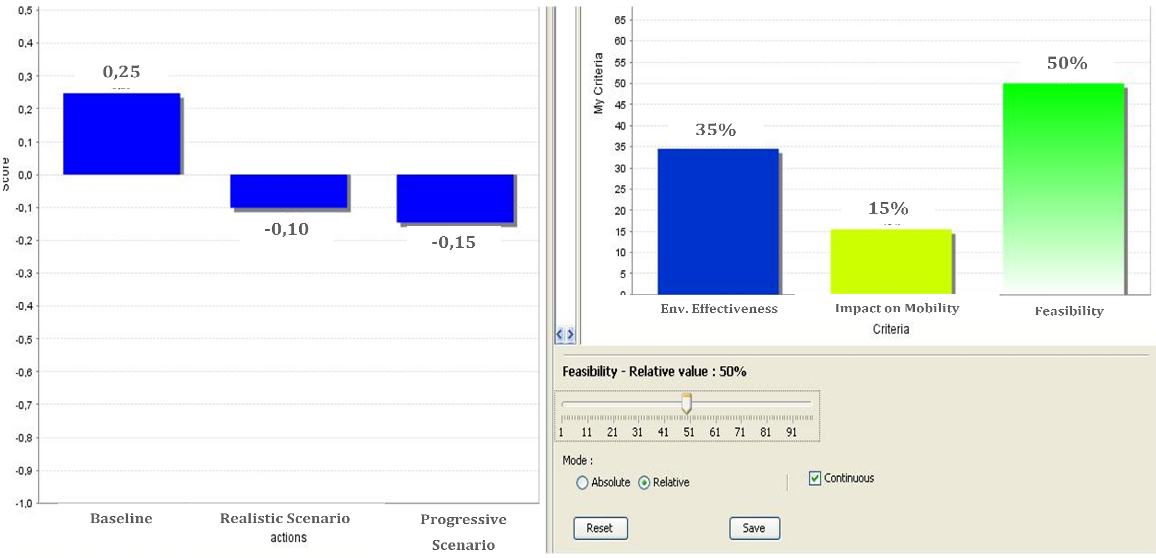


Figure 16: PROMETHEE ranking after sensitivity analysis (feasibility = 50%)



4 Conclusion

In this task, a combination of the PROMETHEE methodology and AHP has been used to evaluate the predefined CLEVER scenarios: baseline, realistic and progressive, on several criteria for the reference years 2020 and 2030. The identified criteria are based on the many concerns to which the stimulation of cleaner cars into the end-user market by means of policy measures refer, namely “environmental effectivenss”, “impact on mobility” and “feasibility”. By means of weight allocation, the CLEVER consortium and CLEVER stakeholders valued the “environmental effectiveness” criterion as most important one (43%), followed by feasibility (38%) and impact on mobility (19%). The performance assessment subsequently showed that the progressive scenario is particularly suited to minimize “fleet emissions” and “amounts of kilometres driven” and to maximize the “average Ecoscore” of the Belgian vehicle fleet and the encouragement towards other modes of transportation (“modal choice”). However, this scenario scores less with respect to its technical, budgetary and socio-political feasibility. The overall ranking of the scenarios, where not only the performance assessments, but also the relative weights of the criteria were taken into account, confirms the absolute ranking of the progressive scenario, followed by the baseline and the realistic scenario. The absolute importance of the progressive scenario especially becomes clear in the reference year 2030. More important than this absolute ranking is the insight that is gained in the strong and weak points of the considered scenarios. If, for example, feasibility becomes the mayor concern for policy makers, than the progressive scenario is clearly outranked by the baseline and realistic scenario. These sensitivities should be taken into consideration when deciding on which scenario to implement.

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