Transportation Research Interdisciplinary Perspectives 29 (2025) 101337

Contents lists available at ScienceDirect

Transportation Research Interdisciplinary Perspectives

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

Investigating the involvement of public transport authorities in MaaS developments

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ARTICLE INFO

Keywords:
Mobility-as-a-Service
MaaS
Mobility integration
Transport planning

ABSTRACT

In recent years, a novel mobility concept that is known as *Mobility-as-a-Service (MaaS)* has emerged in several metropolitan regions. MaaS is presently conceived as a decisive concept in shaping how mobility services are accessed by the users. The relevance of this mobility concept is depicted with various leverages, ranging from offering seamless mobility networks to providing sustainable mobility environments. However, what is still lacking in scholarly research is to scrutinise the level of involvement of public transport authorities in MaaS developments. Therefore, this study investigates the role of these authorities in MaaS plans in three German metropolitan areas namely Berlin, Hamburg, and the Ruhr region *(Ruhrgebiet)*. The investigation is conducted through unfolding relevant literature by employing the thematic analysis method. The findings demonstrate that public transport authorities from the investigated case study areas have displayed visible efforts in integrating public transport forms (e.g., trains, trams and buses) with micro-mobility forms (e.g., bike-sharing) and car-sharing services. But contrarily, there are still challenges in incorporating the use of shared rides (e.g., ride-sharing and ride-sourcing) in their MaaS schemes, and thus, an integrative framework among public transport authorities, private mobility providers and policymakers has been proposed to smoothen the MaaS development process.

1. Introduction

The integration of mobility services is one of the major discussions in transport and mobility research. The upsurge of this academic discourse is mainly driven by the positive outcomes that are expected to be obtained through the paradigm of integrated mobility. The integration of mobility forms is conceived with the benefit of providing seamless mobility connections by unifying the traditional forms of transport with emerging mobility services (Labee et al., 2022). This mobility paradigm is also anticipated to decrease the dominance of private vehicles in transport systems by allowing users to choose mobility forms of their preferences, and also reimburse their travel charges in a single spectrum (Hrelja et al., 2020; Caballini et al., 2023; Manders et al., 2020). Some of the intergovernmental organisations like the European Commission have manifested that the integration of mobility services is a requisite avenue for achieving future sustainable societies (Rindone, 2022). In this sense, distinguishable concepts like *Mobility-as-a-Service (MaaS)* are presently visible in many metropolitan regions (Enoch and Potter, 2023; Kayikci and Kabadurmus, 2022). The concept of MaaS offers the possibility of accessing various mobility services with the use of a single digital interface (Van den Berg et al., 2022; Baldassa et al., 2023; Kamargianni et al., 2016a). MaaS is supported by real-time location data, and it can automatically choose the appropriate mode(s), and route(s), depending on the user's departure and destination inputs. In addition, users have the possibility of completing their payments on the same interface.

Despite that MaaS seems to be unadorned in its contextualisation, the concept is tainted with a variety of complexities in its development process, because MaaS is concealed with multiple players, and its entire aggregation touches various dimensions including the harmonisation of strategies by public actors, which are responsible for smoothening its operational activities. Hasselwander and Bigotte (2022) show that the engagement of public actors can be a principal catalyst for MaaS developments whilst (Fenton et al., 2020) indicate that the involvement of these authorities is essential for formulating long-term mobility solutions. However, what is still challenging is to disclose the role of public transport authorities in MaaS arrangements, and to examine whether the established strategies are positioned to support these developments. Conjointly, the indistinctness of MaaS in literature offers restricted

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https://doi.org/10.1016/j.trip.2025.101337
Received 9 June 2024; Received in revised form 18 December 2024; Accepted 12 January 2025
Available online 30 January 2025

guidance to public authorities in harmonising such strategies (Smith and Hensher, 2020). Besides, there are recurring concerns in many urban areas on whether the MaaS concept has increasingly become an elusive goal from the regulators' side (Casady, 2020) since the concept predominately emerged as a third-party player, mediating both private and public transport actors (Arias-Molinares and García-Palomares, 2020; Esztergár-Kiss et al., 2020). This phenomenon alternated the ambulation of how transport forms are regulated, because the already existing policies for conventional modes of transport do not offer established rules of engagement with private mobility actors. Hence, countries like Germany have tried to re-craft their strategies with the aim of obtaining integrated mobility plans at different scales, including regional levels. The restructuring of these strategies is mainly derived from the European Union where the member states are obligated to lay out plans for mobility integration (Schöller-Schwedes, 2010).

In this transformation process, some of the dimensions for integrating mobility systems have been in one way or another touched upon by public authorities. Nevertheless, there is still a research gap to identify the exact MaaS footprints, developed by these authorities in their transition process. Therefore, the primary objective of this research is to investigate the level of involvement of public transport authorities in the development process of MaaS, and additionally, propose ways on how these authorities can strengthen their participation levels in the planning process for this concept. The study concentrates on three urban metropolitan regions in Germany namely Berlin, Hamburg, and the Ruhr region *(Ruhrgebiet)*. The following two research questions (RQs) are positioned to guide this investigation: (RQ1) How have the public transport authorities been involved in MaaS developments?; (RQ2) How can these authorities optimise their level of participation in MaaS plans? First, a comprehensive examination of these two proposed research questions is situated to provide a clear understanding of the state of MaaS in the investigated case study areas. Second, identify the multi-dimensional traces of MaaS developments from the standpoints of the public actors. Third, recommend a cooperative working framework among the involved stakeholders in the MaaS process. These findings are intended to provide both academic and policy-driven insights that can assist researchers and policymakers to navigate through MaaS-related difficulties.

The remainder of this article is organised as follows: Section 2 denotes the state of the art, and issues-at-stake that prompted to propose the research questions for investigation. Section 3 presents the employed methodological framework, and further details the case study regions. Section 4 summarises the identified results while Section 5 places these outcomes to an analytical discussion with the aim of suggesting how MaaS plans can efficiently be realised. Section 6 summarises the key findings of the study.

2. State of the art

MaaS is an integrated mobility paradigm that has gained momentum in the past decade (Kriswardhana and Esztergár-Kiss, 2023; Butler et al., 2021), and globally, there have been a range of both commercial and pilot MaaS schemes emerging (Matyas, 2020). As a result, some countries have started to procedure the future of their mobility systems in alignment with MaaS initiatives (Hult et al., 2021). Moreover, the offering of multiple mobility services in MaaS schemes creates a complex transport system (Matyas, 2020), and this further sophisticates the understanding of this concept (Hoerler et al., 2020; Alonso-González et al., 2020). Nonetheless, Lajas and Macário (2020) propose that MaaS should be understood first, because if a concept encompasses everything, then it is perceived differently, and thus its realisation process is close to impossible. This being the matter, the positioned research begins by particularly shedding some light on the conceptualisation of MaaS.

MaaS can be viewed as a mobility concept that comprehensively provides access to a variety of mobility services to the users (Alyavina et al., 2020). Huang (2022) conceives MaaS as a concept that merges mobility modes while Utriainen and Pöllänen (2018) argue that MaaS does not only offer a combination of different mobility alternatives, but it goes further to offer circumstances with distinctively upgraded service levels that are characterised by low costs and efficiency. Comparably, the concept is also viewed as a multimodal mobility arrangement that is essentially designed to achieve sustainable strategies (Musolino, 2022). Similarly, Hensher et al. (2021) perceive MaaS as a framework for delivering a portfolio of mobility alternatives, which places the user at the centre of the concept. Chen and Acheampong (2023) view MaaS as a gradual process to the regime of integrated mobility that encompasses digital-enabled mobility services, information and physical infrastructures. Ho et al. (2018) prospect MaaS as a one-stop travel management platform that is essential in trip recreation and payment. Therefore, MaaS has no distinct definition in academic literature, however, all definitions endeavour to capture the underlying idea of grounding transport forms into a single and on-demand mobility service (Mulley et al., 2018).

2.1. Particularities in the MaaS concept

From the above varying MaaS conceptualisations, it is clear that the nature of this mobility concept is multi-dimensional, and it is composed of different layers that are responsible for its evolution process. First, the concept is inseparable from technological advancements, which are usually labelled as intelligent digital technologies (Butler et al., 2021; Esztergár-Kiss et al., 2020). These technological solutions have rapidly emerged in recent years, and can share information within the environments in which they operate, and correspondingly, have the ability to interact with other similar or closely related digital solutions (Gutiérrez et al., 2013). MaaS is one of these innovations, because the service provides combined information, concerning travel schedules, mobility locations, and payment possibilities. In this sense, this study considers the initial layer of MaaS to be characterised by data sharing and integration. Sochor et al. (2018) consider this layer as a stage with classified functionalities, containing centralised information regarding travel planning and assistance while Hasselwander and Bigotte (2022) emphasise that MaaS is based on data-driven approaches that are essential to construe issues like route rationalisation. In fact, Polydoropoulou et al. (2020) report that the lack of streamlined data sharing structures in MaaS can induce to technical barriers in its realisation process. Another vital layer of this concept involves the composition of different mobility forms, which are essential for providing multiple travel choices to the users. However, the accumulation of varying transport modes does not guarantee the success of MaaS, because this service has an imperative characteristic of contributing to the sharing economy (Castellanos et al., 2022). Thus, the configuration of shared mobility services like bike-sharing, e-scooter sharing, car-sharing, ride-sharing, etc., is important for the existence of this concept. Fioreze et al. (2019) conducted a study concerning the likelihood of MaaS uptake and concluded that the increase in the frequencies of the provided mobility alternatives is more likely to increase its flexibility and usage. Likewise, Alonso-González et al. (2020) show that the provision of various mobility forms in MaaS encourages the concept's uptake among people with positive multimodal mobility mindsets.

Besides data sharing and the presence of multiple mobility forms, Yannis and Chaziris (2022) stress the role of physical infrastructures in MaaS design. In some circumstances, specialised forms of infrastructures such as stations for bike-sharing services, parking spaces for services like car-sharing and ride-hailing services, and charging stations for electric mobility are essential for attaining this concept (Qiao et al., 2022; Ignatious et al., 2022). Matyas (2020) also mentions the essentiality of mixed-infrastructure layouts in attaining mobility integration while Esztergár-Kiss et al. (2020) suggest that before MaaS implementation, infrastructure prioritisation should be put into consideration. Wong et al. (2020) conclude that, indeed, a better utilisation of

physical infrastructures can transform the mobility sector into an interconnected ecosystem. Thus, the development of these fabrics reshape mobility systems into compatible environments for MaaS plans. Although infrastructural fabrics are decisive for achieving MaaS, it is also crucial not to neglect the pressing reason for initiating MaaS, because this concept is explicated as a "user-concentric service" where the end users are the main actors within its operational structure (Jittrapirom et al., 2017). Arias-Molinares and García-Palomares (2020) indicate that the bundling of mobility packages in MaaS design is mainly oriented on the particular requirements of the users. Likewise, Barreto et al. (2018) show that the main target of MaaS is to satisfy the requests of the users with suitable means of transport. Zhao et al. (2020) also state that the design of this concept is based on a user-centric approach, co-creativity and interactivity. Conclusively, Lyons et al. (2019) show that physical infrastructures and mobility modes merely form a basis of movement from origins to destinations while the users are at the top in MaaS hierarchy. From the analogy in the above lines, it is evident that constituents such as data sharing, presence of multiple mobility forms, infrastructures, merging of mobility actors and intriguing of concept to the users are at the locus of MaaS development. Therefore, these aspects form a basis for the thematic reporting in Section 4.

2.2. Regulation and participation of public authorities in MaaS developments

The regulation of MaaS has resulted into multiple strenuous exertions, because the concept is intended to bring together several contestants i.e., mobility actors that are usually characterised by conflicting agendas (Zhao et al., 2020). Kostiainen and Tuominen (2019) stress that the current regulatory regimes and mobility markets create a "hard to crack structure" in MaaS realisation. Butler et al. (2021) report that in many cities, there is a need for initiating public strategic guidelines to make MaaS a success while achieving both societal and mobility stakeholders' objectives. However, Hoerler et al. (2020) indicate that the initiation of guidelines alone without having transparent communication channels among the involved actors may slow the MaaS process. Furthermore, Arias-Molinares and García-Palomares (2020) single out the need to spark comprehensible regulations, concerning fair competition among the involved stakeholders. Smith and Hensher (2020) point out the lack of established long-term visions and collective norm-setting in MaaS plans. For this reason, Smith et al. (2019) urge public transport authorities to set clear performance indicators in evaluating MaaS targets. However, Esztergár-Kiss et al. (2020) suggest that these authorities need to be prepared for substantial changes, which extend beyond setting up a digital interface to considering other involved stakeholders' interests. Hasselwander and Bigotte (2022) note that the intervention of transport authorities in MaaS design is essential for its efficiency and mobility equity, nevertheless, the implementation of such interventions should be exercised in an adaptable and realistic manner to increase its robustness. For this reason, Wong et al. (2020) advance further to propose that public transport authorities should set operation parameters that are consistent with the social objectives in their MaaS models.

Many scientific publications point out the importance of public transport authorities in MaaS developments, because these institutions usually have a societal focus, a dominant influence on private transport operators, and they can potentially influence MaaS plans through policies and incentives (Arias-Molinares and García-Palomares, 2020). Nonetheless, few studies have examined the participation of these authorities in the MaaS arrangements. Surakka et al. (2018) compare two European regions (the Growth Corridor Finland and the Basel metropolitan area in Switzerland) to investigate the differences in institutional setups towards supporting MaaS innovations. Hirschhorn et al. (2019) employ a multilevel perspective on socio-technical transitions to assess the response of governance on MaaS in three different European cities (Amsterdam, Birmingham, and Helsinki). Hasselwander and Bigotte (2022) study the public-pushed developments in the Global South to understand the barriers faced by the transport authorities during the MaaS implementation process. In addition, Pagoni et al. (2022) conduct a detailed review to analyse the state of European regulations in order to highlight MaaS barriers and enablers in policy making while Caballini et al. (2023) provide a comparison among 13 MaaS initiatives in Europe to identify the essential characteristics of MaaS in public governance and discover that, although private-driven MaaS implementations are faster, public governance in MaaS plans can provide appropriate entities for developing stable MaaS initiatives. Adding to these studies, this article provides substantial inputs to the scientific community by unravelling the literature to pinpoint the specific roles played by public transport authorities in their initiated MaaS schemes at regional levels.

3. Methodology

The study analyses two separate, but rather interconnected research questions. The exploration begins with investigating what public transport authorities have done in MaaS design, and consequently, various forms of text documents are scrutinised. In this sense, the methodology of thematic analysis is employed to analyse the obtained qualitative data. Thematic analysis refers to a method that is employed to investigate patterns of meaning from the gathered dataset (e.g., texts) (Braun and Clarke, 2006). Correspondingly, Boyatzis (1998) perceives thematic analysis as an approach of making sense out of seemingly unrelated material. This methodological approach is mainly based on theme development, and it undergoes four different phases, embodying initialisation, construction, rectification and finalisation (Vaismoradi et al., 2016). The initialisation stage consists of document search, preparation and coding of the essential categories from the content while the construction stage involves classifying and describing the coded sets of information. The rectification phase incorporates the relation of the coded segments in order to establish a storyline, which provides an opportunity to finalise with laying out further ideas or recommendations.

3.1. Data collection

Approaching with a similar conceptualisation as Estrada (2011), the assessed material is referred to as integral components, containing both theoretical or technical propositions that are positioned to counteract the prevailing direct or indirect challenges (in this case MaaS-related aspects). A combination of these textual materials comprehends measures and practices that public authorities have conducted in the interest of attaining MaaS. The analysed documents include items such as strategic documents, operational and binding contracts as well as other records published by government agencies. Although such documents are characterised as grey material, they contain crucial information for planning (Pappas and Williams, 2011). In addition, this kind of literature provides explicit insights from non-academic audience or practitioners (Adams et al., 2017). Such documents facilitate the transition of knowledge concepts in real-world, more especially in mobility planning, however, it is not possible to follow a systematic approach in searching for such literature documents (Babarczy et al., 2024). Therefore, the identification of the relevant literature in this study follows four steps:

The first step includes the specification of the scope for the investigation, and in this context, Berlin, Hamburg and the Ruhr region in Germany are the selected case studies areas, and these are detailed in Section 3.3. These three areas are selected based on the reason that they belong to the largest metropolitan regions in Germany, and they have embraced digital transformations in their public mobility arrangements. Therefore, the selection of these regions provides an opportunity to examine the evolutionary structure for the prevailing mobility concepts like MaaS. Yin (2009) recommends that in case study research, the investigated areas should aim to provide a holistic and

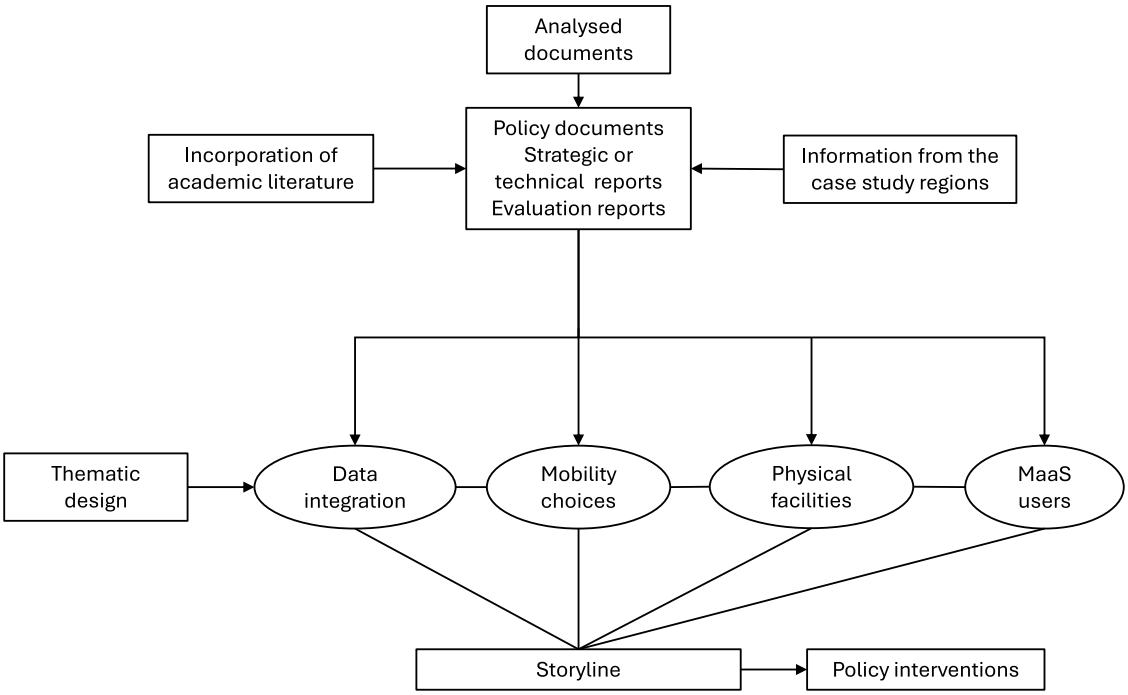

Fig. 1. Summary of the analytical framework employed in the research investigation. Note: lines with arrows at the end demonstrate the flow of hierarchy, and lines without arrows represent relations.

meaningful rendition of actual events. Thus, the findings from these regions are reasonably representative of MaaS evolution in Germany, and they can further provide more insights to urban communities in other countries with similar arrangements.

The second step includes a thorough search on Google and Google Scholar websites, and this is conducted by test-feeding a combination of key terms such as Mobility as a Service, MaaS, mobility integration, integrated mobility, mobility strategies, public transport authorities, policy, and Berlin, Hamburg and the Ruhr region in both English and German language. The employment of such specific key terms in the search process is intended to extensively obtain the relevant documents for the study. The third step involves the collection of policy items, strategic and evaluation reports from governing institutions such as the transport and mobility ministries, city authorities, public transport authorities, research institutions, etc., and these are downloaded from their respective official websites.

The final step comprises the inclusion of peer-reviewed academic literature to strengthen the findings of the study, and further stimulate scientific discussion in this research. In the process of selecting academic literature, a snowballing approach is employed where reference lists from the initially identified articles are used to identify other journal papers. Specifically, all the included documents either contain information, addressing MaaS progress in Berlin, Hamburg and the Ruhr area or they strategically provide potentialities for MaaS design. In this regard, international literature, addressing MaaS from other developed countries is also used to build up the ideas within this study.

In summary, the unfolded documents are primarily selected based on two main criteria: (1) items addressing transport or mobility planning, but especially MaaS or integrated mobility. (2) documents published from the year 2014 to the present (2024). The selection of the year 2014 as the starting period for document search is based on the fact that this was the period when the MaaS concept emerged (Hietanen, 2014).

3.2. Coding and synthesising of data

In this study, the categories of investigation are systematically coded, depending on the themes that are identified from the literature, and these themes are also reflected in the above Section 2. First, open codes are developed through reviewing large text segments and summarising them into meaningful units, which are interlinked to form the main theme categories. This is the initial stage for coding, and it pertains data assemblage and examination to initiate discrete parts of investigation (Strauss and Corbin, 2004). Therefore, the ascertained open codes in this research include data sharing and information integration, mobility choices, infrastructures and end users. Detailed data in these categories from each and every region is summarised, and thus, developed precincts are reported in Section 4. In the described open codes, a transition to axial coding is further made to refine overlapping content from all regions, and this is conducted in a disposition, beginning with Berlin, followed by Hamburg and then the Ruhr region. This stage is further supplemented with continuous analysis, comparison and cross referencing (Williams and Moser, 2019). Thereafter, selective coding is integrated to identify the abstract relations, which lead to the formulation of the final storyline in the research. This storyline is comprehensively reflected in Section 5. Fig. 1 presents the summarised analytic framework for the research design.

3.3. Case study regions

Hancock et al. (2021) indicate that case studies are usually chosen to serve as a practical companion to theoretical research text in order to drive ideas from the analysis into a representation of a phenomenon. Although case study research offers both single and multiple selection approaches (Yin, 2009), this investigation opts for the latter, because it provides a comparative assessment in analysing mobility integration among the following delineated case study areas.

3.3.1. Berlin

The metropolitan region of Berlin is one of the urban areas in Germany that have undergone a lot of transformations. Berlin is the country's capital, and the most urbanised city in Germany, accommodating a population of about 3.5 million people (Lehmann, 2012). Berlin owns the status of being a city, and at the same time, it constitutes to one of the 16 federal states in Germany. This implies that

in Berlin, a single government is obligated to exercise its administrative responsibilities at both state and municipal level in issues like urban planning (Rode, 2019). In recent years, Berlin has positioned itself in proclivity for sustainability. The Senate department of urban mobility, transport and climate protection (state government) adopted a framework that is labelled as the "Green City Charter" (Kalandides and Grésillon, 2021). Here, sustainable strategies and practices are positioned to drive the region into a green course. Correspondingly, measures that promote the use of green mobility are also fostered through the *eMO* initiative. In this arrangement, the region of Berlin supports the use of e-mobility that is targeted to smoothen mobility integration.

The traces of MaaS in Berlin can be tracked from the period when the *IMOVE* project was initiated as a pilot piece of research to examine the scalability of MaaS usage in European countries (Esztergár-Kiss et al., 2020). Since then, the concept has been gaining more attention, and in 2019, the *Berliner Verkehrsbetriebe* (BVG), which is responsible for offering public transport, launched the *Berlin's Jebli* platform that integrates several mobility services (Pickford and Chung, 2019). Furthermore, the mobility system in Berlin is characterised by varying individual mobility services that are offered by private stakeholders. The mixture in existence of multiple mobility services, which are publicly and privately operated, demonstrates a window of opportunity for investigating MaaS in this region.

3.3.2. Hamburg

Hamburg is a metropolitan region with a population of 1.8 million people (Klein and Fischer, 2019). This area is selected based on being the first city in Germany that launched the smart city experimentation (mSL project) that fostered integrated transportation planning (Späth and Knieling, 2020). Hamburg is also one of the regions in Europe that have previously demonstrated strong commitments to advance smart city strategies, especially in the mobility sector (Ruggieri et al., 2021). In addition, the region was recognised for its outstanding advancements in the year 2011. The European Commission awarded this region as the European green capital due to its efforts in urban regeneration and sustainable mobility (Andreini et al., 2014). Later, in 2014, the Senate of Hamburg issued action plans that were intended to decarbonise the city through promoting the use of electric mobility (Ruggieri et al., 2021). Subsequently, Hamburg positioned itself as a smart region by investing heavily in aspects like smart mobility. Today, Hamburg is considered as one of the smartest and liveable cities. Actually, the IESE Cities in Motion Index (CIMI) ranked Hamburg as the 31st smart city in the world (Bär et al., 2020). These footprints for smart and sustainable mobility in this region provide a chance for investigating its MaaS progress.

3.3.3. Ruhr region

The Ruhr region is located in the federal state of North Rhine-Westphalia, and it is considered as the largest urban agglomeration region in Germany with a population of 5.1 million residents (Gruehn, 2017). The denomination of the term "Ruhr" originates from river *Ruhr* that longitudinally flows across several cities in the southern part of this region (Arora and Schroeder, 2022). This region is also well-known for its former coal mining activities that rapidly advanced in the 19th century (Brüggemeier, 1994). These mining practices substantially transformed the Ruhr area into an industrial powerhouse of the country (Lengyel et al., 2022). But, this economic transformation affected and left remarkable imprints of industrialisation in this region. For instance, the Ruhr region was designed as a car-oriented territory with dense transport infrastructures such as road networks and highways, which were positioned to facilitate the industrialisation process (Melkonyan et al., 2020; Pries et al., 2020). Despite the industrialisation history of this region, several scholars have started to recognise this area as an outstanding post-industrial region that is currently transforming its industrial past into a resource for regional urban development (Berkenbosch et al., 2022). Through different initiatives like the "Modal Split" the region has gradually begun to change its image into a car-free mobility system that is characterised by multimodal mobility (Klinger, 2017). Furthermore, the Ruhr region is implementing measures that are essential to curb the dominance of privately owned vehicles and also advance the use of sustainable modes of mobility.

4. Results

This section decomposes the collected outcomes from the identified literature. First, the investigation begins by summarising the characteristics for the identified items, followed by chronicling the overall background of MaaS in Germany, and then reporting the results from the disentangled themes of investigation. These themes are further coalesced to identify their relations. Thus, less supported elements are identified, and consequently, ways for further improvement are suggested in Section 5.

4.1. Characteristics of the included items

The analysis has identified a total of 54 documents, and among which, 31 items are peer-reviewed articles while 23 items are documents published by governing agencies, public transport authorities, research institutions, etc. The majority of the documents *(n = 10)* were published in the year 2019, followed by 2018 *(n = 9)* while 2020 and 2021 feature with seven *(n = 7)* documents each, and the rest of the items are distributed throughout the remaining years. Most of the documents are addressing Berlin, followed by the Ruhr region and then Hamburg. Nevertheless, some of the reviewed items are addressing more than a single region. Furthermore, there are included documents from other countries, which ideationally shed light on the MaaS concept. In brief, the included documents fall into the following categories: (1) analytical investigations, where MaaS-oriented research questions are posed, data is then collected and results are reported (2) conceptual explorations, where the MaaS concept is theoretically unravelled (3) regulation records, where authorities concede on a given mobility programme (4) technical treatise, where professionals from the authorities lay out their ideas for mobility integration (5) evaluation reports, where countable governmental agencies carry out their investigations to assess the progress and effectiveness of their laid programmes. A combination of the evidence from all these items is centred in a theme-wise sense to report the findings. A summary of the content for the included items is listed in Table A.1 in the Appendix Section.

4.2. Origin of MaaS in Germany

The present mobility discourse does not only concentrate on the right of movement, but also on the ways or forms of movement. This has prompted scholars to question the authorities that are responsible for ensuring the seamless movement of people, and these are the so-called public transport authorities. Moscholidou and Pangbourne (2020) stress that these authorities have an important role in steering the path for mobility. The regulatory processes for integrating mobility services in Germany are embedded in different practices, action programmes, guidelines, and legislation from administrative agencies. In the past years, the country has invested in strategies that are aimed at increasing the use of active, shared and public mobility alternatives (Mulley et al., 2019). This is intended to counteract the excessive usage of private vehicles, because as early as 2009, Germany possessed on average a total of 551 private cars in every 1000 inhabitants, and synchronously, the number of households with private vehicles has all along been increasing (Ritter and Vance, 2013). As a result, in the year 2014, traces of "all-around mobility integration" began when the German ministry of economic affairs and energy initiated a door-to-door

mobility programme after realising that public transport had substantially lost its attractiveness to private vehicle traffic (Stopka, 2014). Concurrently, follow-up research projects and pilot studies on passenger navigation, pre-trip planning, and real-time location modelling started (Stopka, 2014). At the same time, the concept of MaaS was initiated in Helsinki, Finland (Hietanen, 2014). This provided a chance for the emergence of this concept into different regions of Germany, because a few years later, MaaS initiatives like *Moovel* were visible in mobility systems (Arias-Molinares and García-Palomares, 2020).

4.3. Data sharing and integration

Kriukelyte et al. (2024) put forward that data sharing in the MaaS process is not only vital for obtaining connectivity within the integrated mobility services, but it is also essential for public actors to make informed decisions. Although the use of smartphones in accessing mobility services has made it easier for service providers to obtain different forms of data (e.g., for origins and destination spots), which is crucial in mobility design. Obtaining such data for mobility integration remains a constraint in many regions of Germany. Despite that in 2017, the European Union laid out a procedure (Delegated Regulation (EU) 2017/1926) that all member states are obligated to develop National Access Points (NAPs) where data from different forms of mobility services like shared mobility services can be accessed for public use (Schneider and Koska, 2023). But up to date, Butler et al. (2021) show that some of the laborious challenges faced by MaaS is to overcome the problem of data sharing. Wong et al. (2020) also stress that the market driven scenarios in which MaaS evolves have a greater impact on data sharing. It seems that in many metropolitan regions, regulating aspects concerning data sharing is still a constraint, because, on the one hand, intense regulation decreases private actors' willingness to innovate, but on the other hand, soft regulation does not neither benefit the authorities nor the end users (Utriainen and Pöllänen, 2018). For this reason, Berlin has tried to solve this challenge by coalescing article §5(6) in the Berlin Mobility Act, where all publicly offered mobility services are obligated to make their real-time travel data accessible, and free of charge for non-profitable purposes such as public mobility integration planning (Stadt Berlin, 2018).

The region of Hamburg is still facing some impediments in its travel data integration, because some of the data is not in real-time (Stadt Hamburg, 2016). Furthermore, there is a need to develop a comprehensive traffic data bank with a standardised digital format, pertaining information that can help to analyse the interaction of different mobility services. Nevertheless, the region is presently upgrading its public data bank platform (Urban Data Platform Hamburg) which is aimed to strengthen integrative data access (Westhagemann, 2017). The Ruhr region is also facing a similar challenge, however, the ministry of the environment, nature and transport for the state of North Rhine-Westphalia is presently developing the *MaaS NRW* programme that is intended to integrate mobility data in the whole state, including the Ruhr region (Lange and Robin, 2022).

4.4. Mobility choices

Lyons et al. (2019) mention that the concept of MaaS is designed based on multiple and compelling mobility forms, which are essential for its competitiveness in mobility systems. In this regard, Berlin can be viewed as an incubation area for multiple mobility forms, because several new mobility services have emerged in the past years in this region. Particularly, the mobility digital traces in Berlin started in the year 2009 when the city obtained its first form of new mobility service, and this was the car-sharing scheme that was offered by *Car2go*. The vehicles within this scheme were offered by the *Daimler* company, in a free-floating scheme, and these were equipped with a GPS tracking system. Indeed, this progress exhibited a further step from the traditional station-based car-sharing schemes (Fromm et al., 2019).

In the year 2011, the *BMW* Group also initiated the *DriveNow* car-sharing service, and thereafter, the *Daimler* company concurrently began to develop the *Moovel* software that was intended to integrate *Car2go*, public trains (offered by the *Deutsche Bahn*) and local public transport in Berlin (buses and trams) (Piétron et al., 2021). The development of this software was an essential step to attract the attention of the public transport authority in Berlin. Additionally, the remarkable change in regional mobility development was prepensed in the master plan for sustainable mobility and low-emissions, which was laid out by the Berlin Senate department for the environment, transport and climate protection (SenUVK) (Günther, 2018), and within this programme of reform, the public transport authority in Berlin *(BVG)* began by providing public electric buses that were aimed to signify the trends of sustainable mobility. In the year 2019, the same department allocated a slot for funding the development of intermodal and multimodal mobility systems under the umbrella of *BVG* (Senatsverwaltung für Umwelt, 2021). Today, the *BVG* has the *Jelbi* digital platform, which integrates the offered public transport forms as well as other private shared mobility services in the region (Bartnik, 2021).

The responsible authority for offering public transport in Hamburg is known as the *Hamburger Verkehrsverbund (HVV)*. In 2013, the *HVV* demonstrated interest in providing integrated mobility since it initiated the *HVV Switch* digital platform that combined car-sharing, bike-sharing, car rental, rail, urban public transport, taxi, and ferry (Kamargianni et al., 2016a). Later in the year 2017, the *HVV Switch Punkte* was strengthened to further connect concentrated neighbourhood with public transport. Presently, there are over 150 points in Hamburg where people can easily access services like car-sharing and bike-sharing in both station-based and free-floating arrangements (Bauer et al., 2020). In this regard, the *HVV Switch* collaborates with other private mobility service providers.

Unlike in the region of Berlin and Hamburg, the development of mobility concepts in the Ruhr area advances from different scales of planning, because this area is not a state on its own, but it is rather a combination of several neighbouring cities. Nevertheless, the region has a combined public transport service provider *Verkehrsverbund Rhein-Ruhr (VRR)*, which offers transport services in a proximity of over 5000 km^2, stretching from Langenfeld in the south to Dorsten in the north, and Dortmund in the east to the Dutch border in the west (Schlingensiepen et al., 2016). To complement public transport, the bike-sharing system *Metropolradruhr* was initiated in this region. This scheme started in 10 different cities with 1200 bikes and 150 stations, covering an area of about 1.520 km^2 (Bracher et al., 2012). The bikes offered in this scheme are predominately station-based. Besides, the *VRR* designed a system where different mobility services can be obtained in a single booking, however, the platform still lacks established incorporation of on-demand services (like ride-sharing and ride-sourcing) (Pfeifer and Ulrich, 2021).

4.5. Evolution of infrastructure facilities

In the same way motorways are designed to accommodate vehicle traffic (Yannis and Chaziris, 2022), MaaS is also a concept that needs essential and sometimes, specialised infrastructures. Although MaaS is often viewed as a digital platform, the concept goes beyond digital arrangements. In fact, Butler et al. (2021) stress that smart mobility concepts such as MaaS are bound to transform the infrastructural dispositions in mobility systems. These transformations are somehow reflected in some of the current regional planning strategies. For instance, some planning authorities (like in Berlin) point out the preference for developing separate public bus, bike lanes, etc., to enhance sustainable mobility (Stadt Berlin, 2018). These advancements in public transport design are measures aimed at attracting users, foster integrated mobility, and ensure the use of emission-free modes. Furthermore, in 2018, Berlin had developed a total of over 600 public electro-mobility charging stations, and the region was planning in its

Table 1
Summary for the analysed MaaS components from Berlin, Hamburg and the Ruhr region.

Strands	Berlin	Hamburg	Ruhr region
Data integration & platforms	Designed the *Jebli* platform, and stipulated a mobility policy regulation to support data sharing.	Owns the *HVV Switch*, and the region is further developing its urban data platform.	Possesses the *VVR* travel application, and there are develops for *MaaS NRW*.
Available mobility choices	Public transport, station-based and free-floating bike-sharing systems, e-scooter sharing, station-based and free-floating car-sharing systems, and taxis.	Public transport, station-based bike-sharing system, e-scooter sharing, station-based and free-floating car-sharing systems, and taxis.	Public transport, station-based bike-sharing system (provided by *Metropolradruhr*), and taxis.
Infrastructural fabrics and development strategies	Laying plans for separate bus lanes and bike-sharing lanes to enhance integrated as well as active mobility, developing of charging stations for electric mobility.	Developing of mobility hubs, designing of more bike stations for the *StadtRAD*, and strengthening the mobility interaction between bike networks and train stations.	Developing of greenbelts, planning more bike stations and networks for fast cycling routes, and allocating more *mobile stations*.
Inclusiveness of end users	Marketing of the *Jebli* on *BVG* official platform and provision of different and subsidised mobility packages to the users.	Spotlighting the relevance of *HVV Switch* and provision of a cheaper alternative to the users.	Marketing the use of public transport (trains, trams, buses) and bike-sharing.

masterplan programme to further allocate more than 700 public charging points (Günther, 2018). In addition, Berlin had already positioned the 2030 vision strategy *(StEK 2030)* as a mechanism for actualising an integrated urban environment that is characterised by shortened travel distances and active mobility (Senatsverwaltung, 2014).

In the same vein, the region of Hamburg is presently planning to design the forthcoming neighbourhoods (e.g., Oberbillwerder and Wilhelmsburg-Mitte) with mobility hubs that are intended to limit the use of private vehicles (Hansestadt Hamburg, 2022). Furthermore, the *Deutsche Bahn*, inscribed a memorandum of understanding with the city of Hamburg to develop train stops coupled with stations for the city's bike (*StadtRAD-Stationen*) (Tschentscher and Pofalla, 2020). Likewise, Hamburg laid out a strategy to transform the region into a "bike city" where 25% of all the daily trips can be covered by cycling (Horch, 2017). The region also initiated a concept of designing coherent bike networks, which can often be used in a distance between 5 to 10 kilometres (Hamburg, 2021).

As far as infrastructural eventuality is concerned, the metropolitan region of Ruhr is developed by conjoined facets of cooperative organisations like *Regionalverband Ruhr (RVR)*, *Emschergenossenschaft* and *Lippeverband*. The essence of these cooperatives is to ensure a systematic regional development that is aimed to enroot aspects like green urban development (Regionalverband Ruhr, 2016). In 2016, the county representatives for the Ruhr region unveiled a new multilevel planning approach that was entitled as the "Infrastructure Ruhr", and this was supported through the EU-Ruhr Dialogue in Brussels (Schwarze-Rodrian, 2021). The term green infrastructure does not only confer to the green elements, like trees, regional parks, etc., but it also underlines multi-spatialities with interconnected systems (Regionalverband Ruhr, 2016). The green thoroughfares that are developed under this programme have sparked mobility transitions in the Ruhr region. At a local scale, different cities have started to engage in sustainable mobility planning, for instance, the city of Dortmund set a strategy of the "Mobility Masterplan 2030" in which it laid out targets for providing mobility equity, supporting the design of bike lanes, walkability, and public transport (Leerkamp and Meißner, 2020). Concurrently, the city of Essen came up with a similar masterplan in 2018, in which more emphasis was put on accessibility, beginning with strengthening the use of public transport (trains, buses, etc.), developing bike infrastructures and sparking intermodal mobility (Stadt Essen, 2018). To achieve this, the local transport authority in Essen *(Ruhr Bahn)* allocated two so-called "Mobile Stations" at the locations *S-Bahnhof Steele* and *Landgericht Essen* where public transport users are given access to a range of mobility services like car-sharing and bike-sharing (Stadt Essen, 2018).

4.6. Inclusion of the end users in MaaS

Unlike conventional mobility services, MaaS users are exceptional in nature. Actually, Alyavina et al. (2020) perceive MaaS as a synergistic fit to the prevailing lifestyles, emerging among young adults. Nonetheless, this raises a red flag, and thus suggests that public transport authorities still need to get involved in the issue of inclusive mobility for all people. In addition, Jittrapirom et al. (2020) show worries that these emerging demographic trends may possibly affect other potential MaaS users (like older adults), and correspondingly lead to a reduction in the support offered by public authorities towards MaaS. Therefore, strategies concentrating on the inclusion of all groups of people like older adults, and those with disabilities should be prior in MaaS plans (Senatsverwaltung, 2018).

In the past years, Berlin has been confronted with mobility inequalities and complexities in the travel behaviours of its residents, mostly among men living in households with children, because 72% of them were often tied to the use of private vehicles in their daily routines (Lötscher et al., 2001). As a counter measure, the public transport authority in Berlin has recently tried to improve public awareness, directed at sensitising the importance of integrated mobility. For example, in the initiative that is aimed to improve on the quality of life in Berlin, this region is illustrated as a modern and smart metropolitan area (Günther, 2018). This instantiates the trends of digital footprints that are compounded with integrated mobility. In addition, the *BVG* informs its users on its official website about the *Jebli* which is its offered MaaS platform (Berliner Verkehrsbetriebe, 2024). Similarly, the *HVV* in Hamburg signifies its mobility integral efforts to its users through the *HVV Switch* website by providing information concerning all the included mobility alternatives (Hamburger Verkehrsverbund, 2024). The advantages for shifting to the *HVV Switch* are clearly stipulated, ranging from offering mobility services at affordable prices to reaching desired destinations (e.g., workplaces) in time. Hamburg also positions itself at using digital channels to inform its users about the innovatory advantages that are embedded in MaaS usage (Westhagemann, 2017). In comparison to Berlin and Hamburg, the *VVR* communicates less information about mobility service integration on its official website (VRR, 2024). Nevertheless, the *VRR* demonstrates substantial efforts in publicising public transport and bike-sharing use. Table 1 summarises the major outcomes from the investigated main themes.

5. Discussion

The participation of public transport authorities in the MaaS process can be exercised in various ways, ranging from MaaS schemes being centrally controlled by authorities to cooperation with private mobility providers (Smith et al., 2018). Henceforth, the advancements in MaaS

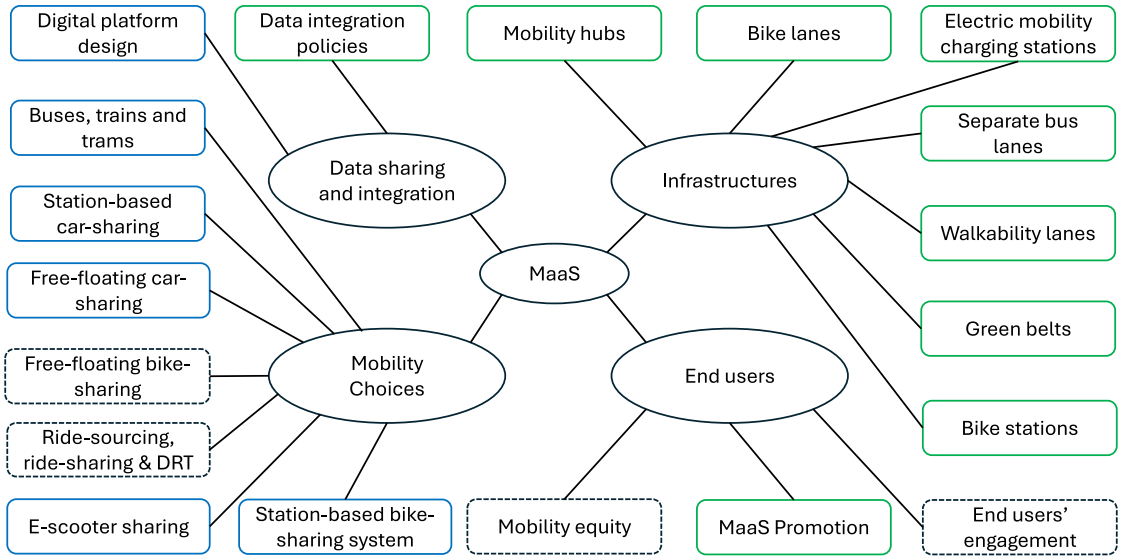

Fig. 2. A thematic diagram summarising both the touched and untouched sub-themes by public authorities from the investigated case study areas. Note: green boxes denote elements in development progress, blue boxes represent the already established elements while dotted boxes illustrate elements that require substantial improvements. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

plans from the public actor's side differ from one region to another, depending on the prevailing plans and strategies. Therefore, to enhance an impartial analysis from the reported results in Section 4, this study adapts an intrinsic set of new mobility alternatives in a MaaS arrangement as reported by Mubiru and Westerholt (2024). These include, bike-sharing, e-scooter sharing, car-sharing, ride-sharing, ride-sourcing and demand responsive transport (DRT). These mobility services are further blended with other forms of conventional public transport (e.g., trains, trams and buses) to comprehensively identify traceable touches of public transport authorities. Thus, the analysis classifies the already developed domains and also identifies those that require further attention. In this analysis, systematisation is employed, because there cannot be clear conceptualisations in complex concepts without classification (Castellanos et al., 2022). Therefore, a gradation is formulated to assist in developing a conceptual corollary in laying out both theoretical and practical contributions of this study.

Among the investigated regions, the *Jebli* in Berlin has the most alternatives, and these include public transport forms (trains, trams and buses), bike-sharing, e-scooter sharing, e-mopeds, car-sharing and taxis (Piétron et al., 2021). In the *Jebli* arrangement, the service of bike-sharing has three private service providers *Bolt, Lime* and *Nextbike*, e-scooters are offered by *Bolt, Lime* and *Voi*, and car-sharing by *Miles* and *SIXT share*. This demonstrates that, although the *BVG* does not individually own most of the services, this authority has made substantial efforts in cooperating with other private stakeholders to develop its platform. This cooperation is a fundamental initiative, because Smith et al. (2019) show that MaaS requires a unique partnership where the private actors play an innovative role in delivering public value (mobility forms in this sense). Among the provided bikes by *Jebli*, the majority of them are predominately station-based. It seems that the *BVG* is more positioned in station-based bike-sharing system since the city also plans by the year 2025, to allocate more places near public transport stations where a total of 50,000 bikes can be accommodated (Stadt Berlin, 2018). For car-sharing in *Jebli*, *Miles* and *SIXT share* services are commonly provided in a free-floating format, and users are not required to pay for parking spaces within the designated areas of operation. This is a vital step by the public authority, because some studies have already indicated that parking-related policies can restrict the use of shared vehicles in metropolitan regions (Kent and Dowling, 2016).

Similar to *Jebli*, the *HVV Switch* demonstrates related characteristics, because, besides offering public transport, this digital platform provides mostly bike-sharing and car-sharing, and the majority of these services are predominantly station-based. Nevertheless, the *HVV Switch* provides locations for charging electric vehicles. Cooper et al. (2019) report that the emergence of new vehicle usage models (e.g., car-sharing), and the development of electric charging facilities sparks system connectivity (which is absolutely in line with MaaS). In the Ruhr region, the *VVR* provides fewer alternatives in its integrated mobility arrangement, but it demonstrates strong bonds with station-based bike-sharing service. Relying on the study of Böcker et al. (2020), this can be viewed as a substantial step in MaaS, because bike-sharing ridership in metropolitan regions is usually higher on routes that are linked to public transport stations.

The study further identifies that the service of ride-sourcing and DRT that usually operate under a similar principle are not supported by the public transport authorities from all regions. These mobility services are not reflected in the provided public transport platforms. On the one hand, the reason behind this may be that ride-sourcing can cause substantial impacts on the taxi industry (Zhou et al., 2022). Public transport authorities may not be ready to initiate a competitive arrangement like ride-sourcing to taxis, because these are already integrated in their digital platforms. In addition, the restricted regulation on ride-sourcing companies in Germany may be a reason for excluding this concept. For example, in the year 2014, the *Uber* service entered the German mobility market with *UberBlack* in Berlin, the local taxi provider filed a complaint, and the Berlin district court issued an injunction against *UberBlack* (Nietsch and Schott, 2020). Since then, ride-sourcing services have been operating under strict legal scrutiny. On the other hand, the users of ride-sourcing may prompt the use of vehicles by exclusively one person at a single time (Wilkes et al., 2021), which does not contribute to cabin space sharing in congested regions. Furthermore, the ride-sharing service seems to be unsupported by all platforms except *Jebli*. This may rely on the fact that ride-sharing seems to be a complex concept in its arrangement, because the driver's and passenger's requests need to be known prior before making the matches, and a single driver may be willing to take multiple passengers while passengers may prefer to have a single rider for various personal reasons (Agatz et al., 2012).

Conclusively, on the one hand, the study summarises that the engagement of public transport authorities in MaaS arrangements from the investigated regions is mostly exercised in digital platform design (e.g., *Jebli* and *HVV Switch*), linking of micro-mobility services

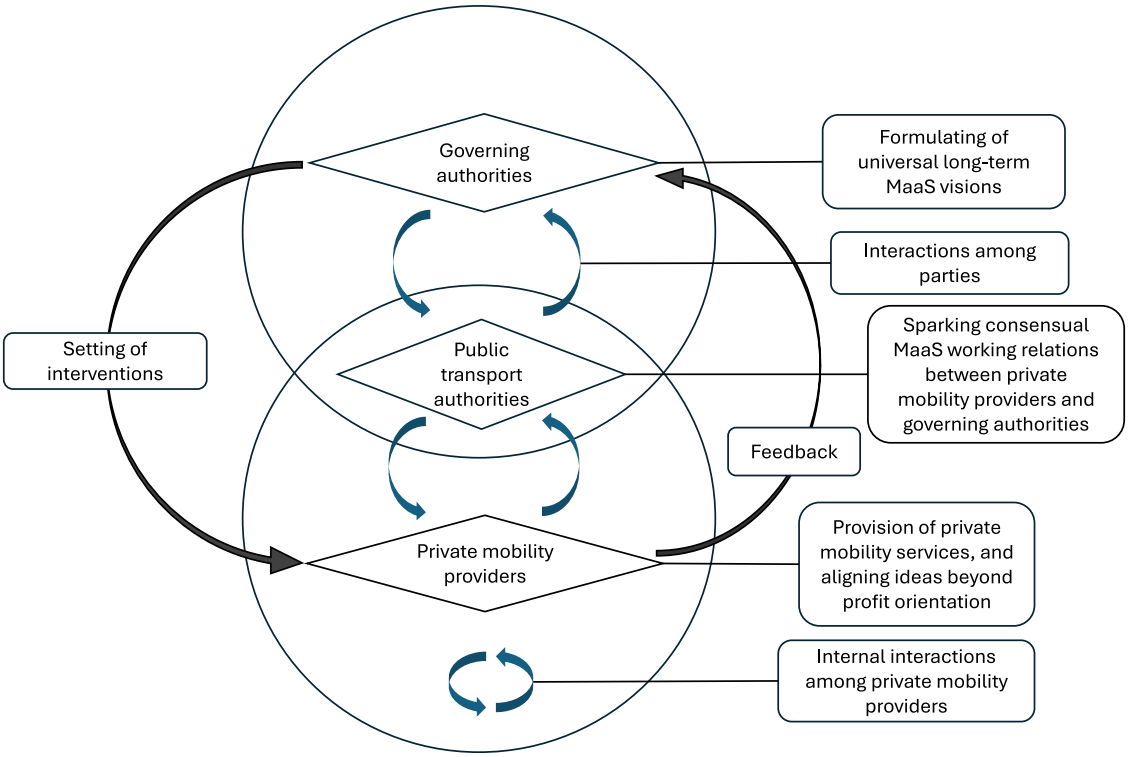

Fig. 3. A proposed framework demonstrating the interactions and responsibilities among public transport authorities, private mobility stakeholders and governing authorities in MaaS.

(e.g., bikes in station-based schemes) to public transport forms, boosting of car-sharing service, and sparking the usage of electric-mobility system. On the other hand, the study identifies concepts that are less touched by these authorities (e.g., ride-sourcing and ride-sharing). Further, some service operation formats like the free-floating bike-sharing system are less supported in these arrangements. As of present, this investigation concludes that the state of MaaS development from the public transport authorities is inscribed in digital platform design that is mainly based on public transport forms, followed by micro-mobility usage, and then car-sharing. Within this identified chain for the mobility services, it is also visible that aspects like data integration initiatives, allocation of electric charging stations, planning for bike stations and bike lanes, and promotion of the MaaS concept are prioritised by these authorities. Fig. 2 provides a combined visual illustration for the sub-themes in both developed and undeveloped MaaS aspects.

5.1. Towards an efficient MaaS implementation

Since MaaS is a complex concept in its realisation framework, this study argues that a comprehensive development of this concept should be oriented on the interaction of crucial players, and these are the public transport authorities, private mobility stakeholders, and governing authorities. In this context, the term "interaction" refers to the myriad ways in which involved players can engage and react to each other (Eberlein et al., 2014). These interactions should not be exercised in a hierarchical disposition, but rather in a mixed conformation where inputs and feedback can be interactive in all directions, because it is clear that all the three players have substantial inputs in the planning process of MaaS. Nevertheless, this study suggests that one of the players should take up a leading role in designing the strategies, which do not completely neglect the goals of the other players. In this structure, the public transport authorities can take up this task, and thus, sit in between private mobility stakeholders and governing authorities. Governing authorities have been included, because it is noticeable that there is a lack of having specific long-term visions for attaining MaaS. Therefore, step-by-step MaaS targets can be developed by public transport authorities, depending on the available resources, and these targets can further be supplemented with the inputs from private mobility stakeholders to help in formulating uniform visions. These interactions provide an opportunity for public transport authorities to clearly understand the prerequisites of private stakeholders for involving in MaaS plans. At the same time, the public transport authorities should further spark interactions with policymakers, because it has been noted that many of the required infrastructures by this concept are indirectly developed through the plans laid out by governing institutions. This reveals that the majority of the challenges in MaaS are systemic and therefore demand for systemic policy instruments (strategic ecosystem building among all players) (Kostiainen and Tuominen, 2019).

For this proposed framework to succeed, roles should be allocated to every player. First, all players should bear the responsibility of informing the public "why" it should opt for MaaS, and for example, abandon the use of private means. Arias-Molinares and García-Palomares (2020) report a piece of astonishing evidence, showing a low percentage of private vehicle owners joining MaaS, and conclude that, if the "why" factor is not carefully addressed, the benefits of MaaS from the users' perspective may remain uncertain. Second, public transport authorities should be ready to position public transport forms (e.g., trains, buses) as the backbone for their MaaS initiatives, however, this comes with the cost of demonstrating quality differences (in factors like punctuality and accessibility) that can attract more users. Third, public transport authorities should not only view private mobility providers as their competitors, but they also need to consider that any additional mobility form in their arrangement may have an added value of attracting more users. Fourth, both public transport authorities and governing authorities should provide a conducive atmosphere where private service providers can have internal interactions among themselves. Because Van den Berg et al. (2022) show that for MaaS to prosper, transport providers have to offer their services at marginal costs or wholesale prices to the platforms. However, this can hardly happen without inter-joint cooperation or agreement. Fig. 3 demonstrates a cycle of interactions among the three main actors in the

proposed MaaS implementation process. The respective responsibilities of these actors are also presented and in this framework, public transport authorities are positioned with a central role of igniting MaaS working relations between the other two actors. Governing authorities are advised to formulate long-term MaaS visions and interventions. Private mobility providers are recommended to work closely with public transport authorities in providing mobility services and leaving room for them to provide feedback, which is important in incorporating their ideas in the formulated long-term strategies by governing authorities.

5.2. Long-term policy recommendations

The concept of MaaS seems ambiguous because it creates multiple challenges in integrating a variety of mobility services. Moreover, the integration process depends on the availability of mobility choices as well as the prevailing socioeconomic factors. Therefore, policy recommendations can vary depending on a given mobility system. Nevertheless, this study attempts to lay out universal key policy recommendations that can be essential for MaaS developments in the investigated regions, and in other countries with closely similar MaaS initiatives.

The planning authorities for mobility systems should explicitly define their MaaS ecosystem, considering the preferences of the users. In fact, Matyas (2020) shows that users usually classify mobility services in MaaS arrangements in three categories. These include the "essential" modes that might be frequently used by the users, "considered" modes that the users may wish to have in MaaS, and "excluded" modes that the users may not wish to have. Therefore, transport authorities should strive to understand the exact type of mobility services that may be preferred by users in the MaaS schemes. This should further be supplemented with funding of MaaS schemes and reforming of the internal organisational structures for multimodal mobility. Such reforms can help to achieve the desired targets and create perfect chains of procedures among all the involved mobility stakeholders.

The MaaS platforms should be designed with simplified and standardised interfaces to allow easy usage by different groups of users who are not well familiar with digital technologies. The use of emerging mobility services like MaaS requires the ability to operate a smartphone to search for routes or make payments for the journey, however, some groups of users like older adults may not be able to navigate through a complicated digital interface. In the same context, Vij et al. (2020) report that older adults whose children have left home are unlikely to use MaaS. This further emphasises the need to simplify MaaS interfaces or create community-based mobility solutions where special groups of people can be assisted in joining MaaS.

Although some of the individual mobility services like ride-sourcing are essential for MaaS plans, transport authorities need to analyse their expansionary strategy in mobility markets, because these services can create competition among more sustainable mobility services. For this reason, Clewlow and Mishra (2017) study the use of ride-sourcing, and conclude that 50% of the total trips within this service would have been taken by public transport, cycling, walking or avoided by the users. Furthermore, the fleet size of ride-sourcing services should closely be monitored by the authorities to ensure that the supply of vehicles does not exceed the demand scales of users. This can help to hinder unnecessary implications associated with traffic congestion and lack of packing spaces.

Conclusively, despite that the study identifies substantial developments among micro-mobility services, some aspects of these services require improvements, for example, it has been noticed that the free-floating bike-sharing system is not strongly supported. This might be due to the difficulties that are associated with this type of arrangement. Nevertheless, the study recommends transport authorities to plan for free-floating systems by allocating usage areas for bikes, and these can be monitored by geofencing technology. This kind of technology can allocate demarcations within which free-floating bikes should be used. Fishman (2019) shows that even large-scale free-floating bike-sharing operators are facing several challenges since many of their bikes are found in a state of disrepair due to vandalism, and as a result, some have ceased their operation activities. Therefore, transport authorities should step-up by allocating safe areas for free-floating bike usage and offering subsidies to operators, because this type of service can be a long-term mobility solution for short commuting distances.

5.3. Limitations and future research directions

This research presents several limitations, first, the investigation acknowledges that the study of MaaS is relatively new, and subsequently, its realisation in the real world is still undergoing several phases of progress. Therefore, few mobility planning documents from the investigated regions comprehensively detail the implementation framework of this mobility concept. Most of the documents generally report the integration of mobility services without detailing essential aspects like data integration formats, mobility package formulation and digital payment mechanisms. This presents a limitation in assessing the critical elements in MaaS plans. Second, the study has selected only three metropolitan regions in Germany, and these may not entirely represent the state of MaaS in low urbanised areas of the country. Third, the employed snowballing method in the analysis is a non-probability sampling technique that can reduce the representativeness of the included sample. Therefore, the study acknowledges that the findings may have been different in circumstances where other approaches like conducting interviews from public transport officials were employed. However, this study intends to exactly assess the existing state of MaaS progress as reported in the unfolded documents. Nonetheless, this poses a potential limitation of identifying the particular points of interest in MaaS developments from the officials' point of view.

As the MaaS concept matures, there are still further examinations required in academic investigations. This study recommends expedited research to understand the varying preferences of private mobility stakeholders in MaaS, and how these preferences can be incorporated in forming mobility packages for both public and private mobility alternatives. Likewise, there should be an investigation to discern the varying preferences considered by the users in making MaaS subscriptions. This can be approached from different perspectives, considering the social and economic factors, mode preferences, and their preferred infrastructures in mobility systems. Furthermore, investigations should be conducted to assess peoples' attitudes and willingness to take up MaaS, because this is less reflected in the analysed literature.

Further explorations should be positioned to assess the differences in the regulation of individual mobility service in MaaS, and how these differences could create tensions in mobility systems. For instance, how could the regulation of micro-mobility services (e.g., bike-sharing and e-scooter sharing) differ in urban areas? Thus, the regulation of key factors like availability, safety, and costs can be approached with a comparative analysis to establish systematic differences and causal relations among the investigated elements. Besides, factors leading to the exclusion of shared rides (ride-sharing and ride-sourcing) by public transport authorities in MaaS initiatives should be scrutinised, and their implications on the entire MaaS system should also be reported. Furthermore, examinations on spatial and temporal distribution of ride-sourcing service should be carefully studied to identify specific time-frames and locations where this service can be required in MaaS arrangements. Finally, the effects of the MaaS concept on regional mobility patterns, travel behaviours, and the relation of this concept in reducing private vehicle ownership among older adults can also be an interesting field of investigation.

6. Conclusions

This research conducts an investigation that addresses the involvement of public transport authorities in MaaS developments. The analysis concentrates on three different metropolitan areas in Germany

including Berlin, Hamburg and the Ruhr region. It has been identified that the advancements of MaaS are encroached from different dimensions by public transport authorities, ranging from providing mobility alternatives to infrastructure evolution. Among all public transport authorities from the investigated areas, it has been found out that the *BVG* in Berlin has positioned itself as a leading authority in MaaS initiatives, because it already designated the *Jebli* platform that integrates multiple mobility forms such as trains, trams, buses, car-sharing, bike-sharing, etc. The region has further approved a set of legislative regulations in its Berlin Mobility Act, and these are aimed at sparking both intermodal and multimodal mobility.

The region of Hamburg demonstrates similar trends like those in Berlin since the transport authority in this area *(HVV)* already initiated the *HVV Switch* where different mobility services are offered. Further, the authority also allocated over 150 locations where the provided mobility services can be obtained. In addition, Hamburg plans to develop mobility hubs in its newly developing neighbourhoods, and this is aimed to boost integrated mobility. The findings further demonstrate that the transport authority in the Ruhr region *(VVR)* is predominantly dedicated to integrate public transport forms (trains, buses, etc.) and bike-sharing service. Comprehensively, it is clear that public transport authorities from all the investigated regions have mainly positioned themselves in digital platform design where mobility integration is primarily based on public forms of transport, micromobility (e.g., bikes) and car-sharing. Nevertheless, these authorities demonstrate weaknesses in supporting shared rides (e.g., ride-sharing, ride-sourcing, etc.) in their integration initiatives. In this sense, an interactive strategic framework among transport authorities, private mobility stakeholders and governing authorities has been proposed to help in MaaS developments. Furthermore, long-term policy recommendations for addressing MaaS challenges have been suggested in this research to assist public authorities in planning for resilient integrated mobility solutions. Finally, possible directions for further research have been proposed to address aspects such as user preferences, regulation of individual mobility services, and assessment of regional mobility patterns in MaaS arrangements.

Funding

This study acknowledges the Open Access funding organised by the Projekt DEAL, Germany.

Declaration of competing interest

The author declares no competing interests in this research.

Acknowledgements

I would like to thank Jun.-Prof. Dr. René Westerholt (TU Dortmund University) for providing constructive comments on this study. I would also like to thank my team members, Liudmila Slivinskaya and Víctor Cobs-Muñoz, for the valuable discussions that greatly contributed to my research. I conclude by appreciating the three anonymous reviewers of this article for their helpful feedback.

Appendix

Please refer to Table A.1 below.

Table A.1
Summary of the included documents.

Authors (year)	Title English (German)	Region	Content summary
Stadt Berlin (2018)	Berlin mobility act (Berliner Mobilitätsgesetz)	Berlin	Regulating mobility measures to improve on traffic safety, traffic management and information
Cepeliauskaite et al. (2021)	Smart mobility services for climate mitigation in urban areas: Case studies of Baltic countries and Germany	Berlin	Assessing the importance of smart mobility in planning for green and cleaner environments
Pfeifer and Ulrich (2021)	The starting point for connected mobility (Der Startpunkt für vernetzte Mobilität)	Ruhr	Strengthening the use of mobile stations and intermodal mobility
Ritter and Vance (2013)	Do fewer people mean fewer cars? Population decline and car ownership in Germany	Germany	Analysing the determinants for car ownership at national level in Germany
Schneidemesser et al. (2020)	Re-claiming the responsivity gap: The co-creation of cycling policies in Berlin's mobility law	Berlin	Exploring citizens' engagement and their claim in political spaces towards policy formulation
Stadt Hamburg (2016)	Intelligent transport system for Hamburg (Verkehr 4.0: ITS-Strategie für Hamburg)	Hamburg	Chances of using digital technology to improve quality of life and mobility in Hamburg
Pollicino et al. (2022)	Regulating Mobility-as-a-Service	EU	Investigating the EU approach in regulating MaaS
Kalandides and Grésillon (2021)	The ambiguities of "sustainable"	Berlin	Assessing Berlin as a representation for a sustainable city in its official marketing strategies
Stadt Essen (2018)	Masterplan for mobility in Essen (Masterplan Verkehr Essen 2018)	Ruhr	Measures for improving quality of life, mobility and use of public transport in Essen city
Tschentscher and Pofalla (2020)	Smart city Hamburg: Connected mobility and intelligent city logistics (Smart City Hamburg: Vernetzte Mobilität und intelligente City-Logistik)	Hamburg	Memorandum of understanding by the Hamburg city and the national railway for developing train stations and bike-stations
Stopka (2014)	Identification of user requirements for mobile applications to support door-to-door mobility in public transport	Germany	Investigating the influence of mobility apps on the demand of public transport usage
Hietanen (2014)	Mobility as a Service — the mobility transport model	Finland	Competitiveness of MaaS towards private vehicle ownership
Arias-Molinares and García-Palomares (2020)	The Ws of MaaS: Understanding Mobility as a Service from a literature review	Spain	A comprehensive understanding of the who, when and where MaaS is required
Kriukelyte et al. (2024)	Actualising sustainable transport: The interplay between public policy instruments and shared mobility providers' business models	Berlin	Assessing the relation between mobility business models and public policies
Schneider and Koska (2023)	Digitisation in the mobility transition: Approaches to promote multimodal mobility platforms and data-supported transport planning (Digital in die Mobilitätswende: Ansätze zur Förderung multimodaler Mobilitätsplattformen und datengestützter Verkehrsplanung)	Germany	Proposing strategies for attaining ecological sustainability and mobility equity in Germany

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Table A.1 (*continued*).

Authors (year)	Title English (German)	Region	Content summary
Bauer et al. (2020)	Reduce emissions, create space and being mobile (Emissionen sparen, Platz schaffen, mobil sein)	Hamburg	How can the use of electromobility be optimised in cities?
Wong et al. (2020)	Mobility as a Service (MaaS): Charting a future context	International	The linking of urban land use characteristics to travel costs and modal efficiency
Mulley (2017)	Mobility as a Services (MaaS) — does it have critical mass?	International	Reducing the negative externalises of transport and maintaining the benefits of agglomeration
Lange and Robin (2022)	MaaS: Digital mobility and connectivity (MaaS: Mobilität digital und vernetzt)	Ruhr	Chances of using digital mobility technology in improving quality of life
Lyons et al. (2019)	The importance of user perspective in the evolution of MaaS	International	Developing of five essential integration levels for MaaS taxonomy
Fromm et al. (2019)	A study on free-floating car-sharing in Europe	Berlin	Investigating the impacts for free-floating car-sharing method on modal shift
Piétron et al. (2021)	Public mobility platforms: Digital policy strategies for the social-ecological mobility transition (Öffentliche Mobilitätsplattformen: Digitalpolitische Strategien für eine sozial-ökologische Mobilitätswende)	Berlin	Potentials of digital platforms in improving public mobility
Günther (2018)	Master plan for sustainable and low-emission mobility in Berlin (Masterplan für nachhaltige und emissionsarme Mobilität des Landes Berlin)	Berlin	Initiating of programmes for sustainable and smart mobility in the city of Berlin
Senatsverwaltung (2014)	The Berlin's 2030 urban development plan for transport and mobility (Stadtentwicklungsplan Mobilität und Verkehr Berlin 2030)	Berlin	Laying the foundation of sustainable mobility in Berlin.
Kamargianni et al. (2016b)	A comprehensive review of Mobility as a Service systems	Hamburg	Significant insights to transport operators in making MaaS schemes more attractive
Butler et al. (2021)	Barriers and risks of Mobility-as-a-Service (MaaS) adoption in cities	International	Assessing barriers and risks MaaS adoption in cities
Schlingensiepen et al. (2016)	Autonomic transport management systems — enabler for smart cities, personalised medicine, participation and industry grid/industry 4.0	International	Integration of data for smart transport systems to support mobility inclusiveness for less the privileged users
Mulley et al. (2019)	Intelligent mobility and Mobility as a Service	International	Illustrating the role of intelligent mobility in smart-ticketing, journey planning and automated vehicle locationing
Yannis and Chaziris (2022)	Transport system and infrastructure	Italy	Highlighting the key trends in urban mobility and sustainable transport policies
Senatsverwaltung (2018)	The initial Germany's mobility law (Deutschlands erstes Mobilitätsgesetz)	Berlin	Streamlining the procedures and strategies for sustainable mobility in Berlin
Hansestadt Hamburg (2022)	Investigation on mobility: Necessary parking spaces and bicycle spaces (Mobilitätsnachweis: Notwendige Stellplätze und Fahrradplätze)	Hamburg	Examining the strategies concerning parking and biking spaces
Moscholidou and Pangbourne (2020)	A preliminary assessment of regulatory efforts to steer smart mobility in London and Seattle	USA & UK	How do regulations hold smart mobility service providers accountable for their impacts on urban environment?
Horch (2017)	The targets for mobility in Hamburg (Mobilität in Hamburg: Die Ziele)	Hamburg	Designing the mobility in Hamburg with aim of improving healthy, environment and climate
Regionalverband Ruhr (2016)	Green infrastructure in the Ruhr region (Grüne Infrastruktur Ruhr)	Ruhr	Combining urban greenery and natural conservation in attaining emission free mobility
Schwarze-Rodrian (2021)	Green infrastructure Ruhr: Urban regeneration through NBS	Ruhr	Positioning of green infrastructures in Ruhr to attain green urbanism and mobility
Utriainen and Pöllänen (2018)	Review on Mobility as a Service in scientific publications	Finland	Understanding the current state of the art concerning MaaS
Leerkamp and Meißner (2020)	Interactions between mobility and spatial development in the context of social change (Wechselwirkungen von Mobilität und Raumentwicklung im Kontext gesellschaftlichen Wandels)	Ruhr	Interactions of spatial developments based on the background of social and technical changes
Jittrapirom et al. (2017)	Future implementation of Mobility as a service (MaaS): Results of an international Delphi study	Berlin	Investigating the opinions of experts on MaaS with the Delphi method
Berliner Verkehrsbetriebe (2024)	The mobility application for Berlin's public and shared mobility (Deine Mobilitäts-App für Berlins Öffentliche und Sharingangebote)	Berlin	Information concerning the usage of integrated mobility services in Berlin
VRR (2024)	The new advantages of using the VVR application in the blick	Ruhr	Information concerning the usage public transport services in the Ruhr region
Smith et al. (2018)	Development scenarios and implications for public transport	Sweden	Insights on the development of MaaS and its effects on public transport
Mubiru and Westerholt (2024)	A scoping review on the conceptualisation and impacts of new mobility services	International	Investigating the minimum requirements for conceptualising new mobility services, and their impacts in mobility landscapes
Smith et al. (2019)	Governing Mobility-as-a-Service: Insights from Sweden	Sweden	Proposing the key roles for public transport authorities in MaaS developments
Kent and Dowling (2016)	Over 1000 cars and no garage: How urban planning supports car (park) sharing	Finland	Reviewing policies and practices to examine the interaction of car-sharing arrangement and urban planning

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Table A.1 (*continued*).

Authors (year)	Title English (German)	Region	Content summary
Cooper et al. (2019)	Electric vehicle Mobility-as-a-Service: Exploring the "Tri-Opt" of novel private transport business models	UK	Applying system thinking in the design of smart EV hubs
Böcker et al. (2020)	Bike sharing use in conjunction to public transport: Exploring spatiotemporal, age and gender dimensions in Oslo, Norway	Norway	Exploring the potential use of bike-sharing in accessing public transport in reference to age and gender
Nietsch and Schott (2020)	The legal framework for ride-sharing businesses and the case of Uber in Germany	Germany	The entrance of Uber practices in Germany, and strict regulation of this service
Wilkes et al. (2021)	Determining service provider and transport system-related effects of ride-sourcing services by simulation within the travel demand model mobiTopp	Hamburg	The integration of both shared and public mobility services in ride-hailing arrangements
Agatz et al. (2012)	Optimisation for dynamic ride-sharing: A review	Netherlands	Optimisation hardships that arise as a result of developing technologies to promote ride-sharing
Tirachini (2020)	Ride-hailing, travel behaviour, and sustainable mobility: An international review	International	The impacts of ride-hailing services in Mobility landscapes
Molander et al. (2012)	Market orientation in public transport research — a review	International	Introducing the concept of market orientation in the field of public transport
Westhagemann (2017)	Digitalisation of traffic (Digitalisierung des Verkehrs)	Hamburg	Laying intelligent solutions for urban mobility and logistic practices
Chen and Acheampong (2023)	Mobility-as-a-Service transitions in China: Emerging policies, initiatives, platforms and MaaS implementation models	China	Examining the evolution of MaaS through investigating policy documents
Lajas and Macário (2020)	Public policy framework supporting "Mobility-as-a-Service" implementation	Portugal	Proposing of a public policy framework for the MaaS concept

Data availability

The data that support the findings in this study are included in the Appendix section of this article.

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