Damanbagh S. et al.
June 2027
Urban Economics and Planning
Volume 8, Issue 3

An analysis of the role of car-sharing development and its effects on the urban economy

Safiyeh Damanbagh[1*], Mahnaz Hosseini Siah Goli[2]

1. Postdoctoral Researcher in Geography and Urban Planning, Faculty of Letters and Humanities, Shahid Chamran University of Ahvaz, Ahvaz, Iran
2. Postdoctoral Researcher in Geography and Urban Planning, Faculty of Letters and Humanities, Shahid Chamran University of Ahvaz, Ahvaz, Iran

Original Article

Received: 2026/09/07
Revised: 2026/10/08
Accepted: 2026/10/22

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HOW TO CITE THIS ARTICLE
Damanbagh S. Hosseini Siah Goli M. An analysis of the role of car-sharing development and its effects on the urban economy. *Urban Economics and Planning* 8(3):146-173.

DOI: 10.22034/uep.2026.601017.2010

Abstract

This study identifies and prioritizes the advantages and disadvantages of developing shared-car systems across five dimensions: economic, social, environmental, infrastructural, and managerial. Methodologically, the study employs a descriptive-analytical approach. The study collected data through a systematic literature review and input from 50 experts. The SWARA and MARCOS methods were employed to determine the weights and rank the criteria. The findings indicate that, despite limitations such as security concerns, cultural barriers, and the absence of a comprehensive legal framework, shared-car systems have considerable potential to improve urban transportation, reduce pollution, and lower transportation costs. According to the MARCOS results, the economic dimension received the highest score (0.715), followed by the environmental (0.685), social (0.666), infrastructural (0.629), and managerial (0.614) dimensions. The first-place ranking of the economic dimension highlights the central role of shared-car systems in reducing transportation costs and optimizing resource allocation, while the second-place ranking of the environmental dimension underscores the close relationship between environmental sustainability and economic efficiency in urban planning. Overall, policymakers should focus on leveraging the economic, environmental, and social benefits of shared-car systems, while infrastructural and managerial barriers should be addressed progressively and in line with growing demand. Developing smart infrastructure and establishing a clear legal and regulatory framework are essential to realizing the potential of this emerging transportation model.

Keywords

Advantages and disadvantages
car sharing
Markos method
urban economy
urban transportation

* Corresponding Author: damanbagh@stu.scu.ac.ir

1. Introduction

Transportation, as the vital artery of modern societies, plays a fundamental role in facilitating the movement of people and goods; its efficiency and reliability constitute an essential pillar for the economic, social, and cultural progress of societies (Serdar et al., 2022:11). However, the ever-growing population and the expansion of urbanization have significantly increased societies' dependence on private vehicles, giving rise to a wide range of negative consequences, including air pollution, heavy traffic, excessive energy consumption, and a rise in accidents (Mamoohi & Rahmani, 2024:78). To such an extent that the transportation sector accounted for approximately 24 percent of global CO_2 emissions in 2020 (Diao et al, 2021:495; Glazener et al, 2022:168). These challenges, coupled with growing concerns over climate change, have driven governments to seek sustainable solutions for urban transportation (Roblek et al., 2021:907).

In this context, shared vehicles have emerged as an innovative solution to address these problems. This system, which has evolved from an innovative idea into a growing industry, enables a reduction in traffic congestion, air pollution, and noise pollution by decreasing the number of private vehicles in circulation (Kim & Jan, 2024:469) and is employed as a sustainable and economical solution for urban transportation in many parts of the world (Plepys & Vélez, 2025:89). Nevertheless, despite its potential benefits, the effective utilization of this system requires a precise understanding of its advantages, issues, and challenges across various dimensions (Barari et al, 2017:22). On the other hand, a review of previous studies indicates that research in the field of shared vehicles has primarily focused on the technical and economic aspects of this system, such as business models, the technologies employed, and user behavior (Hartl et al, 2024:168). However, a comprehensive, integrated examination of the advantages and disadvantages of shared vehicles across various dimensions, including environmental, economic, social, and physical dimensions, as well as the prioritization of the extent of the impact of developing this system in each of these dimensions, has received less attention. In other words, a research gap exists in providing a holistic picture of the multidimensional effects of shared vehicles and determining the relative importance of each dimension from experts' perspective. The present study seeks to fill this theoretical and empirical gap, and its added value lies in providing a systematic framework for evaluating the various dimensions of shared vehicle development and prioritizing them. Accordingly, the present study aims to answer two main questions: 1) what are the advantages and disadvantages of using shared vehicles from various aspects and dimensions? 2) how is the prioritization of the extent of the impact of shared vehicle development in each of the various dimensions from the experts' perspective?

2. Research background and theoretical foundations

In recent years, shared vehicles have attracted researchers' attention as a modern urban transportation mode because they can reduce costs, traffic, and environmental consequences. In this regard, numerous studies have been conducted in two categories — domestic and international research — a selection of which is presented below.

2.1. Research background

This section first reviews domestic studies, followed by international studies, to identify trends in previous studies and identify existing research gaps.

Domestic studies

Kamareh (2017), in a study titled "Presenting effective indicators for the implementation of a personal vehicle sharing system in the Tehran metropolis with an approach to identifying suitable zones, using the Analytic Hierarchy Process, identified the key indicators and suitable zones for implementing a car-sharing system in Tehran. The results showed that, using the Analytic Hierarchy Process, suitable zones for establishing the sharing system can be prioritized, and demographic, traffic, and accessibility indicators are the most important factors influencing this selection.

Barari et al. (2017), in a study titled "Evaluation of the ecological footprint to achieve urban green transport with the introduction of ASI strategy (Case study: City of Sari)," examined the possibility of achieving green urban transportation through the assessment of the ecological footprint. The results showed that Sari's current urban transportation pattern falls short of environmental sustainability indicators, and applying the ASI strategy (including avoid, shift, and improve) can help reduce the ecological footprint and move toward sustainable transportation.

Mamdoohi and Rahmani (2024), in a study titled "Scenario building for the penetration rate of shared autonomous vehicles: A quantitative environmental

analysis," examined the environmental effects of the penetration of shared autonomous vehicles. The results showed that increasing the penetration rate of shared autonomous vehicles can significantly reduce pollutant emissions and improve environmental indicators; however, the extent of this improvement depends on the penetration scenario and the usage pattern.

International studies

Rabbitt and Ghosh (2013), in a study titled "Exploring the feasibility and potential benefits of organised car sharing in Ireland," examined the feasibility and benefits of a car-sharing system. The results showed that organised car sharing in Ireland is economically and environmentally feasible and can help reduce the number of private vehicles, lower pollutant emissions, and improve transportation efficiency.

Agapito et al. (2014), in a study titled "Car sharing as an environmental policy tool: A preliminary analysis," examined the role of car sharing as a tool for environmental policies. The results showed that car sharing can effectively reduce pollutant emissions and improve environmental sustainability in urban areas, and it holds a special place in transportation policy-making.

Baptista et al. (2015), in a study titled "Car sharing systems as sustainable transport policy: A case study of Lisbon, Portugal," examined the effects of the car-sharing system in the city of Lisbon. The results showed that car sharing can reduce private car use, decrease traffic, and improve the sustainability of urban transportation, and functions as an effective policy in European cities.

Brandstätter et al. (2016), in a study titled "Overview of optimization issues in the design and management of electric car sharing systems," examined the optimization issues in the design of electric car-sharing systems. The results showed that optimization in fleet design, station siting, and charging management plays a key role in the efficiency and sustainability of electric car-sharing systems.

Joo (2017), in a study titled "Motives for participating in sharing economy: Intentions to use car sharing services," examined users' motives for using car-sharing services. The results showed that economic, social, and environmental motives are among the most important factors influencing the intention to use car-sharing services.

Nijland and van Meerkerk (2017), in a study titled "Mobility and environmental impacts of car sharing in the Netherlands," examined the environmental impacts of car sharing in the Netherlands. The results showed that car sharing can reduce CO_2 emissions, decrease the number of private vehicles, improve transportation efficiency, and act as an effective solution for environmental sustainability.

Prieto et al. (2017), in a study titled "Car sharing adoption intention in urban areas: What are the key sociodemographic drivers?," examined the sociodemographic factors influencing car-sharing adoption. The results showed that age, income, education, and gender significantly affect willingness to adopt car sharing, and that understanding these factors is essential for the successful development of these services.

Liao et al. (2017), in a study titled "Consumer preferences for electric vehicles: A literature review," examined consumer preferences for electric vehicles. The results showed that factors such as price, driving range, charging infrastructure, and environmental attitudes influence consumer preferences for electric vehicles, and these findings are also applicable to the development of electric car sharing.

Peroli et al. (2018), in a study titled "Business models and tariff simulation in car-sharing services," examined business models and tariff-setting in car-sharing services. The results showed that selecting an appropriate business model and optimal tariff-setting play a key role in the profitability and sustainability of car-sharing services.

Lokhandwala and Cai (2018), in a study titled "Dynamic ride sharing using traditional taxis and shared autonomous taxis: A case study of NYC," examined dynamic ride sharing in New York City. The results showed that dynamic ride sharing can help reduce the number of vehicles, decrease traffic, and improve transportation efficiency, and that shared autonomous taxis have high potential in this regard.

Ding et al. (2019), in a study titled "Life cycle assessment of car sharing models and the effect on the urban transportation global warming potential: A case study of Beijing," examined the environmental effects of car-sharing models in Beijing. The results showed that car sharing can reduce global warming potential and pollutant emissions, although the extent of this reduction depends on the sharing model and the usage pattern.

Ilgen and Höck (2019), in a study titled "Literature Review of the vehicle relocation problem in one-way car sharing networks," examined the vehicle relocation problem in one-way car-sharing systems. The results showed that optimal management of vehicle

relocation between stations plays a key role in the efficiency and user satisfaction of one-way car-sharing systems.

Shaheen and Cohen (2020), in a study titled "Innovative mobility: Carsharing outlook," examined the trends and outlook of the car-sharing industry. The results showed that the car-sharing industry is growing rapidly and, with new technologies and changing consumption patterns, has high potential for future expansion.

Dong et al. (2020), in a study titled "Understanding the competitive advantages of car sharing from the travel cost perspective," examined the competitive advantages of car sharing from the perspective of travel cost. The results showed that car sharing can reduce travel costs and serve as a competitive alternative to owning a private vehicle.

Kortum et al. (2021), in a study titled "User acceptance of electric car-sharing services: The case of the Netherlands," examined the factors influencing the acceptance of electric car-sharing services in the Netherlands. The results showed that price, accessibility, convenience, and environmental attitudes significantly affect user acceptance.

Golbabaei et al. (2021), in a study titled "The role of shared autonomous vehicle systems in delivering smart urban mobility: A systematic review of the literature," examined the role of shared autonomous vehicles in smart urban mobility. The results showed that shared autonomous vehicles have high potential to improve the efficiency, safety, and sustainability of urban transportation.

Safdar et al. (2022), in a study titled "Analysis of factors influencing car sharing adoption: A case study of a megacity in a developing country," examined the factors influencing car-sharing adoption in a megacity. The results showed that price, accessibility, convenience, and environmental attitudes significantly affect car-sharing adoption.

Sauter (2022), in a study titled "Mobility at the crossroads: E-mobility policy and lessons from charging infrastructure across Europe," examined e-mobility policies and charging infrastructure in Europe. The results showed that developing charging infrastructure and supportive policies play a key role in expanding e-mobility and electric car sharing.

Auer et al. (2022), in a study titled "Towards blockchain and IoT-based shared mobility: Car-sharing and leasing as a case study," examined the application of blockchain and the Internet of Things in car sharing. The results showed that these technologies can help improve the security, transparency, and efficiency of car-sharing systems.

Burgard and Scherer (2022), in a study titled "Vehicle sharing or ride sharing: Psychological factors influencing the adoption of car sharing and ride sharing in Germany," examined the psychological factors influencing car-sharing adoption. The results showed that factors such as trust, environmental attitudes, and social norms have a significant effect on car-sharing adoption.

Jani and Filimon (2022), in a study titled "Sustainability, hedonism, usefulness, and social benefits of car sharing: Evidence from Tanzania," examined the various benefits of car sharing in Tanzania. The results showed that, in addition to economic and environmental benefits, car sharing also offers social and hedonistic benefits that influence user acceptance.

Pawłusz (2022), in a study titled "Towards a smart city: A study of car-sharing services in Poland," examined car-sharing services in Poland. The results showed that car sharing can improve urban sustainability, reduce traffic, and act as part of a smart city strategy.

Silva et al. (2022), in a study titled "Environmental impacts of autonomous vehicles: A review of the scientific literature," examined the environmental effects of autonomous vehicles. The results showed that autonomous vehicles can help reduce pollutant emissions, although their effects depend on usage patterns and accompanying policies.

Hosseini et al. (2024), in a study titled "Dynamic relocation in car-sharing networks," examined the dynamic relocation problem in car-sharing networks. The results showed that dynamic optimization algorithms can improve efficiency and reduce the costs of car-sharing systems.

Plepys and Vélez (2025), in a study titled "Environmental impacts of car sharing: Direct and indirect effects," examined the environmental effects of car-sharing systems. The results showed that, in addition to direct effects (reducing the number of vehicles and pollutant emissions), car sharing also indirectly affects travel patterns and user behavior, and a comprehensive assessment of these effects is essential for fully understanding the environmental benefits.

Research innovation

A review of the research background shows that the studies conducted on shared vehicles have primarily focused on limited and specialized aspects of this system; some studies have solely examined the feasibility and environmental benefits of car sharing (Rabbitt & Ghosh, 2013; Nijland & van Meerkerk, 2017; Ding et al., 2019), others have focused on the factors of user acceptance and behavior (Prieto et al., 2017; Kortum et al., 2021; Kim & Jan, 2024), and a

group has attended to the technical, optimization, and business model dimensions of this system (Brandstätter et al., 2016; Peroli et al., 2018; Hosseini et al., 2024). Nevertheless, none of the previous studies has provided a comprehensive, integrated picture of the advantages and disadvantages of shared vehicles in the form of multiple dimensions (environmental, economic, social, and traffic). Existing literature has also neglected to prioritize the impact of developing this system in each of these dimensions from experts' perspectives. In other words, there is a research gap in the absence of a systematic framework to simultaneously and comparatively assess the various dimensions of shared vehicle development and determine their relative importance. Hence, the innovation of the present study lies in providing a comprehensive framework for identifying and categorizing the advantages and disadvantages of shared vehicles across various dimensions, as well as prioritizing the extent of the impact of developing this system in each of the aforementioned dimensions based on the experts' perspective, which, while filling the existing theoretical and empirical gap, can provide practical guidance for urban transportation policymakers and planners in decision-making regarding the investment in and development of this system.

2.2. Theoretical foundations

In the 1980s, the topic of shared vehicles attracted attention in European countries. In Europe, car sharing first appeared between 1987 and 1988. It was introduced in Germany and Switzerland in 1989, when people almost simultaneously raised the idea of replacing a private car with a shared one. Car sharing was then introduced in Austria and Denmark in 1997. In Belgium, it appeared in 2002, and in France in 1999. In the United Kingdom, the so-called new car sharing was introduced in 1999. In Italy, this concept has been in use since 2009 (Hansen & Maria, 2016:2). Owing to these features and benefits, car sharing quickly attracted the attention of authorities and companies and has expanded in many countries (Ding et al., 2019:1137). Statistically, as of October 2018, car-sharing businesses in 47 countries across six continents, with approximately 32 million users, share more than 198,000 vehicles (Shaheen & Cohen, 2020). The development of information and communication technologies has played an important role in the formation and expansion of shared vehicles. Mobile applications, global positioning system (GPS) technologies, and other modern technologies have made it possible to manage and use shared vehicles easily (Suel et al., 2024:105). Shared vehicles are transportation services that let individuals use a car for a short period without needing to own it. This service is particularly useful in densely populated urban areas and for people who do not need a car on a continuous basis. This service enables users to access a vehicle at any time and place they need. As a modern model in urban transportation, shared vehicles possess unique features, including easy, flexible access, lower transportation costs, reduced traffic and air pollution, the use of modern technologies, diverse service provision, and positive effects on the environment. In summary, shared vehicles are recognized as an efficient solution in urban transportation by providing easy and affordable access to cars, utilizing modern technologies, and having positive effects on the environment. As a relatively new transportation phenomenon, shared vehicles have received widespread acceptance (Hosseini et al., 2024:17). This acceptance has prompted researchers and theorists to examine its various dimensions and present theories. Table 1 briefly presents some of the most important theories proposed regarding shared vehicles.

Table 1. Some of the most important theories proposed regarding shared vehicles

Theory	Description	Source
Sharing economy theory	This theory introduces shared vehicles as a prominent example of the participatory economy. The participatory economy emphasizes the shared use of resources and assets, and shared vehicles, by providing the possibility of shared car use, act in line with this principle. This theory holds that the use of sharing models can reduce resource consumption, decrease air pollution, and improve urban quality of life.	ElKattan et al, 2024: 844
Sustainable transportation theory	This theory is based on the principle that the transportation system should be designed to meet people's transportation needs and cause the least harm to the environment. By reducing the number of private cars, shared vehicles help reduce traffic and air pollution and, consequently, play an important role in achieving the goals of sustainable transportation. This theory emphasizes creating cities with sustainable and low-pollution transportation systems. Shared vehicles, especially electric ones, can help reduce air pollution and urban traffic. This approach helps create healthier and more livable cities.	Vélez, 2023:239

Theory	Description	Source
Intelligent transportation systems theory	This theory emphasizes using advanced technologies to improve the efficiency, safety, and sustainability of transportation systems. Shared vehicles, using mobile applications, GPS systems, and other technologies, are part of intelligent transportation systems. This helps improve traffic management, reduce travel time, and increase access to transportation services.	Pawełoszek, 2022:62
Consumer behavior theory	Studies on consumer behavior show that factors such as economic costs, environmental considerations, and ease of use influence people's decisions to use shared vehicles. This theory examines these factors and offers solutions for attracting more users to shared vehicles.	Kim & Jan, 2024:465

In summary, the theories proposed on shared vehicles examine the various dimensions of this phenomenon, including economic, environmental, technological, and social aspects. These theories can help better understand the role of shared vehicles in the urban transportation system and provide solutions for developing and improving this system. Accordingly, the theoretical model of the present study (Figure 1) is based on five dimensions: economic, social and cultural, environmental, infrastructural and physical, and managerial. Each dimension consists of a set of components and, collectively, explains the role and consequences of shared vehicle development. Based on the proposed model, these dimensions and components ultimately affect the urban economy by influencing transportation costs, resource productivity, economic opportunities, access and social equity, and the quality of the urban environment.

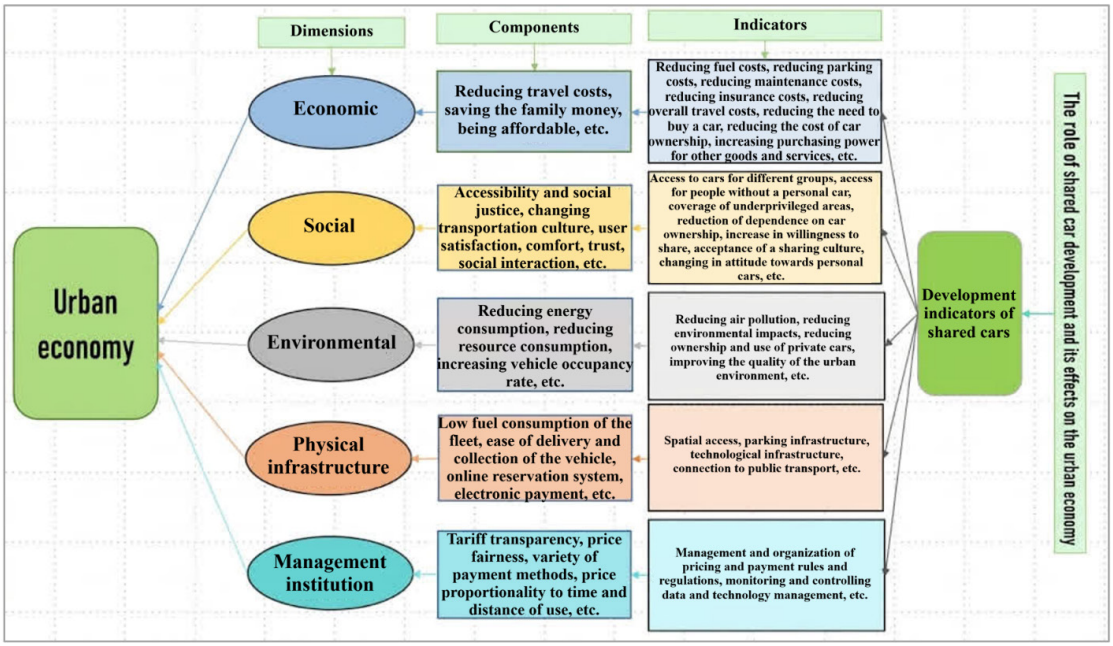

Figure 1. Theoretical model of the research

3. Research methodology

The present study is applied research in purpose and descriptive-analytical in terms of method. This study uses an exploratory, expert-oriented approach in two main stages: in the first stage (descriptive-exploratory), the advantages and disadvantages of shared vehicles were extracted from scientific sources and the research background, and were then purposefully reviewed, revised, and brought to consensus by an expert panel. In the second stage (analytical-quantitative), the confirmed indicators were weighted using the SWARA method and ranked using the MARCOS method.

3.1. Statistical population and sampling

This study provides a general framework for developing shared vehicles in Iranian cities. However, the research data were collected from a sample of experts who are

not tied to a specific spatial context (a particular city) and were collected at the national level. In this regard, the statistical population of the present study consisted of experts and specialists who possessed the necessary theoretical and practical knowledge in the fields of urban transportation, traffic, urban planning, transportation economics, and modern transportation technologies, including university professors, experts from municipalities and transportation organizations, experts from companies active in the field of shared mobility, and related researchers.

Given the lack of a coherent theoretical framework, the lack of precise knowledge of the size and distribution of the statistical population, and also considering the exploratory and expert-oriented nature of the study, convenience sampling was used in the first stage to identify and invite the initial participants. In the second stage, the expert panel was completed using snowball sampling and mutual introduction of experts. In Delphi studies, an expert panel is usually recommended to include 10 to 30 members for limited specialized topics and up to 50 members for multidimensional and interdisciplinary topics. Given the subject's multidimensional nature (environmental, economic, social, managerial, and technical-technological) and the goal of achieving theoretical saturation in identifying the advantages and disadvantages of shared vehicles, the expert panel ultimately consisted of 50 members. The criteria for selecting experts included holding at least a master's degree in related fields (transportation engineering, urban planning, transportation economics, transportation management, transportation information technology, etc.); having research or professional experience in urban transportation, traffic, shared vehicles, or related topics; possessing theoretical or practical familiarity with the concept of shared vehicles and shared mobility; and being willing and volunteering to participate in completing all rounds of the Delphi process. Table 2 presents characteristics of the research experts.

Table 2. Educational qualifications of research experts

Field of expertise	Master's degree (MSc)	PhD	Total
Transport and traffic engineering	6	3	9
Urban and regional planning	5	4	9
Transport and urban economics	5	3	8
Transport and urban management	4	4	8
Civil engineering (transport)	4	3	7
IT and intelligent transport systems (ITS)	3	2	5
Environment and sustainable urban development	3	1	4
Total	30	20	50

3.2. Research dimensions and indicators

To identify and develop appropriate indicators to evaluate the advantages and disadvantages of car-sharing systems, a three-stage process was employed, comprising a review of theoretical foundations, an analysis of existing literature, and consultation with experts.

In the first stage, theoretical frameworks related to car-sharing, shared mobility, sustainable transport, sustainable cities, and the sharing economy were examined. This phase focused on identifying and categorizing the various concepts and impacts of car-sharing. The theoretical review revealed that the implications of car-sharing extend beyond the transport sector, influencing economic, social, environmental, spatial-physical, and managerial dimensions. Consequently, these five dimensions – economic, socio-cultural, environmental, infrastructural-physical, and managerial – were adopted as the initial evaluation framework. This approach aligns with previous shared mobility assessments that analyzed impacts across economy, society, environment, and system performance.

In the second stage, relevant domestic and international studies on car-sharing and shared mobility were reviewed. Indicators and variables used in prior research to assess the performance and effects of car-sharing were extracted and categorized based on their relevance to the current study. By synthesizing these findings with the research objectives, a

preliminary list of components and indicators was developed. During this process, similar indicators were merged, redundant ones were removed, and those lacking a direct correlation with the research scope were excluded.

Because some indicators from international studies may not fully align with the socio-economic, managerial, and physical conditions of the target community, a third stage involving transport and urban planning experts was implemented. The preliminary list was presented to a panel of experts, who evaluated each indicator by importance, relevance, necessity, and applicability. Experts were also encouraged to propose new indicators or suggest the removal or merger of unsuitable ones. To finalize the indicators for car-sharing systems, the indicator structure was first established, followed by a verification of adequacy and non-redundancy. Subsequently, the indicators were assessed for necessity, identifiability, and feasibility through a questionnaire-based expert evaluation. Accordingly, indicators with higher perceived importance and relevance were retained, while insignificant or redundant ones were eliminated or merged. Figure 2 summarizes the overall process of developing the research indicators.

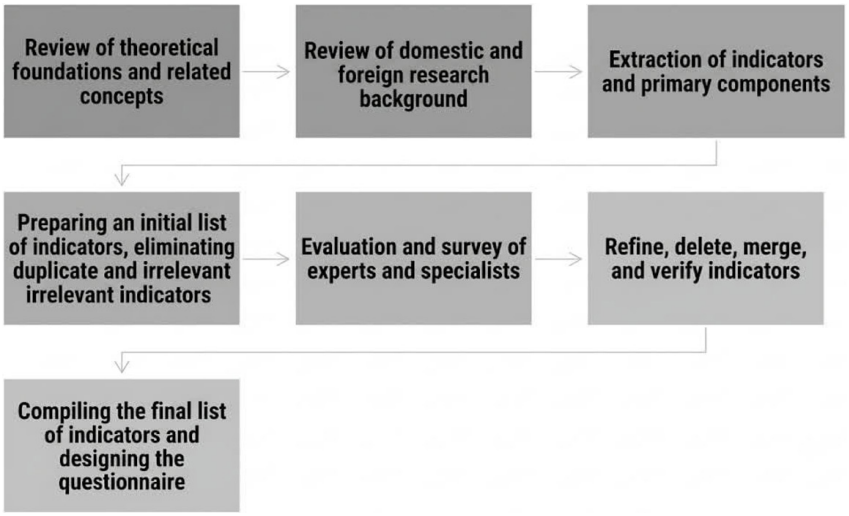

Figure 2. Process of developing research indicators

As a result, the final research indicators were categorized into five dimensions: economic, socio-cultural, environmental, infrastructural/physical, and managerial, as presented in Table 3. This comprehensive set of indicators served as the basis for questionnaire design and evaluating the advantages and disadvantages of shared vehicles. The objective of this process was to establish a set of indicators that are comprehensive, relevant, measurable, and tailored to the specific conditions of the study area."

Table 3. Research dimensions and indicators

Dimension	Code	Component	Indicators
Economic	A	Reduction in travel costs	Reduction in fuel costs; Reduction in parking fees; Reduction in maintenance costs; Reduction in insurance premiums; Reduction in overall travel expenses
		Household economic savings	Reduced need for vehicle purchase; Reduction in vehicle ownership costs; Increased purchasing power for other goods and services
		Cost-effectiveness	Affordability of usage fees; Proportion of cost to service quality; Cost comparison with private cars and taxis
		Economic functions	Reduction in traffic-related costs; Reduction in parking infrastructure costs; Job creation; Boosting related businesses

Dimension	Code	Component	Indicators
Socio-cultural	C	Access and social equity	Accessibility for various social groups; Access for non-car owners; Coverage of underprivileged areas; Suitability of services for the elderly and people with disabilities
		Shift in transport culture	Reduced dependence on car ownership; Increased inclination toward shared mobility; Acceptance of sharing culture; Change in attitude toward private vehicle ownership
		User satisfaction and comfort	Ease of use; Travel comfort; Flexibility; Satisfaction with service quality; Perceived security
		Trust and social interaction	Trust in other users; Trust in the service provider; Respect for others' rights; User accountability
Environmental	B	Air pollution reduction	Reduction in CO2 emissions; Reduction in NOx; Reduction in particulate matter (PM); Reduction in fuel consumption
		Mitigation of environmental impacts	Reduction in energy consumption; Reduction in resource depletion; Reduction in noise pollution; Mitigation of environmental impacts from vehicle production and use
		Reduction in private car ownership and use	Reduction in the number of private vehicles; Reduction in single-occupancy vehicle (SOV) trips; Increase in vehicle occupancy rate; Reduction in distance traveled by private cars
		Improvement of urban environmental quality	Reduction in air and noise pollution; Enhancement of urban space quality; Reclamation of parking spaces and roadways
Infrastructural & physical	D	Spatial accessibility	Number and distribution of stations; Distance to vehicle access points; Coverage of different urban areas; Accessibility across different hours
		Parking infrastructure	Availability of dedicated parking; Sufficiency of parking capacity; Ease of vehicle pick-up and drop-off; Access to suitable parking facilities
		Technological infrastructure	Application quality; Online reservation system; Vehicle geolocation; Electronic payment; Stable internet and communication
		Fleet quality	Number of available vehicles; Vehicle diversity; Age and condition of vehicles; Eco-friendly and fuel-efficient fleet; Vehicle availability upon demand
		Intermodal connectivity	Proximity to metro stations; Proximity to bus stops; Connection to taxis and other transport modes; Ease of intermodal transfer
Managerial	E	Management and organization	Quality of fleet management; Operator responsiveness; Speed of problem resolution; Proper service planning
		Laws and regulations	Transparency of regulations; Ease of registration; Clarity of terms of use; Liability and damage regulations; Monitoring of user performance
		Pricing and payment	Tariff transparency; Fairness of pricing; Diversity of payment methods; Proportion of price to time and distance used
		Monitoring and control	Vehicle status monitoring; Violation control; Complaint handling; Safety supervision; Service quality control
		Data and technology management	User data security; Accuracy of spatial information; Use of data for service improvement; Payment security and privacy

To transform these indicators into a questionnaire, a five-point Likert scale was employed, ranging from 1 ('Very Low') to 5 ('Very High'). Each general indicator was converted into a measurable item, with responses recorded as numerical scores within this range. Higher scores indicate a more positive evaluation. The overall status of the economic, socio-cultural, environmental, infrastructural-physical, and managerial dimensions was quantitatively assessed by calculating the mean scores of the items within each dimension.

3.3. Validity and reliability of the research instrument

To establish the face validity of the researcher-developed questionnaire, a pilot version was administered to a small sample of the target population

(10 experts). They were asked to evaluate the clarity of the phrasing, the comprehensibility of the items, the absence of ambiguity, and each item's relevance to the research objective. Based on their feedback, ambiguous or complex items were identified and refined, and technical terminology was rewritten in simpler language to ensure the questionnaire was clear, fluent, and accessible to all respondents. To assess the instrument's reliability, Cronbach's alpha coefficient was used, which is one of the most widely used methods for measuring internal consistency.

As shown in Table 4, Cronbach's alpha coefficients for all dimensions exceeded 0.80, indicating desirable reliability and high internal consistency among the items in each dimension. Furthermore, the overall Cronbach's alpha for the entire questionnaire was 0.92, demonstrating the exceptional reliability of the research instrument and its robustness for data collection. These values confirm that the questionnaire items effectively measure the intended constructs and that the instrument possesses the necessary validity for statistical analysis."

Table 4. Reliability of research indicators based on Cronbach's Alpha coefficient

Dimension	Number of items	Cronbach's Alpha	Status
Economic	4	0.87	Acceptable
Socio-cultural	4	0.84	Acceptable
Environmental	4	0.89	Acceptable
Infrastructural & physical	5	0.81	Acceptable
Managerial	5	0.86	Acceptable
Overall questionnaire	22	0.92	

To prioritize and determine the weights of the shared vehicle criteria, the step-wise weight assessment ratio analysis (SWARA) method was employed. This method calculates each criterion's relative weight based on expert judgment and the pairwise comparison of their importance. After determining the weights, the MARCOS method was utilized to rank the shared vehicle development indicators. The MARCOS method is based on defining the relationship between alternatives and reference values (ideal and anti-ideal solutions). First introduced by Stoevitch et al. in 2019, the method calculates a utility function for each alternative based on predefined relationships, providing an adaptive ranking based on each alternative's proximity to the ideal and anti-ideal solutions. In this approach, decision priorities are defined by the utility function, which represents the position of each alternative relative to the reference points (Tajmiri Rostami & Farhadi, 2021). Figure 3 illustrates the step-by-step algorithm of the MARCOS method.

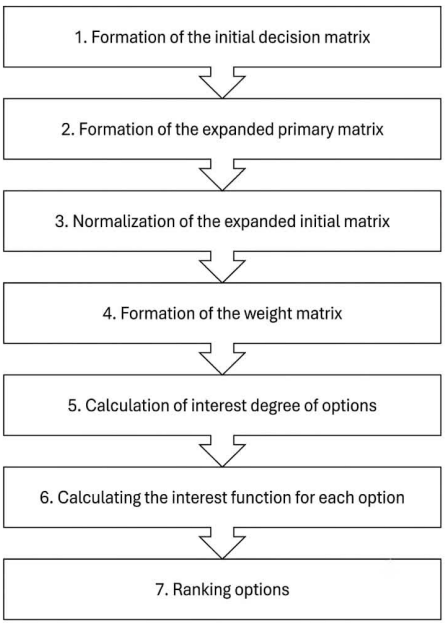

Figure 3. MARCOS method algorithm

Figure 4 shows the research process steps.

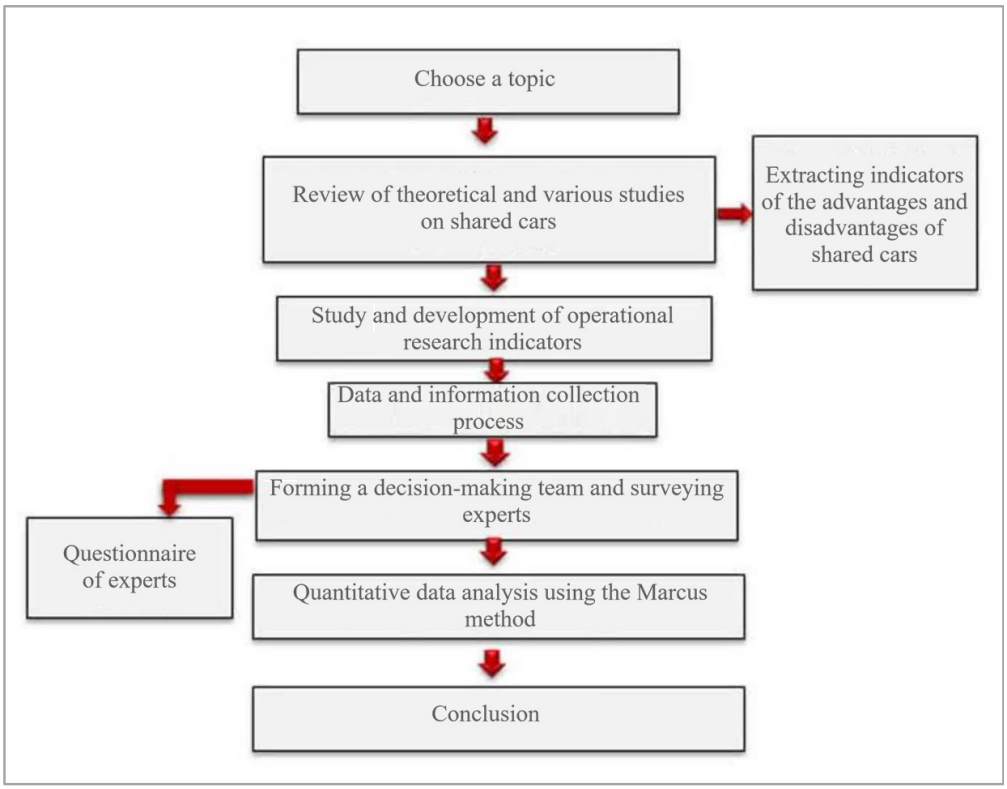

Figure 4. Stages of the research process

4. Research findings

4.1. Identification and analysis of the advantages and disadvantages of shared vehicles

Given the multidimensional nature and far-reaching consequences of shared vehicles, a precise, systematic understanding of the advantages and disadvantages of this transportation model across dimensions is a prerequisite for effective policy-making and planning for its development in cities. Accordingly, this section identifies and analyzes the advantages and disadvantages of shared vehicles and their effects on urban transportation and the economy. Overall, five distinct domains and dimensions of the advantages and disadvantages of shared vehicles were examined. In what follows, the advantages and disadvantages of developing shared vehicles are discussed within each of these dimensions.

Examining the economic advantages and disadvantages of shared vehicles

Using shared vehicles offers numerous economic benefits, some of which are discussed below from the perspectives of various researchers. Kim and Jan (2024) identify reduced ownership costs and eliminated fixed expenses for citizens as among the most significant economic advantages of shared vehicles in cities. They argue that by using shared vehicles, citizens no longer need to bear fixed costs such as purchasing a vehicle, insurance, taxes, technical inspection, and maintenance; instead, they pay only for the time they actually use the vehicle. This is particularly cost-effective for individuals who do not use a vehicle regularly (Kim & Jan, 2024: 467). According to a study by Shaheen and Cohen (2020) in North America, among members using shared vehicles, 80% of households owned no vehicle, and the number of vehicles owned by all households decreased by 50% after joining the shared-vehicle fleet (Shaheen & Cohen, 2020). Chaudhuri et al. (2025) also report that in Europe, 14% to 40% of car-sharing members sold at least one vehicle after joining the shared-vehicle program (Chaudhuri et al., 2025: 346).

Kang et al. (2024) further regard fuel cost savings as a benefit of using shared vehicles, noting that many shared vehicles are electric or hybrid and therefore consume less fuel (Kang et al., 2024: 7542). Similarly, Rabbitt and Ghosh (2016) state that reduced travel costs are among the outcomes of using shared vehicles. They consider shared vehicles a suitable

alternative to taxis and public transportation because, in many cases, using shared vehicles, particularly for longer or group trips, is cheaper than taxis and public transportation. Moreover, shared vehicles enable citizens to access a vehicle at any time and place without prior planning or waiting for a taxi or bus (Rabbitt & Ghosh, 2016: 4). Perboli et al. (2018) also identify increased economic productivity as one of the economic benefits of shared vehicles. They argue that the use of shared vehicles can help reduce traffic congestion and air pollution, which in turn leads to savings in social and economic costs (Perboli et al., 2018: 33). Furthermore, the shared-vehicle industry creates new employment opportunities in various fields, such as fleet management, maintenance and repair, and customer services. Overall, the use of shared vehicles can serve as an economical and efficient option for urban mobility (Currie et al., 2026: 512). Figure 5 illustrates the economic advantages of shared vehicles.

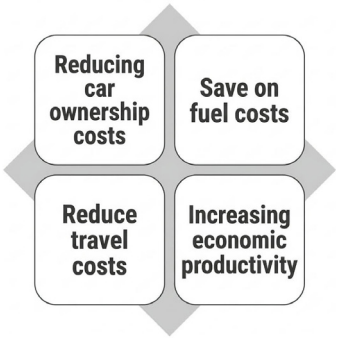

Figure 5. Economic benefits of shared vehicles according to various researchers

Alongside its numerous benefits, shared vehicles can also entail significant economic disadvantages and harms. This section addresses some of these disadvantages and harms from the perspective of various researchers. Sumitkumar and Al-Sumaiti (2024), for instance, note that a decline in demand for private vehicle purchases is one outcome of shared vehicles in cities; as shared vehicles' popularity grows, demand for purchasing private vehicles decreases. This can reduce automakers' sales and, consequently, lower production and employment within the industry. Moreover, the automotive industry is one of the most important and influential industries in the economies of many countries; reduced activity in this sector can have far-reaching effects on the economy (Sumitkumar & Al-Sumaiti, 2024: 12). Kim and Jan (2024) also state that the development of shared vehicles affects automobile-related industries, in that the reduced demand for private vehicles impacts associated sectors such as parts manufacturing, maintenance and repair, and insurance services. When these industries face declining demand and revenue, they may be forced to downsize their workforce or even close (Kim & Jan, 2024: 469). Enzi et al. (2024) identify rising infrastructure costs as a key challenge to developing shared vehicles, arguing that expanding shared-vehicle use heightens the need for new infrastructure, such as charging stations, dedicated parking facilities, and intelligent management systems. Establishing this infrastructure requires substantial investment, which can place a heavy financial burden on governments and municipalities (Enzi et al., 2024: 104). Furthermore, Wen et al. (2021) identify reduced government tax revenue as an outcome of shared-vehicle development, noting that governments earn considerable tax income from vehicle sales, gasoline, and automobile-related services. Reduced vehicle purchases and lower gasoline consumption can lead to a decline in these revenues, confronting governments with financial challenges (Wen et al., 2021: 12).

Examining the social advantages and disadvantages of shared vehicles

The use of shared vehicles offers numerous social benefits, some of which are addressed below.

The use of shared vehicles helps reduce household expenses, and this reduction in costs enables individuals to invest their financial resources in other social domains, such as education, health, and recreation. Shared vehicles make access to transportation easier for individuals who do not own a private vehicle or who, for various reasons, are unable to use one. This is particularly important for low-income social groups, the elderly, and individuals with disabilities. Strengthening the sense of community is another benefit of using shared vehicles. In this regard, Abouee-Mehrizi et al. (2021) state that using shared

vehicles can strengthen the sense of community and increase social interactions among citizens. Sharing a ride with others in shared vehicles provides an opportunity to meet new people and exchange ideas. This is especially significant in large cities, where individuals often experience feelings of loneliness (Abouee-Mehrizi et al., 2021: 195). Safdar et al. (2022) emphasize that motivating and encouraging citizens to use public transportation is a notable social benefit of shared vehicles. Shared vehicles can serve as a complement to public transportation, or individuals can use shared vehicles to reach bus or metro stations. This helps encourage people to use public transportation and reduces dependence on private vehicles (Safdar et al., 2022: 29). Glazener et al. (2022) state that the use of shared vehicles can be effective in improving the health and quality of life of citizens, in that reducing the number of private vehicles on the streets significantly decreases urban traffic. Reduced traffic leads to lower fuel consumption and, consequently, reduced air pollution; in turn, lower air pollution contributes to improved health and quality of life for citizens and helps prevent respiratory diseases (Glazener et al., 2022: 166).

Despite its numerous benefits, the use of shared vehicles also entails several social disadvantages and harms, some of which are addressed below.

The adoption and use of shared vehicles require a change in people's culture and commuting habits. Resistance to these changes can act as a barrier to the development of these systems. In this context, Curtale et al. (2021) emphasize the importance of culture and public acceptance of shared vehicles, arguing that using shared vehicles can change the culture and social norms related to vehicle ownership. A diminished sense of ownership and responsibility toward the shared vehicle is among the social disadvantages of using this type of transportation system. Users are responsible for any damage or harm inflicted on the vehicle during their use. This can raise concerns regarding accountability (Dill & McNeil, 2021: 7). Because individuals do not own the vehicle, their sense of responsibility for its maintenance and preservation may decline. This can lead to neglect of cleanliness, minor damages, and failure to observe safety precautions. A reduced sense of ownership can also result in indifference toward public property and an increase in destructive behaviors. For example, the cleanliness and hygiene of shared vehicles, particularly under frequent use, can be challenging. Failure to maintain cleanliness by some users can lead to dissatisfaction among other users and give rise to health problems (Curtale et al., 2021: 269). Therefore, cultivating a culture for the proper and responsible use of shared vehicles is essential. Privacy and security concerns constitute another social problem associated with the use of shared vehicles. In this regard, Kim et al. (2021) state that, given that shared vehicles are used by various individuals, the likelihood of access to users' personal information and privacy increases. This raises concerns regarding the security and safety of users when using shared vehicles, particularly for women and vulnerable individuals (Kim et al., 2021: 997). Another social problem concerns issues of social justice and unequal access to shared vehicles, which may not be uniform across different cities and regions for all members of society, particularly low-income individuals and residents of marginalized areas. This issue can lead to increased social inequalities and the creation of a divide between different social classes.

Citizens' lack of trust and confidence in the safety and quality of these vehicles, along with their low level of familiarity with and awareness of the benefits of shared vehicles, makes public acceptance of this mode of transportation difficult. Therefore, educating users about compliance with regulations, the proper use of this system, and managing user behavior (preventing violations, damages, and so forth) are important issues that must be addressed. Legal and insurance matters, as well as the handling of user complaints and problems, constitute further cultural and social issues concerning the use of shared vehicles (Burghard & Scherrer, 2022: 13). Figure 6 presents a selection of the social advantages and disadvantages of shared vehicles.

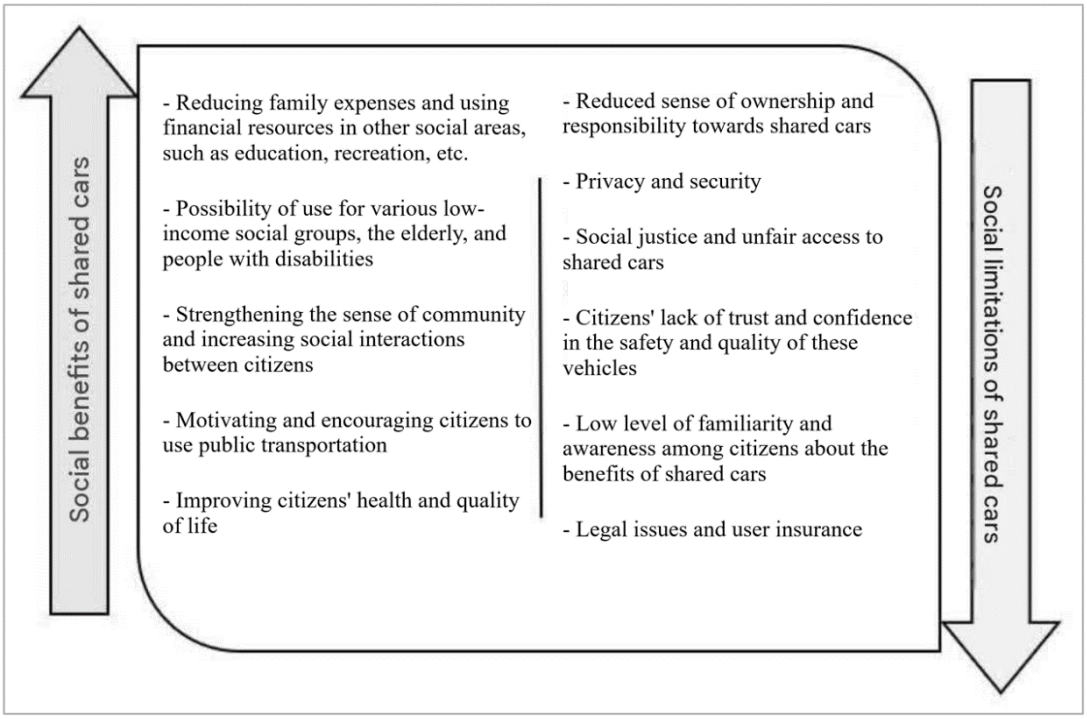

Figure 6. Selected social benefits and challenges of shared vehicles

Examining the environmental advantages and disadvantages of shared vehicles

The use of shared vehicles can yield significant environmental benefits. Some of these benefits are presented below.

Extensive research has examined the environmental consequences of car sharing. Early studies consistently show that car sharing reduces private vehicle ownership, potentially lowering greenhouse gas emissions. According to a study by Plepys and Vélez (2025), passenger transport, particularly within the European Union, is one of the main drivers of climate change, given that more than 80% of personal trips are made by car, accounting for 25% of CO_2 emissions. Therefore, reducing dependence on private vehicles is key to minimizing the environmental impact of personal mobility. This can be achieved by changing travel habits for shorter distances and choosing greener modes of transport, such as public transportation, shared cars, cycling, and walking (Plepys & Vélez, 2025: 89). Accordingly, one of the most important effects of using shared vehicles, especially in large cities, is the reduction of air pollution. With fewer private vehicles on the streets, emissions of greenhouse gases and harmful pollutants also decline, since shared vehicles are often newer and more efficient models that produce lower emissions. Indeed, many car-sharing systems also include electric vehicles, which produce zero emissions (Rabbitt & Ghosh, 2016: 4).

In their study examining the effects of car sharing on reducing vehicle ownership and CO_2 emissions, Nijland and van Meerkerk (2017) show that, owing to reduced vehicle ownership and shared vehicle use, car-sharing members emit between 240 and 390 kilograms less CO_2 per person per year, with a 13% to 18% reduction in CO_2 emissions related to vehicle ownership and use. Their findings indicate that car sharers own 30% fewer vehicles than before joining a car-sharing program, travel 15% to 20% fewer kilometers than before, and emit 13% to 18% less CO_2 related to vehicle ownership and use (Nijland & van Meerkerk, 2017: 85). Ma et al. (2015) also demonstrate that, through the use of a ride-sharing system, 2.2 million kilograms of carbon dioxide can be saved annually in Beijing. Furthermore, reducing the number of private vehicles decreases noise pollution in urban areas, which in turn improves the quality of life in urban areas (Lokhandwala & Cai, 2018: 47).

In their study, Rabbitt and Ghosh (2013) show that vehicle owners who predominantly travel using alternative modes can achieve substantial savings in both cost and CO_2 through car sharing. An annual CO_2 emission reduction of 86 kilotons can readily be achieved through car sharing, and with appropriate policy and financial support, a reduction of up to 895

kilotons is possible (Rabbitt & Ghosh, 2013: 50).

Reducing traffic volume is another benefit of shared vehicles, as reducing the number of private cars reduces traffic in cities. In turn, reduced traffic lowers fuel consumption and air pollution. The use of shared vehicles also contributes to reducing resource consumption; by sharing vehicles, the need to produce new vehicles decreases, leading to lower consumption of natural resources and energy. Overall, by reducing the number of private vehicles, fuel consumption, and air pollution, shared vehicles can contribute to environmental preservation (Plepys & Vélez, 2025: 89). According to Goudin (2016), if all private vehicles in Europe were shared, the existing fleet could be reduced by two-thirds, or approximately 200 million vehicles. Such a reduction would not only diminish the environmental impacts associated with vehicle production and end-of-life management but could also free up a considerable amount of parking space (Goudin, 2016: 7).

Although the use of shared vehicles offers significant advantages, such as reduced traffic and air pollution compared with private vehicle ownership, they also have environmental disadvantages.

Some studies have shown that, owing to easier access to vehicles, users of shared vehicles may travel greater distances than they do when they own a private vehicle. This can lead to increased fuel consumption and air pollution. Furthermore, if the shared-vehicle fleet includes electric vehicles, environmental concerns related to lithium-ion battery production and disposal also arise. Additionally, if the electricity used to charge electric vehicles is not sourced from renewable energy, it can lead to increased pollution from electricity generation (Silva et al., 2022: 18). Moreover, managing a shared-vehicle fleet, particularly in large cities, can be challenging. If vehicles are not serviced and maintained regularly, they can produce higher emissions. Likewise, improperly parked vehicles can increase traffic and air pollution. If shared vehicles run on fossil fuels, they directly contribute to air pollution, greenhouse gas emissions, and climate change. Air pollution from fossil-fuel vehicles can cause respiratory problems, cardiovascular diseases, and other health issues (Golbabaei et al., 2021: 731). By considering these disadvantages and adopting appropriate strategies, people can benefit from shared vehicles while minimizing their negative environmental impacts. Figure 7 presents selected environmental advantages and disadvantages of shared vehicles.

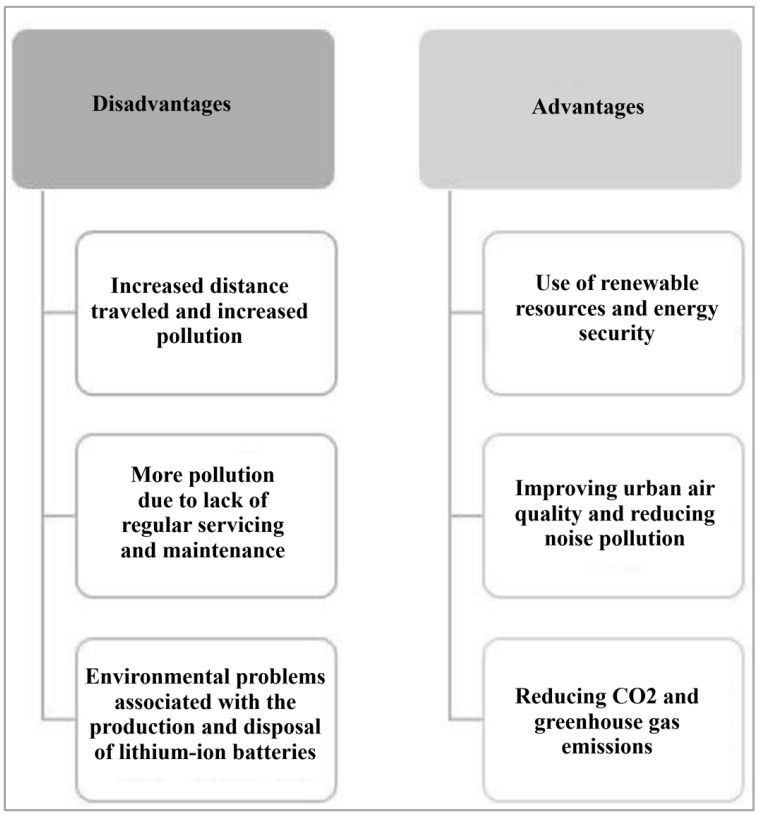

Figure 7. Selected environmental benefits and challenges of shared vehicles

Examining the infrastructural advantages and disadvantages of shared vehicles

Shared vehicles offer numerous physical and infrastructural benefits that can improve urban life and reduce the negative impacts of transportation. Some of the most important of these are addressed below.

Golbabaei et al. (2021) state that one of the most significant benefits of using shared vehicles is the reduced need for parking, particularly in large cities. Fewer private vehicles also reduce parking demand in cities. In turn, reduced parking demand enables municipalities to allocate more space to green and public spaces. Moreover, this can optimize urban space use by freeing up space for other uses such as green areas, sidewalks, and cycling paths. This contributes to the creation of more livable and sustainable cities (Golbabaei et al., 2021: 732).

Enzi et al. (2024) identify reduced infrastructure costs as another benefit of shared vehicles, noting that fewer vehicles and less traffic reduce the need to build and maintain roads and parking facilities. This can lead to savings in public expenditures (Enzi et al., 2024: 105). Curtale et al. (2021) identify reduced traffic volume on urban streets through shared vehicles as another benefit, noting that less traffic means time and energy savings, as well as lower stress and air pollution. Shared vehicles provide citizens with easier access to a vehicle. If shared vehicles are available at various points throughout the city, users can access them with ease. This is particularly beneficial for individuals who do not need a vehicle regularly. Indeed, shared vehicles can serve as an accessible transportation option for individuals who do not have access to a private vehicle, improving transportation access for all members of society (Curtale et al., 2021: 270).

From the perspective of Silva et al. (2022), reduced accidents and human and financial damages are another outcome of using shared vehicles. With fewer vehicles and less traffic, the likelihood of accidents also decreases. Furthermore, shared vehicles are typically newer models with advanced safety features, which can help reduce accident severity. In summary, the use of shared vehicles can improve the quality of urban life, reducing the negative impacts of transportation, and creating more sustainable cities (Silva et al., 2022: 17).

In addition to its considerable benefits, the use of shared vehicles is also accompanied by numerous physical and infrastructural disadvantages, some of the most important of which are addressed below.

Auer et al. (2022) state that one of the main issues and concerns regarding shared vehicles is the examination of technical vehicle problems. Rental companies may fail to periodically inspect and check their vehicles to reduce costs, which can at times create problems for the individual renting the vehicle. Moreover, frequent use by different individuals increases the depreciation of shared vehicles. This can reduce the useful lifespan of the vehicles, increase maintenance and repair costs, and diminish safety. Furthermore, the likelihood of damage to and destruction of shared vehicles is greater, particularly when they are used by unfamiliar or careless individuals. This can lead to increased maintenance and repair costs and reduced vehicle availability (Auer et al., 2022: 13). A shortage of parking space can also constitute another limitation of shared vehicles. In high-traffic cities, finding suitable parking for shared vehicles can be difficult, which can cause user dissatisfaction and increased urban traffic. Another infrastructural limitation concerning shared vehicles is the need for robust information and technology infrastructure, since car-sharing systems require strong IT infrastructure to manage reservations, payments, and vehicle tracking. Any disruption to this infrastructure can lead to serious problems in system performance. Furthermore, extensive and reliable communication networks are needed to track vehicles and provide services to users. Remote areas or those with weak network coverage may be deprived of these services (Roblek et al., 2022: 905). Perboli et al. (2018) stated that the need for charging stations and dedicated parking facilities is one of the issues and problems associated with this type of transportation system. For shared electric vehicles, there is a need for sufficient and appropriate charging stations (Perboli et al., 2018: 35). Moreover, a need is felt for dedicated parking facilities for shared vehicles in high-traffic urban areas. In summary, despite its numerous benefits, the use of shared vehicles requires attention to its physical and infrastructural disadvantages. Careful planning, investment in infrastructure, and appropriate cultural cultivation can help reduce these disadvantages and enable full benefit from the advantages of these systems. Figure 8 presents the selected physical and infrastructural advantages and disadvantages of shared vehicles.

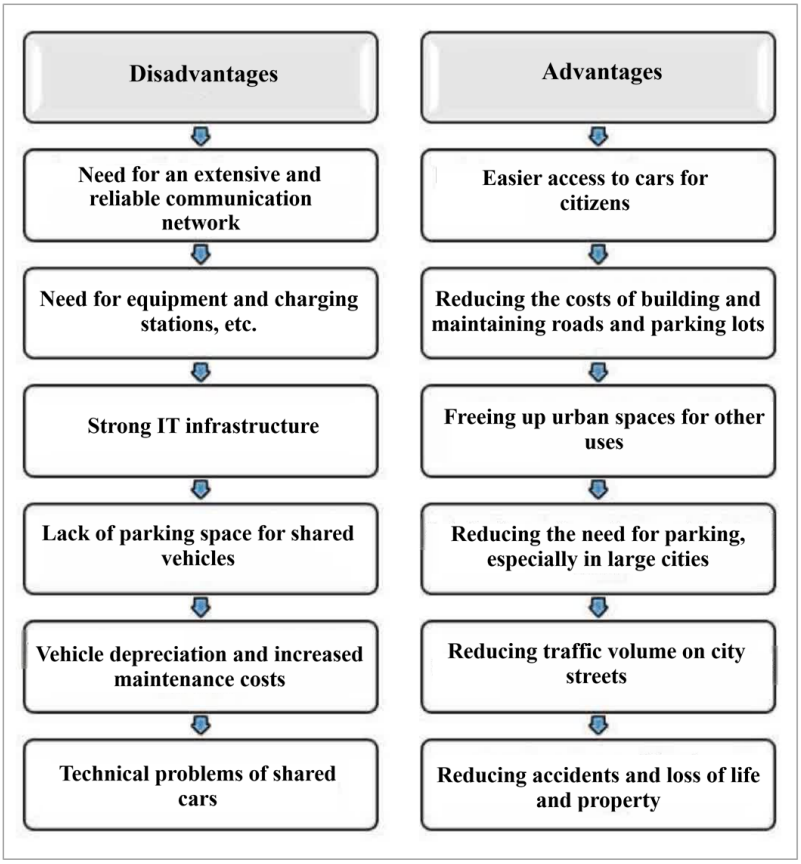

Figure 8. Selected physical and infrastructural benefits and challenges of shared vehicles

Examining the managerial advantages and disadvantages of shared vehicles

The use of shared vehicles can offer numerous benefits for urban management. Some of the most important of these are addressed below.

In this regard, Kim et al. (2021) state that the use of shared vehicles can improve urban management and transportation planning. Data concerning the use of shared vehicles can help municipalities identify the strengths and weaknesses of the transportation system. This enables them to make more informed decisions regarding the development of transportation infrastructure. Furthermore, shared vehicles can contribute to the optimal management of urban resources, such as fuel and energy. This reduces urban management costs and supports the preservation of natural resources (Kim et al., 2021: 802).

As an innovative solution in transportation, the use of shared vehicles is accompanied by numerous benefits. Nevertheless, the management of this system faces challenges and obstacles, some of which are addressed below.

According to Brandstätter et al. (2016), the existence of legal infrastructure and the need for clear laws and regulations in this field are issues related to the use of this transportation system. Indeed, the existence of laws and determining responsibility in the event of an accident or violation during the use of shared vehicles can be challenging. Therefore, successfully managing shared vehicles and supervising their performance requires establishing appropriate laws and regulations for the use of shared vehicles, monitoring the performance of companies providing these services, and addressing violations and abuses in this field. Close supervision of companies providing shared-vehicle services is essential to ensure compliance with safety requirements and the maintenance of service quality (Brandstätter et al., 2016: 442). Illgen et al. (2019) identify financial management and operational costs (such as fuel, maintenance and repair, insurance, and so forth), determining appropriate pricing for services, attracting capital and ensuring sustainable financing, and the development and maintenance of the relevant software and applications as further limitations of this type of system for urban management (Illgen et al., 2019: 194). Given these

disadvantages and harms, policymakers and companies providing shared-vehicle services must seek strategies to mitigate these negative effects. Figure 9 presents the selected managerial advantages and disadvantages of shared vehicles.



Figure 9. Selected managerial benefits and drawbacks of shared vehicles

4.2. Prioritizing the degree of impact of shared-vehicle development on the urban economy

To determine the importance and priority of the degree of impact of shared-vehicle development across the identified dimensions, a combination of two multi-criteria decision-making methods – SWARA and MARCOS – is employed. Accordingly, the five dimensions' weights were first calculated using the SWARA method, and the final prioritization was carried out using the MARCOS method. In what follows, the SWARA method and the steps for calculating the weights are first described, followed by the implementation steps of the MARCOS method.

Calculating the indicators' weights using the SWARA method

In many multi-criteria decision-making problems, one of the most important stages of analysis is determining the relative importance of the criteria. For this purpose, criteria weighting methods are used. These methods help decision-makers determine how each criterion contributes to the final decision. One well-known method in this field is the SWARA method (step-wise weight assessment ratio analysis). Introduced by Krajagić et al. (2010), SWARA is a multi-criteria decision-making method for calculating the weights of criteria that operates based on experts' judgments of the criteria's relative importance. This method was selected owing to the simplicity of its calculations, lower data requirements, and applicability in situations where precise information is unavailable. The implementation steps of this method are as follows:

Step one: sorting the criteria according to importance

Step two: determining the mean value of relative importance (S_j)

Experts evaluated each criterion's relative importance compared with the preceding criterion on a scale of 1 to 5, and calculated its mean.

Step three: calculating the coefficient K_j

The coefficient K_j for each criterion is calculated using the relation $K_j = S_j + 1$.

Step four: calculating the initial weight Q_j

The initial weight of each criterion is calculated using the relation $Q_j = Q(j-1) / K_j$ (for the first criterion, $Q_1 = 1$).

Step five: calculating the final weight W_j

The final weight of each criterion is obtained by normalizing the initial weights: $W_j = Q_j / \Sigma Q_j$.

Table 5 presents the weight calculation results using the SWARA method.

Table 5. Calculation of criteria weights using the SWARA method

Criterion	S_j	K_j	Q_j	W_j
A	–	1.000	1.000	0.406
C	0.50	1.50	0.667	0.271
D	0.60	1.60	0.417	0.169
E	0.70	1.70	0.245	0.099
B	0.80	1.80	0.136	0.055

Determining the importance and priority of the degree of impact of shared-vehicle development across the identified dimensions using the MARCOS multi-criteria decision-making method

At this stage, following a survey of 50 research experts, the scores of the various indicators were determined using the mean value. In the decision matrix of this method, the five research dimensions are placed in the columns and the five alternatives in the rows, with each cell representing the evaluation of each alternative with respect to each criterion. 50 experts completed this decision matrix on a 1-to-5 scale. The responses were then aggregated using the arithmetic mean method, as presented in Table 6.

Table 6. Decision matrix

Indicator	A	B	C	D	E
Economic	5.00	1.00	5.00	4.00	2.50
Environmental	5.00	1.00	5.00	3.00	2.50
Social	4.50	1.00	4.50	4.00	2.50
Infrastructural	4.50	1.50	4.00	3.00	2.50
Managerial	4.50	1.50	4.00	3.00	2.00

Determining the ideal and anti-ideal solutions

In this step, the ideal (AI) and anti-ideal (AAI) values are determined. The ideal value equals the maximum value of each criterion column, and the anti-ideal value equals the minimum value of each criterion column in the decision matrix, as presented in Table 7.

Table 7. Ideal (AI) and anti-ideal (AAI) values

AAI	A	B	C	D	E
	4.50	1.00	4.00	3.00	2.00
Economic	5.00	1.00	5.00	4.00	2.50
Environmental	5.00	1.00	5.00	3.00	2.50
Social	4.50	1.00	4.50	4.00	2.50
Infrastructural	4.50	1.50	4.00	3.00	2.50
Managerial	4.50	1.50	4.00	3.00	2.00
AI	5.00	1.50	5.00	4.00	2.50

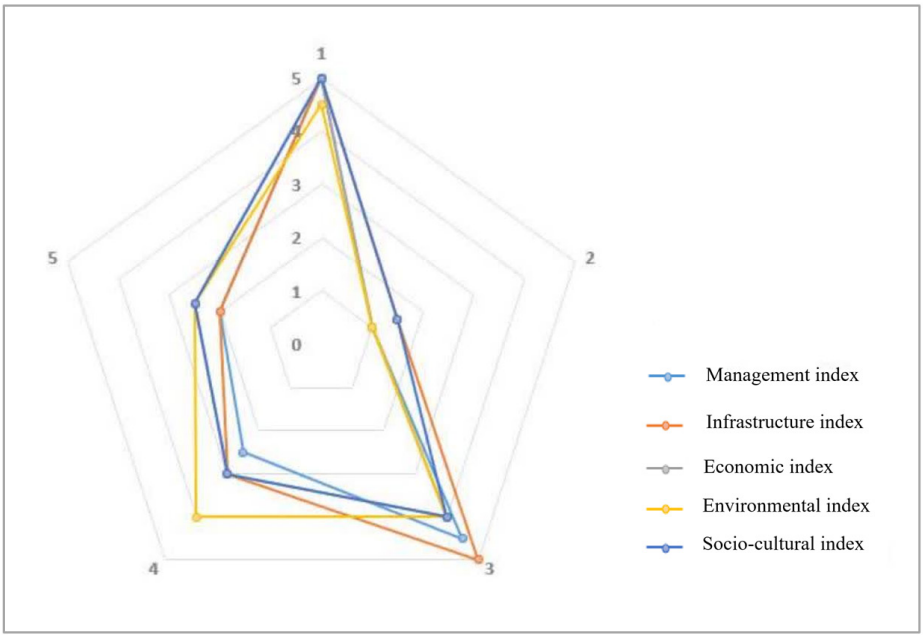

Figure 10. Ideal and anti-ideal values of shared vehicle development indicators

According to Figure 10, from the experts' perspective, the ideal situation receives a higher score than the anti-ideal situation, which indicates the importance of shared-vehicle development in improving urban transportation and the economy.

Normalization of the decision matrix

In this section, the decision matrix is normalized. For normalization, each element of the decision matrix is divided by the maximum value of its column (the AI value). For example, for cell a_1 (the intersection of alternative SC1 and criterion A1), the calculation is performed as follows:

a_1^normal = 0.9 / 1.000 = 0.9

The same procedure is applied to the other cells. Table 8 presents the results.

Table 8. Normalized matrix

Normalization	A	B	C	D	E
AAI	0.900	0.667	0.800	0.750	0.800
Economic	1.000	0.667	1.000	1.000	1.000
Environmental	1.000	0.667	1.000	0.750	1.000
Social	0.900	0.667	0.900	0.750	1.000
Infrastructural	0.900	1.000	0.800	0.750	1.000
Managerial	0.900	1.000	0.800	0.750	0.800
AI	1.000	1.000	1.000	1.000	1.000

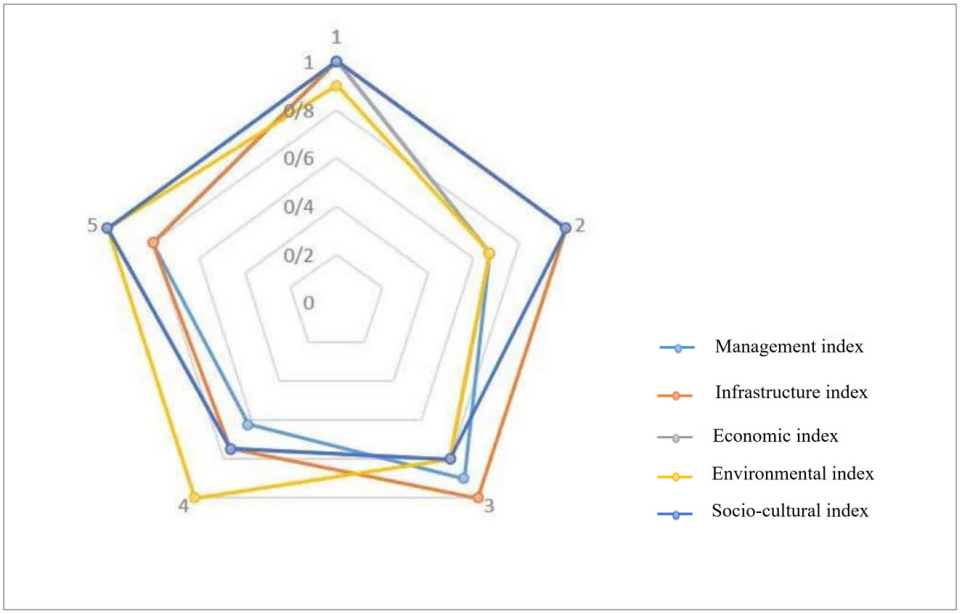

Figure 11. Normalized values of shared vehicle development indicators

Based on Table 4 and Figure 11, all indices are in a positive state in terms of normality.

Weighting the normalization matrix

In this section, the weight of each index, calculated using the SWARA method, is multiplied by the normalization matrix. Table 9 presents the results.

Table 9. Weighted matrix

Weighted indices	A	B	C	D	E	SiSi
AAI	0.365	0.037	0.217	0.127	0.079	0.825
Economic index	0.406	0.037	0.271	0.169	0.099	0.982
Environmental index	0.406	0.037	0.271	0.127	0.099	0.940
Social index	0.365	0.037	0.244	0.169	0.099	0.914
Infrastructure index	0.365	0.055	0.217	0.127	0.099	0.863
Management index	0.365	0.055	0.217	0.127	0.079	0.843
AI	0.406	0.055	0.271	0.169	0.099	1.000

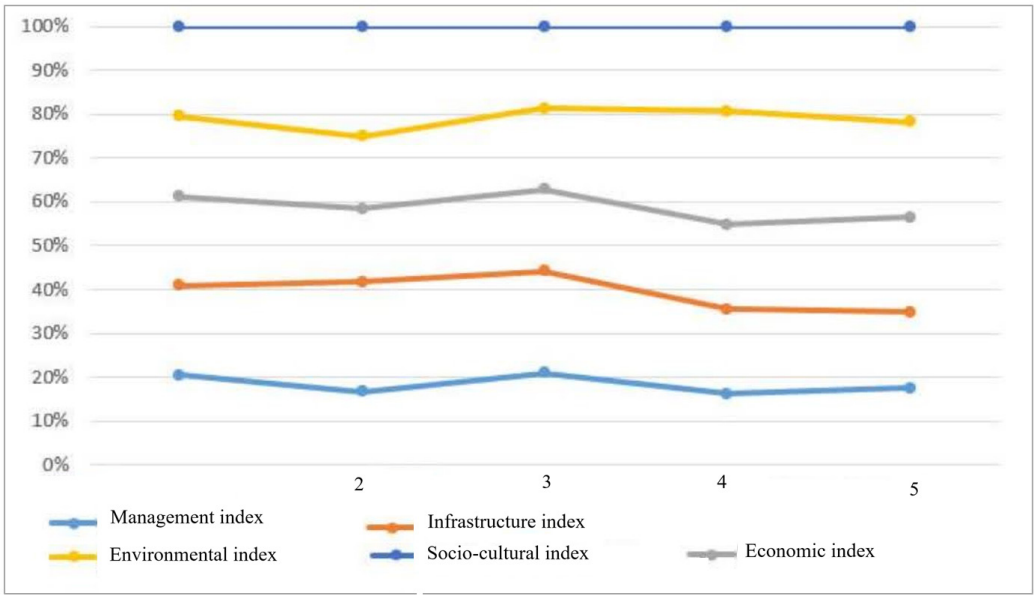

Figure 12. Weight distribution of shared vehicle development indicators

Calculation of option desirability degree

In this section, the positive (K+K+) and negative (K−K−) desirability of the options are calculated. Accordingly, the sum of the rows for AAI and AI in the weighted matrix is first determined, denoted as SaaSaa and SaSa, respectively. Subsequently, the positive desirability degree of each option (Ki+Ki+) is calculated by dividing the row sum of that option (SiSi) by SaSa, while the negative desirability degree (Ki−Ki−) is obtained by dividing the row sum by Saa. Table 10 shows the results.

Table 10. Desirability degree of options

Options	SiSi	K−K−	K+K+
AAI	825.0	—	—
Economic index	982.0	190.1	982.0
Environmental index	940.0	139.1	940.0
Social index	914.0	108.1	914.0
Infrastructure index	863.0	046.1	863.0
Management index	843.0	022.1	843.0
AI	000.1	—	—

Determining the desired performance of the options

In this section, the desired performance of each option is calculated. First, the positive and negative desired performance of each option is obtained using the following relationships; the results are summarized in Table 12.

- Positive desired performance: f(Ki+) = Ki- / (Ki+ + Ki-)
- Negative desired performance: f(Ki-) = Ki+ / (Ki+ + Ki-)
- Final desired performance: f(Ki) = (Ki+ + Ki-) / (1 + (1-f(Ki+))/f(Ki+) + (1-f(Ki-))/f(Ki-))

As shown in Table 11, the values for f(Ki+) and f(Ki−) are the same for all options. This is correct and expected because, in the Marcus method, the ratio Ki-/Ki+ is constant for all options (since they are all divided by the constant values Sa and Saa. Therefore, the distinction between options and their ranking is based only on the value of f(Ki) (the ultimate desired performance), which is itself a function of Ki+ and Ki- (and therefore Si). Simply put, the larger the Si value, the higher the f(Ki) and the better the rank of the option.

Table 11. Desirable performance degree of options

Options/indices	f(Ki−)	f(Ki+)	f(Ki)	Rank
Economic index	0.452	0.548	0.715	1
Environmental index	0.452	0.548	0.685	2
Social index	0.452	0.548	0.666	3
Infrastructure index	0.452	0.548	0.629	4
Management index	0.452	0.548	0.614	5

According to Table 12, the economic index is the most influential factor in shared mobility development, ranking first with a desirable performance of 0.715. This matters from an urban economics viewpoint because shared mobility provides the greatest economic benefits for the city and its residents by cutting transportation costs for families, optimizing fuel use, and reducing the city's infrastructure costs. The environmental index (0.685) and social index (0.666) followed in second and third place, showing how economic goals work together with environmental and social benefits. The infrastructure index (0.629) and management index (0.614) ranked lowest, indicating experts believe institutional and managerial factors are less of a priority than economic gains.

The experts' ranking shows a clear connection between shared mobility and the urban economy. The economic index's top rank suggests that this system's critical role is to lower transport costs and improve resource use in the city. This matches urban economic theories, as transportation is a core part of city infrastructure that affects household spending, worker productivity, and the city's competitiveness. The second rank of the environmental index is also logical; air pollution imposes a heavy financial burden on the city's health system and economic productivity, so reducing it through shared mobility indirectly improves urban economic indicators. The third rank of the social index shows that shared mobility can reduce inequality in accessing city services and improve social justice. On the other hand, the lower ranks for infrastructure and management show that technical and institutional issues are seen as less important than direct social and economic benefits. This finding can guide urban policymakers in allocating resources and designing implementation plans, focusing first on economic, environmental, and social gains, while solving infrastructure and management problems gradually as demand increases.

4. Discussion

The findings of the present study indicate that, from the experts' perspective, the economic index ranks first with a final score of 0.715 in terms of the impact of shared mobility development on urban transport and economics. This is followed by the environmental (0.685), social (0.666), infrastructure (0.629), and management (0.614) indices, respectively. This prioritization aligns with a significant portion of previous research on car-sharing, while simultaneously revealing certain divergences from existing literature.

The primary rank of the economic index aligns with studies emphasizing the financial advantages of car-sharing. Dong et al. (2020) demonstrated that shared mobility can reduce travel costs and serve as a competitive alternative to private car ownership; this finding mirrors this study's results. Similarly, Rabbit and Gosh (2013) confirmed the economic feasibility of organized car-sharing, and Pruvoly et al. (2018) highlighted the critical role of business models and optimized pricing in the profitability and sustainability of these services. This alignment suggests that, in experts' view, shared mobility's most vital function is reducing household transport expenses and optimizing urban resource allocation, which is consistent with the principles of urban economics regarding transportation as a fundamental urban infrastructure.

The second rank of the environmental index aligns with a broad body of literature emphasizing the ecological outcomes of shared mobility. Nijland and Van Meerkerk (2017) reported reduced CO2CO2 emissions and a decreased number of private vehicles as the most significant effects of car-sharing in the Netherlands, while Ding et al. (2019) pointed to the potential for mitigating global warming through shared mobility models in Beijing. Furthermore, Agapito et al. (2014) introduced car-sharing as an effective tool for environmental policies. A key insight from the present study is the synergy between economic and

environmental dimensions; experts perceive the reduction of urban air pollution not only as an ecological benefit, but as a factor in reducing negative externalities imposed on the healthcare system and the city's economic productivity. This finding links directly to the concept of external costs in urban economics; it reflects the experts' understanding of the profound connection between environmental sustainability and economic efficiency in urban planning.

The third rank of the social index aligns with research focusing on social dimensions and equity in access to transport services. Jani and Filmon (2022), in their study in Tanzania, showed that shared mobility offers social and hedonic benefits in addition to economic and environmental gains, which influence user acceptance. Similarly, Preito et al. (2017) emphasized the role of socio-demographic factors in the adoption of car-sharing. The finding that shared mobility can reduce spatial-economic inequality in accessing urban services is consistent with the theoretical foundations of spatial justice, indicating that experts view this system as a catalyst for enhancing socio-economic equity in cities.

One of the study's more noteworthy findings is the lower ranking of the infrastructure and management indices. At first glance, this may seem to contradict literature that emphasizes the pivotal role of infrastructure and management in the success of shared mobility systems. Brandshter et al. (2016) identified fleet design optimization, station location, and charging management as key factors in the efficiency of electric car-sharing systems, and Ilgen and Hook (2019) stressed the role of optimized vehicle redistribution in the efficiency of one-way systems. Additionally, Sater (2022) introduced charging infrastructure development and supportive policies as critical drivers for electric mobility expansion.

However, this apparent contradiction can be explained from two perspectives. First, the lower priority of infrastructure and management indices does not imply insignificance; rather, it suggests that from experts' viewpoint, these factors are secondary to direct economic, environmental, and social benefits and can be developed incrementally in line with growing demand. Second, the difference in the study's context is influential. Many international studies have been conducted in developed countries with advanced transport infrastructures, whereas in the Iranian urban context, economic and social challenges take precedence, and infrastructural and managerial issues are viewed as phased prerequisites. This finding aligns with Kamre (2016), which identified demographic, traffic, and accessibility indices as the most critical factors for implementing car-sharing in Tehran. Furthermore, Mamdouhi and Rahmani (2024) showed that increasing the penetration rate of shared autonomous vehicles could significantly reduce pollutant emissions, reinforcing the importance of the environmental dimension. By providing a quantitative prioritization based on the Marcus method, the present study offers a more comprehensive framework across five dimensions – economic, environmental, social, infrastructural, and managerial – which complements previous research on shared mobility in Iran.

Overall, the findings show a pattern linking shared mobility to urban economics, where direct socio-economic and environmental benefits are prioritized, and infrastructural and managerial issues are treated as phased prerequisites. These results align with much of the global and domestic literature while providing specific interpretations tailored to the Iranian context. Moreover, the relatively small gap between the indices' scores (0.614 to 0.715) indicates that experts consider the various dimensions of shared mobility development to be of nearly equal importance, suggesting that the prioritization is relative rather than absolute. This underscores the necessity of a holistic approach in policymaking for shared mobility development.

5. Conclusion

Shared mobility, as an innovative transportation model, presents a multifaceted array of advantages and challenges across economic, social, environmental, infrastructural, and managerial dimensions. Economically, shared mobility offers significant benefits, including reduced vehicle ownership costs, fuel savings, and enhanced economic productivity. By providing flexible and affordable transport services, it enables individuals to access the utility of a vehicle without the burden of ownership. This shift not only reduces the total number of vehicles on the road – thereby mitigating urban congestion – but also contributes to environmental preservation by lowering fuel consumption and associated emissions. Furthermore, shared mobility reduces maintenance and insurance expenses, allowing users to allocate their financial resources more efficiently. At a macro-

urban level, the decrease in private vehicle density leads to reduced traffic congestion and fuel consumption, yielding positive economic externalities. However, challenges such as the lack of cost-effectiveness for long-distance commuters and dependence on the service's geographical coverage remain significant constraints.

In the social dimension, shared mobility can mitigate spatial-economic inequality by increasing the low-income groups' access to affordable transport services. This aligns with the spatial justice principles, which emphasize the equitable distribution of access to urban services. Other benefits include the enhancement of social capital through shared interactions and the reduction of stress associated with traffic congestion. Conversely, security concerns regarding sharing vehicles with strangers and cultural barriers stemming from a deeply rooted "ownership culture" in Iran constitute the primary social obstacles to the system's adoption.

From an environmental standpoint, shared mobility increases each vehicle's utilization rate and reduces the overall number of cars in circulation, leading to a decrease in air pollutant emissions and the consumption of non-renewable resources. This finding is intrinsically linked to the concept of negative externalities in urban economics, as urban air pollution imposes severe costs on public health systems and overall economic productivity. Nevertheless, the environmental benefits are partially diminished if internal combustion engine (ICE) vehicles are utilized instead of electric or hybrid alternatives.

Regarding the infrastructural dimension, shared mobility can reduce the financial burden on municipalities for infrastructure development and maintenance by decreasing parking demand and optimizing existing transport networks. However, successful implementation requires complementary infrastructure, including electric vehicle (EV) charging stations, dedicated parking hubs, and intelligent management and reservation systems. From an urban economics perspective, investment in such infrastructure must be proportional to demand and guided by rigorous cost-benefit analysis to prevent waste of public resources. In the managerial dimension, smart systems can facilitate optimal fleet management, vehicle allocation, and personalized user services. However, the absence of a comprehensive legal framework governing liability, insurance, pricing, and user privacy remains a critical challenge. From an institutional economics perspective, the shared mobility's success depends heavily on the quality of regulatory institutions and the capacity for coordination among executive agencies.

The prioritization results, derived from the Marcus multi-criteria method, revealed that experts assigned the following final scores to the indices: economic (0.715), environmental (0.685), social (0.666), infrastructure (0.629), and management (0.614). These results indicate that the development of shared mobility has the highest impact on the economic and environmental dimensions and the lowest on the managerial dimension.

The economic index's primary rank suggests that, from the experts' viewpoint, the most critical function of shared mobility is reducing urban transport costs and optimizing resource allocation. The environmental index's second rank reflects the experts' awareness of the profound link between environmental sustainability and economic efficiency in urban planning. The social index's third rank indicates that shared mobility can help reduce spatial-economic inequality. In contrast, the lower rankings of the infrastructure and management indices suggest that technical and institutional factors are perceived as secondary to the direct socio-economic and environmental benefits.

In conclusion, despite cultural, security, and institutional limitations, shared mobility possesses high potential to enhance urban transport systems and, consequently, the urban economy by reducing environmental pollution and lowering economic costs. The expert prioritization suggests that policymakers should focus primarily on leveraging the economic, environmental, and social benefits, while infrastructural and managerial barriers are addressed incrementally and in tandem with growing demand. Strategic planning, smart infrastructure development, and a transparent legal and regulatory framework are essential prerequisites for realizing the full potential of this innovative transportation model.

5.1. Limitations and suggestions for future research

Research limitations

1. Sampling limitations: the statistical population was limited to 50 urban transport experts. While this sample size is sufficient for the SWARA and Marcus methods, the results' generalizability to all stakeholders should be approached with caution.

2. Geographical limitations: this study was conducted on Iranian cities in general. Because shared mobility

development highly depends on each city's local conditions, directly applying these results to any specific city in Iran may be limited. Therefore, while the findings serve as a general framework and guideline, operational implementation in specific cities would require localization and re-validation based on their unique characteristics.

3. Methodological limitations: the findings are dependent on the subjective judgments of experts during the weighting and scoring processes. Furthermore, the data were collected using a cross-sectional approach, which does not capture the temporal dynamics or changes over time.

Suggestions for future research

1. Expanding the sample size: future studies should increase the sample size and include a broader spectrum of stakeholders, including end-users, urban managers, and private sector representatives, to enhance the generalizability of the findings.

2. Comparative urban studies: conducting research in various metropolises and performing comparative analyses would be valuable for formulating localized and city-specific policies.

3. Longitudinal research: it is recommended to conduct longitudinal studies to examine how the importance of different dimensions evolves in response to shifting economic conditions and technological advancements.

4. Exploration of complementary dimensions: future research could investigate additional dimensions, such as legal considerations, data security and user privacy, sustainable business models, and the integration of shared mobility with other intelligent transport systems (ITS).

Authors' Contributions

All authors contributed equally to writing and preparing this manuscript.

Acknowledgments

The authors declare that this research received no specific grant or financial support from any funding agency in the public, commercial, or not-for-profit sectors. Artificial intelligence tools, including Google Gemini, were used to assist in translating the article text into English.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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