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# Systematic mapping of scientific publications on MaaS

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**Abstract**
Mobility as a Service (MaaS) is a concept aiming for the provision of a diversity of transport services to travellers via one single user interface as one integrated service. The intention is to provide flexible mobility services to individuals and families to constitute an alternative to car ownership. This paper aims to provide an overview of the MaaS research area. A systematic mapping study of scientific literature on MaaS up till and including 2020 has been conducted. 193 articles are included in the study through searches in scientific databases and a structured selection and classification process. The findings are analysed and discussed. Eight main topics were identified in the MaaS literature: User aspects, Societal aspects, MaaS functionality, MaaS integration, MaaS implementation, Business aspects, Technology aspects, and Privacy and security aspects. The main results are: (i) Coding schemes defining the structure and scope of the MaaS research area with respect to the main topics and sub-topics, approaches used and contribution types; (ii) a classification of the selected literature on MaaS according to the coding schemes; (iii) analysis and discussions of the findings; and (iv) discussions of trends and gaps in the MaaS research. The study contributes to a broader and more detailed overview of the MaaS research area than previous work and can support the discovery of relevant literature, assist positioning of research within the research area, be used as a foundation for further literature studies, and guide the direction of future work on MaaS.

**Keywords** Mobility as a service · MaaS · Systematic mapping study · Coding scheme · Gap · Trend

**JEL Classification** O33 · Q55 · R41

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## 1 Introduction

Mobility as a Service (MaaS) is a concept providing a diversity of transport services to travellers via one single user interface. Different transport services, which may be delivered by different service providers, are integrated into one MaaS service, preferably with a single payment for the whole journey (Kamargianni et al. 2016). The aim is to provide flexible mobility alternatives that meet all the mobility needs of individuals and families in diverse situations. Thereby, MaaS is intended to constitute a real alternative to private car ownership. In practise, a MaaS service may integrate two or more transport services, within similar or different modes.

Authorities, cities, and mobility providers are aiming for MaaS, as MaaS is assumed to mitigate many of the societal challenges linked to high traffic density, congestions, land use related to transport, and emissions from transport. MaaS has also be tested and evaluated in cities, and the first MaaS operators are providing services in cities and regions. (Arias-Molinares and García-Palomares 2020) provides a literature review on important aspects of the MaaS concept, such as what MaaS is, the history of MaaS, the main actors involved, how MaaS is implemented and the benefits for different stakeholders. The realisation of flexible MaaS services is, however, a challenge. There is for example uncertainties regarding the roles and responsibilities regarding MaaS (Karlsson et al. 2020), the business models for the MaaS value network (Karlsson et al. 2020), and the integration of data into MaaS (Polydoropoulou et al. 2020a). In addition, the potential effects on the society and the environment must be investigated.

The context for our work was a research project investigating the establishment of a national MaaS ecosystem with stakeholders, technical solutions, digital services, and governance structures providing flexibility with respect to the organisation of MaaS services and business models. The scientific literature has attention on the various aspects of MaaS, among others those mentioned above, but we saw a need for a more complete overview of the scientific literature on MaaS. To our knowledge, such an overview does not yet exist. Our motivation has been to make a contribution to such an overview by presenting a *systematic mappings study* of scientific literature on MaaS according to the approach described by (Petersen et al. 2015). The scope and direction of the study were identified in collaboration with project participants and associated stakeholders representing potential MaaS providers, transport service providers, a data integrator and MaaS experts.

The objective of the study has been to provide an overview of the topics covered by the scientific literature on MaaS, to assess the approaches and directions of the research, and to support the identification of relevant literature. The research questions are:

- *RQ1 – Topics.* What topics related to MaaS are addressed by publications in scientific channels and how many publications cover the different topics?
- *RQ2—Type of work.* What are the research strategies used and the type of results provided for the different topics?

- *RQ3 – Trends and gaps.* What are the trends and gaps with respect to research on MaaS?

This article describes the systematic mapping study carried out as an answer to the above. It targets literature on MaaS published in scientific databases up till and including 2020 and covers conference papers, journal articles, and scientific book chapters. From a total of 799 articles found in the databases, 193 articles were included in the study after a systematic selection process. The study is accomplished through a thorough classification of the selected articles according to topics of relevance to MaaS, approaches and methods used (scientific as well as non-scientific), and contribution types. The contribution of the study is fourfold: (1) A structuring of topics, approaches and contribution types found in the scientific MaaS literature represented by *coding schemes* defining the scope of work related to MaaS. (2) A *classification of the scientific MaaS literature* included in the study according to the coding schemes. (3) *Analyses of findings* with respect to the coverage of topics, approached used, and contributions made. (4) Identification and analyses of *trends and gaps* within MaaS research that can enlighten and support the further work, gaps and trends in relation to the European Sustainable and Smart Mobility Strategy (EU Commission, 2021) included.

The paper is organised as follows: Chapter 2 provides an overview of related work, i.e. other work providing a classification and a screening of the MaaS area. Chapter 3 describes the approach followed. Chapter 4 and 5 present the results from the study—the classification schemes used when the scientific literature on MaaS is classified, and the results from the mapping study. Chapter 6 discusses the findings, and the research questions are answered. The quality of the coding and mapping process is also evaluated. Chapter 7 is the conclusion. Online Appendix A lists the articles included in the study, Online Appendix B provides a descriptions of an additional coding scheme on methods, Online Appendix C provides an overview of the articles with a focus on each main topic, and Online Appendix D provide the complete coding overview for all articles.

## 2 Related work

The related work addressed in this section targets work that has contributed to classification schemes that are of relevance to the systematic mapping study on MaaS.

### 2.1 Classification of MaaS topics

Existing literature studies on MaaS are limited in scope but identify and provide overview of selected topics of relevance to MaaS. Table 1 provides an overview of topics addressed in the literature of relevance to our study, and these topics are used as a starting point for the MaaS classification schemes suggested in Chapter 4.

Based on a mapping study on information systems (IS) used in MaaS, (Brendel and Mandrella, 2016) propose a research framework for IS in MaaS. Aspects such

**Table 1** Relevant topics addressed by literature reviews and in literature on research strategies and methods

| Topics | (Brendel and Mandrella, 2016) | (Giesecke et al. 2016) | (Jittrapirom et al. 2017) | (Kamargianni et al. 2016) | (Utriainen and Pollanen 2018) | (Arias-Molinares and García-Palomares 2020) |
|---|---|---|---|---|---|---|
| User aspect | | x | x | | | (x) |
| MaaS functionality | | | x | x | x | (x) |
| Actors | | | x | | | (x) |
| Transport modes and services | x | | x | | x | |
| Tariff options | | | x | | | |
| Sustainability—Environment | x | x | | | | (x) |
| Sustainability—Society | | x | | | x | (x) |
| Travel types | | x | | | | |
| Technology and interoperability | x | x | x | x | | (x) |
| Research strategy/method | x | | | | | x |

as the success of the IS, type of IS, environmental sustainability, transport services supported, and methodology used are addressed.

Work is also done on the conceptualisation and categorisation of MaaS. (Giesecke et al. 2016) identifies four conceptual issues: The nature of travel (purpose, mode, means, distance, etc.); MaaS interoperability with intelligent traffic services; end-user aspects with focus on user attitude and behaviour; and sustainability with respect to environmental, social and economic issues. (Jittrapirom et al. 2017) provides an assessment framework to classify MaaS solutions. The areas identified are transport modes and related services, tariff options, platform (meaning App or Web-application), functionality, type of actors involved, use of technologies, demand orientation, personalisation, and customisation. (Kamargianni et al. 2016) categorises MaaS solutions according to different integration types such as ticket integration, payment integration, ICT integration, and mobility package integration.

(Utriainen and Pollanen 2018) and (Arias-Molinares and García-Palomares 2020) address MaaS from a wider perspective. Both have searched for "Mobility as a Service" in scientific databases and selected "fully MaaS focused" articles. (Utriainen and Pollanen 2018) identify 31 articles of relevance. Exclusion and inclusion criteria are not further explained, but articles on individual services like taxi, car sharing services and services based on automated vehicles are included. Thus, the MaaS definition seems to be wide, or individual services may be included to support the discussion on transport modes and services in MaaS. Four research questions are answered, of which one asks about the research topics within MaaS, comparable to our RQ1. The topics found are the roles of different transport modes and services in MaaS, findings of MaaS pilots and trial which is about the functionality provided and expected societal effects of MaaS.

(Arias-Molinares and García-Palomares 2020) identify 19 articles that are used in snowballing. In total, 59 articles are reviewed and classified based on their country of origin, and whether their work was empirical or conceptual. Empirical studies are defined to be those that provide tangible evidence from MaaS pilots on topics such MaaS users' preferences and travel behaviour and to those doing "different analysis by conducting an experiment". The meaning of experiment is not defined. Conceptual studies are defined to be those doing work on "general theoretical frameworks, regulation/ governance backgrounds, definition approaches, classification schemes, implementation issues, theory models and different scopes of MaaS". Other topics are also touched upon, but the articles are not classified according to these topics, as indicated by the parentheses in Table 1.

### 2.2 Classification of research strategies, methods, and result types

In systematic mapping studies, it is relevant to classify how work has been performed and the type of results produced. (Petersen et al. 2015) call this topic-independent classification and suggests a classification scheme for research in software engineering. The work of (Oates 2005) describes research strategies and methods for information systems and computing, which includes the interaction between social

and technical issues and the development and use of systems based on information and communication technology.

(Hevner et al. 2004) addresses result types deriving from design science research. These are distinct types of artefacts like *constructs*, which are "languages" in which problems and solutions can be defined and communicated, *models* supporting the understanding and exploration of a phenomenon, *methods* providing guidance on how to solve problems, and *instantiations* demonstrating feasibility, providing empirical evidence, and enabling learning about how the artefact affects the real world.

Two of the reviews in Table 1 classify the articles according to the strategies used. (Brendel and Mandrella, 2016) is to some extend a limited subset of (Oates 2005). (Arias-Molinares and García-Palomares 2020) has a focus on evidence and categorises the articles as empirical or conceptual.

## 3 Approach

The work described by this article is a systematic mapping study. (Petersen et al., 2015) and (Kitchenham et al., 2010) address what a systematic mapping study is compared with the more common systematic literature review. Mapping studies have a wider scope, and the number of articles may be large. The research questions are not targeting the outcomes of studies but aim for an overview of for example the research agenda, type of studies carried out, and trends. Due to the broad scope and the high number of articles, the selection of articles and the analyses are based on titles, abstracts, and keywords, and not on the full content of the article. Thus the scientific relevance to the articles cannot be fully judged. The systematic mapping study described in this paper follows the guidelines provided by (Petersen et al. 2015). The sections below address issues from these guidelines.

### 3.1 Study identification

To identify relevant scientific publications, the titles, abstracts and keywords of publications in scientific databases (Scopus, ScienceDirect, ACM Digital Library and IEEE Xplore) were searched. All together, these databases provide a wide coverage of research directions, matching the interdisciplinary nature of MaaS, technology included. The latter was required for the project mentioned above and matches the interests of the authors who have a technical background and a focus on how the technology impacts and is impacted by societal issues. Scopus was selected as the primary database due to a broad coverage of sources, while the other databases were used to find additional articles from complementary sources. The databases were searched in two rounds – first in April 2020, and then in June 2021. In the last round, all articles in the final publication stage, year 2020 included, were selected. In general, the following search was accomplished:

"Mobility as a service" OR (MaaS AND (mobility OR travel OR transport)).

**Table 2** Inclusion and exclusion and criteria

| Inclusion criteria (In) and Exclusion criteria (En) | Decided trough |
|---|---|
| I1: The article is a scientific publication | Title and abstract inspection |
| I2: The abstract is of decent quality and understandable | |
| I3: The abstract addresses topics or challenges linked to MaaS | |
| I4: The MaaS concept addressed is linked to mobility of persons | |
| I5: The abstract clearly indicates a contribution to knowledge on MaaS | |
| E1: The topic is of relevance to MaaS, but MaaS is not emphasized | Abstract inspection Full text inspection when in doubt |
| E2: MaaS is mentioned, but the topic is not of relevance to MaaS | |
| E3: The article is a Workshop report | |
| E4: The article cannot be found | Google/Google Scholar search |
| E5: The article is a duplicate or has a refined version | Comparison |
| E6: Book chapter if the book is not a collection of scientific papers | Abstract and source inspection |
| E7: Content is not an article | Full text inspection |

The expression "mobility OR travel OR transport" was added since we experienced that the MaaS abbreviation also was used within other domains. In Scopus, inspections concluded that articles from the following subject areas could be excluded: agriculture and biological science, earth and planetary science, and biochemistry, genetics and molecular biology. For all databases we excluded articles that were not written in English.

In addition to journal papers and book chapters, we also included conference papers, as MaaS is a relative dynamic research area, and conference publications are considered as relevant when the research agenda is studied. Review articles were included since they have a focus on specific topics that are relevant according to the research questions. We have, however, highlighted that they are reviews.

To evaluate the completeness of our search results, we checked that articles referenced by other literature studies (see Sect. 2) were also included in our search results. We discovered that some conference articles were not included as they were not registered in the scientific databases. Refined versions of most of these articles were however re-published as peer-reviewed articles and thus found. More articles would probably have been found through a systematic snowballing approach, but due to the high number of articles found through the databases this would be too resource demanding so we decided to limit our study to the articles in our search results.

Inclusion and exclusion criteria were defined prior to the screening, and the criteria were refined during the screening to ensure the final set of articles were as relevant as possible. Table 2 provides an overview of the criteria and how compliance was decided. Note that the filtering did not consider the degree of a scientific approach used, as many abstracts do not address the research method used. I1 limits the selection to articles with a title, author(s) and abstract found through scientific databases. I2 ensures the possibility to interpret the content of the abstract to the degree that a coding of the article content is possible. I3-I5 ensure the selected

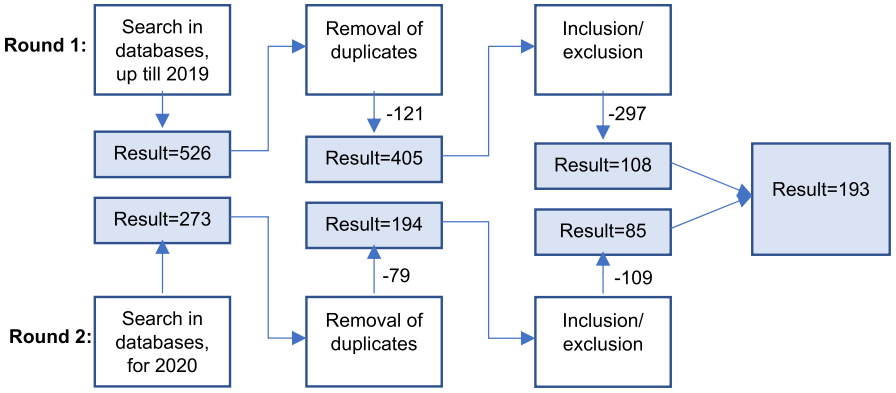


**Fig. 1** Article selection process

articles have a focus on MaaS. I3 filters away articles where "maas" does not mean Mobility as a Service. I4 ensures that that focus is on person transport and not just freight transport, and I5 ensures that MaaS is not just mentioned or used as an example while the real focus of the article is on other topics. Exclusion criteria E1 and E2 are partly about the same and were added during the screening to have more precise criteria as many articles just mention MaaS as a possible deployment area without providing further details on MaaS. As a consequence, we did for example exclude articles on automated vehicles and shared modes focusing on optimal fleet operations. We used E6 to exclude book chapters not being articles, as such chapters usually do not include abstracts that are openly available. E7 excludes the introduction part in journals and proceedings, and other content that is not an article.

The screening was mainly based on title and abstract, but the full text (when available to the authors of this article) was also inspected in cases of doubt (but not read in full detail). In total we were not able to consult the full text for seventeen articles.

### 3.2 Article selection and classification

The study was conducted in two rounds. The first included relevant articles up till the end of 2019. The second round extended the study with articles from 2020. The screening and coding followed the same approach in both rounds. Figure 1 provides an overview of the article selection process.

The articles found in the different databases were compared, and duplicates were removed. The articles were divided between the three authors of this paper, and each article was screened by two researchers independent of each other using the inclusion and exclusion criteria in Table 2. When both researchers agreed, the article was included or excluded accordingly. On uncertainty or disagreement, the third researcher was involved, and a mutual agreement on the inclusion or exclusion was decided. In total 799 articles were found. 200 duplicates were excluded, and

406 articles were excluded according to the criteria in Table 2. In total, the study includes 193 articles (see list of articles in Online Appendix A).

The classification of the selected articles is, as recommended by (Petersen et al. 2015), based on titles, abstracts and keywords. A descriptive coding approach was followed, as defined by (Saldaña, 2021). The coding was done along two dimensions – a topics dependant classification targeting MaaS, and a topics independent classification targeting other aspects of relevance like the type of work (scientific strategy and method), and type of contribution. This also aligns with the research questions.

For many of the articles, the abstract was unclear about the approach used. In these cases, the introduction, method, and conclusion parts of the articles were screened to get the information needed if the full text of the article was available.

The initial coding scheme was defined during the first round of the study. One researcher assigned codes to the articles, without much focus on harmonisation of the terms used. Then, she grouped the codes below main topics, and the use of codes was harmonised, refined, and regrouped. In the meantime, another researcher coded a subset of the articles independent of the first researcher, and they compared the codes used and agreed on refinements of the coding scheme. The codes were also harmonised with the related work in Table 1. In general, this means that the terminology used was adapted to the related work. The main topics were however not changed as the structure was considered more complete than the categories suggested by the related work. The conceptualisation of the MaaS concept provided by the new classification scheme was also considered to better cover different dimensions of MaaS.

One researcher coded each article. Thereafter, another researcher reviewed the coding, and together they agreed on relevant refinements. In addition, the main topic(s) defining the focus of each article were decided. The coding of several articles was also compared to ensure a harmonised approach. As a part of this process, the coding scheme was refined whenever this was needed. The coding resulted in a quite extensive number of codes. Thus, a final revision was done. Some codes were merged and changed to ensure consistency and a more appropriate granularity for a systematic mapping study.

## 4 Results—Classification schemes

This section presents the results from our work with the classification schemes that we used for coding the articles. We first present the topic-specific classifications which covers the MaaS topics found in the literature, and then present the topic-independent classifications which focus on characterising the research done.

### 4.1 MaaS topic classification

An overview of our classification scheme for the MaaS topics found in the articles is shown in Fig. 2. As shown in light blue in the figure, we have identified eight *main topics* (e.g. business aspects) that each have a number of *sub-topics* (e.g.


**Fig. 2** MaaS Topics classification overview

market analysis). Each main topic is further described below, with brief description of their *sub-topics*.

*User aspects.* is about the MaaS users and their relation to MaaS. It includes 5 sub-topics. *User classification* describes who the users are, while *needs* cover mobility needs and preferences. *Acceptance* covers the users' satisfaction and intention to use MaaS, for which *accessibility* (also for users with special needs) is a contributing factor. *User behaviour* covers MaaS effects on how users actually travel including the effects on private vehicle ownership.

*Societal aspects.* is about how MaaS is affected by and affects the society. *Laws and regulations* as well as *transport policy* in general set premises for MaaS. Effects of MaaS include *environmental effects* such as air quality and climate, *societal effects* such as land use, economy, demography, quality of life, and socio-technical aspects, and *traffic and transport* aspects such as safety, density,

and transport distribution across modes. *Mobility patterns* describe detailed mapping of the movement of people.

*Business aspects.* is about the business aspects of the MaaS ecosystem, such as how to make business on MaaS, and the value of MaaS. Sub-topics include *business models*, *market analysis* of business opportunities, *business collaboration* including business agreements and mechanisms for trust and transparency, and the role of *subsidies* in MaaS funding. *Value creation* is about how to create and share value in the MaaS ecosystem, while *value of mobility* is about value from the end users' point of view and includes end users' willingness to pay for services and features. *Products* covers issues such as mobility packages, subscriptions, pay as you go tickets, and bundling of mobility with other service offers, and includes pricing schemes for user groups and reward mechanisms.

*MaaS functionality*. is about functionality supporting the MaaS users. The subtopic *booking and payment* includes sales of travel products and management of travelling documents. *Travel support* before and during travel can include route planning, transfer support and notifications, can be adopted to personal preferences and use gamification techniques to encourage desired travel behaviour. S*pecialised MaaS* include specialisations such as corporate MaaS (CMaaS) and electric MaaS (eMaaS). Articles marked with *features* address functionality characterising a MaaS system in general without being more specific.

*MaaS implementation.* is about the implementation of the MaaS ecosystem and addresses the ecosystem, its implementation process and characteristics, as well as its premises and various aspects of lessons learned. Sub-topics include *MaaS policy*, technical *MaaS solutions*, long-term acceptance and *feasibility of MaaS*, analysis of *implementation barriers* / *implementation enablers* that makes implementation of MaaS more difficult / easier, and *implementation process* aspects and activities. *Ecosystem* is about MaaS ecosystem where stakeholders with distinct roles and responsibilities collaborate, and system of systems share information according to data management governance rules. *Fleet strategy* covers management of vehicles fleets delivering services in a MaaS and strategies with respect to fleet properties like number of vehicles, class of vehicles, localisation, routes, etc. *MaaS strategy* is about strategies related to market, up-take, technology, process, and MaaS service design, and include strategies for integrations toward transport services, and methods and tools for assessment.

*Privacy and security aspects*. addresses security and privacy issues related to MaaS and MaaS reliability. *Business sensitivity* is about issues that may harm the competitive power of businesses, while *privacy* is about protection of personal data in MaaS. *Threats* cover privacy and security threats, e.g. denial-of-service attacks that could block delivery of MaaS. *Cyber security* is about cyber security linked to MaaS, while *countermeasures* address how to mitigate security/privacy threats in MaaS.

*MaaS integration.* is about the integration of systems and data into the ecosystem. Such integrations are crucial for the realisation of MaaS and has to consider how to realise the integration in a way that considers many of the other main topics, e.g.

business, technology and functionality. Sub-topics include *data integration* for combining data from several sources in one, *system integration* between systems implementing aspects of MaaS, and *platform* as a common software foundation on which services supporting MaaS are realised and integrated. ICT *architecture* include specification of concepts, use cases, information, components, protocols, interactions, etc. for MaaS and architectural styles such as micro services.

*Technology aspects.* is about technology of relevance to MaaS solutions and the implementation of MaaS ecosystems. The sub-topics represent directions and principles rather than specific technologies. Sub-topics include *algorithms* for solving specific problems, use of *artificial intelligence* including machine learning in MaaS, *automation* such as automated vehicle operations, use of *decision support* systems in MaaS, and technical *infrastructure and solutions* that MaaS solutions may use. Also covered is *data access* from various sources including data on mobility patterns, and use of *distributed ledger* technology for securely sharing and synchronizing transactions across sites.

### 4.2 Topic-independent classification

As recommended by (Petersen et al. 2015), the articles are classified according to topic-independent classes such as the type of work, the method used for data collection and analysis, and the contribution types provided. The coding scheme for type of work and contribution type are depicted in Fig. 3. The coding scheme for data collection and analysis methods are described in Online Appendix B.

*Type of work.* A classification of the type of work is commonly used in systematic mappings studies, and the codes used in our study are described in Table 3. Those marked with a * are defined by (Oates 2005).

*Contribution type.* The topic dependent coding provides information on the topics addressed but do not specify the type of results they provide. Thus, we classify the articles according to contribution type. Table 4 provides an overview of the three contribution types and codes. An Artefact is something designed or constructed, and the codes indicate the type of artefact, which are based on (Hevner et al. 2004). As stated by the rightmost column, there is a correlation between contribution type and type of work.

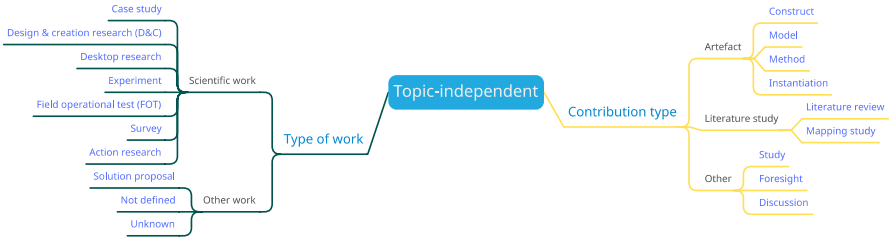


**Fig. 3** Topic independent classification overview

**Table 3** Type of work codes

| Sub-classes | Codes | Descriptions |
|---|---|---|
| Scientific work | Case study* | Investigation of a phenomenon within a real-life context to clarify links between a phenomenon and a context |
| | Design & creation research (D&C)* | Design and/or construction of an artefact. The artefact is tested and evaluated. Evaluation results are used to improve the artefact |
| | Desktop research | Secondary research, i.e. to review previous research to gain a broad understanding of the field |
| | Experiment* | Planned and controlled testing of hypotheses to understand causal processes. Variables are manipulated, and changes are measured. Baseline data facilitate comparison of before and after situations. Experiments should be repeatable |
| | Field operational test (FOT) | Testing in real environment. The testing is less formalised than an experiment. Baseline data may not always be available |
| | Survey* | Data collection from people (e.g. interviews), observations or documents. The data is analysed to give new insight and knowledge |
| | Action research* | Researchers are engaged in alteration work in collaboration with other problem owners/practitioners to change their practice. The effects are evaluated |
| Other work | Solution proposal | Design/construction of artefact without a clear scientific approach |
| | Not defined | Study. Scientific approach is not defined |
| | Unknown | The approach is not defined in abstract and full text is not available |

*According to (Oates 2005)

**Table 4** Codes describing contribution types with correlations to type of work

| Contribution types | Codes | Descriptions | Correlation to type of work |
|---|---|---|---|
| Artefact | Construct* | A "language" for definition and communication of problems/solutions | **Scientific work:** D&C Input may come from surveys, case studies, experiments, etc.**Other work**: Solution proposal |
| | Model* | Supports understanding of a phenomenon and enables explorations | |
| | Method* | Provides guidance on how to solve problems | |
| | Instantiation* | Supports demonstration of feasibility, empirical evidence, and enables learning | |
| Literature study | Literature review | Review of articles content targeting specific goals within a topic | **Scientific work:** Survey |
| | Mapping study | Overview of a research agenda and trends | |
| Other | Study | The outcome of the work is analysed and described | **Scientific work**: Case study, Experiment, FOT, Survey **Other work**: Not defined, unknown |
| | Foresight | The future is foreseen and discussed | Scientific work: Survey **Other work**: Not defined, unknown |
| | Discussion | Ideas, plans, and thoughts are described. There are no concrete results or analysis | **Other work**: Not defined, unknown |

*According to (Hevner et al. 2004)

# 5 Results—Mapping

This chapter presents the findings from the systematic mapping study. First the results from the MaaS topics mapping are presented in Sect. 5.1, before the topic independent mapping is presented in 5.2. Online Appendix A lists the 193 articles included in the study. These are assigned a selection number (S1 – S193), and they are referred to by [S*n*] in this chapter and elsewhere in this article. Online Appendix D provides the full details on the coding of each article, using the codes from Chapter 4 and some additional codes from Online Appendix B.

## 5.1 MaaS topics findings

This section presents the findings from the analysis based on the topic dependent coding done according to the schemes in Sect. 4.1. For all articles, the coding covers 1) the *focus* defined by one or two of the main topics; and 2) the *content* of the articles defined by sub-topics, where sub-topics from any main topic may be used, also those that are not defined as the focus. Note that the content primarily is analysed based on the abstracts of the articles, according to the systematic mapping method used (see Sect. 1 and 3.3).

### 5.1.1 User aspects

18% of all articles in the study, in total 35 articles, have a focus on user aspects. In addition, 16% of the articles with a focus on other topics touch upon user aspects. Figure 4 provides an overview of articles with a link to sub-topics of user aspects. From 2019, a substantial number of articles are published.

Table 7 in Online Appendix C provides an overview of the 35 articles with a *focus* on user aspects. Among these articles, the share with a scientific approach is very high. The contributions are mainly studies with a broad coverage of topics. The articles report from field operational tests (FOTs) on user attitude and behaviour, on effects on the use of and replacement of private cars, and on the effects of MaaS on user behaviour and car use and ownership. There are also a few artefacts, more precisely a MaaS integration taxonomy and a survey tool on user preferences. A literature review address user acceptance and behavioural effects of MaaS among different user groups.

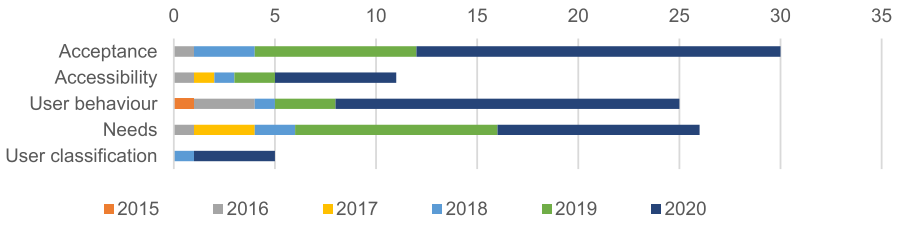


**Fig. 4** Links to User aspects sub-topics in MaaS related articles, distributed per year

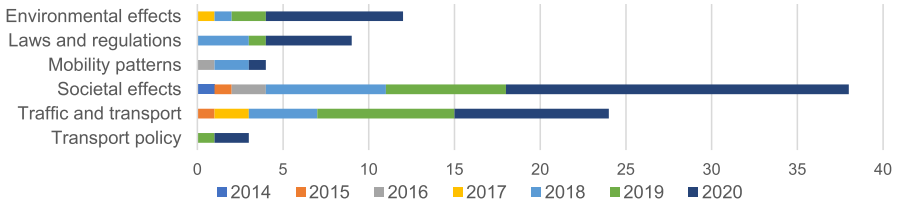


**Fig. 5** Links to Societal aspects sub-topics in MaaS related articles, distributed per year

### 5.1.2 Societal aspects

11% of all articles in the study, in total 22 articles, have a focus on societal aspects, and in addition, 24% of the articles touch upon this topic without having a focus on it. Figure 5 provides an overview of articles with a link to sub-topics of societal aspects. Except for 2017, there has been a steady increase in articles on societal aspects.

Table 8 in Online Appendix C provides an overview of the 22 articles with a *focus* on societal aspects. Among these articles, the share of scientific contributions is high. The majority of the articles is studies, of which one reports results from a field operational test (FOT) on what motivates for a change towards sustainable mobility, the use of economic incentives included (S155). There are also some cases studies. There are two literature reviews, one on smart transports and smart transport effectiveness in the context of smart cities (S62), and one on technology for smart transport (S26). Two foresight studies on smart cars and mobility trends are also provided.

### 5.1.3 Business aspects

14% of all articles in the study, all together 27 articles, have a focus on business aspects, and in addition 22% of the articles with another focus also touch upon business aspects. The diagram in Fig. 6 illustrates how the number of articles on the sub-topics of business aspects has developed over the years.

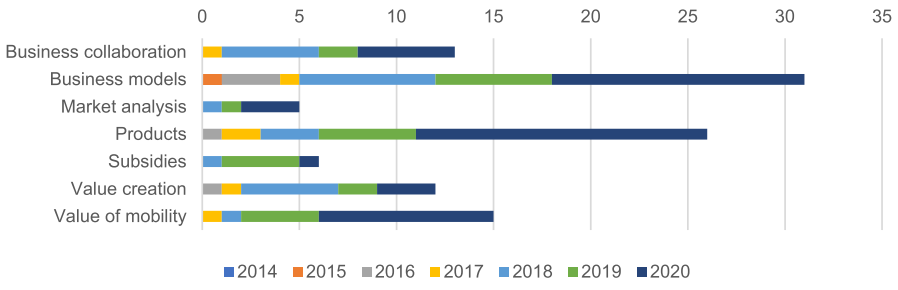


**Fig. 6** Links to Business aspects sub-topics in MaaS related articles, distributed per year

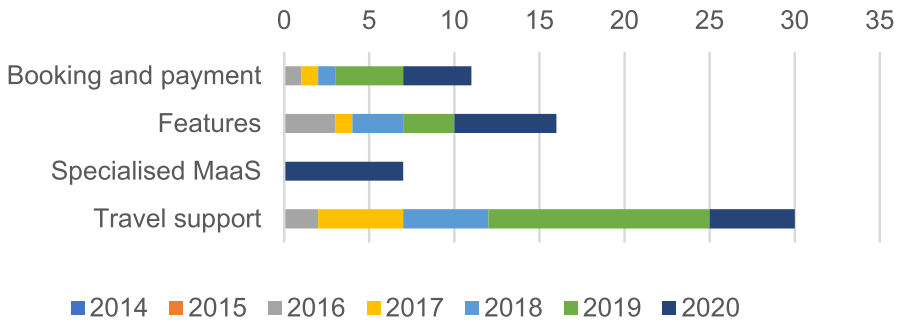


**Fig. 7** Links to MaaS functionality sub-topics in MaaS related articles, distributed per year

Table 9 in Online Appendix C provides an overview of the 27 articles with a *focus* on Business aspects, and among these the share of scientific contributions is high. The contributions are a mixture of studies and artefacts. There are no literature reviews with a focus on the MaaS business aspects. Such a review would have been useful.

#### 5.1.4 MaaS functionality

10% of all articles in the study, in total 19 articles, have a focus on MaaS functionality. In addition, as much as 20% of the articles with another focus touch upon MaaS functionality. Figure 7 shows that there is a large number of articles on various aspects of MaaS functionality, including quite many articles that according to their abstract address MaaS features without being more specific.

Table 10 in Online Appendix C provides an overview of the 20 articles having a *focus* on MaaS functionality, and they have a high share of scientific contributions. Most articles are studies, but just two are from case studies. Some contributions are artefacts, among others an evaluation framework for corporate Maas (S175), algorithms (S87 and S133), and MaaS solutions (S57 and S112). One study provides a topography for MaaS (S162).

#### 5.1.5 MaaS implementation

The number of articles with a focus on MaaS implementation constitute one third of all articles in the study, in total 64 articles. In addition, 15% of the articles with another focus touch upon MaaS implementation. As the diagram in Fig. 8 reveals, there has been a rapid growth in articles on MaaS implementation since 2018, and the trend continues.

Table 11 in Online Appendix C provides an overview of the 64 articles with a *focus* on MaaS implementation. Among the scientific contributions, there is a high share of studies. Two studies report from field operational tests (FOTs) and reports on implementations barriers (S90) and broad spectre of experiences and

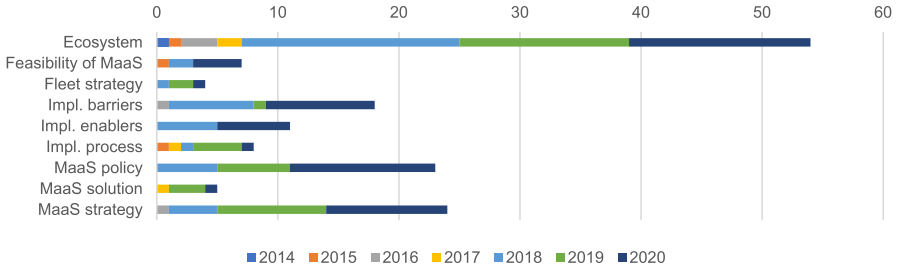


**Fig. 8** Links to MaaS implementation sub-topics in MaaS related articles, distributed per year

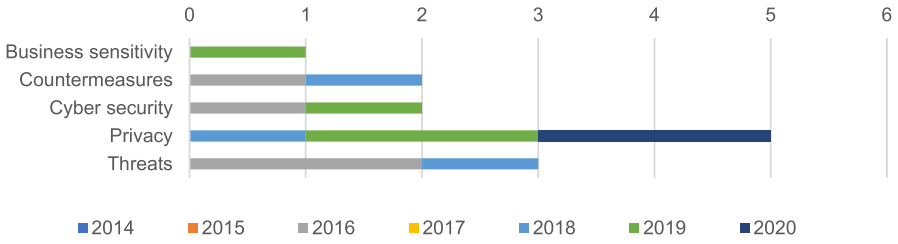


**Fig. 9** Links to Privacy and security aspects sub-topics in MaaS related articles, distributed per year

effects from a MaaS trial (S164). Quite many articles are case studies. There are two literature reviews on MaaS services and their functionality, transport service modes, and expected societal effects (S174), and on user aspects, functionality, the actors involved, and environmental effects (S10). There are also some artefacts (methods, models and instantiation), and one foresight study on MaaS implementation (S83).

### 5.1.6 Privacy and security aspects

3% of all articles in the study, 5 articles have a focus on privacy and security aspects, and in addition 1% of the articles with another focus also touch upon privacy and security aspects. Figure 9 reveals how the number of articles on privacy and security aspects related to MaaS aspects has developed over the years.

Table 12 in Online Appendix C provides an overview of the 5 articles with a *focus* on privacy and security aspects. and They provide a mixture of studies and artefacts, and among these, the share of scientific contributions is 60%.

### 5.1.7 MaaS integration

9% of all articles in the study, in total 17 articles, have a focus on MaaS integration. In addition, 12% of the articles with another focus also touch upon MaaS integration. Figure 10 shows the number of articles on the MaaS integration sub-topics.

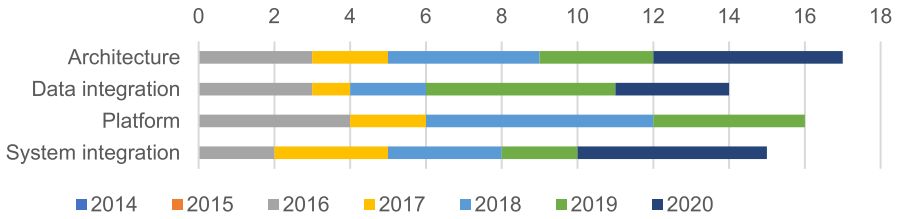


**Fig. 10** Links to MaaS integration sub-topics in MaaS related articles, distributed per year

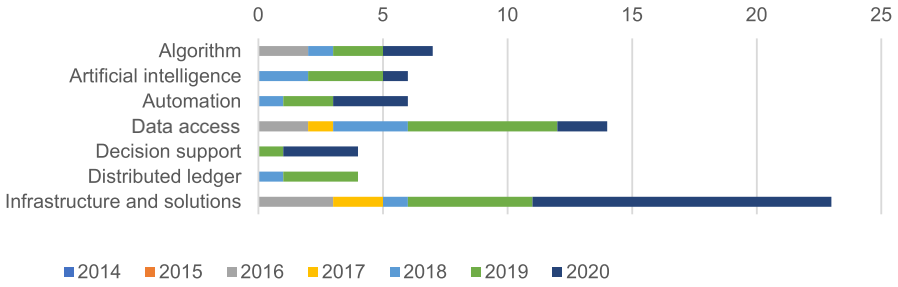


**Fig. 11** Links to Technology aspects sub-topics in MaaS related articles, distributed per year

Table 13 in Online Appendix C provides an overview of the 17 articles with a *focus* on MaaS integration. 24% of the articles (four articles) do not have a scientific approach, or the approach is unknown (marked with a *). For the sub-topic on *microservices*, no articles have a confirmed scientific approach. 3 contributions are studies (S20, S122 and S188). The majority of the articles contributes with artefacts such as models, mainly architectures and designs (S7, S23, S117), and methods such as design methods and frameworks (S34, S72, S87, S173) and integration methods (S19). A few contributions are also instantiations (software implementations) of the architectures provided.

### 5.1.8 Technology aspects

8% of all articles in the study, in total 15 articles, have a focus on technology aspects, and in addition 17% of the articles with another focus also touch upon technology aspects. The diagram in Fig. 11 shows the distribution of articles on technology aspect over the years.

Table 14 in Online Appendix C provides an overview of the 15 articles with a *focus* on technology aspects. Due to the focus on technology, the contribution types for all groups are mainly models, methods, and instantiations. In addition, there is one foresight study on the use of machine learning in MaaS (S36), one mapping study outlining the information system research agenda (S24), and one study of legal aspects linked to data access (S42).

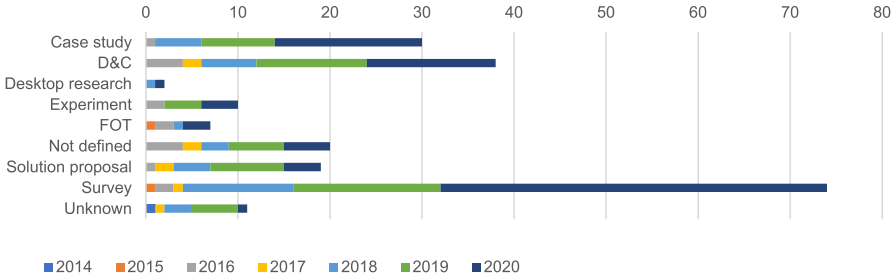


**Fig. 12** Overview of type of work per year

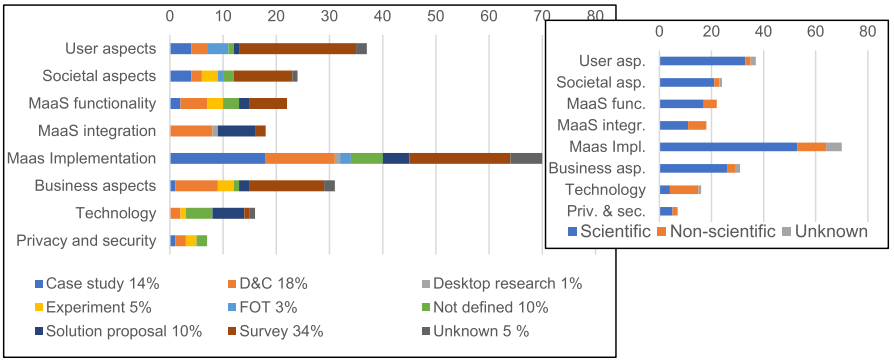


**Fig. 13** Overview of Type of Work per main topic

## 5.2 Topic independent findings

This section analysis the findings based on coding of type of work and contribution types using the codes defined in Sect. 4.2.

### 5.2.1 Types of work

Figure 12 shows the distribution of articles among the diverse types of work over years. Note that the numbers provided are higher than the number of articles since some articles use more than one type of work. In general, the distribution seems to be similar over the different years up till 2020. In 2020, the number of surveys has increased significantly compared to the other types of work.

The diagram in Fig. 13 shows the distribution of type of work per main topic. In total 7 articles (3%) are based on field operational tests. There are 30 "case studies" (14%). Most case studies are about User aspects and MaaS implementation. The "action research" research strategy, where scientists collaborate closely with the practitioners and problem owners in alteration work, e.g. in the improvement of working processes, is not present at all. This might for example be relevant for work on various aspects related to the implementation of MaaS. Altogether, 76% of the articles are scientific work (surveys, field operational tests, experiments, desktop

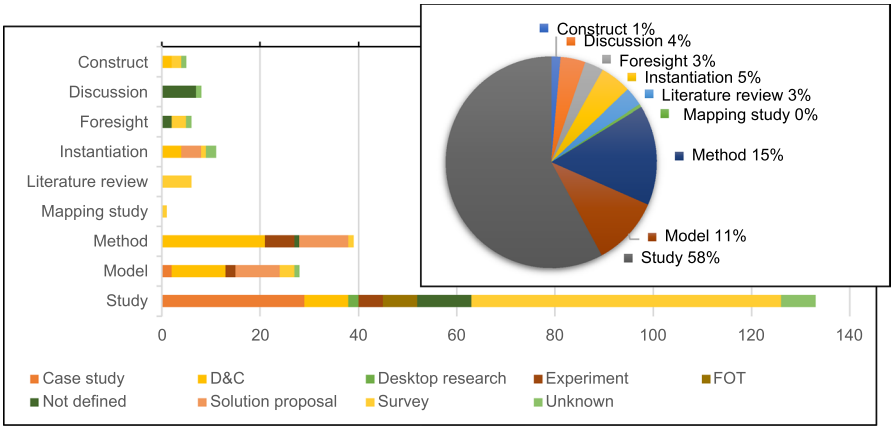


**Fig. 14** Overview of types of contributions per type of work and in total

research, design and creation, and case studies), 19% are non-scientific (solution proposal, and not defined). In total the approach is not defined or unknown for 15% of the publication. The small diagram in Fig. 13 shows the distribution of scientific and non-scientific work among the selected articles for the main topics. The share of scientific work is low for the technology and MaaS integration topics. For the articles on user aspects, societal and business aspects, the share of scientific work is very high.

### 5.2.2 Contribution types

Figure 14 provides an overview of the types of contribution per type of work, and the total share of each contribution type.

The share of literature reviews, mapping studies and foresights is low (all together 6%). Almost 60% of the articles provides a study, and altogether, 32% of the contributes are artefacts (models, methods, instantiations and constructs). The instantiations (5%) are mainly software realising various aspects of MaaS (Apps, platforms, marketplaces, smart contracts, etc.) as well as tools (survey tool and executable behaviour model). There are quite few articles with a construct type of result (1%), i.e., results that in a formalised way communicate definitions, problems, and solutions.

## 6 Discussion and evaluation of the mapping study

In this chapter we discuss our results from chapter 4 and 5 in relation to the research questions RQ1, RQ2 and RQ3. We also discuss the quality of the study with respect to the coding done and the approach.

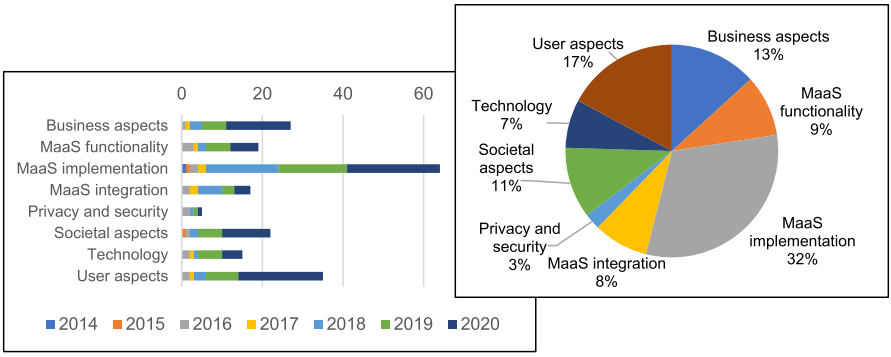


**Fig. 15** Distribution of articles per main topic over years and in total

### 6.1 RQ1 – Topics

The topic classification scheme presented in Fig. 2 along with the descriptions in Sect. 4.1 summarise the main topics and sub-topics we found in the MaaS articles included in this study. We identified 8 main topics which each have between 4 and 9 sub-topics. Figure 15 presents the number of publications per main topics per publication years, and a pie-chart showing the percentage of publications with a focus on each of the main topic. Section 5.1 provides more detailed views, including the number of publications that cover each of the sub-topics of the main topics.

As described in Sect. 3.2, the coding schemes on topics in general includes topics covered by the abstracts of the selected research literature. Topics just appearing in the main text of the article, may thus not be covered. Further issues regarding the quality of the coding are discussed in Sect. 6.4.

The selected main topics are to some extend harmonised with the topics in Table 1. For *User aspects* and *MaaS functionality*, there is an overlap. The *MaaS implementation* and *Business aspects* topics do however go beyond the actors and tariff options topics in Table 1, and the *Societal aspects* topic cover both of the sustainability topics (environment and society). We have added the *Privacy and security* topic since we expect this to be important due to the need for extensive data sharing in MaaS, both regarding businesses and persons. The technology and interoperability topic in Table 1 is split into *Technology aspects* and *MaaS integration* to distinguish between integration, which is a core challenge where aspects across many of the other main topics (e.g. business, technology and functionality) must be considered, and technology, which is technical directions and principles of relevance to MaaS solutions as well as infrastructures and solutions developed outside the MaaS solutions which that MaaS solutions may use and benefit from.

Table 1 has a topic called transport modes and services. We experienced that such information quite often was missing from the abstracts, and we decided not to include such at topic. For the same reason, we also skipped the travel type topic. We see this as a minor problem. Our classification schemes in general target mode-independent knowledge that is useful no matter which modes a MaaS service includes.

From the above we see that the mapping study described in this article confirms the relevance of most of the topics addressed in Table 1. The study also contributes beyond previous work. The selection of articles, the establishment of coding schemes, and the coding are done through a more well-defined and structured approach. The coding schemes provided are more detailed, and in combination with a coding of a high number of articles, this contributes to a more complete and detailed mapping of the MaaS literature. The coding schemes are also an important contribution by themselves. They define a detailed structure of topics of relevance to MaaS which defines the scope of work on MaaS, and the schemes can be used to position work on MaaS.

### 6.2 RQ2 – Type of work

The topic-independent classification schemes in Sect. 4.2 address types of work and the contribution types, and Sect. 5.2 provides an overview of the findings. The coding details for each individual article and a short description of the contributions they provide can be found in Online Appendix D, and Online Appendix C provides an overview of the contribution types of the articles focusing on each main topic. In general, there is a need for more field operational tests and case studies. For the *MaaS integration* and *technology aspects* topics, the share of scientific work among the articles found is far too low. Further details on trends and gaps regarding the type of work used per main topic are provided in Sect. 6.3.

The quality and trustworthiness of scientific results depend on the scientific methods used and how they are described and applied. Based on the work on the coding, we see a need for improvements with respect to this in research on MaaS. Many articles fail to describe the scientific approach, or the quality of the description is too low. It should be easy to find and judge such descriptions, and overall information on approaches and contributions should also be included in abstracts.

The articles in our study are classified as either "scientific work" or "other work" (see Table 3). The latter classification is included due to the problem of scientific quality mentioned above. Several articles in the field of MaaS do not describe the approach used, and we decided to also reflect the content of these articles.

Information about the empirical evidence has a high value, but empirical evidence is not directly addressed in our study as it will require a careful inspection of the full text. The classification according to type of work does however provide an indication on the evidence provided. The articles with type of work set to *field operational tests* and *case studies* should be empirical. *Design & creation research* is empirical if the artefacts are validated in real settings. *Experiments* can be empirical if the design (hypothesis and models included) is properly validated. *Surveys* can be empirical, depending on the hypotheses and the data collection sources and strategies.

Compared to related work, this article has a broad coverage and contributes with a more complete coding framework for types of work. For instance, (Arias-Molinares and García-Palomares 2020) only classify articles as empirical or conceptual as described in Sect. 2.1. In our study, both non-scientific approaches and scientific research strategies are covered, and the classification of the latter is primarily based on (Oates 2005).

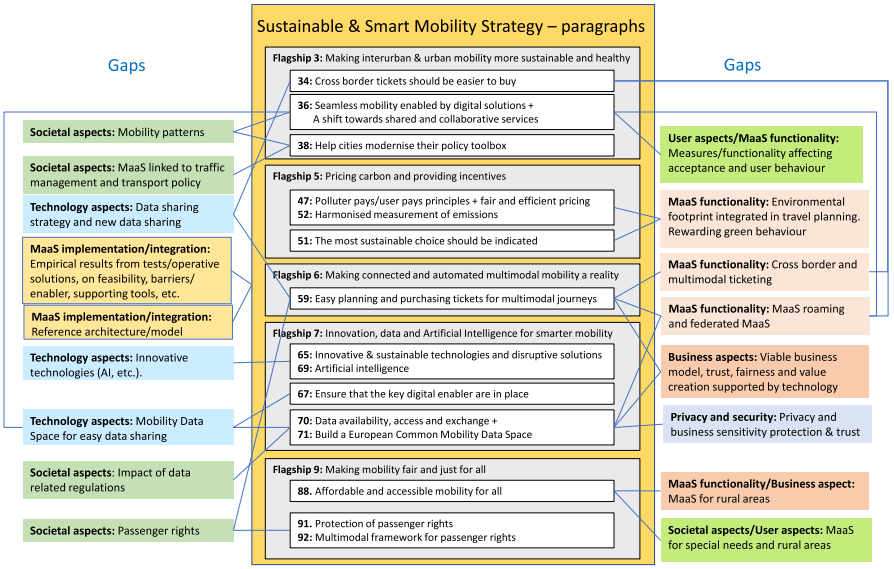


**Fig. 16** Mapping of gaps towards European Sustainable and Smart Mobility Strategy paragraphs

New codes on contribution types are also provided. The insight provided, can hopefully increase the focus on scientific quality in work on MaaS.

### 6.3 RQ3 – Trends and gaps

The trends with respect to research on MaaS are illustrated by the results provided in chapter 5 and by Fig. 15.

In the following sections we identify gaps in research on MaaS by analysing the findings in Sect. 5.1 and 5.2 and the overview of the focus articles within each main topics in Online Appendix C. For each main topic, we identify the most relevant sub-topics for future research through a comparison with needs outlined in European policy documents and in scientific literature. We also assess the use of research strategies.

Regarding the European policy documents, we in particular focus on the European Sustainable and Smart Mobility Strategy (EU Commission, 2021). This strategy was selected since our work was done in a European setting. In addition, we consider the European Commission to be in the forefront on developing strategies that contributes to the UN Sustainable Development Goals, and the strategy is also quite detailed and suited for a discussion on gaps. Figure 16 provides and overview of the most relevant gaps identified for the main topics, and they are linked to the paragraphs of the flagship sections in this strategy. In general, several gaps from several main topics may be associated with each paragraph. The following sections provide more details on the gaps.

### 6.3.1 User aspects

There are many scientific contributions on user aspects. The acceptance of MaaS is however still not so high that the majority of people in urban areas are willing to give up their private cars. Thus, there is a continuous need for research on *acceptance* and *user behaviour* to get knowledge on how this can be achieved and on how to get the shift towards the shared and collaborative services requested by the Sustainable and Smart Mobility Strategy. The research should preferably be empirical and target operative MaaS services and field operational tests. According to (Karlsson et al. 2020), service levels beyond the offered transport services matter more than anticipated. Thus, offerings and features that can improve the attractiveness of MaaS should be addressed, e.g. the effects of economic measures, flexibility, and innovative offerings.

Mobility for all is a key requirement in the European Sustainable and Smart Mobility Strategy. This is of particular relevance to the *accessibility* and *needs* sub-topics. More research on MaaS in rural areas is required as well on MaaS for the increasingly aging population.

### 6.3.2 Societal aspects

The success of MaaS can be verified through *societal* and *environmental effects*. For *societal effects*, the request for mobility for all in the European Sustainable and Smart Mobility Strategy must be emphasized, and there is a need for research on how MaaS can support and affect rural areas. Relevant aspects are for example addressed by (Eckhardt et al. 2018).

The European Sustainable and Smart Mobility Strategy also requests tools that can support cities in their work on transport policies. Many articles touch upon traffic and transport aspects, but quite few articles have a focus on the *traffic and transport* and *transport policy* sub-topics. More research is needed on how the urban environment, from a macro-level perspective, can benefit from a tighter link between MaaS and traffic management. MaaS solutions can benefit from information on current and predicted traffic situations, and MaaS services may influence mobility patterns and thereby be a tool for a more pro-active traffic management. The *mobility pattern* sub-topic is also relevant to the above. More research is needed on the role of MaaS in collection and management of mobility data and the mapping of the mobility patterns of citizens. There is a need for more knowledge on such patterns and on how MaaS can influence the mobility patterns.

The is a huge gap in research on *laws and regulations*. (Karlsson et al. 2020) address the public and private sectors' point of view in Sweden and Finland. Such analyses are needed for more countries.

The European strategy for data (EU Commission, 2020a) aims for a single market for data that can be used to the best of the society, and the European Sustainable and Smart Mobility Strategy requests a common European mobility data space. European legislation may contribute to such a development. The Data Governance Act (EU Commission, 2020b) provides measures to increase trust in data sharing, improve data availability, and overcome technical obstacles. The proposed Data Act

(EU Commission, 2022) clarifies issues related to data including value creation, conditions, fairness, access, and use of interoperability standards. More research is needed on the requirements and possibilities the regulations represent for MaaS. Additional research is also needed on passenger rights, as this topic is addressed by the European Sustainable and Smart Mobility Strategy.

For *societal* and *environmental effects*, *acceptance* and *user behaviour*, there is a need for empirical studies from cities with operative MaaS services and field operational tests. It also is a lack of research-based artefacts that can support assessments of effects, e.g. assessment methods, models for common understanding, and instances like tools.

### 6.3.3 Business aspects

In general, there is a relatively small number of articles on business aspects considering their importance for successful implementations of MaaS. (Karlsson et al. 2020) does for example address the lack of viable business models and perceived business opportunities, and (Polydoropoulou et al. 2020b) and (Smith et al. 2018) address problems with respect to trust and collaboration. Thus, more research is in particular needed on *business models*, *products* (pricing schemes) and *value creation*. Relevant aspects may among others be the effect of trust and fairness on the willingness to collaborate in a MaaS ecosystem, diverse types of values (e.g. economic, the value of environmental and social sustainability, and the value of data), and viable business models for MaaS in rural areas to ensure mobility for all.

The Sustainable and Smart Mobility Strategy requests easy purchase of multimodal and cross border tickets. Research is required regarding how this will affect *business models, products* and *value creation* and how such collaboration can be supported by EU-wide frameworks and infrastructures.

Looking at the contribution types, there are no literature reviews with a focus on the MaaS business aspects. Such a review would have been useful. There is also a need for more field operational tests and case studies. There is also a lack of artefacts that can support assessments of effects, e.g. assessment methods, models for a deeper understanding, and instances like tools.

### 6.3.4 MaaS functionality

The European Sustainable and Smart Mobility Strategy emphasize that travellers should be informed about the most sustainable choices, and that the polluter must pay. Thus, for the *travel support* sub-topic, more research is needed on the calculation of environmental footprints, communication around such footprints with users, and innovative mechanisms to inspire, encourage and nudge desired behaviour, e.g. rewarding mechanisms.

(Karlsson et al. 2020) describes the importance of the service level beyond the mobility services provided. Thus, more research is needed on *travel support* functionality for attractive services that can contribute to the shift towards shared and collaborative services requested by the European Sustainable and Smart Mobility Strategy.

For the *booking and payment* sub-topic, none of the articles seem to go deep into solutions and associated challenges. The Sustainable and Smart Mobility Strategy requests multimodal and cross border ticketing, and also easy planning and purchasing of tickets for multimodal journeys. From the user's point of view, it may be cumbersome to use different Apps and to find, book/re-book and pay for cross border and multimodal journeys. Thus, more research is needed to explore and evaluate different approaches and levels of integration for booking and payment, and implications with respect to data sharing (e.g. needs for new data). New research should also explore MaaS roaming (as in telecom) to support seamless use of the same MaaS App across cities and countries, and federated MaaS where MaaS providers are able to find, integrate and support the use of "all" European transport services by means of easily available data.

In general, the research should be case studies of operative MaaS services and field operational tests. Scientific contributions of type models and instantiation may also be needed for development studies, simulations, and new, innovative functionality.

### 6.3.5 MaaS implementation

The *ecosystem* and *MaaS policy* sub-topics have many common and diverse contributions addressing the MaaS ecosystem from different perspectives and in different contexts. According to (Karlsson et al. 2020), there is a lack of a common understanding of MaaS roles and responsibilities. Thus, there is a need for new contributions that can provide a more formalised and coordinated view upon the MaaS ecosystem. Such a common view is also a necessity for many of the requests pointed out by the European Sustainable and Smart Mobility Strategy, EU-wide solution for multimodal planning and ticketing included.

With respect to the *MaaS policy* sub-topic, there is a need for contributions that can support cities in their work on policies, as requested by the Sustainable and Smart Mobility Strategy. (Karlsson et al. 2020), (Smith et al. 2019) and (Smith et al. 2018) have identified barriers and enablers, but there is a continuous need for more research within all sub-topics to establish knowledge that can provide insight and also ease and support the implementation process under varying condition (changes in the society, new legislation, novel technology, changes in technical infrastructure, etc.).

The research should preferably be case studies targeting operative MaaS services or field operational tests. Artefacts such as methods, models and instantiations are also needed, and their relevance must be validated. Models providing formal descriptions of the ecosystems and constructs providing common vocabularies and concepts may for example support a common understanding of the ecosystem mentioned above. For the MaaS policy sub-topic, it would have been good to have a systematic literature review.

### 6.3.6 Privacy and security aspects

With MaaS, quite detailed data on the mobility of persons is collected, e.g. data on where and when people travel and data on planned journeys, and the systems may know where persons might be at certain moments of time. Such data can be used for many different purposes, purposes that may benefit the society included. Considering the above, there are surprisingly few articles on privacy and security aspects, and there is a need for publications on how privacy and security issues related to MaaS should be managed, and if and how the data can be used to the best of the society. It is also a need for publications on data sharing between businesses and potential exposures of business secrets. These aspects should in particular be addressed with respect to the recent and upcoming regulations on data sharing (see subtopic on laws and regulation for societal aspects).

### 6.3.7 MaaS integration

The current contributions are in general targeting specific systems architectures and specific solutions. MaaS integration is however also about non-technical aspects, and these should to a larger extend be addressed. *Data integrations* is for example also about semantics. The work on *architecture*, *platform* and *system integration* should reflect that MaaS must be a part of the digital transformation of the transport domain where things are done in new ways, supported and enabled by digital technology and digital infrastructures. This is a complex task that includes support and integration of solutions addressed by the other main topic, including "soft topics" such as business aspects, user aspects, MaaS functionality, and feasible implementations of policies, strategies and solutions.

As described for the MaaS implementation main topic, there is a need for a more formalised and coordinated view upon the MaaS ecosystem. This is also of relevance to the *architecture* and *platform* sub-topics. A generic and overall MaaS reference architecture is needed, and thus also more research on how the family of systems in a MaaS ecosystem shall fit into the totality and work together. This is needed as an answer to the request for EU-wide solutions in the Sustainable and Smart Mobility Strategy, and also for the MaaS roaming and federated MaaS functionality mentioned for the MaaS functionality topic. Reference architecture initiatives are used within other areas with digital ecosystems where many systems and stakeholders collaborate (e.g. telecom, banking, and cooperative, connected and automated mobility). Such an architecture is not just about technology. It has to define the ecosystem by means of concepts, responsibilities, requirements, and functionality needed.

There is a significant gap in scientific work. The main contribution types should probably be artefacts, but there is also a need for more studies, e.g. on approaches for the above-mentioned reference architecture.

### 6.3.8 Technology aspects

In general, there is a need for more studies on how the use of technologies in MaaS solutions can contribute to innovations and disruptive solutions that can solve societal challenges. Quite few articles have for example addressed *artificial intelligence* (AI), of which just one is on machine learning. AI can make MaaS more intelligent and facilitate dynamic adaption of the MaaS services to the needs of both travellers and the society. AI is appointed as essential to smart mobility by the European Sustainable and Smart Mobility Strategy, and (Cruz and Sarmento 2020) address a potential link between AI, MaaS, smart buildings and smart cities. AI is also relevant to the *decision support* sub-topic where there is just one article.

There is a significant gap regarding the *data access* sub-topic. The current articles focus on data collection, while the European Sustainable and Smart Mobility Strategy emphasize the importance of data availability, access and exchange. The strategy also requests EU-wide and border crossing, integrated, multimodal information, ticketing and payment services that will require extensive cross-border data sharing and sharing of new data types. (Polydoropoulou et al. 2020a) address challenges regarding access to data and lack of standardised data. New research should establish knowledge from existing data sharing approaches in different countries, both from a technical and strategical point of view. There is also a need for more research on methods and techniques for the collection of mobility data for the mapping of mobility patters (see societal aspects) without violating privacy protection regulations.

There is a gap with respect to *infrastructure and solutions.* The European Sustainable and Smart Mobility Strategy proposes the building of a common European mobility data space (MDS), a part of the initiative on Common European data spaces,[1] and there is work on solutions. MDS might be the next generation of the National Access Points addressed by the ITS Directive, and can support and facilitate the future, EU-wide solutions mentioned above, MaaS roaming and federated MaaS. There is a need for research on barriers and requirements regarding MDS support to MaaS, and also articles on prototype implementations and trials.

There is in general a significant gap in scientific work and scientific publications on technical issues. Artefacts must be established through a scientifical approach, and they must be validated. There is also a need for more studies, e.g. on existing data sharing approaches and MDS in relation to MaaS.

## 6.4 Coding quality

In a systematic mapping, the abstracts are the main sources for the coding. Thus, the quality of the abstracts affects the coding quality. Topics not reflected by the abstracts are not coded. We excluded articles with low quality abstracts. Some abstracts are however still relatively sparsely described, and details may be missing.

[1] http://dataspaces.info/common-european-data-spaces/#page-content.

The authors of this article have a background from software engineering including user perspectives, and they have wide domain knowledge on the transport domain in general as well as on the MaaS ecosystem. Thus we are quite confident about most of the coding schemes, but for the business aspects and societal aspects there might be details that we have overlooked. All together, we do however consider the coding to be of decent quality. The quality of the coding scheme is ensured through the coding process, as described in Sect. 3.3. The final coding scheme is a balance between the need for a structure, simplicity (not too many codes), and coverage.

The classification process revealed that many abstracts and also the full text of many articles did not provide good descriptions of the scientific approach. Thus the coding of the type of work was challenging. Much effort had to be used to find the information needed, and in some cases the information was misleading. Trials with technology prototypes were for example called case studies. In such cases, type of work was coded according to our interpretation of the work conducted.

Surveys were in general identified based on information on the data collection and analysis methods used, e.g. interviews, questionnaires, qualitative analysis and quantitative analyses. In quite many articles, the scientific quality was low, and further details were not provided or not found by us. We have however coded the articles as surveys (i.e. scientific work) due to the doubt caused by not reading the complete full text.

We experienced challenges related to the coding of stated choice experiments, which often are used in investigations on user preferences and the willingness to pay. To our judgement, these are not fully controlled experiments with a baseline and changes in variables to study effects. We found most stated choice experiments to be surveys in which the choice experiment was used as a computer supported data collection method. Many simulation studies were however classified as experiments since they studied the effects of variations in a controlled setting.

We also experienced difficulties with contribution types, and the full text quite often had to be consulted to clarify the contribution. The correlation between the type of work and the type of contribution described in Table 4 did however support correct classifications and improved the coding quality. Whenever a mismatch was detected, the coding was reconsidered. The correlation also helped us to understand unclear descriptions of approaches and contributions.

### 6.5 Process quality

(Petersen et al. 2015) provide a scorecard for mapping studies covering 26 actions in four phases. The two first columns of Table 5 provide an overview of the phases with our scores, and the suggested actions. Completed actions are ticked off ($\surd$). The others are marked with a minus (-).The right column summarises the actions taken and refers to the sections of this article where the actions or results are described. 18 of 26 actions were accomplished, a ratio of 69%. The total score of our study (according to the guidelines provided) is 12 of 14.

**Table 5** Evaluation schema according to (Petersen et al. 2015) and how the guidelines are applied

| Phases + Scores (max) | Actions with indication of fulfilment (√ = fulfilled, − = not fulfilled) | Applied actions |
|---|---|---|
| **Need for map** Score: 2 (2) | √ Motivate the need and relevance | Motivation, objectives, and research questions are expressed |
| | √ Define objectives and questions | Needs of project/stakeholders are considered |
| | √ Consult with target audience to define questions | **See details in** Sect. 1 |
| **Study identification** | Choose research strategy | Choose research strategy |
| Scores: | − Snowballing | Multiple databases are searched |
| Search: 1 (2) | √ Manual | Additional manual searches to find review articles and articles addressing the MaaS |
| Eval.: 2 (3) | √ Conduct database search | |
| Extract: 3 (3) | Develop the search | Develop the search |
| | − PICO (Problem/Population, Intervention/ Indicator, Comparison, and Outcome) | A broad search for "all" MaaS publications based on an operationalisation of the research questions |
| | − Consult libraries and experts | Subject areas are excluded to restrict the number of hits |
| | √ Iteratively try finding more relevant papers | Evaluate the search |
| | − Keywords from known papers | Verified that relevant articles identified by previous literature review are found |
| | − Use standards, encyclopaedias, and thesaurus | |
| | Evaluate the search | Inclusion and exclusion |
| | √ Test-set of known papers | Criteria and rules are identified |
| | − Expert evaluates result | Criteria discussed among researchers |
| | − Search webpage of key authors | Rules for decision process are defined |
| | √ Test–retest | • Two independent screenings of each article. A third in case of conflicts |
| | Inclusion and exclusion | |
| | √ Identify objective criteria for decision | **See details in** Sect. 3.1 |
| | √ Add additional reviewer, resolve disagreements between them when needed | |
| | √ Decision rules | |

**Table 5** (continued)

| Phases + Scores (max) | Actions with indication of fulfilment (√ = fulfilled, − = not fulfilled) | Applied actions |
|---|---|---|
| **Data extraction and classification**<br>Score: 3 (3) | Extraction process<br>√ Identify objective criteria for decision<br>√ Obscuring information that could bias<br>√ Add additional reviewer, resolve disagreements between them when needed<br>√ Test–retest<br>Classification scheme<br>√ Research type<br>√ Research method<br>− Venue | Extraction process<br>The coding was evaluated and refined<br>Full text was consulted when needed and available<br>Articles and coding were compared<br>Classification scheme<br>Coding according to topic, research strategy, method, and contribution type<br>**See details in** Sect. 3.2 |
| **Validity discussion**<br>Score: 1 (1) | √ Validity discussion/ limitations provided | Validity/limitations are discussed<br>**See details in Chapter 6** |

*For study identification,* we did, as described in Sect. 3.2, limit the study to articles in scientific databases. We used broad search criteria linked to MaaS in general, and we decided that articles not found were outside our inclusion criteria. The limited development and evaluation of the search is justified by the broad search. Articles on MaaS are to a high degree of certainty identified. To our judgement, this removed the need for new/additional keywords, PICO, use of standards, etc. Relevant articles not mentioning MaaS in title or abstract, are however not found, and this is especially likely to be the case for some articles from 2015 and earlier, since the concept of MaaS was not commonly used before the master theses of (Heikkilä, 2014). It is a challenge to find a search that can identify such articles without having to screen an overwhelming number of articles, and the screening process would be difficult as it is difficult to judge what is MaaS and what is not when MaaS is not mentioned in the abstracts. We do however consider this as a minor problem as the number of early articles is probably low.

As described in Sect. 3.2, the study address articles registered in the scientific databases. As a consequence, relevant articles from several conference and workshop papers, master theses, reports and other "grey literature" are not included. Snowballing would probably have been the best approach to identify such articles, as well as those not mentioning MaaS in the title or abstract, and the lack of snowballing is probably the major weakness of our study. The number of articles included is however already quite high, and snowballing with all these articles as a starting point was considered as too demanding.

406 articles were excluded based on the inclusion and exclusion criteria in Sect. 3.1. Some articles claim to address MaaS even though they focus on just one transport service within one mode, and they discuss specific issues, often technical solutions, related to this individual mode or service. Such services do however not comply with the definition of MaaS in Sect. 1, and based on exclusion criteria E1 and E2, they were excluded.

Mapping studies and literature reviews on MaaS should be systematic. It should be possible to repeat the process and get comparable results, to extend studies with more recent literature, and to judge the strengths and limitations of studies from the described approach. We consider the structured and systematic approach described in Chapter 3 to be reproducible, and the results provided by this study can also be used as a starting point for additional studies.

*For the data extraction and classification phase*, Table 5 shows that we lack a detailed study of the venue. An inspection of the articles does however show that about 5% are books chapters, 31% are conference articles, and 64% are journal papers. The share of journal papers is increasing. 69 of the 123 journal papers are from 2020.

## 7 Conclusion

In this systematic mapping study, we have classified and provided an overview of the MaaS literature, the year 2020 included. 193 articles are included in the study, which provides an overview of the MaaS research area that is more detailed and

complete than previous work. The work is done according to a well-documented and structured article selection and coding process, which ensures good quality of coding schemes and literature mappings. Such a structured process is not described for previous work.

To round up, we summarise how the research questions have been answered and the main contributions from the work.

**RQ1**: **What topics related to MaaS are addressed by publications in scientific channels and how many publications cover the different topics?** The main topics with sub-topics addressed in the MaaS literature have been identified. The topic-related classification schemes define the scope and structure of the MaaS research area, and the MaaS literature has been coded and analysed with respect to these.

**RQ2**: **What are the research strategies used and the type of results provided for the different topics?** Approaches and contribution types have been identified. Topic-independent classification schemes have been defined for type of work, data collection and analysis methods, and contribution types. The MaaS literature has been coded and analysed with respect to these schemes.

Our main contributions from the work related to RQ1 and RQ2 are the *coding schemes, classification of the scientific MaaS literature,* and *analyses of the findings*. The *coding schemes* define the scope of scientific literature on MaaS and the structuring of topics, approaches and contribution types covered. These schemes can support positioning of research in the field of MaaS. The topic-independent coding schemes can also be reused for classification of scientific literature outside the scope of MaaS. The *classification of the scientific MaaS literature* apply the coding schemes to the selected literature. The result can support researchers and others in the discovery of relevant MaaS literature. For example, our research project mentioned in Sect. 1 used the classified literature to select articles for use in more detailed literature studies, for selection of literature to be presented at thematic meetings, and for identification of barriers and requirements of relevance. The *analysis of the findings* regarding topics, approaches, and contribution types provides a summary of the state of the MaaS literature, providing an overview of the distribution of publications over the years. The results from the analysis were used in the analysis of trends and gaps related to RQ3. In addition, all these contributions mentioned above as well as the structured process described are useful for literature reviews on specific MaaS topics and for further mapping studies covering new literature.

**RQ3**: **What are the trends and gaps with respect to research on MaaS?** The trends and gaps have been analysed. This includes trends regarding the "popularity" of sub-topics within each main topics, changes over years, approaches used, and the types of contributions made. For all main topics, gaps needed to be addressed by future research on MaaS have been identified.

Our main contribution from work related to RQ3 is the identification and analyses of *trends and gaps* within MaaS research. The analysis also include gaps in relation to the European Sustainable and Smart Mobility Strategy (EU Commission, 2021). The intention is to enlighten and support further work on MaaS. One of the main gaps we found is that the scientific quality is too low, especially in technical work, and there is a need for more field operational tests and research on operative

Maas services. The gaps in topics covered, can for instance to help select research areas to focus research on. In general, there is a need for more research on MaaS acceptance and user behaviour. There is also a need for coverage of new functionality, e.g. information on environmental footprint during travel planning, support for special needs, rewarding of green behaviour, cross border and multimodal ticketing, MaaS for rural areas, MaaS roaming, and federated MaaS. Technologies like AI should be utilised to provide smarter MaaS services. Data must be more emphasized, e.g. data on mobility pattern, data regulations, data governance, and European data sharing infrastructures and strategies. Passenger rights, and MaaS in relation to transport policies, urban planning and traffic management need more attention. Business models for MaaS must also be reviewed and investigated. Finally, there is a need for research on successful implementations of MaaS, and on a more formalised and coordinated view upon the MaaS ecosystem, e.g. through a MaaS reference architecture.

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**Data availability** The datasets generated and analysed during the current study are included in the articles. Online Appendix A provides the list of articles used as input, and Online Appendix D provides the coding results.

## Declarations

**Conflict of interest** The authors have no relevant financial or non-financial interests to disclose.



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