

## Urban mobility scenarios until the 2030s

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### ABSTRACT

Urban mobility is particularly affected by technology development. This research focuses on the mobility system of cities in the foreseeable future – that is, until the 2030s. A systematic literature review (SLR) of 62 scientific documents and 52 scenarios predicted and developed by researchers are presented here, providing a comprehensive picture of current urban transport research perspectives. Based on a complex method built for this review, four scenarios ('Grumpy old transport', 'At an easy pace', 'Mine is yours', and 'Tech-eager mobility') have been created, each forecasting a different path towards future urban mobility. The scenarios so formed describe the expected role and potential of emerging mobility solutions (namely autonomous vehicles, shared mobility, and electrification) and include socio-economic and environmental perspectives. By 2030, most likely pathways are the 'At an easy pace' or the 'Mine is yours' scenarios, which means that only an incremental advance, such as a slow shift towards self-driving, electric and shared vehicle use is predicted.

### 1. Introduction

While the future of urban mobility seems uncertain, several concepts are generated by new or improved technologies including autonomous vehicles (AVs), electric vehicles (EVs) and the integration of shared mobility services (Burns, 2013; Dia, 2019; Nijkamp & Kourtit, 2013; Schuckmann, Gnatzy, Darkow, & Heiko, 2012). The evolution is constrained by increasing global challenges, such as rapidly changing and diverse consumer demands and urbanization (Brenden, Kristoffersson, & Mattsson, 2017; Zmud, Ecola, Phleps, & Feige, 2013). As a result, there is a growing demand for mobility services, including passenger and freight transport, which leads to severe problems in larger cities, such as congestion and air pollution (Becker et al., 2020; Menezes, Maia, & de Carvalho, 2017; Tromaras, Aggelakakis, Hoppe, Trachsel, & Anoyrkati, 2018). A key challenge facing future urban mobility is to find an effective balance between economic sustainability, environmental regulations, and travellers' satisfaction (Canitez, 2019; Nikitas, Kougiyas, Alyavina, & Njoya Tchouamou, 2017).

Currently, shared mobility is identified as one of the most promising solutions in urban mobility (Nikitas et al., 2017; Shaheen & Chan, 2016; Standing, Standing, & Biermann, 2019) in order to reduce negative

externalities and to raise user satisfaction. Other ways of reducing negative impacts of urban mobility could be a shift towards low and zero-emission modes, enhancing the role of EVs (Csonka & Csizsar, 2017; Ferrero, Perboli, Rosano, & Vesco, 2018; Lee & Erickson, 2017; Yamagata & Seya, 2013), and moderating travel demand (Bohnes, Gregg, & Laurent, 2017; Lah, Fulton, & Arioli, 2019). Reducing the burden on the environment may be achieved by minimizing travel needs (e.g., enabling telecommuting and distance learning, as well as improving and extending online services) and reorganizing the capacities of on-demand services (Liyanage, Dia, Abduljabbar, & Bagloee, 2019). This could work within the framework of the Mobility-as-a-Service (MaaS) concept (Kamargianni, Li, Matyas, & Schäfer, 2016; Kane & Whitehead, 2017; Smith, Sochor, & Karlsson, 2018), which offers mobility services as packages rather than offering access to individual means of transport.

Another promising way to develop urban mobility systems is the spread of AVs (Burns, 2013; Schuckmann et al., 2012; Tromaras et al., 2018). The purpose of automation is to ensure that various processes are carried out with minimum human intervention and in compliance with required cost-effectiveness criteria (Fagnant & Kockelman, 2015). The expected impacts generated by AVs are the increased performance of the

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transport system, for instance, efficient route distribution (Pauer & Török, 2019), safer transport, individual travel options for people without a driving license, increased energy efficiency and improved land use (Fagnant & Kockelman, 2015; Török, Derenda, Zanne, & Zöldy, 2018). The general approach is to think in terms of the highest automation level for vehicles, as defined by SAE (2018), which is usually foreseen for 2040 or rather 2050 (Bagloee, Tavana, Asadi, & Oliver, 2016).

Previous research into new technologies (Kane & Whitehead, 2017; Lyons, 2018; Nikitas et al., 2017; Tromaras et al., 2018) suggest that the implementation of shared solutions and the development of EVs and AVs are the possible drivers of future mobility systems; however, the role of these innovations in future urban mobility is not yet clear. Therefore, it is necessary to synthesize previous research on future mobility and narrow down the potential outcomes.

Accordingly, this paper provides a comprehensive insight into current expectations of researchers concerning future urban mobility. The objective of this research is to better understand what major trends shape urban mobility in the tangible future, i.e., until the 2030s. This has

been translated into three (sub-)questions:

- What are the *technological innovations* that might shape the future of urban mobility?
- What are the *current issues of urban passenger* transport that thematize researchers' forecasts?
- Based on researchers' forecasts (scenarios), what are the *most likely directions for the alteration* in urban passenger transport?

A systematic literature review has been carried out to achieve the objective, paying particular attention to recent scientific literature (published between 2012 and early 2021). Potential transition pathways towards urban mobility and scenarios were identified.

The remainder of the paper is structured as follows. In Section 2, the methodology – the process of SLR, as well as scenario analysing and building – is introduced. Forecasts and scenarios built are presented and discussed in Section 3. Finally, conclusions and limitations are drawn.

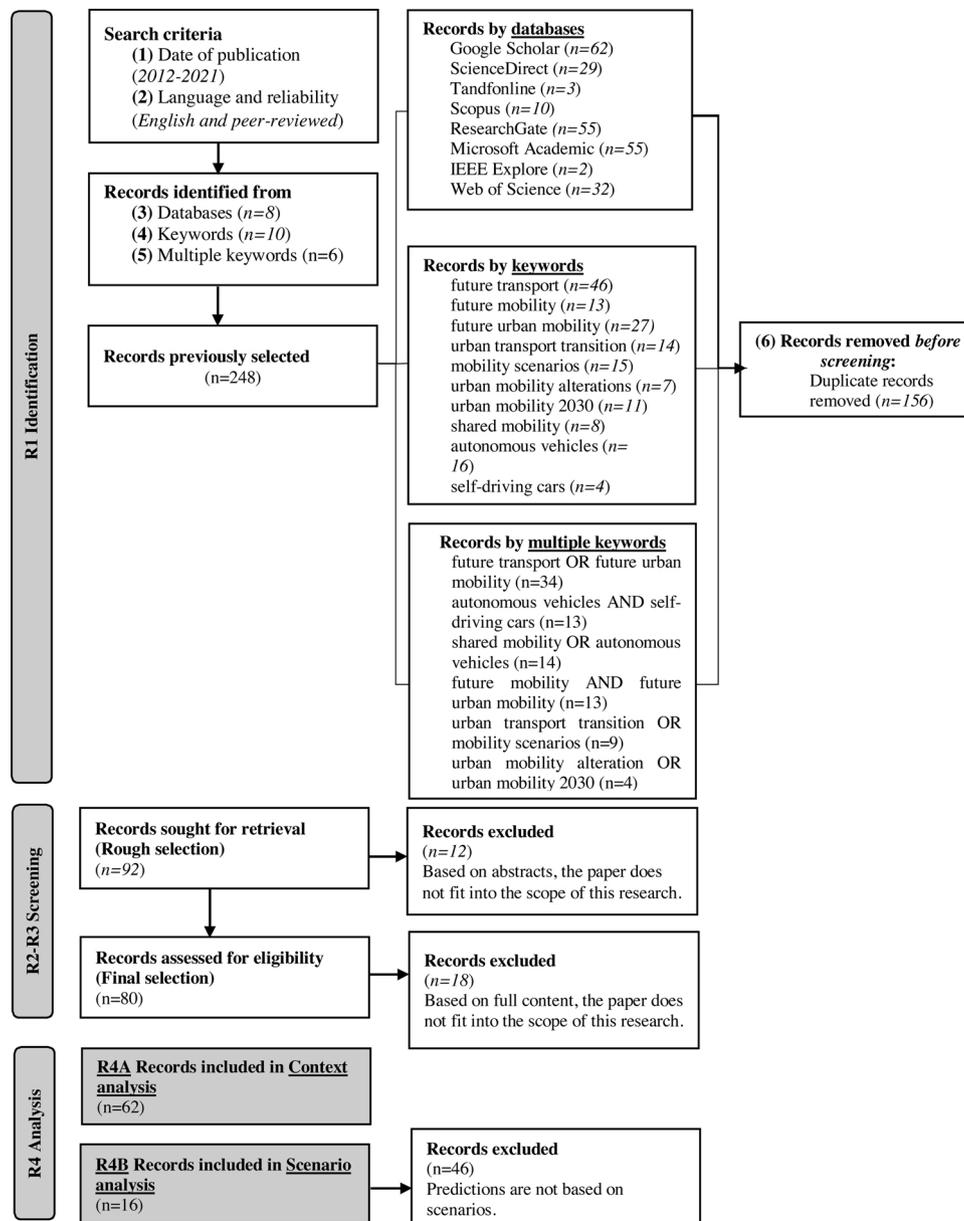


Fig. 1. SLR flow diagram.

## 2. Methodology

To explore the future of the transport sector is challenging, as in addition to technological changes, other aspects, such as user behaviour, policy perspectives and economic constraints also have significant influence. Most researchers have elaborated scenarios using the Delphi method (Jittrapirom et al., 2017; Spickermann, Grientz, & Heiko, 2014) or conducting a literature review (Kamargianni et al., 2016; Sochor, Strömberg, & Karlsson, 2015; Standing et al., 2019).

In this paper, a systematic literature review (SLR) is applied, an exploratory research method to synthesize and critically appraise research into a specific topic according to a pre-defined perspective (Denney & Tewksbury, 2013). SLRs aim to recognize areas that require more consideration from researchers and unify existing concepts. Herein, the SLR is used to analyse trends and scenarios of future urban mobility. Scenarios provide insights into the technological and socio-economic details of alterations as a conceptual proposal and particularly support decision-making in uncertain circumstances, especially for long-term planning (Bishop, Hines, & Collins, 2007; Melander, 2018; Wee & Banister, 2016). The SLR has been carried out following the PRISMA guidelines, an evidence-based set of items for systematic reviews and meta-analyses (Page, McKenzie, & Bossuyt, 2021).

### 2.1. Systematic literature review (SLR) method

Based on the PRISMA framework, a four-step literature analysis method has been elaborated and applied (Fig. 1): identification (R1), screening in 2 phases (R2 and R3), and analysis (R4).

**R1 Identification:** defining the research criteria and conducting a systematic keyword-based search to find papers (for details, see this online Table of records).

- (1) *Date of publication:* defining the time interval. Papers published between 2012 and early 2021 were considered to identify research trends of recent years.
- (2) *Language and reliability:* determining the languages and types of paper. Primarily, papers published in international peer-reviewed scientific journals in English were considered.
- (3) *Database selection:* selecting the search engines. Comprehensive, reliable, and easily accessible databases were selected: Google Scholar, ScienceDirect, Tandfonline, Scopus, ResearchGate, Microsoft Academic, IEEE Explore, Web of Science.
- (4) *Keyword selection:* determining the keywords according to the research objectives: searching papers including urban mobility scenarios or forecasts, and papers relating to urban passenger transport including different system features (especially technological, socio-economic and/or environmental). The following 10 keywords were applied: “future transport”, “future mobility”, “future urban mobility”, “urban transport transition”, “mobility scenarios”, “urban mobility alteration”, “urban mobility 2030”, “shared mobility”, “autonomous vehicles”, “self-driving cars”.
- (5) *Multiple keywords:* determination of keyword-pairs to improve the searching process. Boolean operators were applied: OR searches including similar search terms were conducted to broaden the number of records on future mobility regardless of which term is used in the document, as well as AND searches were run to narrow the search and to capture documents in which both concepts appear.
- (6) *Duplicate records:* removing duplicate records found in several databases. A total of 248 seemingly relevant results were detected in the first step. After organizing the records, duplications (n = 156) were removed, thus 92 papers were included in the first screening (R2).

**R2 Screening based on abstracts (Rough selection):** screening of the identified 92 papers by title and abstract whether they fit in the

scope of the research (to answer RQs). It resulted in the exclusion of 12 papers.

**R3 Screening based on the full content (Final selection):** screening of 80 papers by full text review resulted in the exclusion of 18 papers.

**R4 Qualitative analysis:** two-step analysis of topics and scenarios.

**R4A Context analysis:** an overview of the findings about the future transport in selected papers (n = 62) to explore themes along which scenario analysis (S1 – Thematic scenario analysis – Fig. 2) can be done.

**R4B Scenario analysing and building:** identifying future mobility scenarios. In total, 16 papers included explicit scenarios. These papers have been selected for analysis to formulate complex scenarios.

### 2.2. Scenario analysing and building

In R4, papers including scenarios were further analysed to reveal their basic features (e.g., the similarity of papers, date of publication, methodology applied, geographical scope) (S0). A multi-criteria scenario building method was elaborated (S1-S2) to reveal alternative directions of the future (Fig. 2).

**S0 Synthetization:** analysing the selected papers containing scenarios with the following attributes:

- a *Date of publication:* presenting differences in the interpretation of future mobility trends over time.
- b *Methodology applied:* explaining the reliability and standardization of the results.
- c *Geographical scope:* identifying the regions the results relate to, as well as to clarify the regional issues of each scenario.
- d *Similarity:* determining the similarity of scientific documents. Bibliographic coupling and co-citation analysis are applied to calculate the coupling strength among papers analyzed (Gipp & Beel, 2009). Papers are bibliographically coupled if they cite one or more documents in common (Zhang, Chen, & Li, 2009). In contrast, two papers are co-cited if at least one paper cites both (Gipp & Beel, 2009; Zhang et al., 2009). During step S0, papers with scenarios are examined whether they refer to each other to point correlations between researchers’ perceptions.

**S1 Thematic scenario analysis:** analysing scenarios in terms of themes selected based on the *context analysis* (R4A). A parameter was introduced for *evaluation* (Table 1) to assess the impacts of each theme in each scenario: 1 represents the current stage without relevant changes, 2 promises some (moderate) changes, and 3 indicates an expected future stage with a significant change(s).

Based on this, the evaluation value is  $x_i^j$ ; where  $j$  is the evaluation of key themes (A–F) and  $i$  is the number of scenarios. To determine the aggregated evaluation value of scenarios, the  $x_i^j$  evaluation values are summarized (Eq. 1). Accordingly, aggregated evaluation values (total score) can range from 6 to 18.

$$X^j = \sum_i x_i^j \quad (1)$$

**S2 Scenario building:** in the *Thematic scenario analysis* (S1), key themes are defined to categorize existing scenarios and create new homogenous groups, i.e., comprehensive scenarios based on existing scenarios from the literature. Key themes were selected from the themes that have the strongest influence on urban transport transition. The number of new scenarios depends on the heterogeneity of the existing visions (that is, how many groups can be classified as uniform according to the six themes examined).

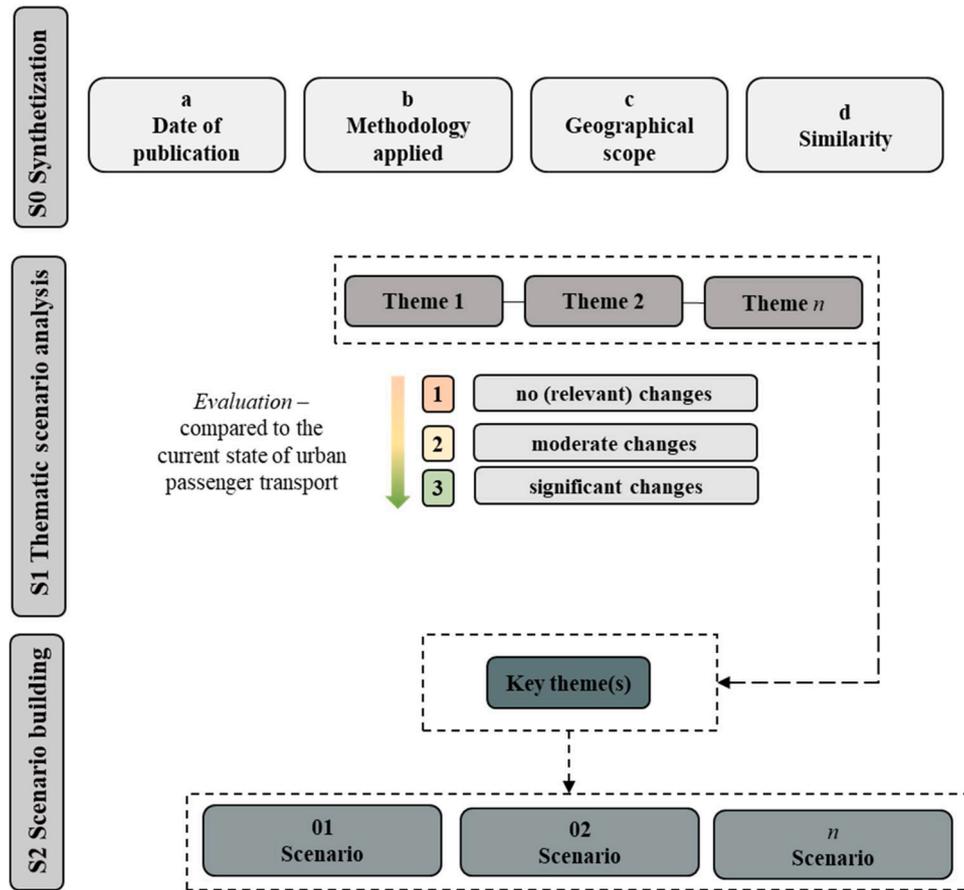


Fig. 2. Scenario analysing and building method.

Table 1  
Evaluation parameter.

$x_i^j$	Meaning	Description
1	current stage without relevant changes	It is stated that the theme does not make a significant change (e.g., <i>the mass public uptake of the technology has not happened</i> ), or its effect is not mentioned.
2	moderate changes	The theme is mentioned and its effects are clearly described (e.g., <i>the spread of the technology is increasing</i> ), but it does not result in radical changes (e.g., <i>conventional means of transport remain essential</i> ).
3	significant changes	The significance of the theme is highlighted (e.g., <i>innovation takes over the role of conventional solutions</i> ).

### 3. Results

#### 3.1. Context analysis

As a result of the literature review, 16 papers contain scenarios and 46 further papers contain forecast trends or particular features of future mobility. In line with the introduction of the present paper providing general overview of current issues and emerging trends, a brief review of these 62 papers is carried out. Mobility-related problems and challenges identified by the papers are as follows:

- Researchers argue that, due to poor performances and the obsolescence of mobility services and vehicles, travel times are increasing (Dia, 2019; McCormick, Anderberg, Coenen, & Neij, 2013; Schuckmann et al., 2012; Wegener, 2013), whilst

consumer satisfaction is decreasing and environmental impacts, particularly *GHG emissions* are worsening (Dong et al., 2018; Schipper, Emanuel, & Oldenziel, 2020; Lyons, 2018; Moradi & Vagnoni, 2018; Waisman, Guivarch, & Lecocq, 2013).

- Social issues, especially *social attitudes*, such as individual beliefs and mobility culture (Bagloee et al., 2016; Bergman, Schwanen, & Sovacool, 2017; Clements & Kockelman, 2017; Madigan, Louw, Wilbrink, Schieben, & Merat, 2017), as well as consumers' mobility-related decisions influenced by economic measures (Manski, 2000; Nijkamp & Kourtit, 2013; Shaheen & Chan, 2016; Standing et al., 2019) were pointed out as significant challenges.
- In the above-mentioned papers, one of the core topics is how to influence users' decision-making to relieve *congestion* and, thus, how to reduce the overload in the urban transport system.

Besides problems and challenges, solutions are also foreseen:

- Several studies (e.g., Currie, 2018; Nikitas et al., 2017; Standing et al., 2019) found that *shared mobility* might be one to face major problems. Intermodal services, MaaS and basic forms of sharing mobility may encourage travellers to dispose their private cars (Liyanage et al., 2019; Madigan et al., 2017; Spickermann et al., 2014). However, some of the papers reviewed (Jittrapirom et al., 2017; Kamargianni et al., 2016; Tokody & Mezei, 2017) underline that the widespread use of shared mobility might have significant social constraints. Furthermore, sharing mobility does not address many of the comfort factors (e.g., driving without any zone restrictions) (Bergman et al., 2017). The integration of AV use into a shared

mobility system or linking it to MaaS is also discussed as a potential solution to mobility problems (Aparicio, 2017; Clements & Kockelman, 2017; Narayan, 2017; Nikitas et al., 2017; Standing et al., 2019; Zawieska & Pieriegud, 2018).

- In general terms, *automation* is considered a tool for creating smart cities and smart mobility (Canitez, 2019; Coppola & Silvestri, 2019; Dey, Fries, & Ahmed, 2018; Pauer & Török, 2019; Seuou, Banissi, & Ubakanma, 2020) and faces several challenges. As regards economic impacts, the increasing adoption of automated technology affects almost every industry (Freudendal-Pedersen, Kesselring, & Servou, 2019; Zawieska & Pieriegud, 2018; Melander, Dubois, Hedvall, &

Lind, 2019, Schoettle and Sivak 2014). Many questions related to technology acceptance, barriers and risks (e.g., moral and legal dilemmas) of driverless cars seem to still be unanswered. The evolution will result in losses in some industries, for instance in employment in the legal profession, in the insurance sector and of professional drivers (Madigan et al., 2017). Moreover, several moral issues, such as re-training redundant workforce or managing human-machine interactions influence the extent of this technology (Bergman et al., 2017; Fagnant & Kockelman, 2015; Török et al., 2018). However, during the transition period and due to the mixed technological scene and the uncertain legal environment, the role of some business

**Table 2**

S0 – Date of publication, methodology applied and geographical scope of scenario-based papers.

Code	Author(s)	No. of scenarios	Scenario	Year	Date of publication	Methodology applied	Geographical scope
P1	Ecola et al.	1	The great reset	2030	2016	expert interviews, cluster analysis	Asia (China)
		2	Slowing but growing				
		3	Wild card - Low probability				
		4	Sub-optimal scenario A				
P2	Kane and Whitehead	5	Sub-optimal scenario B	2030	2017	literature review	Australia
		6	Sub-optimal scenario C				
		7	Sub-optimal scenario D				
P3	Kaufmann and Ravalet	8	Ultramobility	2050	2016	literature review, survey	Europe (France)
		9	Altermobility				
		10	Proxymobility				
P4	Keseru et al.	11	Slow is beautiful	2030	2019	stakeholder interviews	Europe
		12	Data world				
		13	Digital nomads				
		14	Minimum Carbon				
P5	Marletto	15	Auto-city	2030	2014	literature review	Europe (Netherlands)
		16	Eco-city				
P6	Marletto	17	Electri-city	2040	2019	literature review	Europe (Netherlands)
		18	Individual transition pathway				
		19	Shared Transition pathway				
P7	Milakis et al.	20	Smart transition pathway	2030	2017	stakeholder interviews/workshops	Europe (Netherlands)
		21	AV in demand				
		22	AV in doubt				
		23	AV in standby				
P8	Brenden et al.	24	AV in bloom	2030	2017	literature review	Europe (Sweden)
		25	Same same but different				
		26	Follow the path				
		27	Sharing is the new black				
P9	Schippel et al.	28	What you need is what you get	2025	2016	stakeholder interviews/workshops	Europe
		29	Waterberg				
		30	Viga				
		31	Valanov				
P10	Shergold et al.	32	Home ties	2030	2015	expert interviews/workshops	Europe (UK)
		33	Communal Call-out				
		34	Gimme Shelter				
P11	Zmud et al.	35	Home alone and Wired	2030	2013	expert interviews, cluster analysis	Europe
		36	Scenario 1				
P12	Zmud et al.	37	Scenario 2	2030	2014	five-step scenario development based on both quantitative and qualitative (expert opinions) data	United States
		38	No Free Lunch				
		39	Fuelled and Freewheeling				
P13	Banister and Hickman	40	BAU	2030	2013	exploratory research – secondary data analysis	Asia (India - Delhi)
		41	Scenario 1—Lower Carbon Emissions Motor Vehicles 2030				
		42	Scenario 2—Increased Active Travel 2030				
		43	Scenario 3—Towards Sustainable Transport 2030				
P14	Fulton et al.	44	BAU - Limited intervention	2050	2017	exploratory research – secondary data analysis	United States, Europe, Asia (China and Japan)
		45	The 2R Scenario: Electrification and Automation				
		46	The 3R Scenario: Adding Shared Mobility				
P15	Rohr et al.	47	Driving Ahead	2035	2016	Desktop research, expert interviews	Europe (UK)
		48	Live Local				
P16	Julstrup and Uteng	49	Digital Divide	2050	2015	Delphi-method	Europe (Norway)
		50	Controlled mobility				
		51	Technopolis				
		52	Shared mobility				

areas resolving uncertainty (e.g., the legal profession) will increase for a short period (Clements & Kockelman, 2017).

- The future urban mobility predicted is not only shared and autonomous but *electric* (Becker et al., 2020; Csonka & Csiszár, 2017). In that way, sustainability can be delivered (Bohnes et al., 2017; Burns, 2013; Lah et al., 2019; Olsson, Hjalmarsson, Wikström, & Larsson, 2015). However, others (Dong et al., 2018; Fagnant & Kockelman, 2015; Freudendal-Pedersen et al., 2019) call into question the global sustainability of EVs (the environmental impacts of battery production, vehicle life cycle, etc.). Market positioning (Zawieska & Pieriegud, 2018) and service standards (Lopez-Carreiro, Monzon, Lopez, & Lopez-Lambas, 2020) of EVs also come into question. Some researchers (Jittrapirom et al., 2017; Sochor et al., 2015) emphasize that as part of mobility packages, low and zero emission mobility (e.g., human-powered micro-mobility: cycling, scootering, and walking) should dominate.

Based on context analysis, the *themes* selected for the analysis of scenarios (S1-S2) are *automation* (theme A), *shared mobility* (B), *electricification* (C), as well as urban mobility problems to solve: *road congestion* (D), *social attitude* (E) and *GHG emissions* (F).

### 3.2. Scenario analysing and building

**S0 Synthetisation:** Researchers predicted two to four different urban mobility scenarios, allowing us to identify a total of 52 scenarios. Names of authors and basic features (a. *Date of publication*, b. *Methodology applied* and c. *Geographical scope*) of the papers, as well as the list of scenarios and their timespan are shown in Table 2.

d. *Similarity:* only low correlation is detected between some of the scenario-based papers (Table 3). P6 and P16 are bibliographically coupled since they cite P5 in common. P5 and P7 are co-cited since they are cited by P6. P5 and P10 are co-cited since they are cited by P16. In the absence of significant overlaps, a reason for exclusion cannot be identified, therefore, 52 scenarios are analyzed in the next phase (S1).

**S1 Thematic scenario analysis:** interpretation of evaluation values related to *themes* identified in *Context analysis* (R4A) can be seen in Fig. 3.

In line with this, the evaluation of each theme in each scenario was carried out. Table 4 presents the results. The number of squares represents the values of  $x_i^j$  evaluation parameters.

Changes related to automation (A) and shared mobility (B) seem to be the drivers of alterations in future mobility: there are scenarios in which a distinction may be made by the expected level of automation (A) if the total score is relatively high (equal to or above the median of 12) and scores for sharing mobility (B) is above the average. Scenarios

with an overall lower value (below 12) show the same pattern, i.e., the scenarios with the lowest total scores foresee the tangible future without a higher level of automation. This suggests that these are *key themes*, which may determine the clustering of previously created scenarios into new and more comprehensive ones. In other words, by the study of interconnections, values of  $x_i^C$ ;  $x_i^D$ ;  $x_i^E$ ;  $x_i^F$  depend primarily on the alterations of  $x_i^A$  and  $x_i^B$ .

**S2 Scenario building:** Based on S1, four categories may have been distinguished (Table 5).

In scenarios in category I ( $X_i \leq 7$ ) researchers (Brenden et al., 2017; Banister & Hickman, 2013; Fulton, Mason, & Meroux, 2017; Marletto, 2014, 2019; Milakis, Snelder, van Arem, van Wee, & de Almeida Correia, 2017; Shergold, Lyons, & Hubers, 2015; Zmud et al., 2013; Zmud, Phleps, & Ecola, 2014) forecast potential realities without AVs and predict almost the same state of vehicle ownership and road transport dominance as nowadays ( $x_i^B = 1$ ). This is attached to lack of improvements in terms of the level of congestion ( $x_i^D = 1$ ) and environmental problems ( $x_i^E = 1$ ). Only a slight further development and spread of electric vehicles can be detected in these scenarios. These scenarios predict potential future urban mobility in Europe, some of them particularly in the Netherlands (Milakis et al., 2017), Sweden (Brenden et al., 2017), Norway (Julsrud & Uteng, 2015) and outside Europe (Asia – Banister & Hickman, 2013; in the United States – Fulton et al., 2017; Zmud et al., 2014)). In sum, this is the category of a traditional transport system with no significant changes, hereinafter it is named scenario *Grumpy old transport*.

Scenarios in category II ( $8 \leq X_i \leq 11$ ) describe a minimal transformative change (i.e., a slow or moderate reduction of existing urban transport problems) (Banister & Hickman, 2013; Brenden et al., 2017; Fulton et al., 2017; Kane & Whitehead, 2017; Shergold et al., 2015; Zmud et al., 2013; Zmud et al., 2014); Julsrud & Uteng, 2015; Rohr et al., 2016). In addition, a moderate development of automation ( $x_i^A = 2$ ) and spreading of sharing are expected. The geographical scope of slow transition scenarios is mainly Europe, but some scenarios refer to Asia (Zmud et al., 2013; Banister & Hickman, 2013) and the United States (Fulton et al., 2017; Zmud et al., 2014)). This is the category of a traditional transport system with a moderate or slow transition towards automation and shared vehicle use, hereinafter this is the scenario *At an easy pace*.

Reducing the number of privately used vehicles plays a key role in scenarios in category III ( $12 \leq X_i \leq 14$ ) (Banister & Hickman, 2013; Ecola, Zmud, Gu, Phleps, & Feige, 2016; Julsrud & Uteng, 2015; Kane & Whitehead, 2017; Kaufmann & Ravalet, 2016; Keseru et al., 2019; Rohr et al., 2016; Shergold et al., 2015; Schippl et al., 2016). The increasing role of shared mobility ( $x_i^B = 3$ ) is predicted. Shared mobility scenarios are considered for Europe and, in two cases, Asia (China – Ecola et al.,

**Table 3**  
S0 – Reference-reference matrix of scenario-based papers.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
P1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P2	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
P3	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
P4	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
P5	0	0	0	0		1	0	0	0	0	0	0	0	0	0	1
P6	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0
P7	0	0	0	0	0	1		0	0	0	0	0	0	0	0	0
P8	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
P9	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0
P10	0	0	0	0	0	0	0	0	0		0	0	0	0	0	1
P11	1	0	0	0	0	0	0	0	0	1		0	0	0	0	0
P12	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
P13	0	0	0	0	0	0	0	0	0	0	0	1		0	0	0
P14	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0
P15	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
P16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

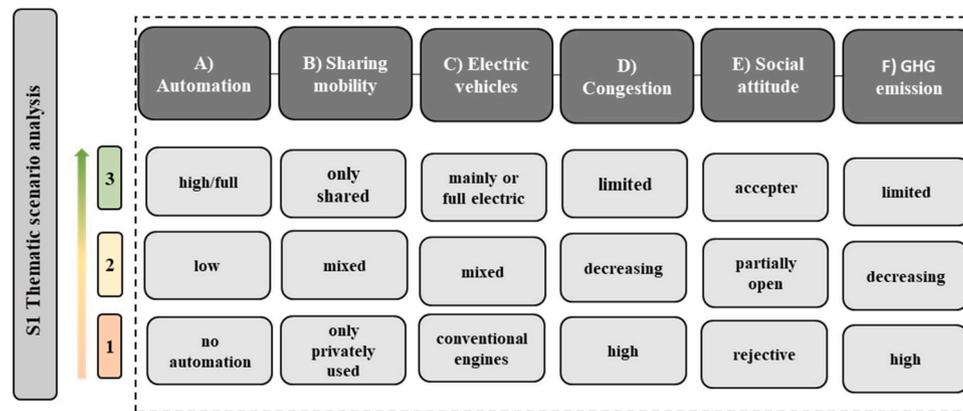


Fig. 3. Scenario analysing and building method – Phase S1.

2016; India – Banister & Hickman, 2013). Most researchers analyse the role of automation in the context of shared mobility, but some scholars (Ecola et al., 2016; Keseru, Coosemans, & Macharis, 2019) predict unchanged levels of automation ( $x_i^A = 1$ ). Social attitudes are slightly or largely changing ( $2 \leq x_i^E \leq 3$ ). In other words, this is the category with a vision of a radical shift towards sharing mobility with a low penetration of automation, hereinafter this is the scenario *Mine is yours*.

Scenarios in category IV ( $15 \leq X' \leq 18$ ) forecast a highly advanced system. The two main characteristics are the prominent role of high automation and shared mobility ( $x_i^A = 3$ ;  $x_i^B = 3$ ) (Brenden et al., 2017; Banister & Hickman, 2013; Fulton et al., 2017; Marletto, 2019; Milakis et al., 2017; Rohr et al., 2016). These visions provide a largely changed picture of future mobility as, due to the emergence of electric propulsions ( $2 \leq x_i^C \leq 3$ ), automation and sharing, environmental problems are widely resolved ( $2 \leq x_i^F \leq 3$ ). Alongside Europe and Asia (Banister & Hickman, 2013), a vision for Australia has also appeared (Kane & Whitehead, 2017). This is the vision of the dominance of sharing-based transport solutions with a high level of automation, hereinafter this is the scenario *Tech-eager mobility*.

### 3.3. General characteristics of scenarios

The proportion in terms of the number of existing scenarios included of the scenarios formulated indicates their relevance: 'Mine is yours' shows 35 %, 'Grumpy old transport' 19 %, 'Tech-eager mobility' 17 % and 'At an easy pace' 29 %. Although the analysis is merely qualitative, shared mobility is suggested to shape urban mobility transition in the future. However, the proportion of scenario 'Grumpy old transport' is also significant whilst forecasting no transformative changes.

The period analysed in the existing scenarios is diverse, therefore, the uncertainty of predictions regarding tangible future (the 2030s) is relatively high. Among the scenarios for 2030, the proportion of scenarios formulated presents minimal alteration. The dominance of 'Mine is yours' remains remarkable (35 % of the visions belong to this group), but the importance of 'Grumpy old transport' declines to 18 %, and the proportion of 'Tech-Eager mobility' is slightly higher (18 %).

Publication dates of scenarios are summarized in Fig. 4. Over the last few years, a remarkable shift in findings can be seen. The results show that the role of the scenarios supporting the 'Grumpy old transport' future was greater in the earlier publications than after 2016. Scenarios forecasting future potentials of shared mobility is nearly equally relevant in the analysed years. Visions related to 'Tech-eager mobility' only appear in post-2016 literature.

### 3.4. Description of scenarios

The scenarios formulated are described in terms of mobility

challenges and socio-economic issues, as follows.

#### 3.4.1. Grumpy old transport

The Grumpy old transport scenario forecasts an urban transport system very similar to the current one, in which the use of privately-owned cars is the most conventional way of private mobility (Banister & Hickman, 2013; Milakis et al., 2017; Zmud et al., 2014). Shared mobility services are attractive only to a narrow segment (Fulton et al., 2017; Julsrud & Uteng, 2015)). The dominant groups are generation Y and Z, and the use of shared services is not expected to become widespread (Brenden et al., 2017; Marletto, 2014, 2019). Even with automation developments, no breakthrough is expected, and the sale of vehicles at the current automation level (SAE 2 or 3) remains constant (Fulton et al., 2017; Zmud et al., 2013)).

**3.4.1.1. Challenges in transport.** Due to private car ownership, the level of vehicle kilometers travelled increases, and overcrowded roads continue to be a common issue (Banister & Hickman, 2013; Milakis et al., 2017; Zmud et al., 2014). The 'ever-increasing' presence of private cars contributes to congestion, whilst inadequate infrastructure and obsolete mobility services (public transport with no serious innovation) make passenger transport difficult in larger cities. The basic capacity of the urban transport system is further strained by urbanization processes (Milakis et al., 2017). Due to excessive traffic, the burden on the environment caused by industry continues to grow (Marletto, 2014, 2019). If this scenario is realised, the contribution of the transport sector to environmental pollution will be challenging.

**3.4.1.2. Socio-economic factors.** In general, slow transition is mainly due to consumer behaviour. Travellers prefer convenience-oriented ways of fulfilling mobility needs (Fulton et al., 2017)). Comfortable, seamless mobility, even with the negative effects of congestion, seems to be dependent on using cars (Brenden et al., 2017; Zmud et al., 2013). Individual car ownership is consistently regarded as a status symbol in many countries, and travellers consider shared mobility as a useful possibility only until they can afford to own a car (Fulton et al., 2017; Milakis et al., 2017). Lack of communication between stakeholders and decreasing 'coopetition' are typical. Due to consumers' reluctance, the government and transport companies do not see any major benefits from the rapid improvement of mobility services. Progressive legislation and supportive policies are lacking, so the rise of any innovative mobility solutions is dismissed; automation is available for only the elite class (Fulton et al., 2017; Zmud et al., 2013)).

#### 3.4.2. At an easy pace

In this scenario, some moderate changes can be detected. Although the dominant transport mode remains privately-owned cars (complemented by public transport) (Brenden et al., 2017; Zmud et al.,

**Table 4**  
Evaluation of scenarios by themes.

i	Scenario	$x_i^j$						Xi
		A	B	C	D	E	F	
18	Individual transition pathway	1	1	1	1	1	1	6
36	Scenario 1	1	1	1	1	1	1	6
15	Auto-city	1	1	1	1	1	1	6
31	Valanov	1	1	1	1	1	1	6
39	Fuelled and Freewheeling	1	1	1	1	1	1	6
44	BAU - Limited intervention	1	1	1	1	1	1	6
25	Same same but different	1	1	2	1	1	1	7
21	AV in demand	1	1	2	1	1	1	7
40	BAU	1	2	1	1	1	1	7
50	Controlled mobility	1	1	2	1	1	1	7
22	AV in doubt	2	1	2	1	1	1	8
23	AV in standby	2	1	1	1	1	2	8
32	Home ties	2	1	1	1	2	1	8
4	Sub-optimal scenario A	2	1	1	1	2	2	9
8	Ultramobility	2	1	1	1	2	2	9
45	The 2R Scenario: Electrification and Automation	2	1	2	2	1	1	9
51	Technopolis	2	1	1	1	2	2	9
1	The great reset	2	1	2	2	1	2	10
34	Gimme Shelter	2	1	1	2	2	2	10
38	No Free Lunch	2	1	2	1	2	2	10
48	Live Local	2	1	1	2	2	2	10
26	Follow the path	2	1	2	2	2	2	11
29	Waterberg	2	1	2	2	2	2	11
33	Communal Call-out	2	1	2	2	2	2	11
35	Home alone and Wired	1	3	1	2	3	2	12
11	Slow is beautiful	1	3	1	2	3	2	12
9	Altermobility	1	3	1	3	2	2	12
41	Scenario 1—Lower Carbon Emissions Motor Vehicles 2030	2	1	2	2	2	2	11
10	Proxymobility	1	3	1	3	2	3	13
16	Eco-city	1	3	3	2	2	2	13
27	Sharing is the new black	1	3	2	2	3	2	13
37	Scenario 2	1	3	3	2	2	2	13
42	Scenario 2—Increased Active Travel 2030	1	3	3	2	2	2	13
17	Electri-city	1	3	3	2	2	3	14
30	Viga	1	3	3	2	2	3	14
6	Sub-optimal scenario C	1	3	3	2	2	3	14
19	Shared Transition pathway	1	3	3	2	3	2	14
2	Slowing but growing	1	3	2	2	2	3	14
12	Data world	1	3	3	2	2	3	14
52	Shared mobility	1	3	2	2	3	3	14
13	Digital nomads	3	3	2	2	3	2	15
28	What you need is what you get	3	3	3	2	2	2	15
43	Scenario 3—Towards Sustainable Transport 2030	1	3	3	3	3	3	16
46	The 3R Scenario: Adding Shared Mobility	3	3	2	2	3	3	16
47	Driving Ahead	3	3	2	3	2	2	15
49	Digital Divide	3	3	2	2	3	3	16
3	Wild card - Low probability	3	3	2	3	3	3	17
5	Sub-optimal scenario B	3	3	3	2	3	3	17
14	Minimum Carbon	3	3	3	3	3	3	18
24	AV in bloom	3	3	3	3	3	3	18
7	Sub-optimal scenario D	3	3	3	3	3	3	18
20	Smart transition pathway	3	3	3	3	3	3	18

Legend:  $x_i^j = 1$  current stage without relevant changes, 2 moderate changes, 3 significant changes.

2013), progress towards change in vehicle propulsion varies. The role of EVs is increasing significantly, but, at the same time, the role of shared mobility is improving slowly (Kane & Whitehead, 2017; Shergold et al., 2015). Further, the spread of automation is slow, and faster development is expected only in the USA (Fulton et al., 2017; Zmud et al., 2014), China and Japan (Fulton et al., 2017); Banister & Hickman, 2013). Due to excessive use of cars, environmental and traffic problems remain serious and unsolved.

3.4.2.1. *Challenges in transport.* Transport problems continue to be

significant, but some measures strive to reduce their impacts. Zone restrictions are introduced to mitigate congestion in urban traffic. Some forms of employment, such as flexitime, home-office and the emergence of home-based positions are able to reduce the amount of travel required. This would also result in a slight reduction in congestion (Banister & Hickman, 2013; Zmud et al., 2013). Due to the increase in the use of EVs, GHG emissions are less likely to increase (Brenden et al., 2017; Julsrud & Uteng, 2015).

3.4.2.2. *Socio-economic impacts.* Leading players in industry are still the oil companies and car manufacturers (Zmud et al., 2013, 2014). The market share of electric and self-driving car manufacturers is expected to grow (Fulton et al., 2017; Rohr et al., 2016)). Willingness to change mobility habits is increasing, but not explicitly towards sustainable modes. Due to general improvement in living standards, more and more people can afford to buy a car (Julsrud & Uteng, 2015; Shergold et al., 2015). The need for comfortable and meaningful travel is growing, other options are used only when there is no alternative.

3.4.3. *Mine is yours*

In this scenario, major changes may be predicted. The sharing-based economy business model has immense market-shaping power (Julsrud & Uteng, 2015; Schippl et al., 2016). The role of shared mobility dominates transport modes. Further, the spread of EVs and the decline of the manufacture of vehicles with traditional propulsion are typical (Kaufmann & Ravalet, 2016; Keseru et al., 2019). The large-scale development of automation does not appear. Shared mobility and EVs reduce some traffic problems and the negative impact of transport on environment is diminished (Ecola et al., 2016; Shergold et al., 2015).

3.4.3.1. *Challenges in transport.* The increase of shared mobility reduces transport problems (Julsrud & Uteng, 2015; Schippl et al., 2016). In addition, other modes, such as public transport, cycling and walking are integrated, enabling door-to-door travel. The importance of alternative micro-mobility vehicles (e.g., e-bikes and e-scooters) is also increasing (Ecola et al., 2016; India – Banister & Hickman, 2013). To establish high-quality and integrated solutions, significant developments in rail and public transport services are needed (Kane & Whitehead, 2017; Rohr et al., 2016). The role of private cars has hugely decreased. To minimize carbon emissions, urban traffic is shaped by strong regulations: car-free areas as well as zero-emission zones are created (Ecola et al., 2016; Shergold et al., 2015).

3.4.3.2. *Socio-economic impacts.* A significant proportion of commuters uses shared vehicles; however, the role of public transport is further reinforced (Ecola et al., 2016; Keseru et al., 2019). This can be achieved through major infrastructure and service improvements (for instance, by the implementation of MaaS). In addition to traditional industry players, car-sharing and ride-sourcing companies become more powerful and the role of producers of EVs is growing, whilst oil company penetration is minimized (Ecola et al., 2016; Kane & Whitehead, 2017). Users accept the alterations, prefer sharing economy solutions; they become open to new mobility options, and less and less eager to owning cars (Banister & Hickman, 2013; Julsrud & Uteng, 2015). Consequently, several automotive companies may leave the market. The environmental consciousness of the whole of society increases, resulting in a decreased need for mobility (Kane & Whitehead, 2017; Shergold et al., 2015). Due to strong individualization and flexible employment, the boundaries between private life and work disappear, but this benefits the transport sector. Travellers can reduce travel demand to decrease travel time and costs, and this attitude can greatly relieve the already optimized transport system (Ecola et al., 2016; Kaufmann & Ravalet, 2016; Keseru et al., 2019).

**Table 5**  
Identification of categories based on evaluation values.

No.	Aggregated evaluation value	Evaluation value $X_i^j$						Description
		j = A	j = B	j = C	j = D	j = E	j = F	
I	$6 \leq X_i \leq 7$	1	1	$\leq 2$	1	1	1	Most of the themes indicate a constant state, except Electrification (C), which may indicate a slight advance.
II	$8 \leq X_i \leq 11$	2	1	$\leq 2$	$\leq 2$	$\leq 2$	$\leq 2$	A slight development of Automation (A) is foreseen in each case, without changes in Sharing mobility (B). No significant changes are foreseen in other themes (at least one of them indicate moderate changes).
III	$12 \leq X_i \leq 14$	1	3	$2 \leq C \leq 3$	Automation (A) indicates no development, while Sharing mobility (B) is going to highly dominate. Other themes indicate some development, incl. the value of 3 in one or two of them.			
IV	$15 \leq X_i \leq 18$	3	3	$2 \leq C \leq 3$	$2 \leq C \leq 3$	3	$2 \leq C \leq 3$	Automation (A), Shared mobility (B) and Social attitude (E) indicate significant changes in each case and one or two further themes promise moderate changes.

Legend: A = Automation, B = Shared mobility, C = Electric vehicles, D = Congestion, E = Social attitude, F = GHG emission.

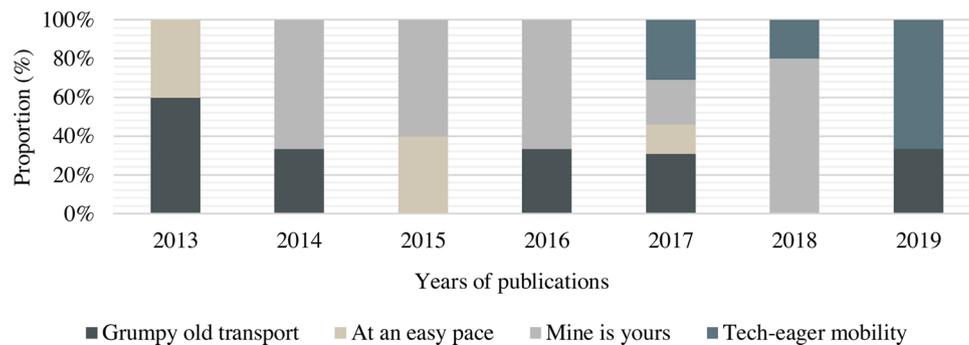


Fig. 4. Years of publications.

3.4.4. Tech-eager mobility

This scenario predicts the most intense transition. Technological advances affect the transport process as well as travel behaviour. Vehicles with a high level of automation will have become widely available. AVs and EVs go hand-in-hand; both technologies are highly advanced, strengthening each other’s market position (Marletto, 2019; Milakis et al., 2017). However, public transport remains one of the most effective means of transport. Transport is completely environmental-friendly and traffic problems are minimized owing to shared and autonomous vehicles (Brenden et al., 2017; Milakis et al., 2017).

3.4.4.1. Challenges in transport. Although AVs are widespread, transport is predicted more likely to be mixed in the near future when conventional and autonomous vehicles run on the same road at the same time (Marletto, 2019; Milakis et al., 2017). AVs are connected, resulting in optimised traffic flow, travel time and minimised congestion. Even though total kilometers travelled increase, the transport infrastructure is not overloaded, as a consequence of the shared use of AVs (Brenden et al., 2017; Milakis et al., 2017). In addition, the role of public transport remains significant, although its importance is somewhat reduced as a consequence of shared mobility services, especially in last-kilometer travel. Even if travellers use AVs in a non-sharing form, the number of cars per household is also likely to decline, as only one AV can meet the needs of a whole family (Banister & Hickman, 2013; Fulton et al., 2017; Rohr et al., 2016). The spreading of AVs may also contribute to land use change. As less parking space is needed, current parking lots can be used for other purposes (e.g., green areas, non-motorized transport modes). Pedestrian traffic has also increasing importance due to the reorganization of the infrastructure (Rohr et al., 2016; Kane & Whitehead, 2017). As a consequence, the impact of transport on the environment is reduced.

3.4.4.2. Socio-economic factors. The market is dominated by EV and AV manufacturers and sharing companies in cooperation with public transport (Marletto, 2019; Milakis et al., 2017). Supportive policies allow the smooth application of technology. Changes predicted have the greatest impact on travel behaviour. Travellers switch to low emission mobility forms; they are less likely to own cars and even be licensed drivers (Brenden et al., 2017; Fulton et al., 2017)). They appreciate integrated and ICT-based mobility solutions (MaaS applications, e-ticketing, real-time information, etc.). Moreover, the productivity of travellers is increased using AVs (Fulton et al., 2017; Kane & Whitehead, 2017; Rohr et al., 2016)). The divide between private and professional spheres could be blurred; employees can work from anywhere without wasting time driving a car (Marletto, 2019; Milakis et al., 2017). Overall optimal time control reduces the need for fast transport, which can positively influence users’ perception of each transport mode.

4. Conclusion

In this paper, the methods and outcomes of a literature review concerning the tangible future (until the 2030s) of urban mobility are summarized. With a systematic literature review, employing 10 keywords and 8 search engines, 62 recently published papers discussing the emerging trends and the innovations of the future of urban mobility have been analysed. In sum, 52 scenarios outlining the possible future state of mobility have been identified and evaluated by a complex method. Based on the context analysis, a multi-criteria scenario analysis with six themes (role of automation, sharing mobility, electric vehicles, congestions, GHG emissions and social attitudes) that, according to the literature, significantly affect the future paths of urban mobility, has been applied. On this basis, answers to the research questions posed in the Introduction are as follows:

- Based on context analysis, *the spread of shared mobility solutions, electrification, and automation of vehicles are the technological solutions that shape the future of urban mobility*. Scenario analysis proved that key themes are shared mobility and automation along which four distinguishable directions of alteration (scenarios) are created for 2030.
- Based on the context and scenario analysis, *opportunities to reduce GHG emissions, road traffic congestion, and travelers' ambivalent attitudes are the key current issues that thematize current transportation research*.
- Based on the SLR, 52 scenarios have been identified in the literature that can be arranged in a matrix in line with the key themes (progress of automation and spread of shared mobility services). As result, four scenarios that synthesize researchers' current forecasts have been formed: 'Grumpy old transport', 'At an easy pace', 'Mine is yours', 'Tech-eager mobility'. The scenario 'Tech-eager mobility' is dominated by sharing-based transport solutions with a high level of automation. The scenario 'Mine is yours' is led by sharing mobility with low penetration of AVs. The scenario 'At an easy pace' is based on traditional transport modes with slow transition towards shared mobility and the massive use of AVs. And the scenario 'Grumpy old transport' represents no relevant changes. Based on the scenarios formed, the transition towards higher automation and shared mobility will be rather slow. *By the 2030s, the most likely scenarios are 'At an easy pace' and 'Mine is yours'. This means that only an incremental advance, such as a slow shift towards self-driving, electric and shared vehicle use can be predicted.*

It has to be underlined here that due to the limited number of papers presenting future mobility scenarios, only 16 scientific papers could be used to identify complex scenarios. Other key limitations of this study are different scope, timeframe, aims, and methods applied in the papers analysed.

Bearing this in mind, the next step of this research is the review of other sources, particularly the visions of urban and mobility planners (e. g., in the standardised approach in sustainable urban mobility plans provided by common European guidelines) to understand what professionals forecast. Furthermore, as social aspects are significant in the spread of urban mobility innovations, another research direction is modelling the factors influencing the acceptance of emerging mobility solutions. Moreover, the recent impact of the COVID-19 crisis indicates that previous assumptions and mobility planning criteria need to be reconsidered. This suggests that the research community quickly has to formulate new scenarios or identify potential mobility pathways to let decision-makers reconsider policies that are the basis of financial programs for the upcoming years.

#### CRediT authorship contribution statement

**Márk Miskolczi:** Conceptualization, Methodology, Data analysis, Visualisation, Writing – original draft, Writing – review & editing. **Dávid Földes:** Conceptualization, Methodology, Validation, Writing – review & editing. **András Munkácsy:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Melinda Jászberényi:** Conceptualization, Supervision, Writing – review.

#### Declaration of competing interest

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

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