Review

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Cooperation-Oriented Multi-Modal Shared Mobility for Sustainable Transport: Developments and Challenges

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Posted Date: 13 November 2024

doi: 10.20944/preprints202411.0850.v1

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Review

Cooperation-Oriented Multi-Modal Shared Mobility for Sustainable Transport: Developments and Challenges

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Abstract: There is an increasing adoption of shared mobility for improving transport systems performance, reducing excessive private vehicle use, and making full utilization of existing infrastructure. Despite numerous studies in exploring the use of shared mobility for sustainable transport from different perspectives, how it has improved the sustainability of existing transport and what impact it has on various stakeholders are unclear. A systematic literature review, therefore, is carried out in this study on developing and adopting shared mobility for pursuing sustainable transport in urban traveling. Four emerging themes including (a) attitude and intention, (b) cooperation behaviors, (c) operations and decisions, and (d) performance evaluation have been identified, and some research gaps and challenges are discussed. An integrated framework for developing cooperation-oriented shared mobility is proposed. This leads to better understanding of share mobility and its use for sustainable transport.

Keywords: sustainable transport; shared mobility; travel behavior; cooperation; collaboration; mobility as a service

1. Introduction

With the growing population and the increasing urbanization, the number of vehicles across the world is increasing rapidly (Chen and Deng, 2022; Molla et al., 2024). As a result, urban transport systems are facing numerous challenges due to growing traffic congestion, increasing environmental pollution, and growing greenhouse emissions (Shaheen et al.,2016; Chen and Deng, 2019). How to develop sustainable transport through adopting cooperation-oriented mobility solutions, therefore, is becoming critical (Duan et al., 2022).

Cooperation-oriented transport is about sharing and integrating all kinds of transport resources in urban traveling for improving individuals' mobility (Chen and Deng, 2022). This involves various stakeholders such as government departments, enterprises, public organizations, and individuals taking cooperative decisions from planning, design, construction, and management to operations and maintenance of transport systems to meet multiple, often conflicting objectives (Chen and Deng, 2019; Molla et al., 2024). Cooperation-oriented transport provides stakeholders with more flexible, reliable, safe, and convenient transport services (Chen et al., 2017). This helps to address the growing challenging of urbanization and sustainable development.

The increasing use of cooperation-oriented transport leads to the wide adoption of innovative mobility solutions, including mobility as a service (MaaS) (Molla et al., 2024) and multi-modal shared mobility (MSM) (Meng et al., 2020). MaaS bundles transport options from multiple providers into consolidated digital platforms for delivering integrated mobility services (Duan et al., 2022). It provides travelers with latest technologies (Storme et al., 2020; Li and Voege, 2017) to combine information from different transport modes and services with payment models and product packages

 doi:10.20944/preprints202411.0850.v1

(Butler et al., 2021). MSM is a flexible and low collaboration requirement transport form that links available transport modes through transport providers, sharing bicycles, automatic driving, and buses for enhancing individuals' mobility (Wong et al., 2020). These two innovative solutions share many common features, therefore often lumped together in pursuing sustainable transport. The adoption of such innovative solutions has demonstrated their potential in addressing the emerging challenges of urbanization and enhancing the sustainability of urban transport systems (Butler et al., 2021).

The growing adoption of innovative shared mobility solutions leads to numerous studies to understand how their use can help improve the sustainability of urban transport and what impact that they have on stakeholders (Butler et al., 2021). Despite numerous studies in exploring the application of shared mobility solutions in urban transport, how such applications have improved the sustainability of existing transport systems and what impact they have on individuals are unclear. A research question is, therefore, formulated in this study for addressing these issues as follows: What are the latest development and challenges in pursuing cooperation-oriented shared mobility for sustainable transport?

This study carries out a systematic review of the related research in shared mobility for sustainable transport. Such a review is conducted based on Emerald, ScienceDirect, SpringerLink, and Web of Science during the last ten years. Four emerging themes from existing studies including (a) attitude and intention, (b) cooperation behaviors, (c) operations and decisions, and (d) performance evaluation have been identified, and existing research gaps and challenges are discussed. An integrated framework is proposed for developing cooperation-oriented shared mobility, leading to better use of shared mobility for pursuing sustainable transport in urban traveling.

In what follows, the systematic review method is given in Section 2. A descriptive analysis of the identified literature is then described in Section 3. The emerging themes on shared mobility use for sustainable transport is identified in Section 4. Existing research gaps and challenges in utilizing shared mobility for sustainable transport are elaborated in Section 5. An integrated framework and the conclusion are finally presented respectively in Sections 6 and 7.

2. The Review Method

This study follows a structured approach in conducting a systematic review in exploring the utilization of shared mobility for developing sustainable transport (Wolfswinkel et al., 2013). The adoption of this approach requires defining the review scope first before determining the terms for searching the selected database. This leads to the determination of the review sample and the examination of the selected sample. Finally, the review results can be summarized for reporting. This systematic review process is presented in Figure 1 as follows.

The review scope determines the boundary of the research topic, the sources, the type of literature, and the criteria and methods that the study uses to select, evaluate, and synthesize the literature (Wibowo et al., 2022). This study sources the related literature from Emerald, ScienceDirect, SpringerLink, and Web of Science. This is because these databases have an extensive coverage and strong representation in the publication of quality research articles in shared mobility (Benjaafar et al., 2019; Benjaafar & Hu, 2020).

Several search terms have been used for ensuring a broad coverage of the study including 'shared mobility', 'cooperation consciousness', 'conscious cooperation', 'travel behavior', 'ridesharing', 'ride-hailing', 'car sharing', 'bike sharing', 'on-demand service platforms', 'MaaS', 'MSM', and 'sustainable transport'. Adopting these search terms in the search ensures that all the relevant literature in shared mobility can be identified (Hu and Creutzig, 2022).

Several criteria have been adopted to ensure the selection of the most relevant articles in the study. The document type, for example, is restricted to scholarly journals. The language is limited to English. The selected articles were published between 2014 and2024. Conference papers, book chapters, and white reports are not considered. Such articles may offer valuable insights. Peer-

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reviewed journal articles, however, are more indicative of cutting-edge research with higher impact (Wibowo et al., 2022).

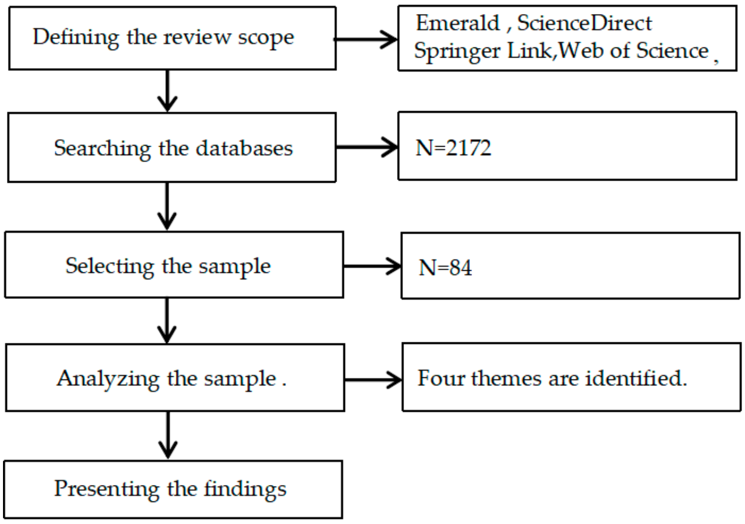

Figure 1. The systematic literature review process.

The determination of the review scope and the search terms leads to the implementation of the search queries in the selected databases. It results in the retrieval of 2,172 articles from these four databases. This shows that shared mobility is a widely covered concept for developing sustainable transport.

The initial search result above is further screened to determine the final sample for detailed analysis. Such a screening process is done manually with the focus on the title and the abstract of each article for checking their relevance to this study (Wolfswinkel et al., 2013). As a result, 201 articles are selected. After removing the duplicated articles, 84 articles have been obtained for further analysis. The selected sample is finally coded and analyzed manually. Four emerging themes are then identified, and existing research gaps and challenges in the development of shared mobility for pursuing sustainable transport are discussed in the following.

3. Descriptive Literature Analysis

The sample of the identified articles is examined with respect to (a) publication trend, (b) publication outlet, and (c) study context (approaches, methods, and theoretical lens). Figure 2 presents an overview of the publication trend over time. It reveals that there is a non-linear time trend. There, however, appears to be an increasing interest in shared mobility. The 84 articles identified, 78 articles are published in 2019 and after.

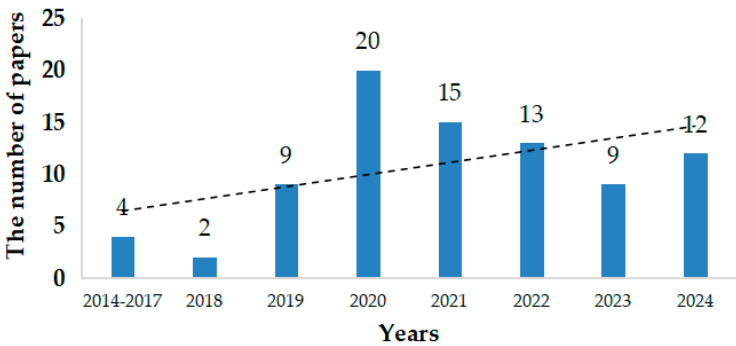

Figure 2. An overview of the publication trend.

The publication outlet of the sample article is analyzed. Figure 3 presents the distribution of the articles across different outlets. It shows that most selected articles are from high-quality outlets listed as in Figure 3. It reveals that Transportation Research Part A and Part B have published the most articles on shared mobility, followed by Part C and Travel Behavior and Society.

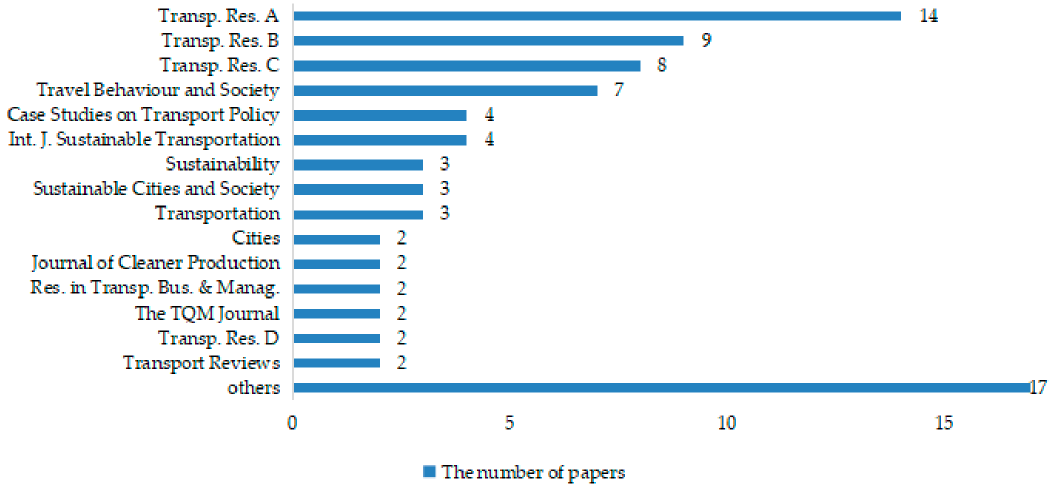

Figure 3. The distribution of the articles in outlets.

The study context of the sample is examined. Table 1 presents the result. It shows that survey and simulation are the prominent methods in quantitative studies and case studies and field studies are the mainstream method in qualitative research. Econometric modelling with behavioural theories is the prevailing framework. It also reveals that mixed-methods approaches and experiments have demonstrated their applicability in the shared mobility studies.

Table 1. Studies on research approaches, methods and theoretical lens.

Approaches	Methods	Theories/Models	No of Articles
Qualitative	Review	None	7
	Interview	Social practice theories, dynamic capability theory, systems theory	3
	Case study	Innovation theory, stakeholder theory, supply-demand value proposition, technology-organization-environment framework	8
	Field study	Stakeholder theory, organizational socialization framework	4
Quantitative	Survey	Econometric model, behavioral theory	17
	Modeling, simulation	Game theory, evolutionary game theory	7
		mathematical model	16
	Experiment	Data mining, statistical techniques	9
Mixed-methods	Interview+ Survey	None	4
	Case study+ Survey	None	6
	Other	None	3

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The distribution of the articles in the four databases is analyzed. As shown in Figure 4, ScienceDirect and Web of Science are the two prevailing databases which track the publication of most articles.

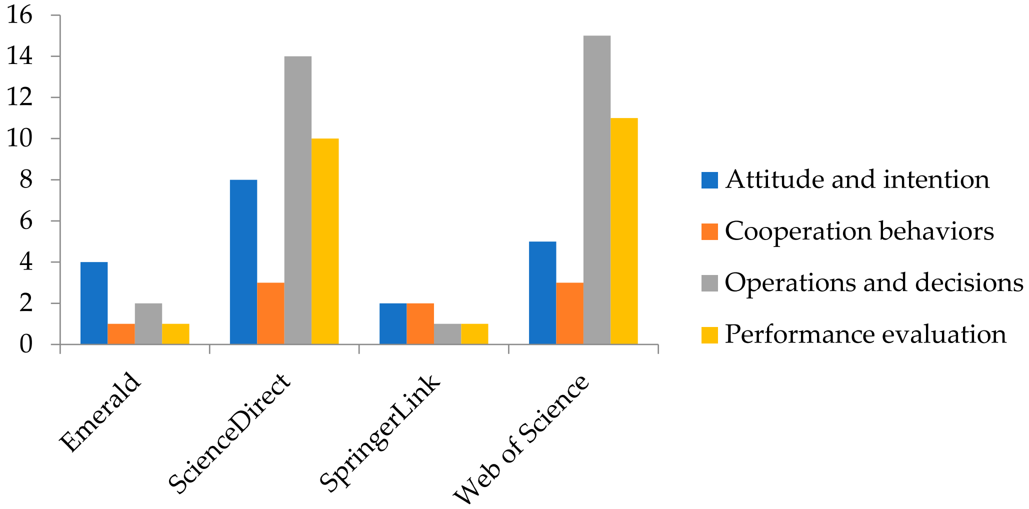

Figure 4. The distribution of the four themes.

4. Emerging Research Themes

An examination of the sample leads to the identification of four themes in exploring the use of shared mobility for sustainable transport. These four themes include (a) attitude and intention, (b) cooperation behaviors, (c) operations and decisions, and (d) performance evaluation, discussed as follows.

Attitude and intention

Exploring individuals' attitude and intention in utilizing shared mobility for pursuing sustainable transport has attracted increasing interest, leading to numerous studies being conducted. Such studies can be classified into sub-themes of (a) understanding individuals' attitude, (b) exploring individuals' intention, and (c) investigating the willingness to pay (WTP).

Attitude-based studies focus on what motivates individuals in adopting shared mobility for pursuing sustainable transport. Ciasullo et al. (2018), for example, explore the use of carpooling based on text analysis finding that economic performance, environment consideration, comfort, traffic, socialization, reliability, curiosity are critical to carpooling use. Moody et al. (2019) investigate the adoption of Uber and Lyft, revealing that individuals' discriminatory attitude is critical to their use. Ahmed et al. (2021) examine how to influence user satisfaction in adopting ridesharing, discovering that perceived quality and value for money are the critical determinants for its use. Li et al. (2022b) show that the critical determinants for utilizing ride-hailing services depend on user orientation, travel characteristics, and perceived performance in urban traveling.

Intention-oriented studies concentrate on investigating what affects the intention of individuals to purchase shared mobility products and services in urban traveling. Mattia et al. (2019) and Chahine et al. (2024b), for example, reveal that subjective norm, perceived behavioral control, and attitude affect individuals' intention to adopt shared mobility products and services. Herberz et al. (2020) find that environmental concerns, status, financial situation, independence, safety, and hedonic motives are critical for individuals' intention to utilize shared mobility solutions. Duan et al. (2022) discover that costs, network externality, institutional factors, behavioral factors, environmental concerns, travel options, and socio-economic influence are critical to the intention of individuals in using MaaS. van Veldhoven et al. (2022) demonstrate that environmental value, ease of use, time saving, ownership, price, compatibility, digital savviness, and hedonic motivations are critical to individuals' intention to the utilization of shared mobility. Molla et al. (2024) state that platform personalization,

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customizability, functional integration, network integration governance, and information schema congruity affect individuals' intention to utilize shared mobility solutions such as MaaS.

WTP-aligned studies examine how much that individuals are prepared to pay for mobility products and services and identify what influences their WTP. Asgari and Jin (2019), for example, investigate individuals' WTP for the use of autonomous vehicles, finding that driving pleasure, reasons for mode choice, trust and technical savvy are the critical determinants. Liljamo et al. (2020) explore individuals' WTP for MaaS offerings, discovering that mobility costs, household's income and gender are the dominant factors. Vij et al. (2020) survey 3985 representative Australians about their use of MaaS, revealing that age and lifecycle stage are the critical determinants in predicting individuals' WTP for MaaS products. Lopez-Carreiro et al. (2021a) discover that the need for control, privacy concerns, environmental awareness, and services integration are the critical determinants of individuals' WTP for MaaS. Lopez-Carreiro et al. (2021b) examine individuals' WTP for MaaS, highlighting that demographic, socioeconomic, and travel-oriented variables are critical. Table 2 summarizes the related studies above.

Cooperation behaviors

Cooperation is about individuals working together to achieve shared objectives (Klein and Ben-Elia, 2016, 2018). Individuals make pro-social choices through cooperation even if such choices impose greater costs or confer less benefits (Hanaki et al., 2007). In transport, cooperation behaviors are about individuals making specific travel decisions for the community's benefits in a voluntary manner (Chen and Deng, 2022).

Understanding what cooperation behaviors are and how cooperation behaviors can be developed directly affect the development of shared mobility for sustainable transport (Alessandretti et al., 2020). An examination of such studies in this perspective has identified three sub-themes including (a) behaviors patterns, (b) critical factors for adopting cooperation behaviors, and (c) formulation and evolution of cooperation behaviors.

Table 2. Attitude and intention based studies.

Themes	References	Approaches	Critical Factors
Attitude	Ciasullo et al. (2018)	Text analytics	Economic and environmental efficiency, comfort, socialization, reliability, curiosity
	Moody et al. (2019)	Survey	Discriminatory attitude
	Ahmed et al. (2021)	Survey	Perceived quality, value for money
	Li et al. (2022b)	Multinomial logistic model	User orientation, travel characteristics, perceived performance
	Chahine (2024a)	Latent class analysis	Benefits and barriers
Intention	Mattia et al. (2019)	Structural equation modeling (SEM)	Attitude, subjective norm, perceived behavioral control
	Herberz et al. (2020)	SEM	Environmental motives, status, financial, independence, safety, hedonic motives
	Duan et al. (2022)	Survey	Costs, network externality, institutional factors, behavioral factors, environmental concerns, options, socio-economic influences
	van Veldhoven et al. (2022)	Confirmatory factor analysis (CFA)	Environmental value, ease of use, time saving, ownership, price, compatibility, digital savviness
	Molla et al. (2024)	Survey	Personalization, customizability, functional integration, network integration governance, information schema congruity

	Chahine et al. (2024b)	SEM	Attitudes, perceived behavioral control, and social norms
WTP	Asgari and Jin (2019)	SEM	Driving pleasure, reasons for mode choice, trust, technical savvy
	Liljamo et al. (2020)	Linear regression	Costs, income, gender
	Vij et al. (2020)	Survey	Age, lifecycle stage
	Lopez-Carreiro et al. (2021a)	Cluster analysis	Control, privacy, environmental awareness, services integration
	Lopez-Carreiro et al. (2021b)	Gologit model	Demographic, socioeconomic, travel-related variables

Exploring individuals' behavior patterns in urban traveling helps understand the utilization of shared mobility products and services under various contexts. This leads to many studies using some common theories to understand the cooperation behavior in utilizing shared mobility. Chen and Deng (2019), for example, present a conceptual framework to examine the interplay between social networks, information use, and conscious cooperation in shared mobility use, leading to three common cooperative behavior patterns being identified. Biehl et al. (2019) investigate the shift from using private vehicles to adopting shared mobility solutions from the community perspective finding that there is a significant difference in the utilization of shared mobility in different communities. Young and Farber (2019) examine the difference between ride-hailing users and other mode users regarding their socio-economic characteristics, discovering that ride-hailing is a phenomenon of wealthy young people. Bi and Ye (2021) investigate travel behavior of ride-sourcing users, leading to the identification of several user patterns through fusing Didi ride-sourcing data using the Latent Dirichlet Allocation model. Vega-Gonzalo et al. (2024) explore how shared mobility use affects car ownership in various population and geographic areas, discovering that the availability of shared mobility solutions can reduce private car ownership.

Critical factor-based studies concentrate on understanding what affects the development of cooperation behaviors in the use of shared mobility. Acheampong et al. (2020), for example, explore ride-hailing adoption in Ghana, finding that ease of use, safety risks, control, and a car dependent lifestyle significantly affect the ride-hailing use. Schikofsky et al. (2020) discover that autonomy, competence, the need of relating to peer groups, and expected usefulness are critical for the adoption of shared mobility. Lesteven and Samadzad (2021) explore the behavior of ride-hailing users in Tehran, finding that smartphone use and income level are critical. Shi et al. (2021) reveal that accessibility to bus stations negatively affects the utilization of ride-hailing in Chengdu. Zhou et al. (2022) show that weather conditions, travel time, and safety significantly influence the shared mobility adoption in Nanchang.

Some studies have been conducted in examining the formulation and evolution of cooperative behaviors in adopting shared mobility. Anagnostopoulou et al. (2020), for example, investigate how individuals change their mobility behaviors, finding that there is a positive behavioral change for more sustainable choices in the utilization of shared mobility. Chen (2015) proves that cooperative behaviors can be developed under specific conditions. Chen (2020) presents a dynamic model for developing cooperative behavior in the use of shared mobility, discovering that such behavior is associated with information use and social networks. Li et al. (2022a) presents a mathematical model for developing cooperative behavior in utilizing shared mobility. Gao et al. (2024) reveal that there is a non-linear relationship existent between bike-sharing and ride-hailing in the adoption of shared mobility for sustainable transport. Table 3 summarizes the discussion above.

Operations and decisions

Individuals' attitude, intention, and behavior are critical for utilizing shared mobility in pursuing sustainable transport (Chen and Deng, 2022). Understanding cooperation behaviors of shared mobility adoption, therefore, requires exploring various shared mobility operations and decisions on strategic, tactical or operational layers (Chen et al., 2020). This results in many studies being conducted in exploring how shared mobility operations and decisions are made for improving

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sustainable transport. Such studies are caried out from the perspective of specific shared mobility modes, MaaS and MSM.

Table 3. Cooperation-based studies.

Themes	References	Approaches	Critical Factors/Main Findings
Behavior patterns	Chen and Deng (2019)	Cluster analysis	Three cooperation behaviors patterns
	Biehl et al. (2019)	Focus group	The acceptance of shared mobility is different in communities
	Young and Farber (2019)	Statistical analysis	Ride-hailing is related to wealthy young people
	Bi and Ye (2021)	Data mining	Ridesourcing user patterns
	Vega-Gonzalo et al. (2024)	Multilevel ordered logit modeling	Shared mobility reduces private car use
Critical factors	Acheampong et al. (2020)	SEM	Ease of use, safety risks, control, car dependent lifestyle
	Schikofsky et al. (2020)	SEM	Autonomy, competence, feeling of being social groups, usefulness
	Lesteven and Samadzad (2021)	Logit model	Smartphone use and income level
	Shi et al. (2021)	Logistic model	Accessibility to bus station
	Zhou et al. (2022)	Logit model	Weather condition, travel time, safety
Formulation and evolution	Chen (2015)	Game theory	Cooperation behaviors
	Anagnostopoulou et al. (2020)	Experiment	Positive results on behavioral changes
	Chen (2020)	Latent class cluster analysis	Cooperation is related to information use and social networks
	Li et al. (2022a)	Game theory	Cooperation can be developed
	Gao et al. (2024)	Random forest model	Bike-sharing and ride-hailing have non-linear effect on the use of metro

Single mode-based studies examine the adoption of specific shared mobility solutions and their impact on various stakeholders. Hong et al. (2017), for example, develop a ride-matching method to support better decisions for carpool commuters. Chen et al. (2020) propose a dynamic programming model for helping platforms better adjust supply and demand for optimizing their operations performance. Jian et al. (2020) present a comprehensive operation scheme to integrate shared vehicles and shared parking for improving the total social benefit of utilizing shared mobility. Ke et al. (2020) construct a ride-hailing model for investigating how ride-pooling affects traffic congestion and travel time. Sun et al. (2020) develop a theoretical model for exploring how ride-hailing platforms allocate customer requests to two (Inform and Assign) matching systems in facilitating the mobility of individuals. Yan et al. (2020) find that combining dynamic pricing and waiting mechanisms can optimize ride-hailing platform operations. Nguyen et al. (2022) propose an activity-based travel demand model to understand the operations of car sharing services . Xu et al. (2021) develop a generalized framework for examining how various operations strategies affect transport systems performance in pursuing sustainable transport. Guo et al. (2023) present a theoretical framework to better address the fragmentation of shared mobility markets with healthy competition between shared mobility providers.

MaaS-oriented studies explore the strategic or operational decisions of MaaS offerings with a focus on functionalities, customization, and integration of specific societal goals. Karlsson et al. (2020), for example, propose an analytical framework for MaaS development and implementation at the marco, meso and micro levels in urban traveling. Meurs et al. (2020) propose a comprehensive framework for developing and testing cooperation between and among transport providers in MaaS. Butler et al. (2021) develop a conceptual framework to help guide future research and MaaS development. Guyader et al. (2021) examine MaaS adoption revealing that institutional logics are the underlying reason for the tension in stakeholder collaboration. Alyavina et al. (2022) discuss the key dimensions of MaaS and contextualize its operational management for long-term sustainability. Athanasopoulou et al. (2022) explore the features of MaaS platforms finding that individuals prefer non-feature requirements more than feature ones. Xi et al. (2024) propose a mathematical model for maximizing the profit of MaaS platforms through making effective operational decisions. Yao and Zhang (2024) develop a matching framework for join pricing and assigning decisions in the multi-modal transport network that has incorporated MaaS systems.

MSM-aligned studies explore the impact of MSM operations and decisions on stakeholders. Cohen and Kietzmann (2014), for example, discuss how existing MSM business models affect the relationship between MSM providers and governments for sustainable transport. Ambrosino et al. (2016) introduce a conceptual framework for managing different transport services through using services agencies. Meng et al. (2020) find that the availability of various mobility modes improves individuals' accessibility to meet multiple, often conflicting objectives of various stakeholders. Shokouhyar et al. (2021) conduct a three-phase study, leading to the identification of 18 challenges and 12 constructs to the sustainability of MSM. Deng et al. (2022) design a profit-sharing scheme for improving the profitability of digital platforms through cooperation in multi-modal transport networks. Narayanan and Antoniou (2023) develop a choice model for three shared mobility solutions for understanding how the use of these solutions is influenced by socio-demographic characteristics, trip-related variables, and supply parameters. Bandiera et al. (2024) propose a mathematical model to examine the interplay between MSM providers and individual users. Table 4 summarizes the discussion above.

Performance evaluation

Evaluating the performance of shared mobility is critical for developing sustainable transport (Chen and Deng, 2019). There are many studies in this regard that can be divided into three sub-themes including performance evaluation of specific shared mobility initiatives, performance evaluation of shared mobility development, and impact assessment, discussed as follows.

Table 4. Operations and decisions based studies.

Themes	References	Approaches	Critical Factors/Main Findings
Single shared mobility	Hong et al. (2017)	Data-driven clustering	Carpool programs contribute to less congested traffic and environment-friendly travel
	Chen et al. (2020)	Mathematical model	Dynamic strategies help platforms adjust supply and demand for achieving optimization goals
	Jian et al. (2020)	Mathematical model	Bundled mobility offerings can improve providers' profit and individuals' social welfare
	Ke et al. (2020)	Macroscopic diagram	An optimal model for minimizing the time cost
	Sun et al. (2020)	Queueing theory	Insights on how platforms allocate rides
	Yan et al. (2020)	Mathematical model	Price variability is reduced and capacity utilization, trip throughput, and welfare are increased
	Xu et al.(2021)	Macroscopic fluid model	A model for policy control
	Nguyen et al. (2022)	Mathematical model	A mathematical model
	Guo et al. (2023)	Game/integer linear program	Market design can reduce inefficiency and promote healthy competition
MaaS	Karlsson et al. (2020)	Case study	A consistent characterization of business models

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	Meurs et al. (2020)	Case study	A conceptual framework for cooperation
	Butler et al. (2021)	Literature review	Desired MaaS outcomes, supply side barriers and demand side risks related to MaaS adoption
	Guyader et al. (2021)	Case study	Experimenting innovative solutions for key learnings about shared mobility ecosystems and stakeholders
	Alyavina et al. (2022)	Literature review	Areas for affecting MaaS' capacity
	Athanasopoulou et al. (2022)	Literature review	Non-features requirements are highly valued
	Xi et al. (2024)	Mathematical model	A novel e-MaaS ecosystem
	Yao and Zhang (2024)	Mathematical model	A new MaaS platform design
MSM	Cohen and Kietzman (2014)	Qualitative exposition	Existing models are fraught with conflicts, a merit model is the most promising one
	Ambrosino et al. (2016)	Literature review	The role of a shared mobility centre in MSM use
	Meng et al. (2020)	Literature review	Shared mobility requires collaborative partnership
	Shokouhyar et al. (2021)	Delphi approach	18 challenges and 12 constructs are critical to the sustainability of MSM
	Deng et al. (2022)	Game theory	Platform profit increases through cooperation
	Narayanan and Antoniou (2023)	Multinomial logit model	A choice model for selecting mobility services
	Bandiera et al. (2024)	Mathematical model	A novel mathematical model on the interaction between providers and users

There are many studies assessing the overall performance of specific shared mobility initiatives. Jin et al. (2018), for example, conduct a systematic review on how ride-sourcing affects efficiency, equity, and sustainability, finding that ride-sourcing positively affects economic efficiency. Erhardt et al. (2019) explore the negative impact of Uber and Lyft, showing that transport network companies (TNCs) contribute the most to traffic congestion in San Francisco. Henao and Marshall (2019) examine the change of performance indicators of TNCs showing that ride-hailing adds approximately 83.5% more vehicle kilometers traveled (VKT) to transport systems in the Denver region. Tirachini and Gomez-Lobo (2020) examine how ride-hailing affects VKT, revealing that ride-hailing increases VKT unless its applications can substantially increase the occupancy rate in Mexico City. Tirachini et al. (2020) investigate the impact of shared mobility on travel behavior, transport sustainability, congestion, pollution, and crashes. Shen et al. (2021) present a solid empirical basis to state that transport authorities need work with private mobility service companies by studying a carpool incentive experiment in the Seattle region. Vélez (2024) conduct a literature review to investigate the environmental impact of shared mobility solutions including car sharing, carpooling, bike-sharing, and scooter/moped sharing. Coenegrachts et al. (2024) employ latent class cluster analysis and k-means clustering to provide an explorative analysis of the shared mobility market in 311 European cities, indicating that there are nine shared mobility systems clusters in European cities.

Performance-oriented studies explore the development of shared mobility focusing on MaaS. Matyas and Kamargianni (2019) examine whether MaaS can be adopted to promote shared mobility, finding that many people are willing to adopt such services. Reck et al. (2020) conduct an extensive review on MaaS design, thus developing a framework to compare design, development and outcome of such design choices. Zhang and Zhang (2021a) propose an alliance-based framework for Chinese MaaS systems, summarizing that the key to MaaS project success is related to industry alliance, government support, and data sharing. van den Berg et al. (2022) show that shared mobility products are different in how stakeholders are affected by the utilization and availability of mobility technologies. Muller et al. (2021) conduct a review of current simulation tools to assess the sustainability impact of MaaS from a systems perspective. Hensher et al. (2021) find that offered MaaS bundles has an encouraging impact on private car use by employing discrete-continuous choice modelling conduced on a Sydney MaaS trial project. Ho et al. (2021) develop a mixed logit choice model for understanding individuals' selection between pay-as-you-go (PAYG) and four MaaS subscription plans, revealing that mobility bundles has a significant market and PAYG is preferred by those with varying travel needs. Lindkvist and Melander (2022) examine the MaaS literature, revealing that MaaS promises to deliver both social and environmental sustainability. Kriswardhana and Esztergár-Kiss (2023) investigate various critical factors that affect the adoption of shared mobility, leading to the identification of various environment and individual factors that affect the utilization of MaaS. Carbonara et at. (2024) employ a multi-case study to examine the impact of MaaS, revealing that similar strategies have been adopted in the transition to MaaS.

Impact-aligned studies examine the availability of shared mobility initiatives and their impact on stakeholders. Arias-Molinares and García-Palomares (2020), for example, conduct a case study to explore the development of MaaS, finding that there is little cooperation between stakeholders in existing shared mobility projects. Becker et al. (2020) run a joint simulation for a city-wide transport system, revealing that MaaS schemes may increase transport systems efficiency and reduce energy consumption. Christensen et al. (2022) apply social practice theories to assess the influence of MaaS, discovering that MaaS designs should consider the routinization and entanglement of individuals' daily mobility practices. Ho (2022) assesses the viability and environmental sustainability of MaaS based on a five-month field trial, finding that MaaS use does affect individuals' travel behavior. Krauss et al. (2023) conduct an experiment in Germany to explore the influence of mobility behavior on the use of MaaS bundles, stating that utilizing shared mobility offerings reduces private car use. Aba and Esztergár-Kiss (2024) carry out a MaaS pilot study in Budapest with the provision of detailed information about various perspectives of the service providers in MaaS adoption. Table 5 summarizes the discussion above.

Table 5. Performance evaluation-oriented studies.

Themes	References	Approaches	Critical Factors/Main Findings
Specific shared mobility	Jin et al. (2018)	Literature review	Ride-sourcing affects efficiency, equity, and sustainability
	Erhardt et al. (2019)	Regression model	TNCs contribute to growing traffic congestion
	Henao and Marshall (2019)	Experiment and survey	Ride-hailing increases VKT
	Shen et al. (2021)	Regression	Carpooling generates promising outcomes
	Tirachini and Gomez-Lobo (2020)	Monte Carlo simulation	Ride-hailing increases occupancy rate, leading to increased VKT
	Tirachini et al. (2020)	Survey	VKT depends on various factors
	Coenegrachts et al. (2024)	Latent class clustering	Individuals have access to shared mobility
	Vélez (2024)	Literature review	Travel behaviour, shared mobility modes, and local contexts are critical
Shared mobility performance	Matyas and Kamargianni (2019)	A Mixed MNL model	MaaS bundles can introduce more travelers to use shared modes
	Reck et al. (2020)	Experiment	A framework compare stated choice studies
	Hensher et al. (2021)	Choice model	MaaS can change travel behaviour

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	Ho et al. (2021)	Logit choice model	PAYG is a preferred option for shared mobility
	Lindkvist and Melander (2022)	Literature review	Sustainable business models for shared mobility
	Muller et al. (2021)	Literature review	Comparative assessment of simulation tools for shared mobility solutions
	Zhang and Zhang (2021a)	Literature review	Cooperation, government support, and data sharing are critical to shared mobility projects
	van den Berg et al. (2022)	Game theory	MaaS benefits consumers by increasing competition and removing marginalization
	Kriswardhana and Esztergár-Kiss (2023)	Literature review	Environment factors and user groups
	Carbonara et at. (2024)	Case study	The MaaS operations process
Impact assessment	Arias-Molinares and García-Palomares (2020)	Case study	Governance and collaboration is critical for developing MaaS
	Becker et al. (2020)	Simulation	MaaS increases system efficiency, while substantially reducing energy consumption
	Christensen et al. (2022)	Interview	MaaS should consider embodied routinization and entanglement of mobility practices
	Ho (2022)	Choice modeling	MaaS affects travel behaviour
	Krauss et al. (2023)	Preference experiment	Shared mobility use reduces car use
	Aba and Esztergár-Kiss (2024)	Case study	MaaS is effective for reducing private car use

The discussion above shows that shared mobility is an evolving phenomenon that stresses on shared use rather than ownership of transport facilities (Chen and Acheampong, 2023). This means that sustainable transport needs more cooperation between stakeholders (Pangbourne et al., 2018; Shokouhyar et al., 2021). Individuals focus on efficiency, economics, and flexibility. Transport authorities pursue more on social equity, reliability, and environmental friendliness. Often such goals are hard to be cooperative in pursuing sustainable transport (Coenegrachts et al., 2024). To address these challenges, innovative mobility solutions are required (Guan et al., 2024; Lyons et al. 2019).

5. Research Gaps and Questions

The systematic literature review above helps to identify the gaps and research questions in developing sustainable transport. Such research gaps and questions are discussed with respect to the four themes as follows.

Attitude and intention

Attitude and intention are the driving factors that affect individuals' selection of shared mobility products and services in urban traveling (Chen and Deng, 2019). Despite numerous studies in exploring the attitude and intention from different perspectives, most studies focus on investigating the critical factors that influence the attitude and intention in adopting shared mobility. It is unclear whether existing findings can be applied to the utilization of cooperation-oriented multi-modal shared mobility. The specific elements and mechanisms that influence individuals' attitude and intention to choose collaborative travel options within a multi-modal shared mobility context for sustainable transport remain largely unknown.

Cooperation behaviors

Conscious cooperation behaviors imply proactive acceptance and adoption of specific shared mobility products and services in pursuing sustainable transport (Chen and Deng, 2019). Exploring the behavioral pattern of individuals leads to many studies with the use of representative behavioral theories. Despite much progress being made, much of the research, however, concentrates on the behavior patterns of specific shared mobility solutions. In pursuing sustainable transport, multi-modal shared mobility is often required for achieving multiple and seemingly conflicting objectives which particularly needs more cooperative behavior in travel choice decisions. There is lack of investigation in examining the formation and evolution of cooperation behaviors in the adoption of the multi-modal shared mobility.

Operations and decisions

Operations and decisions are crucial to the achievement of specific objectives that various stakeholders pursue in shared mobility. Existing studies have tried to explore how operations and decisions have affected the shared mobility use. However, there are few studies in exploring the adoption of various mobility modes in pursuing sustainable transport through developing cooperation-oriented shared mobility.

Performance evaluation

There are many studies in evaluating the performance of shared mobility based on economic and non-economic criteria. Quantitative indicators such as VKT, VMT and qualitative indicators such as traffic congestion, emission or environmental hazards are considered. Existing studies explore how the adoption of shared mobility affects individuals' behaviors in urban traveling, transport performance and social welfare, and examining the critical factors and mechanisms to the implementation of shared mobility initiatives. There is, however, lack of studies in exploring the economic, environmental and societal benefits of cooperation-oriented shared mobility. It is unclear of why some cooperation-oriented shared mobility pilots or trials have positive impacts while some not. Table 6 summarizes the research gaps and questions discussed above.

Table 6. Research gaps and questions.

Themes	Topics	Gaps	Research Questions	References
Attitude and intention	Attitude Intention Willingness to pay	• Few studies examine the influential factors of attitude, intention, and WTP in multi-modal shared mobility context • Lack of studies in exploring the influence mechanism of attitude, intention, and WTP in multi-modal shared mobility context	• What are the influential factors of attitude, intention, and WTP related to cooperation-oriented shared mobility? • How do influential factors affect attitude, intention, and WTP related to cooperation-oriented shared mobility?	Ciasullo et al. (2018); Asgari and Jin (2019); Liljamo et al. (2020); Vij et al. (2020); Lopez-Carreiro et al. (2021a,2021b); Duan et al.(2022); Veldhoven et al. (2022); Molla et al. (2024); Chahine et al. (2024b)
Cooperation behaviors	Behavior patterns Critical factors Formulation and evolution	• Most articles focus on the behavior patterns of single shared mobility or MaaS rather than cooperation-oriented shared mobility • Only a few studies focus on critical factors influencing on single shared mobility or MaaS • Few studies investigate formulation and	• What are the behavior patterns related to cooperation-oriented shared mobility? • What affects the cooperation-oriented shared mobility behavior? • How do the formulation and evolution of cooperation-oriented shared mobility behavior?	Chen and Deng (2019); Young and Farber (2019); Acheampong et al. (2020); Schikofsky et al. (2020); Lesteven and Samadzad (2021); Shi et al. (2021); Zhou et al. (2022); Li et al. (2022a);

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		evolution of cooperation-oriented shared mobility		Gao et al. (2024); Vega-Gonzalo et; al. (2024)
Operations and decisions	Single shared mobility MaaS MSM	• Lack of studies on addressing of operations and decisions issues in cooperation-oriented shared mobility	• What are the differences of operations and decisions between MaaS, MSM and cooperation-oriented shared mobility? • How to develop effective and viable operations and decisions strategies/solutions of cooperation-oriented shared mobility?	Hong et al. (2017); Chen et al. (2020); Jian et al. (2020); Butler et al. (2021); Xu et al.(2021); Alyavina et al. (2022); Athanasopoulou et al. (2022); Guo et al. (2023); Xi et al. (2024); Yao and Zhang (2024)
Performance evaluation	Specific shared mobility Shared mobility development Impact assessment	• Lack of sufficient understanding the causes of resulting in different impacts of shared mobility pilots or trials • Most studies on performance evaluation and related impact assessment focus on specific shared mobility or MaaS	•Why do some cooperation-oriented shared mobility pilots or trials have positive impacts while some not? • How to comprehensively assess outcomes involving economic, environmental and societal aspects of cooperation-oriented shared mobility pilots or trials?	Jin et al. (2018); Erhardt et al. (2019); Reck et al. (2020); Tirachini and Gomez-Lobo (2020); Hensher et al. (2021); Muller et al. (2021); Zhang and Zhang (2021a); Lindkvist and Melander (2022); Krauss et al. (2023); Kriswardhana and Esztergár-Kiss (2023); Aba and Esztergár-Kiss (2024)

6. An Integrated Cooperation-Oriented Shared Mobility Framework

Developing shared mobility for sustainable transport requires holistic consideration of the four themes discussed above. These four themes are closely related based on the collaboration and cooperation between stakeholders. Figure 5 presents a framework for better describing the interplay between these themes and stakeholders.

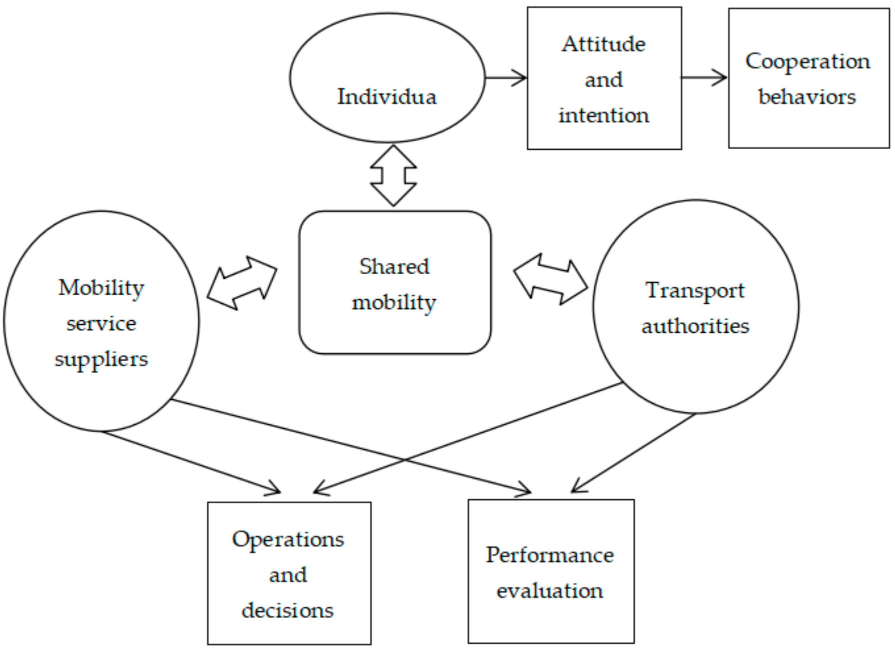

Figure 5. A conceptual framework of the relationship between the themes and stakeholders.

The acceptance and adoption of shared mobility originate from individuals' travel needs. These travel needs exert a direct effect on the attitude and intention of individuals in the use of shared mobility, and these attitude and intention propel various cooperation and non–cooperation behaviors. These behaviors then represent the demand side of the transport system. They provide specific benefits from economic, environmental, and societal perspectives (Chen and Deng, 2022).

The supply side of shared mobility includes mobility service providers and mobility operators (Chen and Deng, 2019). They deliver innovative mobility products and services with respect to specific government regulations and rules in their operations and decisions. These operations and decisions are assessed for understanding the performance and impact of such products and services. Transport authorities play the role of coordination and management involving planning, operations, and evaluation of shared mobility.

Shared mobility conforms to carbon footprint reduction advocate, thus being an attractive solution for sustainable transport (Zhang and Zhang, 2021a). It emphasizes sharing trip-rides or transport equipment rather than exclusive use or ownership (Wilson and Mason, 2020; Wong e al., 2020). Shared mobility, however, does not meet the travel need of every individual. To address such a challenge, other transport modes are required. This leads to the adoption of multi-modal shared mobility that includes private cars, bikes, and public transit (Shaheen et al., 2016).

Excessive use of private cars, however, may exert negative externalities and deviate from sustainable transport (Shaheen et al., 2017). It shows that the adoption of multi-modal shared mobility requires a balance between meeting individual travel needs and satisfying sustainable development goals. This needs individuals to make more cooperative choices in shared mobility (Chen and Deng, 2019).

Cooperation and collaboration are the foundation to the pursuit of multi-modal shared mobility for sustainable transport (Chen and Deng, 2022). This is determined by the cooperation feature, operations difficulty and output performance that individual transport modes have in providing mobility services. The cooperation feature is about the needs of specific transport mode on how much cooperative consciousness is required in adopting shared mobility. Operations difficulty is linked to the degree of difficulty for the demand side (individuals) to adopt this transport mode and the degree of difficulty for the supply side (providers) to operate related modes. Output performance is the reflection of achievement of sustainable objectives that shared mobility pursues. With the consideration of these three features, existing mobility solutions can be assessed, leading to the development of the summary of the cooperation matrix for developing sustainable shared mobility, shown as in Table 7.

Table 7 reveals that MaaS needs the highest level of cooperation between various stakeholders for sustainable transport. This means that the use of MaaS requires more conscious cooperation and collaboration between stakeholders. MaaS generate the best output performance with respect to the sustainable objectives. It is, however, difficult for the adoption due to various challenges in pursuing sustainable transport through cooperation and collaboration between stakeholders. This dilemma calls for novel shared mobility solutions capable of integrating the advantages of MaaS while addressing the challenges that it faces in facilitating the mobility of individuals in urban traveling.

Table 7. The cooperation matrix for developing sustainable shared mobility.

Transport mode		Cooperation	Operations	Output	References
Shared mobility	Sharing vehicles	Moderate	Moderate	Moderate	Jian et al. (2020); Narayanan and Antoniou (2023); Chahine et al. (2024b)
	Ridesharing	Moderate	Moderate	Moderate	Hong et al. (2017); Ke et al. (2020); Narayanan and Antoniou (2023);

					Vega-Gonzalo et al. (2024)
	On-demand ride services	Moderate	Moderate	Moderate	Young and Farber (2019); Sun et al. (2020); Xu et al. (2021); Li et al. (2022b); Guo et al. (2023)
	Micro-mobility	Moderate	Moderate	Moderate	Shi et al., (2021); Zhou et al. (2022); Zhu et al. (2023)
Non-shared mobility	Private vehicle	Inconspicuous	Low	Moderate /Inferior	Zhou et al. (2020); Mock (2023); Vega-Gonzalo et al. (2024)
	Other ownership modes	Inconspicuous	Low	Moderate /Inferior	Meng et al. (2020); Shokouhyar et al. (2021); Delclòs-Alió et al. (2023)
MaaS		Conspicuous	High	Excellent	Alonso-González et al. (2020); Meurs et al. (2020); Butler et al. (2021); Alyavina et al. (2022); Xi et al. (2024)

A cooperation-oriented shared mobility (COSM) framework is, therefore, proposed in this study to better address the challenge that existing shared mobility solutions suffer from. Such a framework can facilitate the development of sustainable transport through better satisfying multiple but often conflicting objectives of stakeholders by combining multiple travel modes in urban traveling (Carbonara et al., 2024; Tian et al., 2024; Pamucar et al., 2022). To reduce the collaborative barriers between mobility service providers, COSM does not require integrating multiple travel services into integrated platforms. It is committed to make the allocation of transport resources in a transparent manner by providing diversified travel modes for reducing traffic congestion and improving mobility services efficiency. COSM is an effective integration of MSM and MaaS for fulfilling the needs of stakeholders through cooperation and collaboration.

Figure 6 presents an integrated COSM framework. This framework includes the main components and their relationships in an urban transport ecosystem. It provides flexibility, efficiency, safety, reliability, environmental friendliness, and transport equity for the mobility of people by leveraging every mode's specific advantages.

A COSM ecosystem has four components. The first one is users. The second one is mobility service providers including (a) traditional services providers, (b) incumbent services providers, such as public transit, paratransit, shuttles, taxis, (c) self-services providers, such as private vehicles, e-scooter, bicycle, and (d) supportive services providers, such as mobile communication operators, information system developers, and data analysts. The third one is mobility operators often referred to as transport services platforms such as Uber, Lyft, or Didi. These platforms have numerous drivers who provide individuals with required services. They serve as the moderator for connecting providers and users. The fourth one is transport authorities who act as the intermediator and supervisor (Benjaafar et al., 2019).

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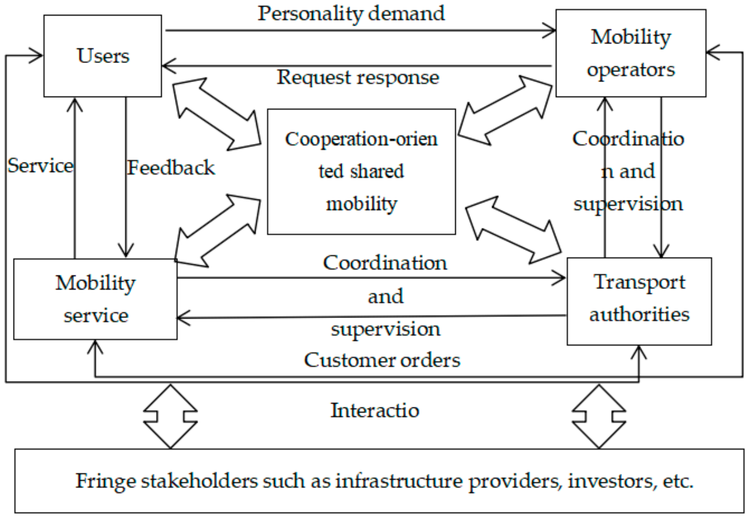

Figure 6. An integrated framework of cooperation-oriented shared mobility ecosystems.

There are complicated interplays between these four components. In shared mobility, individuals first send their travel demands through digital platform typically in a smart-phone app owned by mobility operations. These demands are transformed as a customer order through platforms. These orders are communicated to mobility service providers as soon as the platform matches the request with appropriate providers. The provider can then supply the individuals with the required services. In this process, transport authorities act as an intermediate role that ensures the mobility market is being operated according to the relevant regulations and policies.

There exist some differences between COSM and MaaS. The main difference between COSM and MaaS lies in the implementation difficulty of COSM that is much lower than MaaS. COSM does not require a single digital interface to provide integrated planning, booking, payment, ticketing and other core functions as required in MaaS (Molla et al., 2024). Users' travel needs could be fulfilled by multi-services providers (MSPs) via multiple digital platforms. Collaboration is one of the essential elements for MaaS, while how to collaborate sufficiently exerts significant challenges because of the competitive nature among the different MSPs (Matowicki et al., 2022, Butler et al, 2021; Tirachini, 2020). MSPs can mitigate the requirements through cooperation between stakeholders. The other prominent difference lies in that COSM may not exclude the use of private vehicles (Wilson and Mason, 2020; Wright et al., 2020). All travel modes can be incorporated to achieve more efficient and flexible mobility. This inclusion shows that COSM can strive to fulfill multi-goals of stakeholders while providing more flexible services through cooperation and collaboration.

COSM has several advantages compared to existing shared-mobility solutions. These advantages are reflected in the difficulty of implementation (Tian et al., 2024) and the output performance (Jin et al., 2018). As a flexible and effective transport solution, COSM has enormous adaptability, which is realized by effective combination of specific mobility modes. COSM can incorporate private vehicles use in providing more choices in those suburban areas with low occupancy public transit or shared mobility travel modes (Carbonara et al., 2024; Zhou et al., 2020). This inclusion brings individuals more flexibility and efficiency in urban traveling. Furthermore, COSM does not commit to pursue a single online interface. It allows the use of diverse digital platforms with more safety, social inclusion and less collaboration requirements appeal than an integrated online interface (Guan et al, 2024; Kayikci et al., 2022; Bushell et al, 2022; Surakka et al., 2018). In summary, COSM can create compelling value for those pursuing higher efficiency and lower barriers solutions.

7. Conclusion

A systematic review is implemented in this study on the adoption of shared mobility for pursuing sustainable transport. As a result, the emerging themes and the challenges associated with the use of shared mobility for sustainable transport have been identified. An integrated framework through integrating MaaS and MSM has been developed for facilitating the development of shared mobility in pursuing sustainable transport.

The study shows that there are important distinctions between traditional shared mobility and COSM. There are many research questions that need to be addressed. Firstly, studying users' attitudes, intentions and behaviors in COSM travel choice requires a better understanding of the relationship between the critical factors and COSM adoptions. Secondly, exploring how specific COSM operations and decisions are made is required for more insights on the planning and designing of COSM operational strategies and policies. Finally, assessment the implementation of different COSM initiatives is necessary, as such evaluations can provide appropriate suggestions for tackling the enormous challenges on sustainable transport development in fierce urbanized environments.

Acknowledgement: This work is supported by the National Natural Science Foundation of China (Grant no. 72171102).

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