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Article

A Road Network for Freight Transport in Flanders: Multi-Actor Multi-Criteria Assessment of Alternative Ring Ways

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Abstract: Even though road transport is an essential part of freight distribution, there is a lack of customized routing networks to convey freight over the road. The present paper addresses this deficit by proposing general principles to elaborate a regional freight route network in Flanders. However, assigning regional freight traffic to a particular road network involves complex trade-offs between multiple interests, such as corporate accessibility, communal livability, additional network links and available space. The paper recommends the multi-actor multi-criteria assessment tool (MAMCA) to incorporate stakeholder objectives in the evaluation of possible freight network scenarios. The tool is applied for the specific case of Anzegem, a road village amid regional freight attraction poles that suffers particularly from heavy freight flows. The impact of four alternative ring ways is assessed according to the interests of the involved parties and compared to the reference scenario. Results show that transport companies advocate supra-local accessibility, while governmental and citizen stakeholders value traffic safety and livability. Since the reference scenario does not comply with these critical stakeholder objectives, an alternate scenario is proposed. As such, MAMCA applications assist policy-makers in building consensus among multiple actors in the realization of transportation projects.

Keywords: sustainable truck routing; road infrastructure; heavy transport externalities; multi-criteria analysis; stakeholder participation

1. Introduction

Despite several strategies to enhance the modal shift of freight transport, the amount of European road tonne-kilometres is predicted to increase from 1711 billion in 2005 up to 2812 billion in 2050, maintaining a modal share of 40% [1]. These inevitable facts require research on truck road infrastructure and the impact of the freight that they convey.

A particular body of research determines how the separation of cars and trucks can contribute to road capacity, by implementing truck lanes, truck-only roads and pricing strategies [2–6]. Other authors have investigated truck driver perceptions towards the impact of heavy freight flows [7–9]. Several additional studies specify technical design requirements, *i.e.*, road pavement material, load factor, lane width and road alignment, in order to reduce road maintenance costs of heavy freight traffic [10–12]. Still, as Hubsneider [13] and Arentze *et al.* [14] point out in their contribution to navigation systems for trucks: there is a lack of information on preferred truck routing networks with customized dimensions to convey heavy freight flows. The present study addresses this deficit by proposing theoretical principles to elaborate a regional freight route network for Flanders. Moreover, multiple authors contributed to sustainable logistics by assessing the performance of product design, supply, production and distribution (see [15] for an overview). As such, several methodologies are used to determine the negative impact of logistical developments. Life-Cycle Assessments are generally used to evaluate the manufacturing process [16] or the supply chain [17]. Still, other methods like Material Recyclability in Product Design [18] and surveys to identify practices in Green Procurement [19] have been used. With respect to freight transport infrastructure, the Social Cost-Benefit Analysis [20] is commonly conducted to identify the societal net benefit of the infrastructural investment. This paper applies a participatory Multi-Criteria Analysis to assess the impact of freight transport infrastructure. By analyzing the practical case of a regional freight route connection in Flanders, lessons have been gleaned on how to establish a freight route network in a densely populated region characterized by a dispersed spatial structure.

The introductory section of the paper proceeds with the problem of excess freight traffic and identifies the interests at stake in assigning regional freight traffic to a particular road network. Section 2 renders structural principles to construct a regional freight route network, while specifying the Flemish context. Next, a participatory assessment methodology is proposed to determine the impact of alternative freight route scenarios (Section 3), which is applied for the specific case of Anzegem (Section 4). The contribution of the methodology to participatory decision-making constraints is discussed in Section 5. Finally, Section 6 concludes the main findings of the paper.

1.1. Generic Road Infrastructure

Roads are generally categorized according to three traffic functions: facilitating traffic flows on macro level (through roads), vehicle distribution on meso level (distributor roads), or providing access on micro level (access roads). According to several authors, each function should be homogeneously fulfilled to systematize safe and efficient vehicle circulation [21,22]. This functional traffic homogeneity involves a hierarchical road structure, where similar types of vehicles (*i.e.*, heavy freight) are allocated to designate roads under a particular speed regime [23].

So, road design and road layout are crucial instruments to compel functional traffic homogeneity. Recognizable road design (e.g., lane width; roadside objects) enhances correct driver behavior and improves the interaction between vehicles, other road users and the environment [24,25]. Still, heavy freight is currently carried throughout the entire hierarchical network, regardless of the function and layout of the road. Not every road can however serve as a proper freight route to convey the three general truck categories as defined by the OECD, *i.e.*, workhorse vehicle (<50 t and <22 m), high capacity vehicle (<70 t and <30 m) and very high capacity vehicles >52 t and >30 m) [26]. Hence, trucks should be designated to a preferential network with credible and custom dimensions to preclude negative externalities from freight flows.

The grid of through roads consists of the most suitable freight-carrying layout (lane width 3.75–3.50 m) and offers the quickest connection between international freight attraction poles (e.g., sea and airports) and/or regional freight attraction poles (e.g., business parks and industrial zones). Distributor and access roads (lane width 3.30–2.75 m) ideally harbor only destination freight traffic considering their regional insignificance [27]. Still, particular regional attraction poles, located non-contiguously to the customized road grid, designate freight transport to distributor (or secondary) roads and throughout sensitive areas (e.g., inner cities and residential communities). The mixed traffic functions on these roads evoke tensions between residential livability and corporate accessibility.

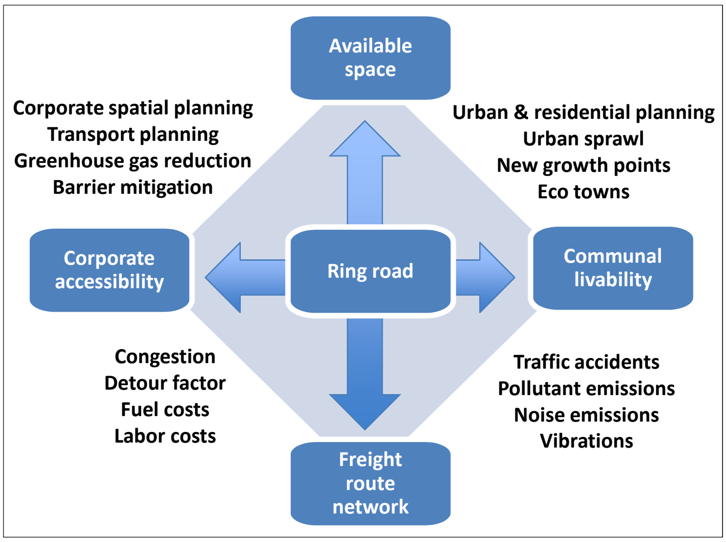
1.2. Network Deficits

Assigning regional freight transport to a particular road network requires the selection of suitable freight roads, the determination of dominant freight flows and the identification of affected tension areas. A crucial trade-off in this assignment is the equilibrium between corporate accessibility and communal livability. Meeting both needs is ideally the most eligible solution. Hence, ring way infrastructure can in particular cases be used as an alternative to maintain full access to regional business parks and industrial zones, while reducing the impact of heavy freight flows on inner cities and residential communities.

Supplementary network links entail however an additional trade-off between the existing network extension and the available space. Figure 1 illustrates the trade-offs in assigning regional freight to a particular route network in the context of a network extension, by means of two reciprocal arrows. The upper rectangle axes between the trade-offs demonstrate environmental properties, while the economic and social effects are depicted on the lower axes.

Specific studies determine the positive influence of ring road infrastructure on central areas [28–31]. By-pass traffic benefits public livability by augmenting traffic safety and reducing noise and pollutant exhaust emissions, while improving transit travel time. The main contribution of the present paper is to assess how alternative ring way scenarios complete regional freight routing networks, while balancing socially acceptable, economically feasible and ecologically justifiable trade-offs. To illustrate this evaluation framework, the particular case of Anzegem will be examined according to a participatory assessment methodology.

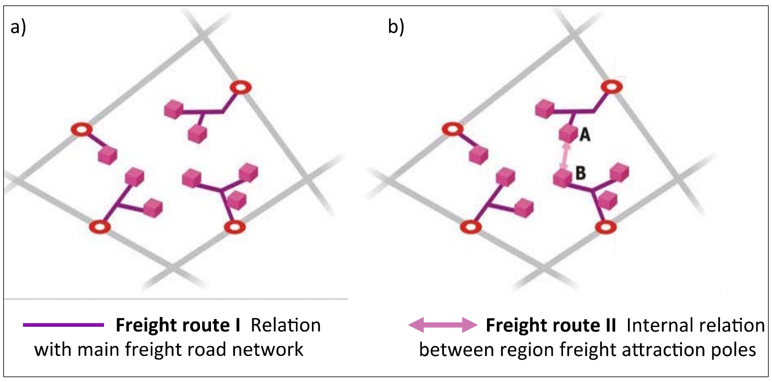
Figure 1. Framework for ring road extension in the context of a sustainable freight route network.



2. Constructing a Regional Freight Route Network in Flanders

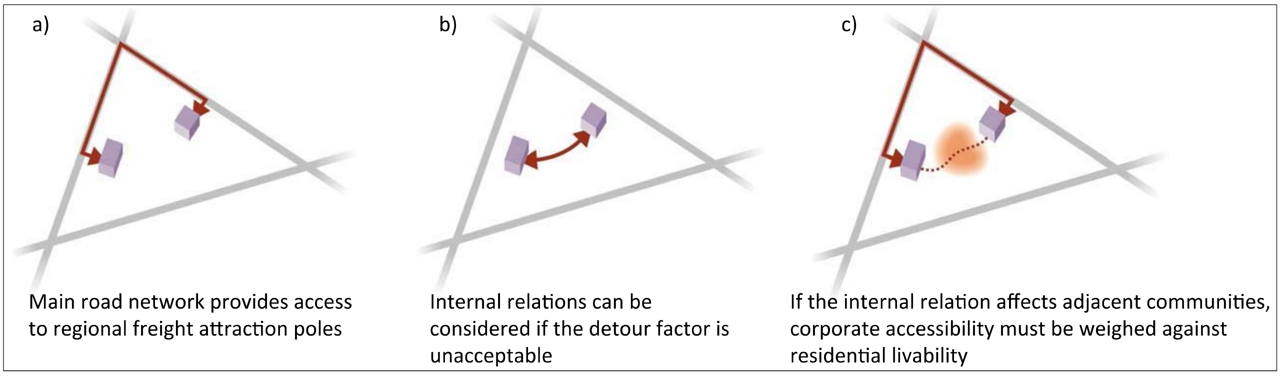
The freight network in Flanders is hierarchically structured according to three levels [32]. Main freight routes (through roads) on the highest-level harbor freight flows between the international freight attraction poles. Freight routes type I (distributor and access roads) connect regional freight attraction poles with main freight routes. Freight routes type II (distributor and access roads) cover only internal relations between two regional freight attraction poles when there is no freight route type I or main freight route available. Figure 2 illustrates the later regional freight road types. The functionalities of the regional freight network comprise: connecting regional attraction poles with the main road network (freight route I, Figure 2a); collecting regional freight traffic between the local level and the main network (freight route I, Figure 2a); and channeling regional freight flows if alternatives on the main road network are deficient (freight route II, Figure 2b).

Figure 2. Regional freight routes and relation with the main freight road network (Source: [32]).



The first two regional network functionalities are inevitable in the supply chain. Still, the later channeling function between the attraction poles (Figure 3b) can only be accepted when the detour factor (deviated route divided by the shortest route) over the main network is unacceptable (Figure 3a). Pertinent indicators to determine the acceptable detour factor are: effective distance in kilometers, travel time in minutes, kilometers costs and traffic safety [32]. An internal channeling relation can only be considered if the detour factor on the main network exceeds 1.3 for hinterland connections or 1.4 for regular connections, under a mesh size of 40 km [27]. The travel time and related kilometer cost throughout the internal freight route (type II) is required to be considerably lower, while collision probability ought to decrease. Still, channeling freight on regionally insignificant roads results quite often in pressure on adjacent communities (Figure 3c).

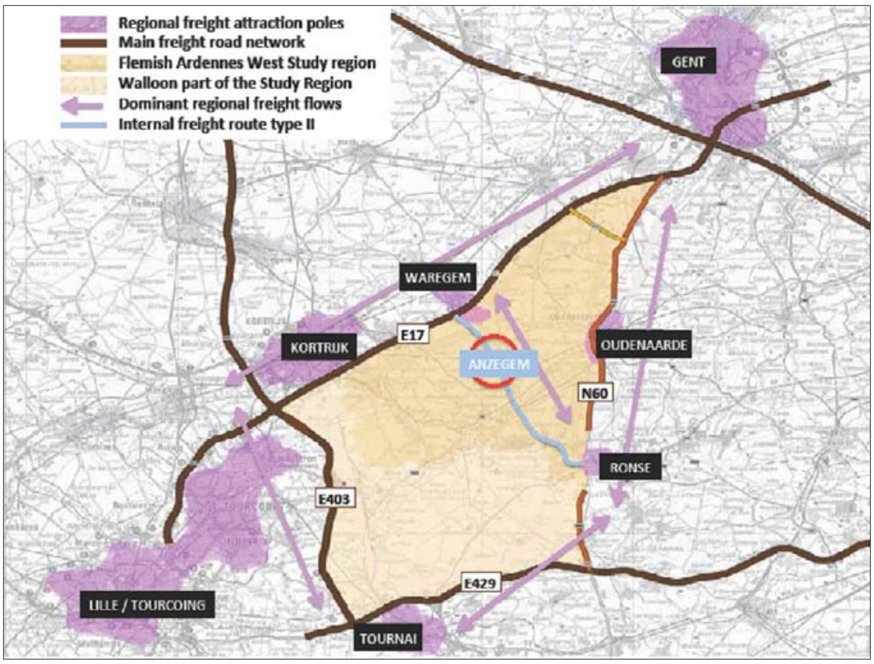
Figure 3. Suitability of internal relations (freight route II) (Source: [32]).



2.1. The Anzegem Case

Internal relations in the western part of the Flemish Ardennes suffer particularly from heavy freight traffic. The nuisance is widely acknowledged by governmental bodies and a thorough examination of suitable regional freight routes has been highly requested. Figure 4 illustrates the Flemish Ardennes study region, which is demarcated by the main road grid: E17 in the northwest, N60 in the east and E403–E429 in the south. The purple urban areas signify the regional freight attraction poles, while the dominant regional freight flows are indicated by the purple arrows.

Figure 4. Flemish Ardennes West study region (Source: adapted from [32]).

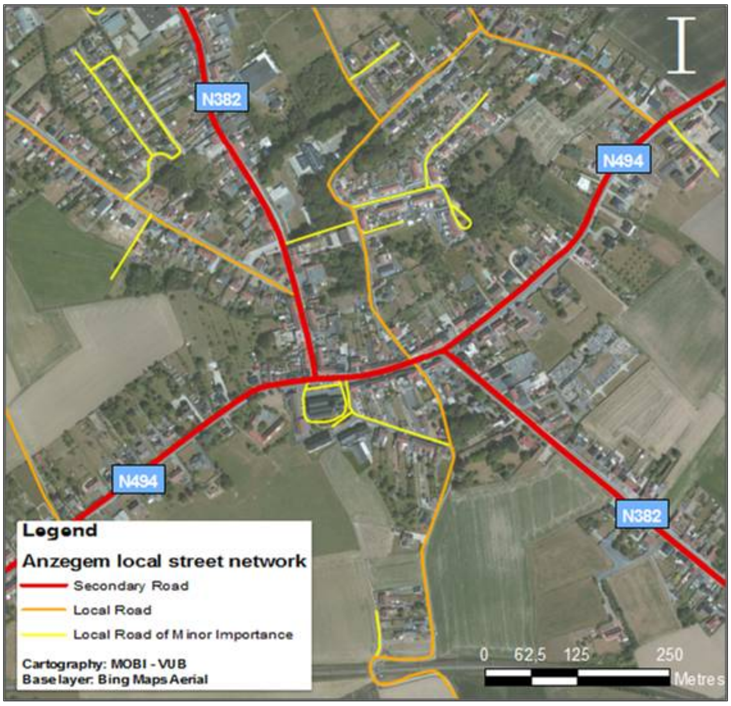


Permanent freight flows between the industrial zones in Kortrijk/Waregem (E17) and the industrial zones in Ronse/Oudenaarde (N90) force carriers to address secondary (or distributor) roads (e.g., N382–N36), since the detour factor over the main road network is 1.7 up to 2 for the equivalent connection. The study region comprises in addition central industrial zones non-contiguous with the main road network, like Ruien Business Park and Anzegem intermodal terminal. Dominant freight flows between the specified industrial zones puts significant pressure on peripheral villages in the area. Particular municipalities have implemented tonnage restrictions to restrain the impact of heavy freight flows in the central areas. Other municipalities, like Anzegem, have considered the implementation of ring ways.

The ring way over Anzegem (N382) is remarkably relevant in the completion of the regional freight route network. The N382–N36 takes a central position in the study region, harbors predominantly supra-local and interregional traffic and provides direct access to the industrial zones in Waregem, Ruien and Ronse. This initial secondary road can as a result be qualified as a potential internal freight route (type II) to reduce the detour factor over the main road grid. The actual freight route (type II) classification could enhance corporate accessibility, but will affect the livability in neighboring communities, like Anzegem in particular.

Anzegem is an elongated road village with three small residential entities along the N382. The village contains 14,300 dwellers and is located in the southeast of West Flanders. Anzegem is a typical example of the dispersed Flemish urban planning and ribbon development, where initial communities along secondary roads progressed to central areas with mixed residential, commercial, supra-local- and local traffic functions. The trade-offs between these functions are in the case of Anzegem reinforced by two angled curves (intersection N382 and N494, Figure 5), which impede transit traffic throughout the village. The correlation between these bottlenecks and the local and supra-local traffic entails negative externalities for the community (accidents, traffic noise emissions, exhaust gas emissions) and for the corporations (increasing travel time and travel costs).

Figure 5. Intercepting N382 and N494 in central Anzegem.



Classifying the N382 as an internal freight route (type II) triggers the negative externalities in the central area of Anzegem. A potential ring way can mitigate these externalities by distributing the supra-local traffic and the local traffic. This paper attempts to address the social, economic and environmental impact of alternative ring ways scenarios for Anzegem, by integrating specific stakeholder targets in the assessment process.

3. Assessment Methodology

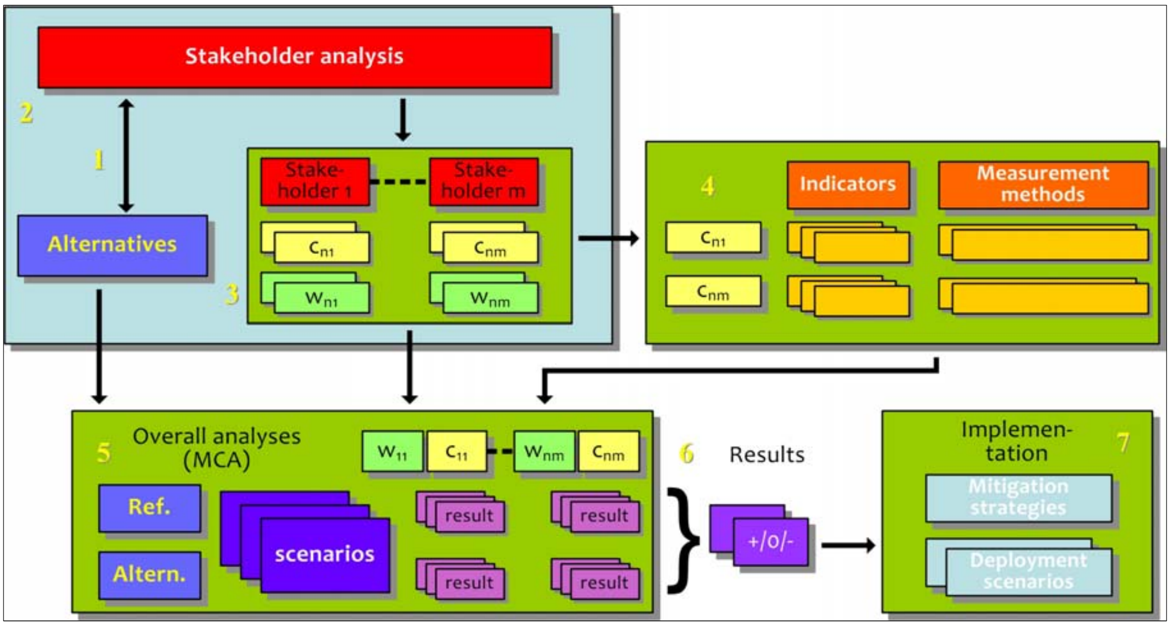
The realization of new transport projects results quite often in controversies since they benefit, but also harm particular groups of citizens. Conflicting objectives among communities are especially manifested in densely populated regions like Flanders (456 inhabitants per km^2 in 2010), where infrastructural projects involve a large quantity of stakeholders. Meeting the needs of stakeholders contributes to the successful implementation of transport projects. Stakeholders provide governments with context specific information from those affected, create contestability towards a wide range of received information and solve problems regarding the consequences of the project in the context of social learning [33]. The later aspect gains particularly relevance within extensive evaluations, focusing on the social, economic and environmental effects of transport infrastructure, where public involvement is employed as an instrument to produce knowledge on sustainable development [34–37].

Stakeholders can be defined as individuals with interests in a particular issue, determining whether the individuals can affect (active stakeholder) or will be affected (passive stakeholder) by the ultimate outcome of that issue [38,39]. Although certain studies question the purpose and effectiveness of stakeholders in public participation [40–42], the influence of stakeholders on the realization of transport projects cannot be denied. Particular infrastructural transportation projects in Flanders (Seine-Scheldt-West hinterland waterway project [43]; Oosterweel bridging project [44]) are provisionally procrastinated due to stakeholder influence. The key lesson from these projects is to involve stakeholders from the initial project stages.

Despite the significance of stakeholder consultation, there is a deficit in transport related assessment strategies which incorporate stakeholder perspectives. Today, six evaluation methods are ubiquitously used to evaluate transport projects: Cost-Benefit Analyses (CBA), Cost Effectiveness Analysis (CEA), Economic-Effects Analysis (EEA), Economic Impact Analysis (EIA), Social Cost-Benefit Analysis (SCBA) and Multi-Criteria Analysis (MCA) [38,45]. Largely, the forementioned methods perform evaluations from a utilitarian point of view, principally based on Willingness To Pay. This monetary mono-criterion miscarries however with the complex interaction between socio-economic and biophysical systems, which gains significance in the evaluation of contemporary transport projects. Multi-criteria assessments are by comparison more suited to perform comprehensive evaluations, since they are able to examine social, economic and environmental aspects of sustainable transport projects in terms of impacts against a range of criteria [46]. Still, none of the traditionally mono- or multi-criteria evaluation approaches discussed above, integrate stakeholder perspectives in the assessment process.

Particular studies stress the benefits of combining participatory methods with analytical multi-criteria assessment approaches [47–49]. However, few studies propose a systematic evaluation tool to incorporate stakeholder objectives, while including a wide range of criteria in the impact assessment of transport projects. The analytic multi-actor multi-criteria analysis methodology (MAMCA) [50] integrates stakeholder preferences into the generic multi-criteria procedures. The MAMCA methodology comprises seven logical steps, as illustrated in Figure 6.

Figure 6. The seven steps of the MAMCA methodology (Source: Macharis *et al.* [51]).



First, the possible (1) alternative scenarios to address the decision problem are identified, demarcated and classified. The alternatives can take various configurations (e.g., policy scenarios, technological solutions, infrastructure investments, *etc.*), depending on the nature of the problem. Alternative scenarios can clearly outrank each other or can comprise overlapping elements. Particular alternatives submitted for assessment in this application enclose overlapping road segments.

The second step (2) examines the citizens who affect or can be affected by the outcome of the decision and categorizes them into stakeholder groups. Each actor group is briefed on the assessment content and the participatory procedures. Next, the identification of individual stakeholder objectives and interests towards the decision problem takes place. The MAMCA methodology allows open interviewing to identify the stakeholder objectives [51,52] or validation of a predefined list of possible interests to determine the objectives [44]. For this application, the individual stakeholders evaluated a list of apposite interests, which were aggregated according the direct ranking and rating approach [53] in specific criteria per stakeholder group.

The objectives per stakeholder group are consequently (3) translated into criteria and weighted according to their relative importance. To allocate the weights of the criteria, the pairwise comparison mechanism [54] is used, which compels stakeholders to set priorities for the preferred criteria. Still, other weighing methods like the point allocation approach [55] can be applied. The weights of the stakeholder groups are equally divided according to their corresponding share in the transport project (general interest) and to underscore the democratic nature of the group decision process. The weights of the stakeholders can however be differentiated [56], which can be relevant if the input of a particular stakeholder group is more significant in the final objective of the evaluation. As a result of the first three analytical MAMCA steps, a weighted decision tree is generated for further analysis (see upper blue frame Figure 6).

To make the previously identified stakeholder criteria more tangible, (4) indicators and measurement methods are identified to measure the extent to which each alternative complies with each criterion. These indicators can be quantitative or qualitative in nature. Direct measurements generate data for quantitative indicators. Quantitative indicators are derived from the literature or from expert consultations and measured on a Likert Scale ranging from −2 (important negative effect) to +2 (important positive effect). As a result of the measurements, the alternatives can be lexicographically differentiated according to the criteria, to support the pairwise comparison of the alternatives in the next step.

The fifth step subjects the alternatives to (5) the overall analysis. Hence, multi-criteria assessment procedures are used to determine the extent to which the alternatives contribute to the criteria. Any MCA group decision support method (GDSM) can be applied, of which the Analytic Hierarchy Process (AHP) and the PROMETHEE-GDSS are most commonly used [38]. As every MCA method includes particular assets and drawbacks (see [57] for an overview), multiple techniques depending on the preferences of the assessor can be applied. This paper applies the conventional AHP methodology developed by Saaty [58], since its user-friendliness is particularly beneficial to support the decision-making process [59,60]. The AHP consists of three generic steps [61], *i.e.*, construction of a hierarchy, setting priorities by means of the pairwise comparison mechanism and verifying the consistency in the pairwise judgments. The MAMCA constructs a participatory hierarchical tree by conducting the first three steps. Next, priorities are set by means of the pairwise comparison mechanism and the logical consistency is verified in the fifth MAMCA step. The preference for a certain alternative compared to another alternative is expressed on a 1–9 ratio scale [62] and subsequently inserted as scalar in a comparison matrix per criterion, to determine the overall eigenvectors (relative scores) per alternative. In order to verify the logical consistency in the pairwise judgments, the consistency ratio is determined, by dividing the consistency indices by the random indices computed by Saaty [58]. The consistency ratio of each priority matrix may not exceed 10% to be considered as reliable.

The next step (6) determines the outcome and interpretation of the assessment results. The multi-criteria analysis generates a priority ranking, which provides an overview of the assets and drawbacks of each alternative with respect to the assessment criteria. More important than the ranking is the multi-actor analysis, disclosing the specific alternatives supported by the critical criteria of particular stakeholder groups. To verify the robustness of the results, a sensitivity analysis can be conducted to examine the significance of weight modifications on the final outcome.

The assessment outcome is finally (7) implemented as valuable context specific information to resolve the decision problem. The preferences and objections of each stakeholder group towards the strengths and weaknesses of the individual alternatives, serve as policy recommendations to elaborate a generally accepted policy scenario. Overlapping or fuzzy scenarios can be prospectively implemented as a generally accepted policy mix, in contrast to tangible outranking alternatives. To realize the generally accepted scenario, practical deployment schemes and implementation paths are developed, which provide more insight into the chosen alternative and the entailed impact. As a result, an optional feedback loop can be generated towards the previous MAMCA steps, to enhance the final implementation of the chosen alternative.

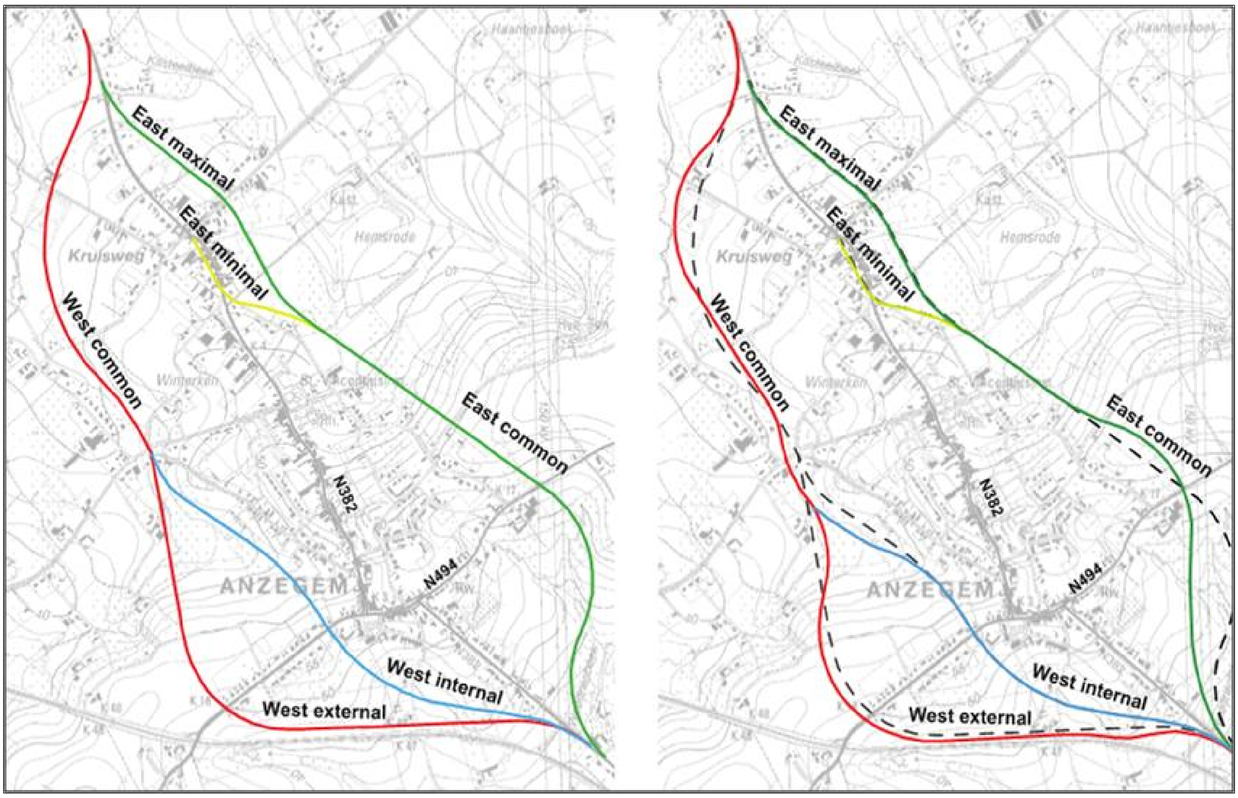
In conclusion, stakeholder involvement can proceed in five out of the seven methodological steps: (2) identification of individual stakeholder objectives, (3) allocation of the criteria weights, (4) selection of indicators and measurement methods and (5) in the setting of priorities for the preferred alternatives in the overall analysis. Most applications embed stakeholder preferences in the 2nd and the 3rd methodological steps [52,63,64].

4. Applying the MAMCA for the Anzegem Ring Way Case

4.1. Demarcation of the Alternatives

The Flemish Road and Traffic Agency (AWV) designed four ring way scenarios to address the heavy freight flow annoyance throughout the Anzegem road village. Figure 7 (left map) renders the initial AWV detour proposal, inserting two central scenarios within each of the two variations: scenario west (external and internal) and scenario east (minimal and maximal). Both western and eastern scenarios include an individual and a shared section. A compulsory strategic environmental impact assessment (EIA directive 2001/42/EG) of the four proposed ring ways disclosed particular environmental constraints along the scenario courses. The initial scenarios are consequently slightly modified to reduce their environmental impact, *i.e.*, avoid habitation, minimize brook crossing and mitigate barrier effects. The improved scenarios are demonstrated on the right map in Figure 7, contiguous to the initial scenarios (dashed).

Figure 7. Initial ring way scenarios (left) and modified scenarios according EIA (right) (Source: adapted from [65]).



The environmentally enhanced ring way scenarios (right map Figure 7) and the existing central passageway (N382) are applied as alternative scenarios to submit for evaluation:

(1) The external western alternative branches from the N382 in the south along the railway, over the N494, aligns the common western section, to connect at the N382 in the north.
(2) The internal western alternative separates at the N382 in the south, but intersects the N494 closer to the village centre before aligning with the common western section.
(3) The minimal eastern alternative carves through a predominant common course from the N382 in the south, over the N494, to connect early at the N382 in the north.
(4) The maximal eastern alternative continues after the predominant common course over the N494, to join the N382 in the north after the last part of the village.
(5) The reference alternative comprises the current passage throughout the village centre (N382), with two intersecting angled curves over the N494.

4.2. Stakeholder Analysis

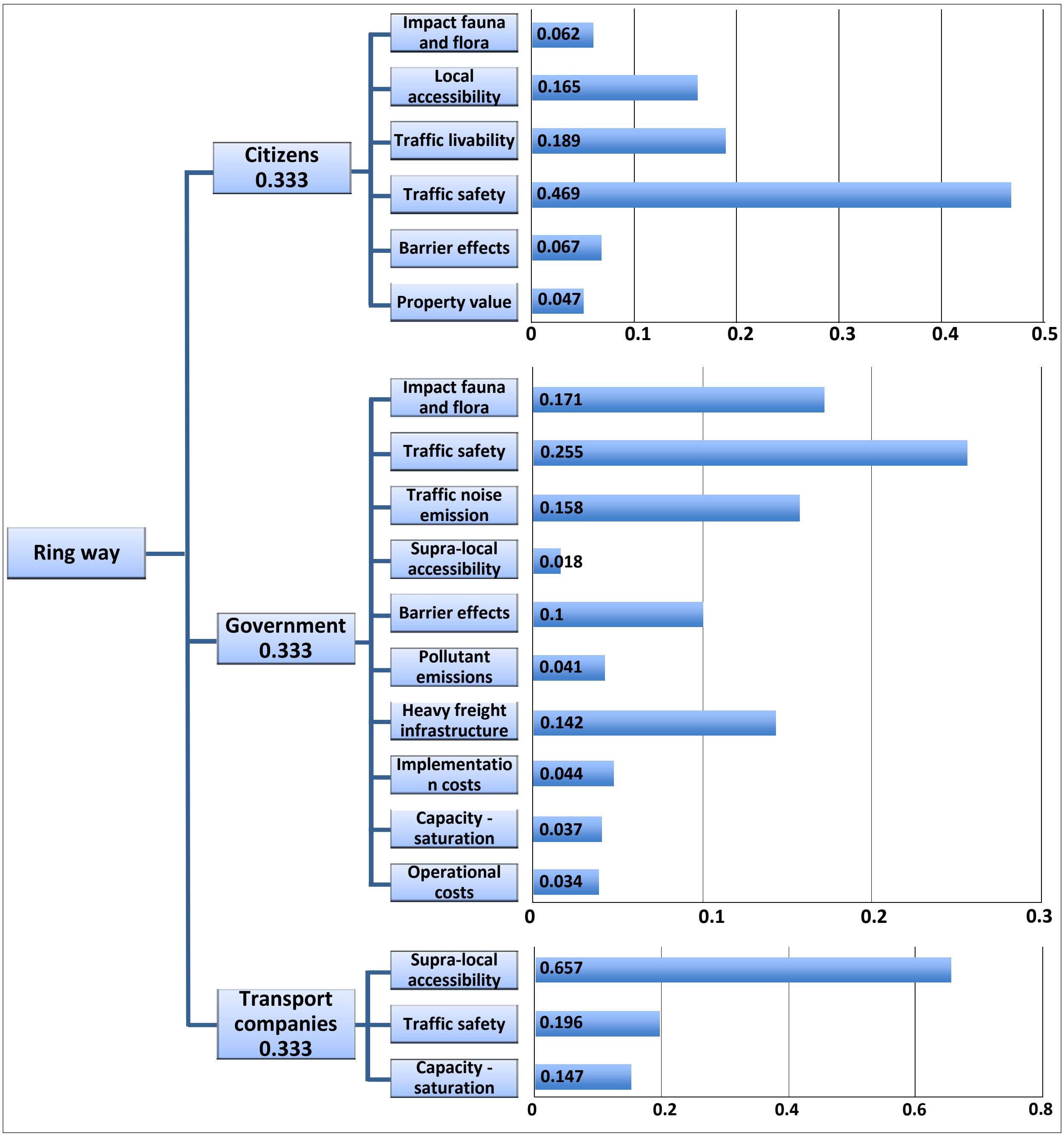
Three principal stakeholder groups are involved in the implementation of a ring road: Flemish governmental bodies, local citizens and local transport companies. For the governmental actor group, 237 municipal mobility coordinators were queried, who represent the majority of all Flemish municipalities (308). The representation of the governmental actor group is chosen to be more comprehensive than the local stakeholder groups, based on their direct involvement in establishing the Flemish regional freight route network. For the particular network extension in Anzegem, local stakeholders were identified. Three representative voices of the local cycle union, the local family and welfare council, and the action committee against the bypass provided the objectives for the citizens' stakeholder group. Three specific corporations, who convey freight throughout the Anzegem road village, specified the interests for the transport company actor group.

4.3. Demarcating and Weighing the Assessment Criteria

The criteria to assess the scenarios are deducted from the objectives of the stakeholder towards the pending ring road. To determine the individual objectives, pertinent principles from the European Impact Assessment Guidelines [66] were presented to each stakeholder. Next, stakeholders validated the predefined list of principles by preferring the most valuable principles (criteria), relying on the pairwise comparison mechanism. This mechanism forces the stakeholders to choose between the most valuable assessment criteria in relation to the other criteria. The preferences for each assessment criterion are pairwise compared, expressed on a 1–9 ratio scale [62] and accordingly transmitted to eigenvectors per criterion. The eventual overall eigenvectors per criterion signify the weight of that respective criterion.

After conducting the first three analytical MAMCA steps, a weighted decision tree (Figure 8) can be set up, which exemplifies the assessment criteria and the allocated weights per stakeholder group. The different stakeholder groups are weighted equally (0.333) towards the overall objective. The weighed objectives serve as local assessment criteria, which are mutually weighed according to the pairwise comparison mechanism. The governmental stakeholder group identified more specific assessment criteria than the end-user stakeholder groups (citizens and transporters), as their facilitating role in cognitive enhancement and moral development is considered more significant in the group learning process [42].

Figure 8. Weighted decision tree with criteria and allocated weights per stakeholder (in decimals per total of one stakeholder).



4.4. Identification of Indicators and Measurement Techniques

Indicators and measurement units determine the tangible impact of each assessment criterion on the individual alternatives. Indicators provide as variables an operational representation of a system attribute [67] and summarize relevant information in a simplified form to enhance monitoring, benchmarking and communication. The operational representations can have a qualitative or quantitative nature and may measure contributions to multiple criteria [44].

The indicators and measurement methods for each assessment criterion were traced in the literature [29,68–78]. Table 1 illustrates the indicators and measurement units per criterion.

Table 1. Criteria, indicators and measurement units to assess the impact of ring ways.

Group	Criteria	Indicator	Unit of measurement
Social	Traffic safety	Accident numbers	Fatal and injury accidents
	Traffic noise emissions	Decibels	>55 dB (A)
	Traffic livability	Vibrations, pollutant emissions and noise	2.0 Hz PPV < 18 mm/s, NO_x, CO, PM_{10}, $PM_{2.5}$, SO_2, O_3, >55 dB (A)
Environmental	Impact fauna and flora	Habitat directive area	Square kilometers
	Barrier effects	Isolated species	Number of species
	Pollutant gas emissions	Immission concentration	CO_2, NO_x, CO, PM_{10}, $PM_{2.5}$, SO_2, O_3
Economic	Local accessibility	Travel time	Minutes
	Supra-local accessibility	Travel time	Minutes
	Property value	Price	Euro
	Heavy freight infrastructure	Customized dimensions	Kilometers road
	Implementation costs	Cubic meters earth moving	Euro/m^3
	Capacity—saturation	Congestion	Number of vehicles, vehicle loss hours
	Operational costs	Road infrastructure length	Euro/km

4.5. Overall Analysis

The overall analysis determines the extent to which the alternatives comply with the individual assessment criteria, validated by the indicators and their measurement units. This application uses the Analytic Hierarchy Process (AHP) to perform the overall evaluation, which compares the five alternatives pairwise to each assessment criterion in the AHP based decision support software Expert Choice [79]. As such, the assessor intercalates preferences for each pair of alternatives towards each assessment criterion in the program. The software allows not only a clustering of the criteria per stakeholder group to support an actor-based assessment, but calculates the overall eigenvectors per alternative and verifies the consistency in the pairwise judgments automatically.

The data for the indicators, which substantiate the pairwise comparison, is derived from available studies such as the Strategic Environmental Impact Assessment Report [65] and the Freight Road Network Manual [32].

4.6. Application Results

Comparing the alternatives pairwise to the weighted decision tree (Figure 8) entails tree priority matrices, where the alternative scenarios are ranked according to their contribution to the assessment criteria. These priority matrices are illustrated by performance figures (Figures 9–11) per actor group to disclose the preferences of the stakeholders towards the individual ring way alternatives. The multi-actor figure (Figure 12) integrates the preferences of each actor group to compare which alternatives are specifically endorsed by particular stakeholder groups.

Figure 9. Objectives for the citizen stakeholder group.

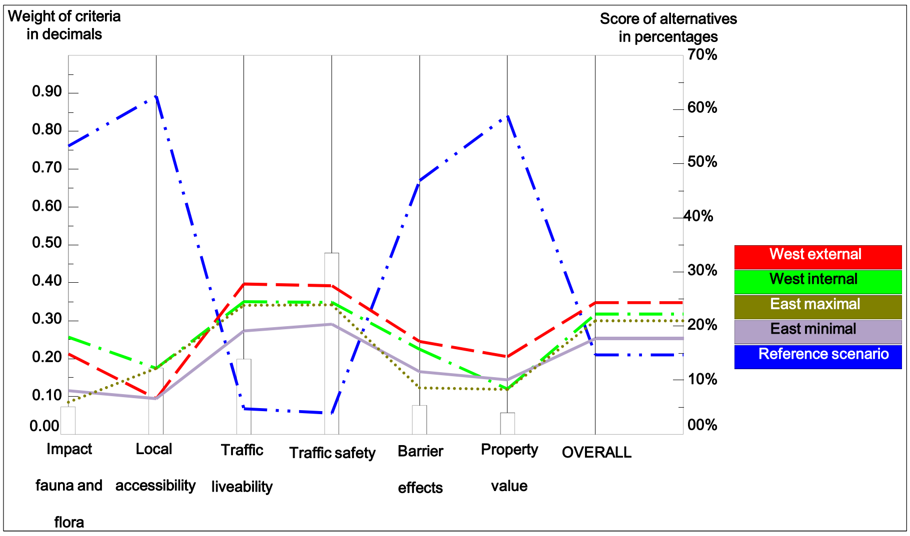


Figure 10. Objectives for the transport company stakeholder group.

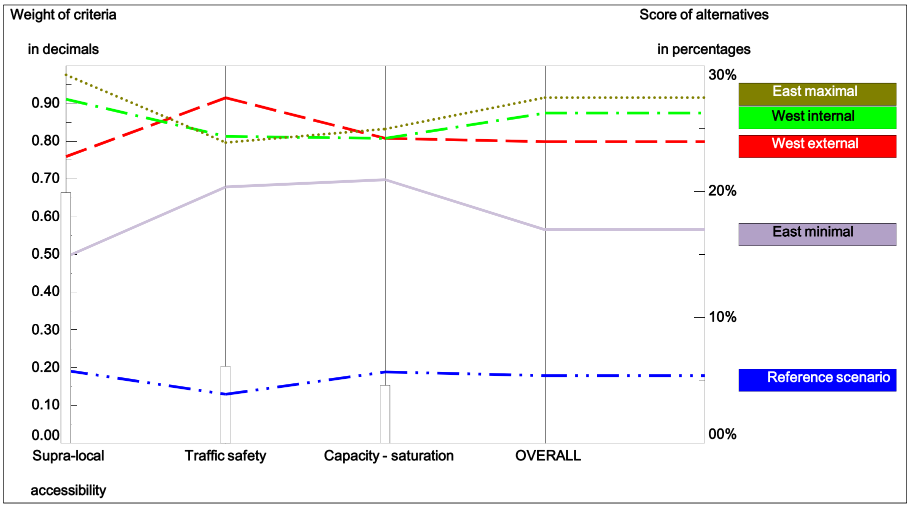


Figure 11. Objectives for the governmental stakeholder group.

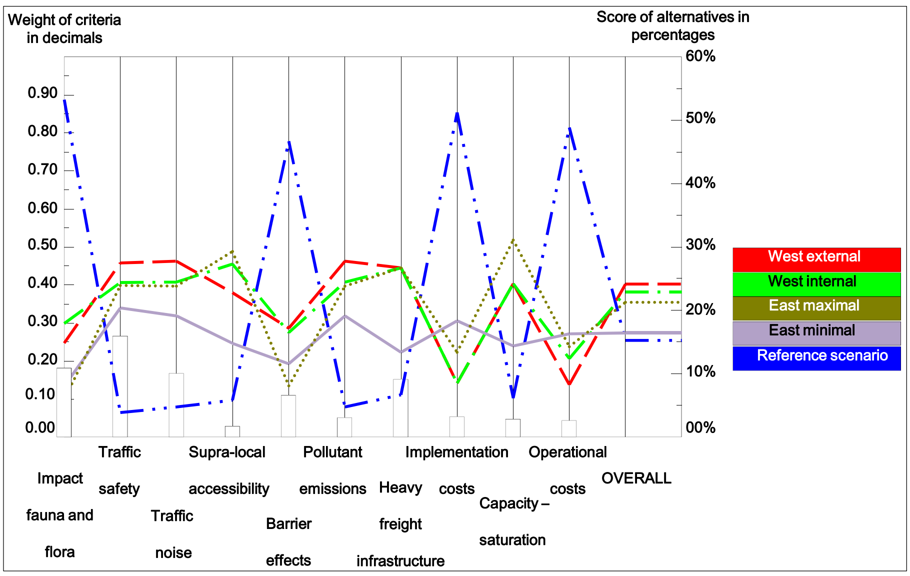
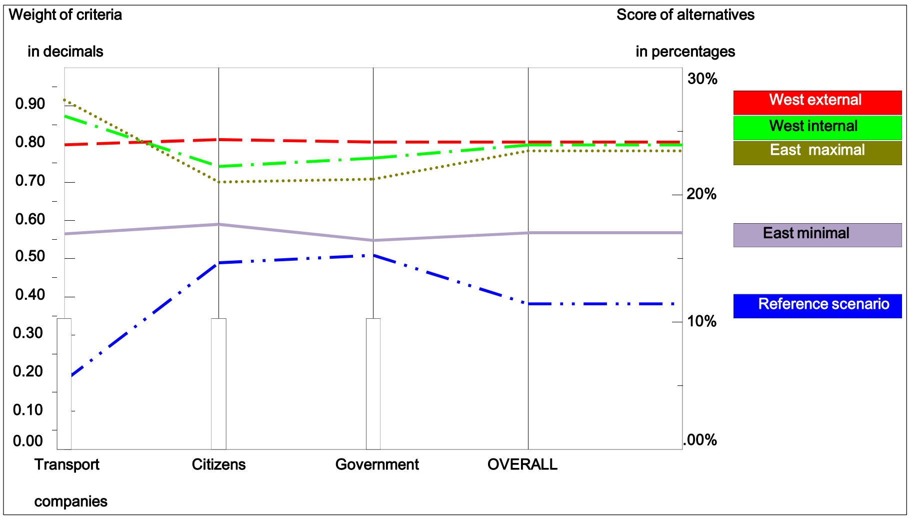


Figure 12. Multi-actor view.



The colored (dashed) axes in the priority matrices represent the alternative scenarios, which intercept the vertical assessment criteria axes, illustrated on the lower vertical axis. These intercepts exemplify the outcome of the pairwise comparison, which are expressed as eigenvector scores in percentages on the far right vertical axis. The sum of the different scores of the alternatives is equal to 100%, expressing the total preferences of the stakeholder group. The overall vertical axis aggregates the eigenvector scores per criterion in overall eigenvector scores per scenario. The rectangular beams signify the weights of the criteria, which are expressed in decimals on the far left vertical axis. The sum of the weights per criterion is equal to 1.

Traffic safety, traffic livability and local accessibility constitute the critical assessment criteria for the citizens' stakeholder group (Figure 9). The reference scenario (RS) complies only to a minimal extent with the first two critical criteria, since it processes a threefold amount of traffic (average 410 passenger car equivalents per peak hour during 2007 in one direction) in comparison to the other secondary roads in Anzegem. The implementation of a bypass would decrease the transit traffic throughout the RS from 75% to 91% [65]. The decreased traffic intensity contributes to the reduction of accidents, noise emissions, pollutant gas emissions and traffic vibrations in the central area of the village. The western external scenario is the most interesting alternative for the citizens' stakeholder group. The distant location of this scenario reduces interaction between local and supra-local traffic and exposes only a minimal amount of residents to traffic noise, pollutant gas emission and traffic vibrations. The western internal and eastern maximal scenarios pave their course contiguously to residential ribbons, which reduces livability and enhances interaction between local and supra-local traffic. The eastern minimal scenario is considered as the least interesting alternative ring way, since a major part of its individual section coincides with the RS.

The transport companies advocate the implementation of a bypass scenario in general. Figure 10 indicates the preferences within the corporate actor group, disclosing supra-local accessibility as the most valued criterion. Two angled curves along the RS (intersection N382 and N494, Figure 5) and a mix of residential, commercial and local traffic functions in central area impede transit traffic. The supra-local accessibility of the alternative scenarios is determined by the longitude of the scenario courses. The western external scenario covers particular detour curves to bypass the village. The eastern minimal scenario comprises the shortest longitude, but coincides partially with the RS. The eastern maximal and western internal scenarios are consequently the most attractive possibilities for the corporate actor group.

Figure 11 renders the preferences for the governmental stakeholder group, who validated more specific criteria with respect to the community interests in the realization of the transport project (e.g., disaggregation of traffic livability in traffic noise emissions and pollutant gas emissions). Traffic safety, impact on fauna and flora, traffic noise, heavy freight infrastructure and barrier effects are valued as the critical criteria within this actor group. A remarkable finding in the disaggregation of the traffic livebility criterion is the preference of traffic noise criterion over the pollutant gas criterion. The western external scenario is the most interesting alternative regarding its traffic safety merits and limited amount of dwellers exposed to noise emissions. All alternative bypasses cater customized dimensions for heavy freight infrastructure in contrast to the current N382 passageway. Still, the RS satisfies environmental criteria like impact on fauna and flora and barrier effects. The alternative ring way scenarios degrade the rural structure of the region by slitting brook valleys of environmental value. The impact of the eastern scenario courses is considerably higher than the western scenarios because they disrupt high valued habitat directive areas in the northeast of Anzegem. The eastern coursers occupy about 1.65 ha of environmentally valuable land compared to merely 0.53 ha for the western courses [65].

4.7. Analysis of Assessment Results

The multi-actor analysis (Figure 12) provides the scores for the individual alternatives per actor group. Each actor group obtained an equal weight (see 3rd step, Section 3), as illustrated on the vertical axes. The overall ranking renders the RS as the least attracting alternative for all stakeholder groups; because it does not comply with critical assessment criteria, *i.e.*, traffic livability, traffic safety, supra-local accessibility and heavy freight infrastructure. The government and citizen actor groups support the western external scenario situated at roughly the same overall vector percentage as the western internal and eastern maximal scenario. However, the western external scenario harbors a higher level of traffic safety and livability as a result of its remote position from the village centre. The western external scenario contains in addition fewer barrier effects, since the southern course paves right next to the railway. The corporate actor group advocates the implementation of a ring way in general, but prefers the scenarios west internal and east maximal due to their supra-local accessibility assets. The eastern minimal scenario is the least supported ring way scenario, since the northern section of the scenario coincides with the RS.

4.7. Implementation

The last methodological step investigates deployment schemes and implementation pathways to transmit the gathered information into reality. While the assessment results disclose comparable positions between the governmental and citizens actor groups in the realization of a ring way, the transport companies show divergent objectives. The external western scenario can be considered as a consensus between the involved parties since it complies foremost with the critical objectives of all stakeholders.

Feedback from the assessment criteria, the indicators and the measurement methods can strengthen the development of the deployment schemes. Mitigating elements as identified in the operationalization of the assessment criteria, *i.e.*, isolation of species and soil movements, can have a decisive influence on the clearance of the scenarios course. A frequent occurring problem in the implementation of infrastructural projects is the gap between the preparation studies and the actual implementation of the project, which is often carried out by several different governmental departments. Clear communication between the study departments, the public executive departments and the subcontractors contribute to the desirable implementation of the chosen alternative. The optional feedback loop in the last methodological step of the MAMCA enhances therefore the desired outcome of the scenario implementation.

This *ex-ante* impact assessment of the disputed ring way alternatives disclosed the western external scenario as most interesting option to reconcile accessibility and livability. The proposed scenario enhances supra-local accessibility, benefits traffic safety and livability due to its secluded location, exerts a less degrading impact on the landscape, but is however more expensive. As such, an additional trade-off (see Section 1.2) should be settled between the costs of an alternative and its public health and life quality merits. The strengths and weaknesses of these possible network extensions support the Flemish Government and the Anzegem Municipality in completing the regional freight route network and seizing a final decision regarding the Anzegem ring road. This case study was commissioned by the Flemish Policy Research Centre Traffic Safety, which assists the Flemish Government in prioritized policy themes.

5. Discussion

The present paper advocates a combination of analytical multi-criteria assessments procedures and participatory strategies to enhance group decision-making theory. Still, there seems to be no clear consensus on how public participation contributes to the decision-making processes [80,81]. The value of public participation is not only causatively related to the participation methods and the way they are applied, but to the personal beliefs of the involved stakeholders as well. Hartley and Wood [41] document procedural constraints, *i.e.*, poor provision of information, poor execution of participation methods, failure to influence the decision-making process; and constrains of respondents, *i.e.*, poor public knowledge and the "not in my back yard syndrome" as key barriers for effective public participation. Still, as Rosenström and Kyllönen [40] note, the success of a participatory decision-making process depends primarily on the kind of effect you are willing to achieve through participation. Desired effects include: more democratic representation of existing interests (fairness), solving mutual problems by linking the private interests with the shared interests of fellow citizens (social learning) and improving the implementation of the decision outcome (competence) [40,42].

The MAMCA methodology meets particulars of the cited participation barriers by the profound screening of the respondents and by providing information on the assessment content (stakeholder analysis, step 2). The participatory procedures can additionally be executed in a structured format by means of the various methodological steps (see end Section 3). However, barriers like "not in my back yard syndrome" and failure to influence the actual decisions, remain embedded in the general participatory deficit of the decision-making process. The identification of deficiencies in whether respondents pursue pure egoistic interests before collective ones and how decision-makers disregard participatory policy recommendations remains a challenging task within group decision-making theory.

The type of participatory output that MAMCA applications aim for involves, in the initial stage, the instrumental use of public knowledge to improve the decision outcome. Public hearing is, in the context of identifying stakeholder objectives (step 2), a more appropriate strategy than public contribution to fundamental decisions. Still, expanding stakeholder involvement to additional MAMCA steps (e.g., allocating weights to assessment criteria, step 3) enriches the social learning processes by disclosing the critical criteria per stakeholder. Including stakeholders in the overall analysis (step 5, pairwise comparison of the alternatives towards assessment criteria) enhances the democratic representation of the involved actors even further, by integrating their preferred alternatives into the actual assessment process. The multiple steps in the MAMCA methodology allow a hierarchy of participation guises, depending on the assessment purpose and its application. This hierarchy coincides with Arnstein's [82] frequently quoted "ladder of participation" [33,83–85], which structures participation in terms of control of public participants over the decision-making process.

The proposed assessment methodology aims to contribute to the need for powerful theoretical tools, which build consensus among multiple actors in the realization of transportation projects. The combined participatory strategies (stakeholder consultation) and interdisciplinary strategies (multi-criteria assessment) fulfill progression towards transdisciplinary research methodologies [86].

Interdisciplinary approaches, like the MCA, combine knowledge from exact and social sciences, with the ambition to integrate unrelated methodologies [87], in reaching a common research objective. Multi-criteria assessments examine social, economic and ecologic aspects of transport related projects in terms of impacts against a wide range of criteria. As such, the pairwise comparison mechanism is used to overcome the incommensurability of qualitative criteria.

Transdisciplinary research strategies, like the MAMCA do not only gather knowledge from academic bodies to integrate distinct disciplines in reaching a common goal. Knowledge from citizens and practitioners (non-academic bodies) is used as well to promote a mutual learning process between the intense interactions of multiple stakeholders [86].

Still, particular deficiencies can be noted in the MAMCA methodology with respect to the interpretation and composition of the stakeholder groups. The assumed homogeneity of the stakeholder groups and the exclusion of particular relevant stakeholders [84] distort as reinforcing factors the participative representation of the entire stakeholder community. As the governmental actor group consists of a larger number of stakeholders with respect to the implementation of the freight route network on the Flemish regional level, the local citizens' stakeholder group might be underrepresented to embody the citizens of Anzegem. Preferences of particular stakeholders such as the primary and secondary schools in the village; and residents dwelling circumjacent to the alternative or reference scenario are not included due to time constraints. As for the corporate stakeholder group, other corporations such as small municipal businesses could be integrated as well. While the integration of additional stakeholders contributes to democratic representation of the stakeholder groups, it should be acknowledged that the preferences (weighed objectives) of the stakeholders per actor group cannot be considered as homogeneous. They represent individual stakeholder preferences, which have been aggregated into group preferences according to the direct ranking and rating approach [53] and weighed according to the pairwise comparison approach [54].

The paper applies the Analytic Hierarchy Process to conduct the MAMCA. However, other MCA methodologies can be used to perform the overall evaluation, since the AHP method includes particular disadvantages. The pairwise comparison in the AHP can become impossibly tedious and impracticable if the hierarchical decision tree contains too many alternative scenarios and/or assessment criteria. Deleting or adding a specific assessment criterion exerts an influence on the final scores of the other alternatives, or can even cause rank reversals [88]. The AHP approach does not always provide a strictly correct ranking of the alternatives, but compensates by means of trade-offs between good and bad performing criteria. Hence, detailed and often important information is disregarded in the aggregation of the scores towards the criteria [61]. Particular authors like Laarhoven and Pedrycz [89] forwarded the fuzzy AHP as an extension of the conventional AHP to overcome this deficiency. Still, most fuzzy AHP approaches fail in verifying the logical consistency in the priority setting [90]. The fuzzy preference programming (FPP) developed by Mikhailov [91] and improved by Rezaei [90] complies with this deficit.

6. Conclusions

The present paper proposed generic principles to construct a regional freight road network and applied a participatory methodology, which integrates stakeholder objectives in the decision-process of assigning regional freight traffic to a specific road network. As such, the paper aims to contribute to the lack of information on preferred truck routing networks with customized dimensions for heavy freight, as highlighted by Hubsneider [13] and Arentze *et al.* [14]. A practical case on the impact of a particular network extension is assessed in order to produce knowledge on conveying freight through the densely populated and spatial complex region of Flanders. Determining the strengths and weaknesses of each alternative scenario assists the policy-makers moreover in building consensus among the actors involved in the realization of the infrastructural project.

The specific case of Anzegem illustrated that certain stakeholder groups support particular ring way alternatives. Citizen stakeholders support the western external scenario, since it complies foremost with the critical traffic safety and livability criteria. The corporate actor group advocates the ring way realization in general, but prefers the western internal and eastern maximal scenarios regarding their supra-local accessibility assets. Governmental stakeholders encourage the western external scenario because it has a less degrading impact on the rural environment and contributes to traffic safety and livability as a result of the remote location.

This contribution performed a sustainability assessment of a freight network extension on the micro level of Anzegem. Further research needs to be dedicated to heavy freight bottlenecks on internal relations in the multiple Flemish sub-regions and their relation to the main freight roads. Next, regional freight attraction zones should be concentrated in the vicinity of each other to reduce freight interaction with residential areas. Integrating stakeholder concerns in the evaluation of probable network extensions contributes to a common accepted freight route network, which optimizes corporate accessibility and communal livability throughout the entire Flemish region.

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Conflicts of Interest

The authors declare no conflict of interest.

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