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DOI
10.1016/j.cstp.2022.08.005

Publication date
2022

Document Version
Final published version

Published in
Case Studies on Transport Policy

Citation (APA)
Blad, K., Homem de Almeida Correia, G., van Nes, R., & Anne Annema, J. (2022). A methodology to determine suitable locations for regional shared mobility hubs. *Case Studies on Transport Policy*, *10*(3), 1904-1916. https://doi.org/10.1016/j.cstp.2022.08.005

Case Studies on Transport Policy 10 (2022) 1904–1916

Contents lists available at ScienceDirect

Case Studies on Transport Policy

journal homepage: www.elsevier.com/locate/cstp

A methodology to determine suitable locations for regional shared mobility hubs

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ARTICLE INFO

Keywords:
Shared mobility hub
Multimodal transport
Geographic information systems
Multi-criteria analysis
Multi-actor multi-criteria analysis

ABSTRACT

As a solution to the high greenhouse gas emissions and declining quality of life caused by private vehicles, the shared mobility hub is introduced. The shared mobility hub is a place where multiple modalities come together, including public transport and shared private mobility. As the shared mobility hub is a relatively new solution, limited research is available on the topic, especially on finding potentially suitable locations for allocating them. In this research, this knowledge gap is addressed by developing and testing a generic methodology to determine suitable locations for a specific type: the regional shared mobility hub. The regional shared mobility hub is located outside a city center being able to act as an intermodal point of transfer. The developed methodology is a combination of two existing methods: the GIS Multi-Criteria Analysis (MCA) and Multi-Actor Multi-Criteria Analysis (MAMCA) available in the literature. The method is able to score and weight different criteria which determine regional shared mobility hub suitability, taking the end-user (traveler), operator, and government perspectives into account in the weighting. Results are presented in multiple heat maps based on scenarios with varying stakeholder weight importance. The methodology developed consists of five criteria that measure location suitability (potential demand at a certain location, hub implementation costs, generalized travel costs from and to the hub, link to surroundings, and societal impact) measured by nine attributes. In this method, the choice is made for the Analytic Hierarchy Process (AHP) to determine the criteria weights. The developed methodology is applied to the region of Rotterdam (The Netherlands) to analyse if the methodology produces useful results for policy implementation. From multiple analyses, it appears that the methodology is suitable for tackling the location suitability determination problem, as it produces intuitive results.

1. Introduction

In the Paris Climate agreement, 195 countries agreed on lowering greenhouse gases in the upcoming years (Government of the Netherlands, 2019). A substantial part of these greenhouse gases is emitted by passenger transportation, in particular road vehicles like cars (European Commission, n.d.). With the declining quality of life in city centers (Harbers and Snellen, 2016), the need for sustainable mobility that uses less space in those areas increases. Improved public transportation, fostering of active modes (walking, cycling), and the introduction of shared mobility provide a solution to this problem. However, these solutions imply a major role of multimodal travel which introduces less attractive transfers in travellers' trips. To provide a more attractive transfer between those various modes, and to solve the issue of lack of space in urbanized areas, the concept of a shared mobility hub is put forward. In the shared mobility hub, all previously transport modes (public transport, walking, cycling, private vehicles and shared mobility) come together at one location. The shared mobility hub is defined as a physical point in which a convenient transfer is offered between the available modalities, which includes in any case shared mobility, and possibly other private and public transportation. This definition is based on the current definition of the mobility hub, with the addition of shared mobility which should always be included in the shared mobility hub.

The shared mobility hub is designed to offer the traveler several options of traveling greener. This can be either achieved by letting the traveler switch to public and/or shared transport for their entire trip, or by offering a transfer at the hub, leading to a multimodal trip. Public

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https://doi.org/10.1016/j.cstp.2022.08.005
Received 21 March 2022; Received in revised form 26 July 2022; Accepted 8 August 2022

transport plays a central role in these multimodal mobility hubs (Miramontes et al., 2017), supplemented by shared mobility services, like car sharing or bike sharing. The service should be integrated into multimodal trip planners, and integrated in terms of pricing and/or access namely through MaaS apps. The convenience offered to the end-user by these features aims to make multimodal travel easier for the traveler.

1.1. *Research gap and contributions*

In the existing literature, very little is said about shared mobility hubs. The hub is a recent innovation in mobility, which is one of the reasons for the limited available papers that delve into the topic. The available research mainly focuses on the facilities and adoption of the shared mobility hub (Miramontes et al., 2017; Bell, 2019; Aono, 2019). Research on suitable locations for shared mobility hubs from a multi-actor perspective is non-existent to the best of the authors' knowledge. Whilst Enbel-Yan and Leonard (2012) introduce guidelines for the integration of hubs in the existing networks and urban context, the shared mobility function of the hub is not mentioned in that report.

Existing research on multimodal transfer locations might partially fill the gap, as, for example, a location-finding methodology is described in literature on Park&Ride locations (Faghri et al., 2002). The distinction between a regular public transportation node and a shared mobility hub is sometimes difficult to identify. However, according to the authors, the shared mobility hub can be seen as a unique facility, because of the sustainability of the transportation modes offered, integration of shared mobility services, the inclusion of additional facilities at the hub, and integrated route decision support. The offered modes use almost exclusively low-pollution power sources, like electricity. The electric bus, train, metro, tram, (shared) electric vehicle and bike can all be connected to a shared mobility hub. The hub also contributes to sustainable transportation by providing the opportunity of making a trip fully or partly by shared electric vehicles instead of privately-owned gasoline vehicles.

We aim to have both a scientific and practical contribution with this paper. From a scientific perspective, we think that we are the first paper that explores the topic of suitable shared mobility hubs locations from a multi-actor perspective. Practically, we think that contributing to a method that can find suitable shared hub locations may result in better use of these shared hubs and, thus, in a more sustainable transport system.

1.2. *3. Research objective*

The objective of this paper is to develop and test a methodology that can determine suitable areas in which a shared mobility hub could be located, incorporating the government, end-user and operator perspectives.

The methodology is developed as a quick scan for classifying the potential of locating a regional shared mobility hub in a particular area, not as a methodology to find the exact location of a hub in the street network. By deciding to develop a quick scan, a generally applicable framework is established, suitable for a general application in a region.

The focus of the methodology is on passenger hubs only. The factors influencing the potential of a location for a freight mobility hub are different from the passenger hub location factors, as freight has characteristics that will lead to different high potential locations for shared mobility hubs. Besides, the focus is only on regional shared mobility hubs and not residential (neighborhood) hubs or central hubs in a city, as the factors influencing their potential differ per mobility hub type. Literature research states that the regional hub is the least researched type of hub.

The paper is structured as follows. In section 2, a literature review on shared mobility hubs is presented. In section 3, the methodology to evaluate the potential of locations for regional shared mobility hubs is introduced based on factors found in section 2. The developed methodology is applied to the region of Rotterdam (The Netherlands) in section 4. Afterwards, the results of this application are analyzed and discussed in section 5. Finally, the paper ends with the main conclusions and recommendations in section 6.

Table 1
The adopted shared mobility hub classification required to determine the type of hub investigated in this research.

	Residential mobility hub	City mobility hub	Regional mobility hub
Urban context	>500 addresses/km^2	>2500 addresses/km^2	<2500 addresses/km^2
Modes offered	Shared mobility	Shared mobility, PT	Shared mobility, PT, car parking
Transportation function	Provide an alternative to car possession	Improve the city's accessibility	Improve reach PT, provide an alternative to car usage
Target groups	Residents	Residents, visitors, commuters	Residents, visitors, commuters

2. Literature: context, identifying criteria for suitable locations and methodologies for locating hubs

The literature study serves three purposes. The first is streamlining the definition of a shared mobility hub. The second is to identify factors influencing the potential of a location. Finally, current methodologies on the topic of mobility hub location finding are reviewed to form the basis for the to be developed methodology.

2.1. *Definition of shared mobility hub and its typology*

The shared mobility hub is a recent topic, with no well-established definition and typology, whereas a hub definition and typology are needed to determine the potential for a hub. To come to a hub definition and typology, existing literature on the shared mobility hub is reviewed. In the academic literature search engine Scopus, the keywords "mobility hub", "public transport node", "park ride" and "transferium" are used to find relevant literature, complemented by the name of a specific country in which the mobility hub is under investigation, or "definition", "typology", "features" or "location" to find literature on that specific aspect of the mobility hub. Additionally, the TU Delft repository provides Master's theses and academic research, and Google search is used to find government documents and reports, technical reports, other university Master's theses etc.

An overview of the papers found on the definition, typology and features of the shared mobility hub is presented. The definition used in this study is derived from several sources, including Miramontes et al. (2017); Enbel-Yan and Leonard (2012); Li (2020), in which attempts were made to define the shared mobility hub in general. The adopted definition is: "A shared mobility hub is a location where multiple sustainable transport modes come together at one place, providing a seamless connection between modes, offering besides public transport several shared mobility options, but also potentially including other amenities, ranging from retail, workplaces, to parcel pick-up points like lockers."

A classification of shared mobility hubs into three types is made based on the urban context and function in the transportation system, using literature by Van den Berg (2020); Atkinson et al. (2020); Aono (2019); Van Gils (2019). A hub only offering shared mobility for residents, not purposely connected to the public transport system, is referred to as a residential shared mobility hub, whereas the city and regional shared mobility hub offer public transport and focus on multiple target groups. The main distinction between the city and regional shared mobility hub is the urban context: the city shared mobility hub is located in very dense city centers, as opposed to the regional shared

Table 2
The selection of influential factors to be used in the regional shared mobility hub location potential determination methodology, along with the involved perspective and explanation of the influence.

Factor	Perspective	Explanation	Source
Demand	Operator	A higher number of users leads to greater earnings for the hub/public transport/ shared mobility operators, causing a higher shared mobility hub potential from that perspective.	Van den Berg (2020)
Costs	Operator & Government	Investment and operating costs are leading factors in deciding on the approval of a project. A convincing business case is needed to execute a transportation project, for both the operator and government. Therefore, lower costs increase the feasibility of the project.	Talen et al. (2018)
Economic function	Government & End-user	In the case of integration of the hub with surrounding facilities, the additional space needed for the hub is limited, which is important for the government. Additional non-mobility features will not use additional space when these are already present. For the end-user, the attractiveness of the hub increases due to the economic function.	Gerretsen et al. (2018)
Added connectivity	Government & End-user	The government aims to offer mobility for all inhabitants, the shared mobility hub can improve this connectivity. Higher additional connectivity contributes to the inclusiveness induced by the shared mobility hub and is therefore desired from the end-users perspective as well.	SEStran (2020)
Generalized travel costs of using the hub	End-user	A decrease in the generalized costs of the trip due to the usage of a shared mobility hub increases the attractiveness for the end-user.	Koopmans et al. (2013)
Increase in travel time reliability	End-user	A low travel time reliability means that the current situation is unattractive, due to congestion or parking problems. An increase in reliability of the travel time offered by the shared mobility hub makes the hub more attractive from the end-user's perspective.	Atkinson et al. (2020)
Impact on quality of life & emissions	Government	A higher reduction of parking problems and congestion induced by the hub will lead to a higher impact on quality of life issues & greenhouse gas emissions.	SEStran (2020)

mobility hub, located in less densely populated parts of a city or outside of a city. This distinction is important, as the regional shared mobility hub offers car parking, which contributes to generating other intermodal chains. Generally, the city shared mobility hub does not facilitate private car usage, due to the lack of space in highly urbanized areas. An overview of the distinctive properties of the three defined hub classes is presented in Table 1.

To be able to determine the potential for a shared mobility hub, a certain mobility hub type should be selected since location factors might differ per hub type. In this research, the choice is made to further investigate the location of regional shared mobility hubs. The regional shared mobility hub is a hub that offers modalities including, but not limited to, shared mobility, public transport and car parking. In the literature, it is mentioned that very little is known about the locations of regional shared mobility hubs, contrary to the greater amount of information available on residential hubs and city shared mobility hubs. Therefore a methodology to determine the potential of locations for regional shared mobility hubs might have a higher impact on the development of hubs in the future.

2.2. *Factors influencing the potential location for shared mobility hubs*

The factors influencing the potential of a location for a regional shared mobility hub are examined using an extensive literature review. The keywords used to come to a definition of the mobility hub are used in this search as well, with the addition of the keyword "location" to obtain results more relevant to the location. From this research, it follows that the mobility hub has two important functions: an economic and a mobility function. In the literature, the mobility function is often split into three parts, based on the identified target groups: a shared mobility hub positioned as a transfer point at the activity side of the trip, the home side of the trip, and a location in between. An important aspect is that for those three positions in the trip, only multimodal trips are considered, as the regional shared mobility hub focuses on multimodal transportation. In combination with the interests of the different stakeholders this leads to a selection of influential factors, which are the input for the methodology developed in the next section.

A strategic study on mobility hubs in Scotland by SEStran (2020) listed several factors influencing the potential of a location. The demand is marked as an important factor, e.g. measured by the population and workplaces in an area. The level of additional connectivity offered by the mobility hub in a certain area also determines the potential of a regional mobility hub. It should be kept in mind that the hub is intended to reduce emissions and improve the quality of life in a city, so the extent to which this improvement is realized determines the potential of a certain location for a regional shared mobility hub.

Additional factors to enhance the methodology are found in other research work. The investment and operational costs are mentioned as a main influential factor for the feasibility of an innovative mobility concept in Talen et al. (2018), whereas the generalized travel costs are important for the traveler, as these costs are a measure for the accessibility change (Koopmans et al., 2013), which is essential in calculating the hub potential of an area. In Atkinson et al. (2020), the generalized travel costs factor is found to be important for the end-user, just as is the change in travel time reliability induced by using the hub. A complete overview of the included influential factors in this research is given in Table 2.

2.3. *Methodologies for locating mobility hubs*

Before developing a methodology to incorporate all factors, current literature on existing methodologies is reviewed. In a paper by Frank et al. (2021), a decision support tool is introduced to locate multimodal mobility hubs in rural regions. This tool consists of two optimization models, one aiming at improving the accessibility to POIs, and the second one aiming at improving workplace accessibility. Public transportation, travel itineraries and on-demand modes are included in this methodology. In the developed model, potential mobility hubs may only be located at current public transportation nodes. The output of the model can be used to support multi-criteria decision-making. Spatial and social perspectives are not integrated into the model, it is focused on a transport perspective.

Yu et al. (2013) used a similar approach, in which passenger attraction, defined as a product of connectivity and accessibility, is used to define candidate nodes. In the next step, construction costs and the served population are taken into account to find optimal hub locations while considering overlapping service areas.

A study by Tavassoli and Tamannaei (2019) specifically addresses the competitiveness of Bike-and-Ride services against the car. The mobility hub targets trips made by private cars in order to lower greenhouse gas emissions. A hub network design problem is solved in this study with the substitution of private cars as the main objective. Demand, costs and connection to the public transport system determine the potential of a location. Candidate hub locations are selected from both the existing public transport network and high-demand locations, and consecutively a network is designed by the algorithm.

A paper by Yatskiv and Budilovich (2017) focuses on traffic on macro-level and transit mobility issues in order to suggest an approach to planning efficiently operated transportation hubs. The authors found accessibility, interconnectivity ratio and closeness centrality as indicators to analyse future public transport network variants.

Aydin et al. (2022) apply a MCDM method under uncertainty to solve the location selection problem for mobility hubs. Interval type-2 fuzzy AHP (Analytic Hierarchy Process) and WASPAS (Weight aggregated sum product assessment) are used to determine the weights of the criteria and find the scores of the proposed locations. The study is based on experts from the city of Istanbul, Turkey, and a finite set of alternatives is used as input for the MCDM methodology.

Multiple studies have been introduced in the past years to support decision-making related to multimodal mobility hubs. Frank et al. (2021) and Tavassoli and Tamannaei (2019) propose an optimization model, aiming at finding the best hub locations to replace as many car trips as possible. Yu et al. (2013) also provide a mathematical model in which accessibility and connectivity are used as factors influencing a location's potential for placing a hub.

Yatskiv and Budilovich (2017) and Aydin et al. (2022) investigated factors influencing the potential of a location for a mobility hub, in which accessibility is an overlapping theme, while Aydin et al. (2022) also include less documented criteria like demographic patterns and structural suitability. Experts evaluated a limited set of alternatives based on criteria and sub-criteria.

From these previous studies, it follows that an approach has yet to be developed to integrate different types of criteria from various perspectives in a data-based methodology using a non-finite set of potential hub locations. This approach is proposed in the next section.

3. Development of the suitable hub location methodology

With the overview of influential factors, a methodology is developed to estimate the potential of an area for a regional shared mobility hub. The methodology is aimed to be used to spatially evaluate multiple alternatives incorporating the interests of the stakeholder groups. So the method should be able to score alternatives on the criteria identified in section 2 and, subsequently, weigh these scores from the perspective of the different stakeholder groups. In the application, it is deemed important that the output is visual for policymakers, in the style of a heat map. Additionally, it is important to include both quantitative and qualitative evaluation criteria in the methodology, as both types are important as seen in the literature review; for example, both the demand (quantitative) and the existing facilities around the location (qualitative) should be taken into account. These requirements lead to the selection of the Multi-Criteria Analysis (MCA) as the best method to be applied.

The MCA is a widely used methodology to evaluate decision problems, as this method makes it possible to incorporate quantitative and qualitative criteria in the evaluation of multiple alternatives (Macharis et al., 2009). Two extensions to the general MCA methodology are required to meet the goal: multiple perspectives should be incorporated explicitly, as this is an important part of the research question, and the result should be visually represented. The focus on the incorporation of multiple stakeholder groups led to the Multi-Actor extension of the MCA (MAMCA), in which different stakeholders are explicitly incorporated into the MCA (Macharis et al., 2009). In addition, the spatial evaluation of the alternatives requires the methodology to incorporate the spatial element in the analysis. This is why the choice is made to include Geographic Information Systems (GIS) in the method, as GIS can represent the output visually. The GIS-MAMCA combines the spatial analysis and decision support from GIS with the decision-making process of MAMCA. GIS can identify a suitable area for a new hub by performing overlay operations to find a location that satisfies all criteria the best. The exact procedure for the GIS-MAMCA is presented in Fig. 1. The problem, constraints and alternatives are spatially defined, whereas the regular MAMCA defines the decision maker's preferences and evaluation criteria.

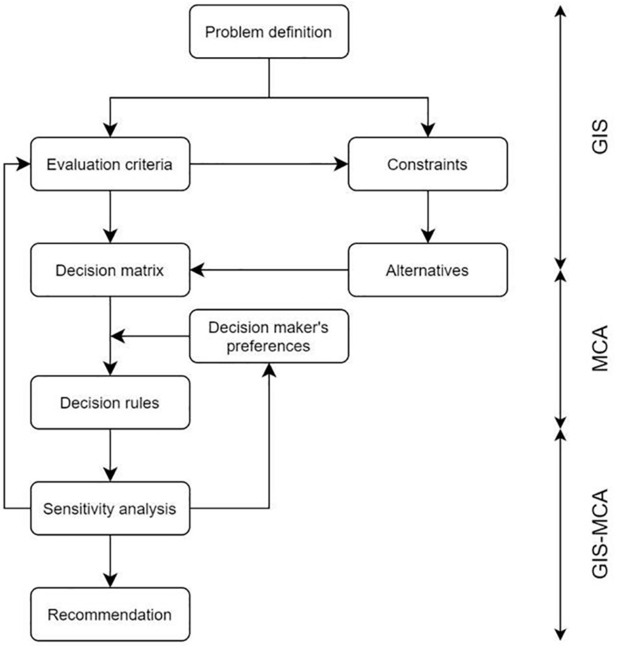

Fig. 1. *Flowchart for using the GIS-MCA method, adapted from (Malczewski, 1999).*

In the GIS-MAMCA method the following steps have to be taken:

1. Define alternatives: The alternatives that will be used in the analysis are defined first. These alternatives are all areas/cells (geographic shapes) in the region that satisfy the urbanization constraint posed in Table 1. As the regional shared mobility hub is the investigated hub type in this research, the posed constraint for the cells is a maximum address density of 2500 addresses/km^2.
2. Define criteria and weights: The determination of the criteria and weights is done based on the stakeholder objectives. The used methodology for finding the weights is the Analytic Hierarchy Process (AHP). In this methodology, trade-offs between criteria are done by the stakeholders, to establish the weights that will be allocated to the criteria.
3. Criteria, attributes and measurement methods: Attributes are constructed to operationalize the criteria. These indicators should be measurable and are often quantitative.
4. Overall analysis and ranking: All alternatives are evaluated according to the determined weights and criteria.
5. Results: The scores of the various alternatives are given. A sensitivity analysis is performed, to see the results of changes in the weights.

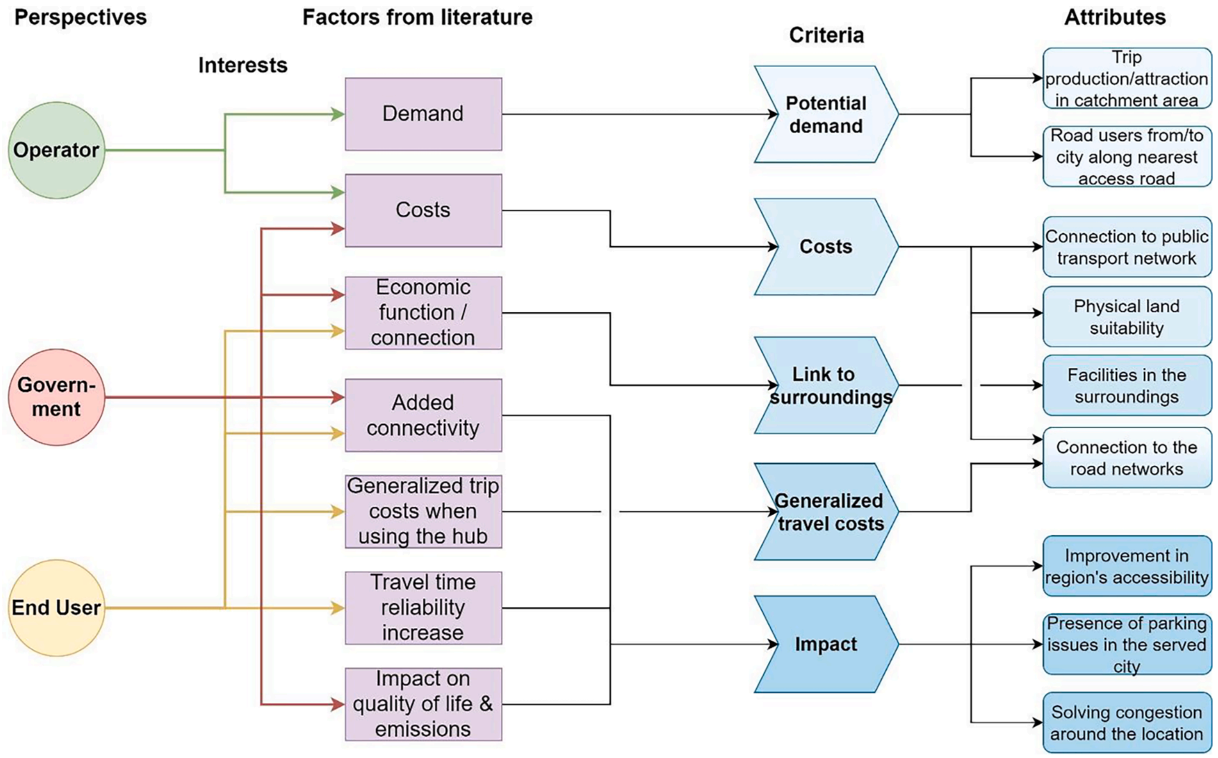

Fig. 2. The perspectives adopted in this methodology with their interests, being factors influential for a hub location choice. In this methodology, these factors are combined into five criteria with measureable attributes, their relationship is shown in this figure.

3.1. *Computations & procedures*

Within the developed methodology, there are computations and procedures applied which are presented in this section. Two basic concepts are required to obtain the correct score out of the input data (Malczewski and Rinner, 2015) for the GIS-MAMCA. These concepts are value scaling and criterion weighing.

In order to make sure that the influence of an attribute is not dependent on the actual values of the input data, but on the relative values, the data is scaled. The least preferred attribute value is given the value 0, whereas the most preferred value is given the value 1. This procedure is called normalization, i.e. scaling all data into the range of 0 to 1. The scaling factors are completely dependent on the provided input data; a change in input data will lead to a change in the scaling factor.

Weights are assigned to the criteria, measured by the normalized attributes, to indicate that not all criteria are of equal importance. To determine the importance of one criterion compared to another, ranking, rating, entropy-based and pairwise comparison methods are available. For this paper, the pairwise comparison method is a feasible method, to incorporate the stakeholders' opinions. This is more precise than only a ranking but less specific than exact weights allocated to each criterion by each stakeholder. In the pairwise comparison method, multiple procedures are available, but the AHP the most common procedure in GIS-MCA is adopted in thispaper Al-Shalabi et al. (2006) and Macharis and Ampe (2007) show the common use of AHP in GIS-MCA. AHP is a logical, well-structured framework that makes complex problems more manageable.

The attributes provide a way of measuring the criteria. These criteria and attributes are described in the upcoming subsections. A full overview of the criteria and attributes, with the link to the influential factors from the literature and the stakeholders, is presented in Fig. 2.

3.2. *Potential demand*

The potential demand for a regional shared mobility hub in an area is of high importance from the operator's perspective, as it determines the passenger numbers of the offered mobility service. From a business point of view, demand should be as high as possible. In the method, the distinction is made between the shared mobility hub as an access/egress point for its corresponding catchment area, both on the home and activity trip end, and the shared mobility hub as mainly a transfer point in

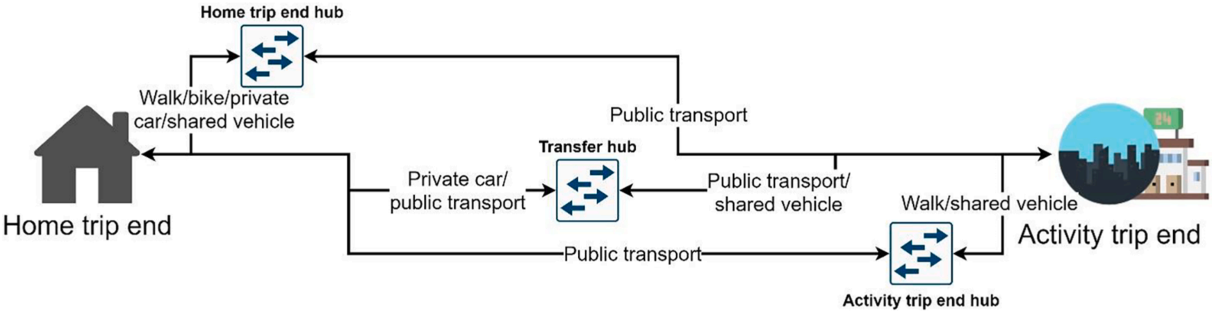

Fig. 3. The possible hub trip end positions.

a trip. A graphical explanation of the trip end positions can be found in Fig. 3. Consequently, two attributes are introduced to measure the criterion 'potential demand', each referring to one of these trip functions.

Attribute: Trip production/attraction in the catchment area (local demand).

The trip production/attraction is based on the social-economic data (population, workplaces and facilities) of the locations in the region. The trip production/attraction in the catchment area of the shared mobility hub is used to measure the potential demand from/to this catchment area. The word "potential" is used here, as not all travelers will make a switch from the currently used mode of transport (namely the car) to a shared mobility hub. As the switch from car transport to multimodal transport using a shared mobility hub is the aim of the hub, only the car production/attraction is taken into account.

Attribute: Road users from/to the city along the nearest access road (transfer demand).

Next to the local demand, the demand for the facility as a transfer location is included. This is operationalized as the vehicle intensity at the nearest access road, usually being a road/highway, from/to the main cities in the region. This way, traffic with an origin outside of the studied region, headed for the city is also included in the demand. This attribute relates to the transfer mobility function of the shared mobility hub as referred above. A part of the local demand might also travel via the nearest city access road to the city, meaning that this traffic is double counted.

3.3. *Costs to realize and operate a hub*

From the operator and government perspective, the introduction of a shared mobility hub is accompanied by costs. Two types of costs are taken into account: the one-time investment costs and the operating costs of the shared mobility hub. The investment costs will be most relevant for the government, as these costs are mostly covered by a local/regional/national authority, while the operating costs are more relevant for the hub, public transport and shared mobility operator. As a proxy for both costs, the connection to the current road and public transport networks and the physical land suitability are the measured attributes.

Attribute: Connection to the road & public transport networks.

For the government, the connectivity to the road network relates to the costs. A road should be constructed to connect the shared mobility hub with the main road network, as road traffic flows may become too high for the local road network to process. As an indication of the length of the road and therefore the costs, the distance to this main road network is used as an attribute. The same holds for the connection to the regional cycle network.

For the operator, the connectivity to the public transport network is relevant, because costs are involved when adding or rerouting bus lines. This factor is composed of the distance to the public transport network and the presence of a railway station. The rerouting distance of transit lines is a measure of the additional costs involved for the public transport operator due to the rerouting of their lines via the proposed location. Ideally, the exact cost of rerouting and upgrading an existing public transport line (towards the city center) is used as an attribute, but simplifications should be made because those costs cannot be calculated directly since they are case-specific. The best possible approximation is the distance to a high-quality bus/tram line, to give an indication of the additional infrastructure and vehicle hours needed to redirect the service via the shared mobility hub. Furthermore, as part of the connection to the public transport networks, the presence of a train/metro/light rail station is added, as the presence of such a station can significantly reduce the investment costs.

Attribute: Physical land suitability.

Concerning the costs of integrating the shared mobility hub, spatial integration is most relevant. For the construction of a regional shared mobility hub, space is needed to accommodate a public transportation stop, bike and car parking, sharing and additional facilities. Comparing the land usage of these facilities, car parking will require the largest area of land. Therefore, the presence of a car parking facility would ease the integration of the shared mobility hub significantly. Furthermore, the integration concerning existing structures should be taken care of, as relocation of these structures would entail high costs. The zoning plan should allow for the location of a shared mobility hub, so the presence of, for example, an environmental protection area makes it more difficult if not impossible to build such a facility. The first measurement of this attribute is the presence of a parking area at a location. As a second measurement, the suitability of the land is determined, in which land having an uncategorized function (including vacant areas) has the highest suitability (100 %), while forest or agricultural land are estimated to have a suitability of 25 % for a hub. The presence of buildings in an area further reduces the suitability. The third measurement is the owner of the land, in which publicly-owned land has higher suitability (value 1) than privately-owned land (value 0).

3.4. *Link to the surroundings*

The economic importance of the shared mobility hub, as found in the literature, leads to the "link to surroundings" criterion. The inclusion of other facilities in the shared mobility hub, like retail, catering and parcel pick-up points, improves the potential of a shared mobility hub. To incorporate this factor in the location potential, the presence of one of these facilities at the location provides an opportunity to integrate mobility at that location. For example, the presence of a supermarket would lead to a higher potential for a regional shared mobility hub, as the mobility function can be integrated with the existing economic function in the area.

Attribute: Facilities in the surroundings.

A selection of facilities should be made to include this criterion in the analysis. Based on the features that can offer an added value for the shared mobility hub, the following facilities are relevant: a library, healthcare facility, sports center, grocery store, parcel pick-up point and retail facilities. The presence of these facilities within a certain distance from a location provides a higher mobility hub potential, because of a potential collaboration/integration of the mobility function and the economic function.

3.5. *Generalized travel costs*

Incorporating the costs for the end-user (the traveler) is more challenging. From the point of view of the individual end-user, the travel costs/time that can be saved by using the shared mobility hub at a specified location are important. However, in finding the best position for a shared mobility hub, this factor can only be taken into account by aggregating all individual travel costs/time savings. To indicate these possible savings, the connection to the current main road and cycle network is used, which is related to the additional travel time and costs imposed when driving/cycling to the shared mobility hub.

Attribute: Connection to the road networks.

The road network connectivity is the leading factor in determining the additional costs/travel time for users, and this factor is split up into two parts: The distance to a main road/highway and the distance to a regional cycle route.

3.6. *Impact*

For the traveler, current traffic problems lead to additional travel time and a lower travel time reliability of their trip. Furthermore, for the government, these traffic problems have consequences. The quality of life in the city and around the main roads decreases because of congestion, whereas pollution and nuisance cause problems for the inhabitants of a municipality, and congestion limits the accessibility of a city. These problems can exist in the city which is served by the regional

Fig. 4. The Rotterdam region in The Netherlands, adapted from Rijkswaterstaat (2020). Orange and red stretches on the left map represent congested roads.

shared mobility hub or on the route to/from the city.

Additionally, the regional shared mobility hub can have a positive impact on the accessibility of an area. The connection between the region and the city center and vice-versa can be improved by placing a hub, and the accessibility of a region itself can be improved by providing shared mobility and a connection to the public transport and road network. To be sure of the impact of the hub location on mitigating traffic problems, the occurring congestion and the region's accessibility should be recalculated for every area upon the introduction of a shared mobility hub.

Attribute: Improvement in the region's accessibility.

The improvement in the accessibility of a region can be measured in terms of the increase in facilities and workplaces that can be reached from the selected location within an arbitrary travel time, caused by the introduction of a shared mobility hub. This change in accessibility should be determined for every potential location (geographical unit) in the region of choice. To measure this attribute, the number of potential users in an area of 800 m around the potential hub location is determined, with a correction factor for the distance to the location. This factor is linear, with a value of 1 for users present at the location of the hub, and 0 for users at a distance of>800 m from the hub.

Attribute: Presence of parking issues in the served city.

The presence of parking issues in the served city might indicate a need for a shared mobility hub, as providing a replacement for or transfer of the car to a different modality tackles the lack of space problem in the city. Shared modes and public transport require less space in a city, so these parking issues can potentially be mitigated when using a (remote) shared mobility hub. This attribute can be operationalized by using information from the local authority on parking pressure and/or parking fares. Higher parking pressure or fares indicate the presence of parking issues in the city served by the shared mobility hub. This attribute does not relate to the parking issues at the potential location of the hub.

Attribute: Solving congestion around the location.

The aim of this attribute is to give a higher score to locations from which the car route to the city center is congested. In this way, it is attempted to improve the score of locations upstream of where the congestion occurs, a location in the middle of or downstream of the congestion is a less favorable location for a shared mobility hub, as users will encounter congestion before reaching the hub. The actual level to which the hub can solve congestion at a certain location is not measured, but as a very rough estimate, the presence of congestion within 1000 m of the location is included to identify whether congestion is present near the potential location.

4. Case-study: Rotterdam region

This methodology is applied to a case-study to test it. To be able to apply the methodology to a region, multiple steps were taken. These steps are briefly described in this section.

Region selection: In the application, the first step was to select a region for which the shared mobility hub potential will be evaluated. The region is selected based on data requirements and current societal issues. Due to the presence of a detailed, up-to-date traffic model and the fact that the highways around this large city are among the most congested highways of The Netherlands, the choice was made to apply the methodology to the Rotterdam region in the Netherlands. The position of Rotterdam in the Netherlands is shown in Fig. 4. Rotterdam is located within the metropolitan region of Rotterdam-The Hague (MRDH). The MRDH, a collaboration of 23 municipalities (Metropoolregio Rotterdam Den Haag, 2020), is considered one of the most important areas in The Netherlands, with 2.4 million inhabitants and 1.2 million jobs.

Stakeholder interviews: Stakeholders were interviewed to gather information on the weights for the trade-offs between the criteria and to provide additional insights into the facilities included in a shared mobility hub. The nine interviewed experts are part of the relevant stakeholder groups, namely public transport companies Arriva, RET and NS represented the operator perspective, the Municipality of Rotterdam represented the government perspective, the public transport consumer platform of a Dutch province (OV-Consumentenplatform Drenthe), the association for business drivers (VZR) and the Royal Dutch Touring Club (ANWB) the end-user perspective. Additionally, one independent expert on public transport and shared mobility from a research group linked to the TU Delft was interviewed, to obtain more objective information on the criteria.

Weights allocation using scenarios: To explicitly incorporate the interests of the stakeholder groups, multiple scenarios with varying stakeholder configurations were developed. By doing so, more insights can be gained given the uncertain influences of the different stakeholders' perspectives. In this research, four scenarios are developed with

Table 3
Weights allocated to the criteria for the scenarios used in the method application.

Criterion	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Potential demand	0.22	0.11	0.11	0.44	0.13
Costs	0.21	0.25	0.10	0.27	0.38
Generalized travel costs	0.05	0.02	0.10	0.02	0.05
Link to surroundings	0.14	0.14	0.21	0.07	0.13
Impact	0.38	0.48	0.48	0.19	0.31

varying stakeholder importance, and a fifth scenario is formulated to incorporate the uncertainty of the importance attached to the costs from the stakeholders' point of view. The weights for the criteria extracted from the expert interviews are established for every scenario as seen in Table 3.

1. Scenario 1: All stakeholder groups are equally important: 33.3 % operator, 33.3 % government, 33.3 % end-user.
2. Scenario 2: The government is more important than the other stakeholders. This is a realistic scenario, as the government often has the largest financial contribution to the project. In most cases, the government makes the final decision whether the hub development can proceed or should be stopped. The stakeholder influence in this scenario is: 16.7 % operator, 66.7 % government, 16.7 % end user.
3. Scenario 3: The stakes of the end user are the most important in this scenario. This scenario is realistic when focusing on the interests of the end-user. The stakeholder influence in this scenario is: 16.7 % operator, 16.7 % government, 66.7 % end user.
4. Scenario 4: The public transport/shared mobility operator is allocated the highest influence in this scenario. This scenario expresses the importance of the operators as the service providers at the shared mobility hub. A low potential of a location from the operator's perspective will lead to a lower willingness of the operator to offer their services at that location. The stakeholder influence in this scenario is, therefore: 66.7 % operator, 16.7 % government, 16.7 % end user.
5. Scenario 5: In this scenario, the weights are equally distributed over the three stakeholder perspectives. What changes in this scenario is that the costs criterion is three times more important than the original score from both the operator and government perspectives. This scenario is realistic in present times, as governments are currently very hesitant to fund new projects. Furthermore, the costs criterion has a high level of uncertainty, as no literature on the costs of a shared mobility hub exists. A lot of these projects are pilot projects.

Based on the defined scenarios, the final weights resulting from the trade-offs from the expert interviews are established by using AHP. This implies that trade-offs between criteria are made by experts. Due to the fact that the experts in this method application are familiar with the Dutch and/or Rotterdam context, the weights cannot be used directly in a method application in another region. If our method were to be applied in another context, the specific weights can be found by interviewing experts or stakeholders familiar with that context. The applied weights for every scenario are found in Table 3.

GIS tool selection: A GIS tool was selected to execute the developed methodology in an application. The three GIS tools which were considered were ArcGIS, FME and QGIS. All three tools are suitable for performing a MCA, leading to the choice being made based on the user-friendliness and knowledge in-house. The decision was made to use FME, a GIS tool developed by Safe Software to efficiently process and integrate (geographical) data (Safe Software, n.d.), which is mentioned as the most user-friendly tool for first-time GIS users.

Data gathering: The needed data to operationalize the attributes is gathered from various sources. The region's traffic model (V-MRDH 2.6), topographic data on the land usage (TOP10NL, open-access available from PDOK (n.d.)), landowner data from the municipality and the national cycle route database are the used sources to operationalize all attributes of the methodology, except for the presence of

Table 4
The criteria and attributes from the methodology, with the corresponding attribute and the data source for the method application.

Criterion	Attribute (methodology)	Attribute (method application)	Unit	Data source
Potential demand	Trip production/attraction in the catchment area	Production/Attraction	Trips per day multiplied by correction for distance (1 for 0 m, 0 for > 800 m)	Traffic model (V-MRDH 2.6)
	Road users from/to city along the nearest access road	Traffic along the road from/to city center	Traffic per day multiplied by correction for distance (1 for 0 m, 0 for > 1000 m)	Traffic model (V-MRDH 2.6)
Costs	Physical land suitability	Presence of a parking area	Yes/no (1/0)	Topographic file (TOP10NL)
	Physical land suitability	Physical land suitability	Very suitable (1)/Likely to be suitable (0.75)/unlikely to be suitable (0.25)/not suitable (0)	Topographic file (TOP10NL)
	Physical land suitability	Land owner	Owned by municipality (1)/other owner (0)	BRK Rotterdam
	Connection to public transport network	Presence of high-quality bus/tram link	Linearly decreasing from HQ bus/tram link within 0 m (1) to HQ bus/tram link at a distance of > 1000 m (0)	Traffic model (V-MRDH 2.6)
	Connection to public transport network	Presence of light rail/metro/train station	Linearly decreasing from Station within 0 m (1) to Station at a distance of > 400 m (0)	Topographic file (TOP10NL)
	Connection to the road networks	Presence of regional cycle route	Linearly decreasing from Reg. cycle route within 0 m (1) to Reg. cycle route at a distance of > 1000 m (0)	National cycle route database
	Connection to the road networks	Presence of main road	Linearly decreasing from Main road within 0 m (1) to Main road at a distance of > 1000 m (0)	Topographic file (TOP10NL)
Generalized travel costs	Connection to the road networks	Presence of regional cycle route	Linearly decreasing from Reg. cycle route within 0 m (1) to Reg. cycle route at a distance of > 1000 m (0)	National cycle route database
	Connection to the road networks	Presence of main road	Linearly decreasing from Main road within 0 m (1) to Main road at a distance of > 1000 m (0)	Topographic file (TOP10NL)
Link to surroundings	Facilities in the surroundings	Number of retail workplaces	Retail workplaces within catchment area multiplied by correction for distance (1 for 0 m, 0 for > 400 m)	Traffic model (V-MRDH 2.6)
Impact	Solving congestion around the location	Maximum I/C-ratio in vicinity for main roads	Value of the maximum I/C-ratio within 1000 m	Traffic model (V-MRDH 2.6)
	Improvement in region's accessibility	Reached users (socio-economic data)	Potential users within catchment area multiplied by correction for distance (1 for 0 m, 0 for > 800 m)	Traffic model (V-MRDH 2.6)
	Presence of parking issues in the served city	–		Not used

parking issues in the served city. This attribute is not included because it does not vary in the region, as the served city is the same for all areas in the Rotterdam region. Some other attributes are slightly changed in the method application, due to the availability of data. An overview of all used attributes in the method application and the link to the attributes from the methodology is given in Table 4. All distances used as a unit in the method application are Euclidian distances.

Data preparation: The data is prepared for usage in the GIS tool. The size of the areas in the method application was chosen as a grid cell of 100x100 meters. 100x100 meters is approximately the limit posed by the accuracy of the input data. The zones in the traffic model and accuracy of the topographic data led to this choice, as a smaller cell size will not lead to a large improvement of the method application compared to the additional calculation time.

Then, the urbanization constraint was applied, so cells that do not fit the definition of a regional shared mobility hub are filtered out. Subsequently, the data is prepared for usage in the GIS tool, meaning that the attributes are given a value. For all attributes, the value depends on the presence or quantity of a certain element, corrected for the distance to the cell. As the final step before the method execution, the data is normalized to a scale from 0 to 1, in which the value 0 is given to a value leading to a low shared mobility hub preference, and a value 1 leading to a high shared mobility hub preference.

Method execution: FME Workbench 2020.2 was used to run the method application, where after the output for every scenario is exported, results were visualized in QGIS Desktop 3.10.10. The results, including a QGIS background map, were then exported and presented.

Some assumptions were made to be able to execute the method application using the available input data. These most important assumptions are listed below.

- A simplification is made concerning the impacts of the regional shared mobility hub in the method application. The actual impacts of a hub in the area are not calculated as the regional mobility hubs are not inserted in the traffic model. Instead, non-iterative measurements are used to estimate the score of a cell on the impact criterion. This means that the improvement in the region's accessibility is only measured in the number of users in the catchment area of the hub, and the solving congestion attribute is simplified to the presence of congestion close to the cell.
- Future developments in the region such as new road infrastructure are excluded as the method assumes the current situation. Detailed data on future developments are often not easily available. But the method can easily be applied under future conditions.
- For the'Road users from/to city along nearest access road' attribute, only traffic from or to the main served city is taken into account. This is an underestimation of the actual transfer demand of the regional shared mobility hub, as users from/to other cities might also use the hub as a Park&Ride facility. As the actual transfer demand is location specific and very difficult to extract from the available data, this is not included in this method application.

5. Results & analysis

Each scenario resulted in a map covering the extent of the region, with the potential for a regional shared mobility hub evaluated for every grid-cell in this region, except for the extremely urbanized areas (address density > 2500 addresses/km^2). The result for the first scenario, with equal influence of every stakeholder group, is given in Fig. 6.

The first four scenarios largely resemble each other; differences in scores are found to be small. For a selected part of the region, only small differences in scores can be seen in Fig. 5. The fifth scenario, in which the costs are given three times the higher weight, is more distinct in some places. A much higher number of cells score high in scenario 5, as 1302 cells score a green score (0.363 or higher), compared to 581–801 high-scoring cells in the four other scenarios. This can be observed in Fig. 7. To find out more about the reliability of the results, several steps are taken. An overview of the steps with the corresponding outcomes is presented in Table 5.

From Table 5, it appears that the methodology responds logically to the performed analysis steps. However, the methodology seems to be relatively insensitive to changes in the weights of the attributes and stakeholder perspectives. The reason for this can be found in the high number of contributing attributes and a relatively small variation in the values of these attributes. Moreover, a variation in stakeholder weights affects multiple attributes, leading to an even smaller variation in the score.

In the analysis of the high-scoring locations from the method application, plausible results are produced. The best high-scoring area, which is represented by number 1 in Fig. 5, is an area in which all elements possibly leading to a high regional shared mobility hub potential come together: a congested highway passes by the cell, large traffic numbers from/to the city center are found on the road crossing the area, a high workplace and student population are found nearby and a metro station with an adjacent parking (Park&Ride) area is present. Furthermore, this site is located outside of the city center, so it will not lead to additional car traffic in the center. This high potential is completely in agreement with the usage of the Park&Ride area nearby: the Kralingse Zoom Park&Ride area is the most frequently used Park&Ride facility in the entire Rotterdam-The Hague metropolitan area (van de Werken, 2018). This area also seems to be very useful in transportation networks. Users from the catchment area, being mostly commuters for the adjacent business park and students of Erasmus University, can use a regional shared mobility hub to switch from public transport to a shared bike, to accelerate their last mile from the hub to their company/university. With that, public transport is made more attractive due to a decreased total travel time. Besides, car users from both southern and south-eastern directions can make the shift at the regional hub from their car to a more space-efficient mode like the metro or a shared bike, to bypass any congestion or parking problems in the city center. As this area is situated close to the route to the city center, additional travel time/costs for the end-user can be limited to just the transfer time. When making this transfer more attractive by offering facilities at the hub, likely, travelers will use the hub even more.

For a further test of the plausibility, the proposed locations for shared

Fig. 5. The output of the method application for a selected part of the region, shown for scenario 1 to 5. Green cells have a high hub potential, red cells have a low hub potential.

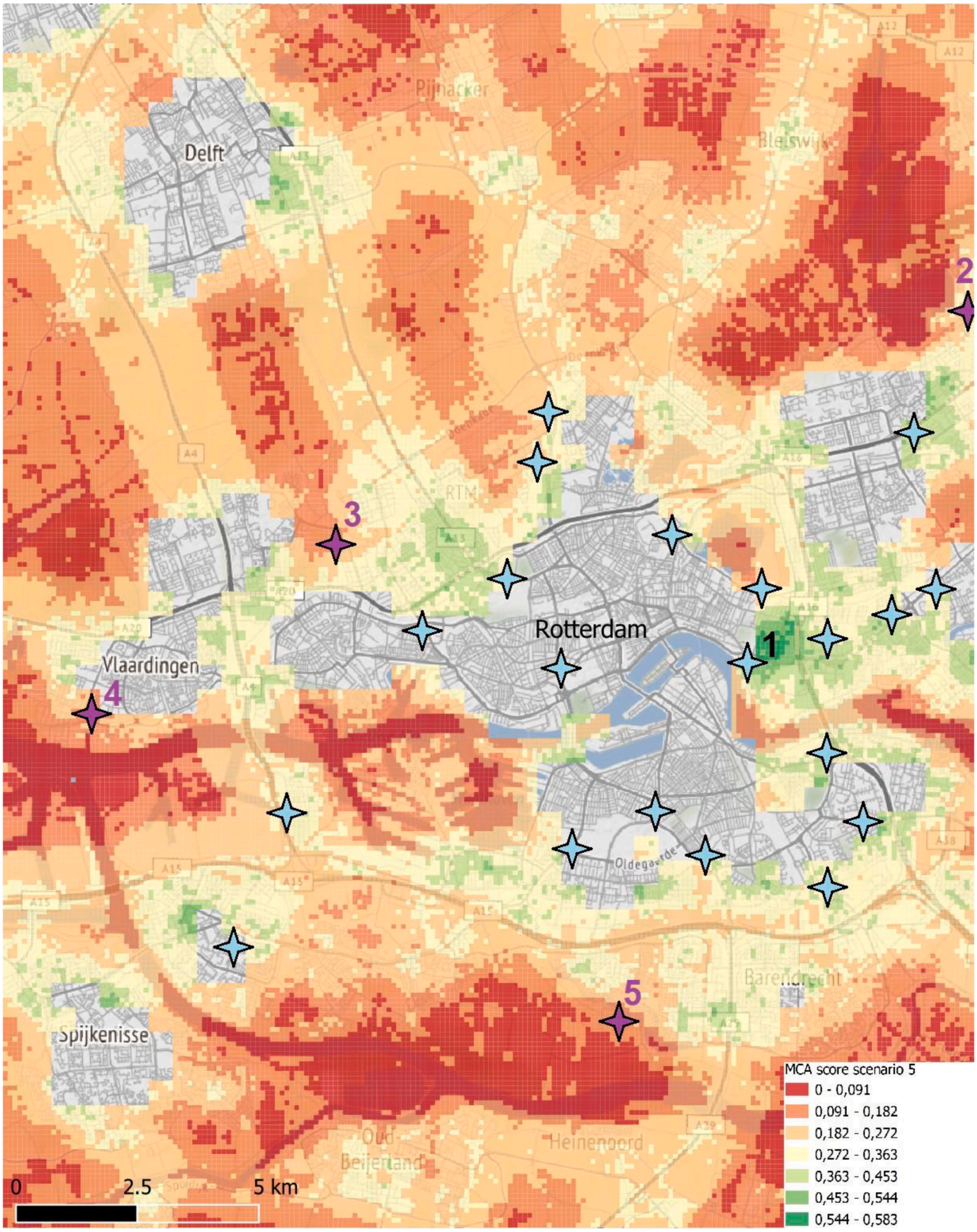

Fig. 6. Output of the application of the methodology for the Rotterdam region in scenario 5. The blue and purple stars represent the proposed hub locations from the MRDH study. The number 1 is the highest potential area, numbers 2–5 are the low-potential proposed hub locations, which are discussed in the main text.

mobility hubs from a strategic document by the Rotterdam-The Hague Metropolitan Region (MRDH) were projected on the output of the method application, leading to the observation that scenario 5 best matches the proposed locations. This is a logical result, as the MRDH report mainly considers the connection to the existing public transport network, which is an attribute to measure the (investment/operating) cost criterion in the method application. Scenario 5 is the scenario that allocates a higher weight to the cost criterion, so this should logically be a better fit for the proposed locations. In the MRDH report, four hub locations indicate a city mobility hub, due to the very high urban density. Of the remaining 22 proposed locations, 18 are situated in a high-potential area in scenario 5 of the method application. Two of the four low-potential locations are situated at locations at which future developments are planned, the numbers 3 and 5 in Fig. 5. The remaining two low-potential locations are further examined.

Number 2 on the map is placed at the Nesselande metro terminus, in a suburb at a distance of 10 km from the city center of Rotterdam. Number 4 is placed at the Vlaardingen-West metro station, at a slightly larger distance from the city center. The contribution of the attributes to the final MCA score in scenario 5 is compared to the average

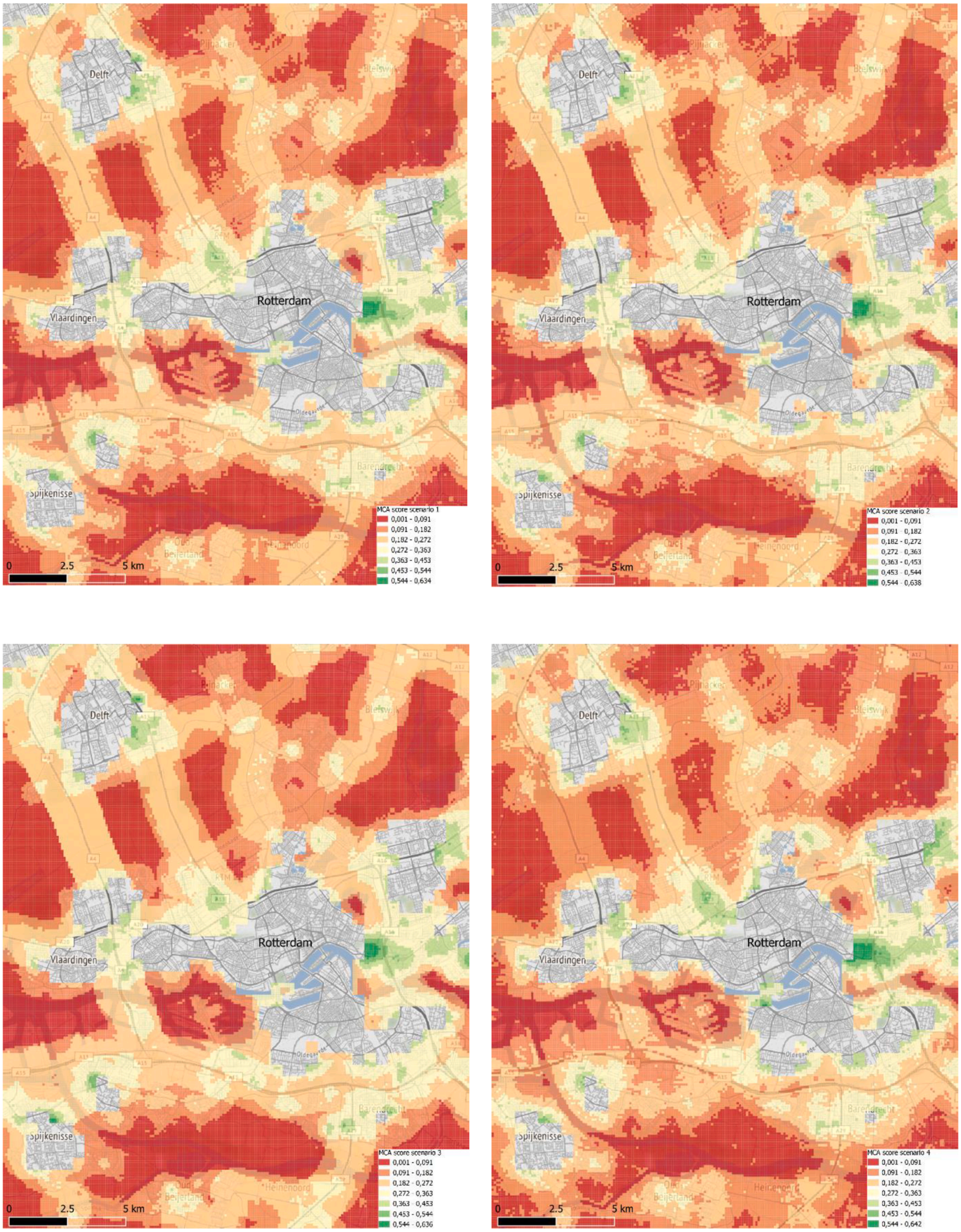

Fig. 7. Output of the application of the methodology for the Rotterdam region in scenario 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right).

contribution in high-scoring areas in Table 6. For both locations, a metro station, parking area, and regional cycle route are present, positively influencing the score. The number of users in the catchment area, trip production/attraction, and land suitability attributes are approximately equal to the expected value for high-scoring cells. These cells score much lower than expected because of the absence of a main road and facilities close to the location, the absence of a congested road around the location, and a very low traffic volume from/to the city. This is remarkable, as the mobility hubs in the MRDH report are proposed with the focus on the transfer function of the mobility hub, so a location near the main roads from/to the city would be expected. A low score of these locations in the method application is justified, as low potential for a regional mobility hub of the locations can be expected in reality.

One important methodological limitation emerges from the analysis steps, which is a result of the normalization of all attributes. The actual attribute values are discarded as a consequence of this process, and normalized on a scale from 0 to 1. Therefore, the highest attribute value in the region is scaled to 1, the lowest attribute value to 0. For the attributes in the demand criterion, this means that the importance of the actual value is ignored, since the scaling factor depends on the

Table 5
Result of the steps taken to analyze the performance of the methodology and its application.

Analysis step	Result	Description
Overall check of the result	Logical	Rural areas with no roads nearby and water areas have low potential, and areas close to the highway have high potential.
Scenario comparison	Insensitive method	The method is relatively insensitive to a change in stakeholder group influence. The various scenarios are only slightly different.
Attribute contribution	Some irregularities	The used scaling factors in the normalization cause unwanted deviations from expected attribute contributions to the final score.
Verification	Some irregularities	Irregularities related to the input data and used GIS tool. Normalization leads to a very small number of cells that score high on certain attributes.
Sensitivity analysis	Insensitive method	This analysis results in relatively low sensitivity of the method for both a change in perspective weights (stakeholders) and attributes weight.
Robustness analysis	Robust method	The outcome is robust for a large part of the high-scoring cells in the region, meaning that the spread in MCA scores between the scenarios is low for most cells that score high in one of the scenarios.
Omitting urbanization constraint	Logical	The lack of space in the centers causes this methodology to be unsuitable for application in extremely dense city centers. Nevertheless, a high trip production/attraction would cause city centers to score high in this methodology. From the analysis, it is found that the highest scoring cells can be found in city centers.
Analysis of high-potential locations	Logical	Regional urban centers and suburban centers are identified as high potential areas, along with areas around rail stations and congested roads.
Comparison with region’s proposed hub network	Logical	The proposed hub locations are an 82 % match to the high-cost scenario (scenario 5), the mismatch can be substantiated by future developments and the other criteria used in that report.

maximum value in the region, instead of a scaling that depends on the significance of the value.

6. Conclusions and recommendations

6.1. Conclusions

In this paper, it is shown that the potential of areas for a regional shared mobility hub can be determined using a GIS-Multi-Actor Multi-Criteria Analysis (GIS-MAMCA), a methodology combining the GIS-MCA and Multi-Actor MCA (MAMCA). This methodology is applied to a region by a GIS analysis, the output is visually represented in a heat map for every scenario, and the results seem fairly plausible.

The perspectives of the stakeholder groups are reflected in the allocation of weights to the criteria:. In finding a suitable location for the regional shared mobility hub, all stakeholders’ points of view should be incorporated, which can be done by using this methodology.

The method is in principle applicable to other cases, as the referenced literature is gathered from multiple countries throughout Europe and North America. The method can be easily applied to other regions in The Netherlands by using the same data; the only requirement is the availability of a traffic model, as the application largely relies on these data.

The developed methodology contributes to the existing literature by providing a generally applicable methodology to determine the potential of areas for a regional shared mobility hub. The shared mobility hub distinguishes itself from conventional public transport nodes by the integration of shared mobility and an added value to passengers and the neighborhood by providing facilities. A methodology to determine the potential of areas for a shared mobility hub is not available yet; the first step is taken in this paper to address this research gap is, by providing this methodology for a specific hub type, the regional shared mobility hub. But more research must be done in this new field.

Table 6
Percentage contribution of the individual attributes to the MCA score in scenario 5, compared to the average contribution of the attributes in the top-scoring cells in the region. A green cell color indicates a relatively high contribution of the attribute to the MCA score, a red cell indicates a relatively low contribution.

Attribute	Average % score contribution	Hub 4: Actual contribution	Hub 2: Actual contribution
Production/ Attraction	9.33 %	12 %	8 %
Traffic along the road from/to city center	2.77 %	0 %	0 %
Presence of parking area	5.37 %	25 %	21 %
Presence of high-quality bus/tram link	6.2 %	0 %	10 %
Presence of light rail/ metro/train station	0.49 %	12 %	11 %
Physical land suitability	17.84 %	20 %	15 %
Land owner	6.09 %	0 %	15 %
Presence of regional cycle route	5.43 %	10 %	9 %
Presence of a main road	12.91 %	0 %	0 %
Number of retail workplaces	3.17 %	3 %	0 %
Maximum I/C-ratio in the vicinity	16.93 %	0 %	0 %
Reached users	13.49 %	18 %	11 %
MCA score	**100 %**	**100 %/0.27**	**100 %/0.32**

6.2. Recommendations

In the process of developing and applying the methodology, limitations are identified (see section discussion), leading to recommendations for both policymakers, which are the potential users of the methodology, and recommendations for future research.

From the cost point of view, it seems obvious to decide on upgrading an existing public transport node to a regional shared mobility hub. It should be considered that these locations are not necessarily the highest potential locations for a shared mobility hub. The cost aspect is only one of the criteria which should be incorporated in deciding on a regional shared mobility hub location, the other criteria in the methodology can cause an existing public transport node to be less suitable for a hub.

A useful addition to the methodology would be the incorporation of the price of land, to better evaluate areas on the cost criterion. By including this factor as an attribute in the methodology, the methodology might become suitable for extremely urbanized areas as well, as the constraint can be replaced by the attribute. Nevertheless, a regional mobility hub with a focus on the transfer from car to shared/public transport will be less suitable in densely populated areas, especially city centers, as this can lead to congestion in this area. Due to the ambiguity of this attribute with the ‘land owner’ subattribute, the choice is made to not include the price of land in the methodology and its application.

To better estimate the impacts of the regional shared mobility hub in selected areas, the highest potential locations can be inserted into a traffic model. This way, the actual impacts can be estimated, leading to a more rigorous estimation of this criterion. Before implementing the regional shared mobility hub, this step should always be performed.

Additional research is suggested on two topics. Firstly, the methodology can be extended for usage on regional hubs with both a passenger and freight function. To do so, the same steps can be performed, meaning that all factors influencing the location potential are identified from the literature, whereafter these factors are converted to criteria in the methodology. Trade-offs between the passenger and freight transport function should be made, which will be difficult, as the characteristics strongly differ among these two transport functions.

Secondly, the methodology can be improved by using revealed preference research results on current shared mobility hubs usage. The actual usage of a hub will not be a one-on-one match to the potential of a location for the hub due to factors that are very difficult to measure, such as personal characteristics and behavior.

CRediT authorship contribution statement

Koen Blad: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft. **Gonçalo Homem de Almeida Correia:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Rob van Nes:** Conceptualization, Formal analysis, Methodology, Supervision. **Jan Anne Annema:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The first author would like to thank SWECO for funding this research project.

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