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Framework for connecting the mobility challenges in low density areas to smart mobility solutions: the case study of Estonian municipalities

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Abstract

Innovation in mobility is proceeding at fast pace, the future disrupting technologies ranging from automation and connectivity to micro-mobility and electric propulsion. This research effort is justified by the impressive array of challenges that urban centres will face in the following decades, such as ageing population, urbanization and pollution. It is therefore understandable why the concept of Smart City is being researched and the major cities around the world are already carrying out trials for Smart Mobility Solutions. Still this trend, as many others, is not evenly spread but follows the urban/rural divide characterizing many of the current socio-economical phenomena. This paper, following the principles of responsible innovation, tries to build the case for a renewed research effort about smart mobility in low density areas. This is accomplished by presenting the results of a wide surveying effort across Estonian municipalities, focusing on the outputs from rural and small suburban centres. The results report what are the main mobility challenges across the region and what hindering factors are preventing envisioned solutions. Finally, the paper ties the identified mobility challenges to available Smart Mobility Solutions that arose from the surveying activity and from literature, assessing both feasibility and transferability.

Keywords: Transport policy, Low density areas, Smart mobility, Mobility as a service, Demand responsive transport, Case study

1 Introduction

To guarantee that the urbanization trend common to most areas of the globe will be sustainable [1], technological solutions are arising at a fast pace. In the transport domain these are usually referred as Smart Mobility Solutions (SMS). Still, most of these aim to meet certain objectives and to solve challenges in specific environments. As a result, their implementation context is usually still ambiguous Gross-Fengels & Fromhold-Eisebith [2] or very narrow, which makes transferability hard to

assess. Besides, as it will be showed in the paper, the state of the art of SMS in LDA (low density areas) setting is still scarce, since the majority of the SMS are developed and tested in urban settings. This makes it even harder to upscale the literature findings from the reported implementation context to more general case studies.

In Europe, small or rural communities and rural areas constitute 27% of the population. Such communities suffer from untackled issues concerning accessibility to work, education, health and other services Lorenzini

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et al. [3], Shergold et al. [4]. These challenges come with financial and political constraints in providing an equal public service infrastructure for communities with low population levels. Indeed, as many other socio-economical processes, SMS implementations are characterized by two different speeds, arisen across the urban–rural divide. As a consequence, the opportunity provided by smart mobility solutions are being currently designed and tested mostly in a Smart City context Cowie et al. [5], Bosworth et al. [6], Mounce et al. [7]. On the other hand, as argued by Gross-Fengels & Fromhold-Eisebith [2], low density areas, i.e. municipalities with less than 50,000 residents,¹ can also benefit from it. According to Gross-Fengels & Fromhold-Eisebith [2], smart mobility in rural areas can also contribute to broader societal goals ranging from employment and entrepreneurship to economic, social and sustainability strategies. Yet, rural and smaller suburban municipalities face specific challenges that would call for tailored SMS solutions.

The aim of the paper is to answer to the following research questions for the Estonian case study:

- Literature calls for "tailored" Smart Mobility for less populated areas, what are the current challenges that these currently face and which solution(s) does the literature provide?
- What are the main hindering factors and how do they impact the feasibility of existing solutions in LDA?

Estonia was selected for this analysis as a country where most municipalities are small or very small in the global context. Estonia is a very small country by population (1.3 M) and was selected as a majority of its 79 municipalities are not densely populated (75 municipalities have population smaller than 50,000).

By reporting the results of a surveying activity carried out across 35 Estonian municipalities, the paper highlights these specificities and builds a case for a renewed focus on the subject. The reported challenges are analysed on the basis of the identified hindering factors and of the LDA's features, they are then compared against available SMS solutions. The results allow to single out the challenges that are not met by any SMS and the ones that, even if met, are not feasible due to hindering factors specific of LDA.

The paper is structured as it follows: in Sect. 2, a literature review is carried out (on policy, smart mobility

solutions and DRT), limited to LDA; in Sect. 3 an overview of the process exploited to carry out the analysis is provided and the resulting framework is described; in Sect. 4, the Estonian background is detailed. In Sect. 5, the results are reported while Sect. 6 presents the authors' discussion and conclusions.

2 Literature review

2.1 Policy landscape for LDA

Mounce et al. [7, 8] analyzed the interplay between the role of governments in supporting transport services and the degree of rurality across Europe. However, after clustering European countries into four, they did not find a strong relationship between rurality and support for rural mobility. Rather recently, the European Commission has started to pay more attention to LDA via Sustainable Urban Mobility Plan (SUMP) framework.² According to this SUMP, smaller municipalities (e.g. population of 10,000–100,000) have less financial and human resources and tend to have a stronger car-dependency and weaker public transport. LDA also tend to have well-connected social communities with more walkable and bikeable routes. On the other hand, SMS themselves can change policy environment Akyelken et al. [9], Audouin & Finger [10], Docherty et al. [11].

In addition, Audouin & Finger [10] have adapted the multi-level governance (MLG) analytical framework with Local, Metropolitan and National levels to study the MaaS commercial solution in the Helsinki Metropolitan Area; this framework also includes the Multinational level in other studies (e.g. Scholten et al. [12]). This paper adopts a MLG framework when analyzing the challenges of local governments in Estonia through three classes: local, local and national or local, national and multinational level.

2.2 Smart land & smart mobility systems

SMS tailored for LDA are rare, in the following an overview of the state of the art is provided.

Bosworth et al. [6] analyzed the mobility needs identified by stakeholders in rural UK. Businesses and citizens were involved to identify the mobility needs. Then, SMS were identified and validated against the rural stakeholders. Car-pooling and -sharing schemas were mentioned in tandem with real time data and electronic micropayments. According to the findings, the services with the highest potential are micro-mobility ones. Bosworth et al. [6] also analyzed the MaaS social hub, where local transport is integrated with the broader network.

¹ According to OECD and Eurostat, a city is expected to have a minimum urban population of 50 000 residents (<https://ec.europa.eu/eurostat/web/cities/spatial-units>; <https://data.oecd.org/popregion/urban-population-by-city-size.htm>) [39, 40].

² <https://www.eltis.org/in-brief/news/new-sump-topic-guide-smaller-cities-and-towns> [41].

Finally, Bosworth et al. [6] identified the lack of an IoT infrastructure in LDAs as one of the structural barriers against SMSs.

Cowie et al. [5] advocated for a responsible rural research innovation approach and describes the limits specific to rural areas for CAVs technologies, smart grids and IoT. Gross-Fengels & Fromhold-Eisebith [2] argued that SMS might transform rural areas, if tailored on the new case studies and are not just transferred from the urban setting. It provides a list of both hindering and promoting factors at various level. A fostering factor is for example the ability to encourage local collaborations in a simpler manner due to the lower number of players and to the community led relationships. Still the lack of physical and digital infrastructure makes softer SMS (e.g., micro-mobility) better suited for these experiences. An example is the Mitfahrbank, a public bench equipped to indicate the intended travel direction, for potential co-riding partners to stop and offer a lift Gross-Fengels & Fromhold-Eisebith [2].

Mounce et al. [7] reported a cluster analysis identifying financial and policy frameworks across Europe supporting rural transport services. It provides best practices for implementations related to ICT, intermodal service coordination, DRT, shared mobility and good governance.

Tollis et al. [13] presented an analysis of the mobility projects carried out in LDA in France stating how peri urban and rural areas are lagging behind in terms of designed SMS. Similar hypotheses may be found in Zavratnik et al. [14], Hensher [15].

Hensher [15] explored a bus-based point-via-point-to-point service integrated with a traditional bus service as MaaS. Porru et al. [16] provided an analysis of a flexible bus services focusing on policy applications and requirements. It is one of the few studies evaluating LDA and IoT applications. A list of Smart Mobility project is also provided, three of which are dedicated to rural transport.

Vishwanath et al. [17] focused on suburban case studies and flexible public transport instead. An economic assessment is provided as well, even though the degree of detail is limited by the lack of real-world data. The described multimodal fleet would need smart data usage and a MaaS like structure to be viable.

Banister [18] described the possibilities granted by emerging technologies related to flexible transport system, such as: advanced mathematical optimization methods, database techniques and fuzzy logic analyses for decision making. Bruzzone et al. [19] advocated instead for further simulation studies for more precise analyses. Still, these activities require highly specialized workforce while one of the barriers against the deployment of SMS in LDA is the lack of such specific skillsets at disposal. This lack of skillset is indeed one of the main hindering

factors arising from the surveying work reported in Sect. 5.

DRT coupled with an e-bike service was implemented in Velenje, a rural area in Slovenia, as described by Aguiari et al. [20]. Butler et al. [21] reviews 33 studies related to spatial and temporal transport disparities, focusing on how SMS may alleviate transportation disadvantages and considering spatiotemporal dimensions. The considered SMS are autonomous vehicles, flexible transportation services and free-floating e-mobility.

The underlying risk is that an unequal distribution of SMS services may increase inequality against LDA. To tackle it, Eckhardt et al. [22] lists “marketing and education”, “digital neighborhoods” and “active transportation infrastructure”. The study reports of a case study in Finland, in which MaaS solutions in rural areas and Public-Private-Partnership were assessed through trials. A comparison between urban centered MaaS solutions and rural centered ones is drawn. According to the authors, urban MaaS complements existing public transport services with the aim of reducing congestion and emissions, rural MaaS on the other end integrates different services and user groups through on-demand and sharing services with the aim of improving accessibility and efficiency.

In Fig. 1 summarizes the SMS studied in LDA environment.

2.3 DRT (integration of smart mobility solutions)

In this section, a dedicated look at DRT solutions is provided, given that DRT has been heralded as the main solution to LDA mobility structural issues Mounce et al. [7, 8], Raveau [23]. In small communities with sparse population, where it is challenging to operate conventional fixed public transport, DRT services aim to improve access to health care, employment and other mobility needs Berg & Ihlström [24], Franco et al. [25], Nyga et al. [26]. In future, DRT is forecasted to play an even bigger role with the use of self-driving vehicles Bischoff et al. [27], Boesch et al. [28].

Still, most of LDAs have been observed to be dependent on partnership and lacking the required expertise to operate the automated DRT services, facing issues with training workforce or with union contracts and operating services Avermann & Schlüter [29], Frangulea [30], Haglund et al. [31], Jokinen et al. [32], Perera et al. [33], Shaheen et al. [34]. But challenges and opportunities for DRT in LDA are not limited to resources and skill levels. The administrative and legislative provisions for DRT in LDAs are still weak at EU level and in most of the European countries. Only a few have applied a thorough coverage under coordination divisions Mounce et al. [7, 8]. Despite the low coordination at the EU level, some innovative initiatives for rural mobility can be traced across

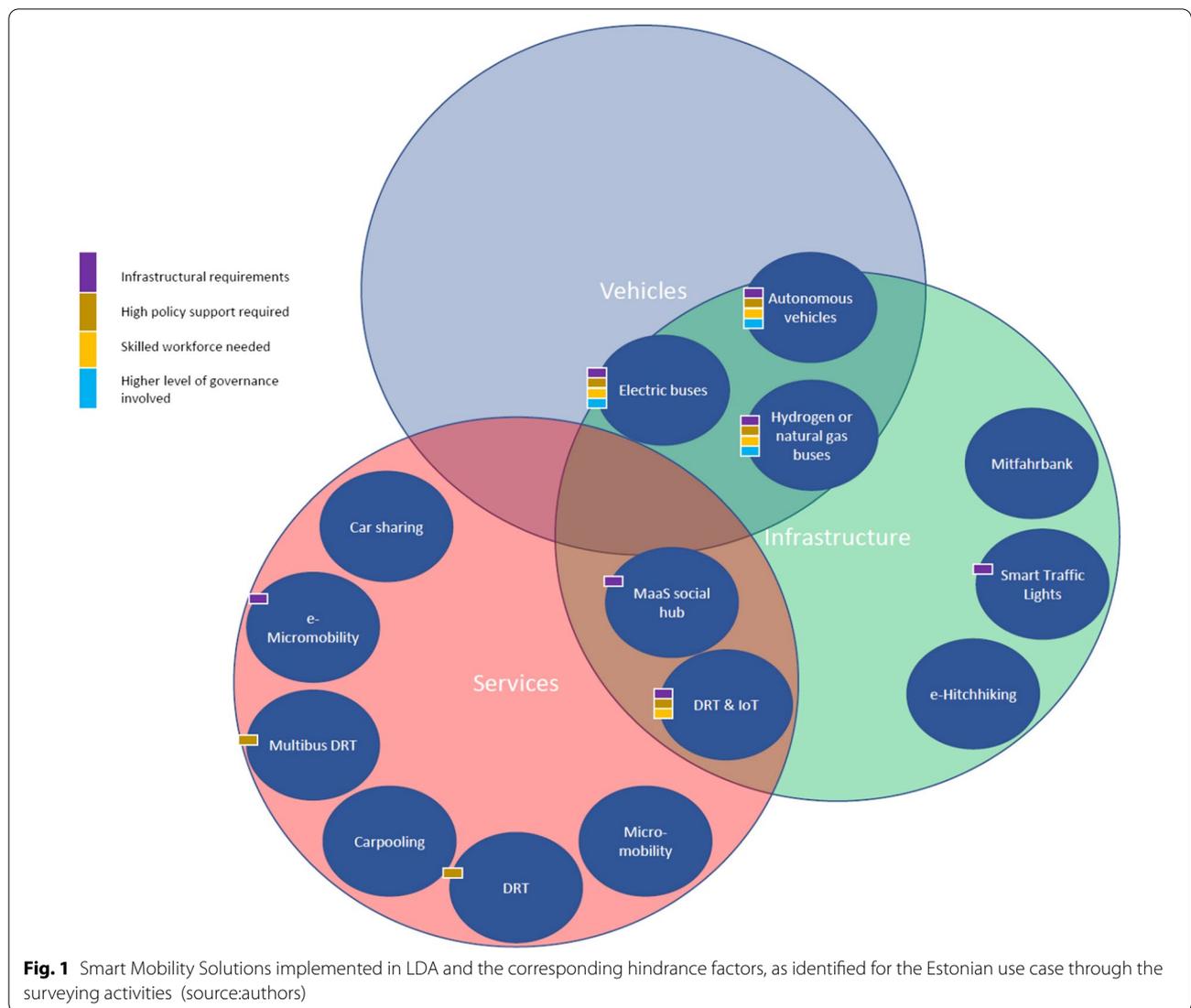


Fig. 1 Smart Mobility Solutions implemented in LDA and the corresponding hindrance factors, as identified for the Estonian use case through the surveying activities (source:authors)

Europe. Recent projects SMARTA and SMARTA-2 are landmarks in piloting of rural smart mobility solutions [3, 7, 8].

Because of the lack of cooperation, DRT has mostly been implemented as a safeguarding measure, as a predefined solution for areas otherwise inaccessible, without expanding the learnings of rural DRT on other planning streams Frangulea [30], Gross-Fengels & Fromhold-Eisebith [2], Mounce et al. [7, 8], Velaga et al. [35]. Such integration needs a strategic parasol at national and EU level to extend the empirical evidence to be useful in integrated planning and design practices.

Hence, a coordinated response to develop a policy framework to devise and implement the DRT and other on demand mobility solution at EU level can

influence LDAs and how mobility challenges are addressed. Still, from the literature it seems that, so far, DRT has not been integrated/innovated through new SMS. This, other than being a finding of its own, allows us to add only two SMS items in the following analysis: current DRT, and joint DRT and Internet of Things (IoT) implementation.

3 Methodology

3.1 The methodological framework

The paper applies a theoretical framework to identify which future challenges may indeed be addressed by existing SMS and the related feasibility against hindering factors for LDA. Figure 2 presents the research framework as it was conceived and applied to the Estonian case study.

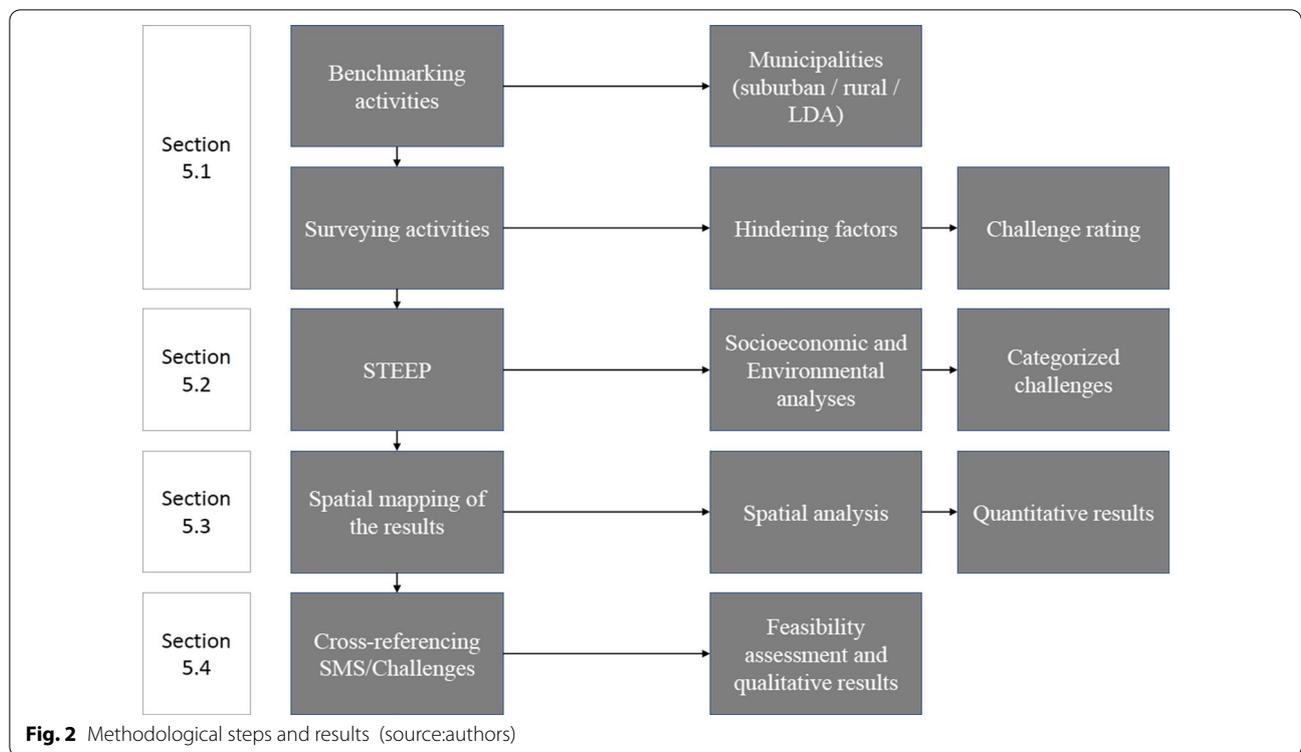


Fig. 2 Methodological steps and results (source:authors)

Figure 2 summarizes the main steps, namely: surveying activity and identification of challenges (and their rating), STEEP classification and qualitative cross-referencing, assessment of the SMS feasibility related to each challenge.

3.2 The surveying activities

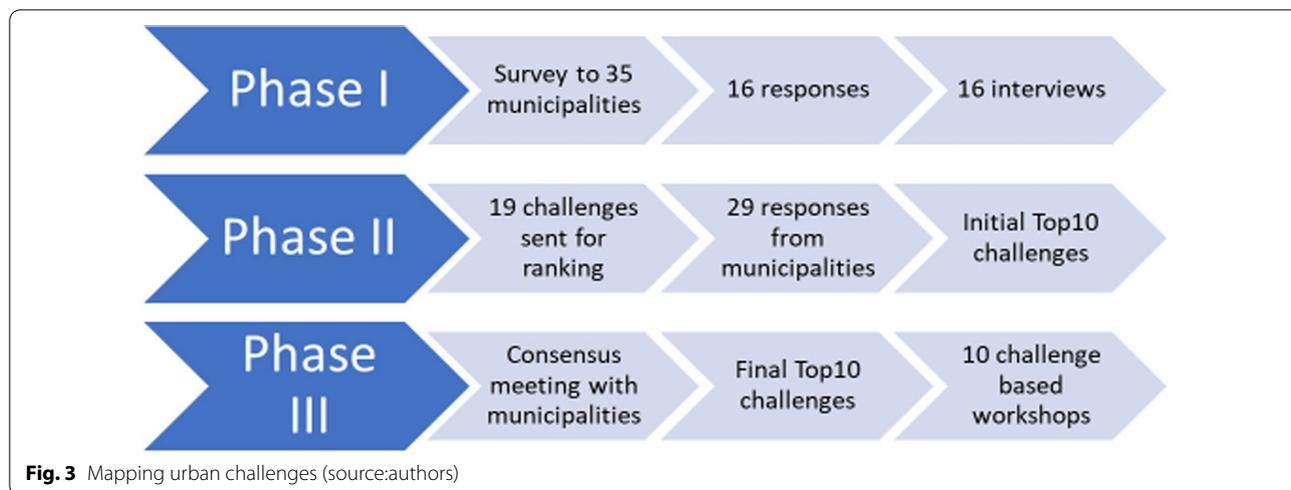
The proposed analysis is described in its application of qualitative methods to analyse the Estonian case study. Estonia has a very small country by population (1.3 M) and was selected as majority of its 79 municipalities are not densely populated (75 municipalities have population smaller than 50,000). 35 of these took part into interviews, a questionnaire and a workshop. The results of this analysis allowed to identify the main hindering factors and guided the authors towards the main subjects to consider in the literature review: SMS, Demand Responsive Transport and Policy Landscape. Finally, the identified SMS from literature were related to the challenges and scored against the identified hindering factors.

The data analysed in this paper was collected in 2020 in three phases. In the Phase I, a questionnaire was sent out for 35 Estonian municipalities involving five topical areas (Mobility being one of them). Later, interviews were conducted with all representatives who participated in the survey. In Phase II, individual local-government-challenges were grouped into mutual challenges. For the

validation of this list, these responses were sent back to all participating local governments, independent whether they responded to the questionnaire. In this step, local government were asked to rank each urban challenge in the scale of 0–3 whereas 0 is not relevant and 3 very relevant. 29 local governments out of 35 participated in this stage. Based on this, a list of the top 10 challenges was initiated. In Phase III, follow-up challenge-based workshops were conducted with invited local governments’ representatives from the sample of 35 local governments, the top 10 challenges were discussed and as a result, some changes were collectively made. Of these 10 challenges, 8 were more strongly related to mobility and will be further analysed through the rest of the paper (Fig. 3).

3.3 The STEEP approach

Before analyzing the surveying outcome and the related SMS, the identified challenges were clustered through STEEP lenses in five classes (Social, Technologic, Economic, Environmental, Policy giving the name to the approach). The STEEP methodology is exploited to highlight which of five macro-areas account for the most challenges and may call for a renewed research effort. To analyze the different streams of knowledge connected to the ecosystem of mobility, the STEEP framework provides a system to organize and characterize the various contexts of knowledge into macro socio-technical



Social	Technological	Economical	Ecological	Political
<ul style="list-style-type: none"> • Social changes, such as demographic change, change of people behavior and lifestyle 	<ul style="list-style-type: none"> • Technological advance and integration such as innovations and product development trends 	<ul style="list-style-type: none"> • Economic environments such as overall economic growth, interest, income, market, and competitor 	<ul style="list-style-type: none"> • Ecological impacts of products and/or services, both physically and biologically 	<ul style="list-style-type: none"> • Political changes involving laws, regulations and policies such as development goals, incentives or policy burdens

Fig. 4 STEEP analysis framework [38]

environment. Everard et al. [36] used STEEP characterization to investigate the transformation of emergent concerns into the permanent change in societal levels and norms. Similarly, Steward et al. [37] applied this classification to inspect the interconnectedness of human activities and their impact on meeting sustainability goals. The STEEP framework was chosen because it inspects institutional and governance issues as a part of political dimension, as mentioned in Everard et al. [36], while excluding the legal category. Indeed, as it was described in Sect. 3.1 and arose from Sect. 4, municipalities tend to frame challenges and solutions in terms of governance. It is important to highlight that no other framework (i.e.,

PEST, SLEPT PESTLE, STEER) covers the infrastructural decision-making dimension of the mobility ecosystem as an independent dimension [36]. In the presented analysis, the infrastructural challenges were categorized as a part of political and institutional decision-making, instead (Fig. 4).

4 Case background of Estonia

Estonia is a European country, bordering Russia to the East and Latvia to the South, Finland (oversea) to the North and Sweden (oversea) to North-West. Estonia is one of the smaller countries in the European Union by population (24th among 27 in EU) with 1.3 million

residents (with 69% ethnic Estonians, 24% ethnic Russians and 7% other). In terms of density, Estonia is among least populated countries in EU with 31 people per square kilometer³ with rather flat land and over 50% of territory covered with forest.⁴ It has a total land size of 42,390 km² which, by comparison, is slightly bigger than Belgium or the Netherlands even though the population of them is 8–12 times bigger than Estonia's, respectively. Over the past 20 years, the population of Estonia has declined by 3–4% mainly due to negative birth rates in 1990-s during the rapid transition of the country; the population has been stable with very small growth during the last 5–6 years mainly due to migration.⁵ Furthermore, the population in Estonia is ageing as the cohorts of 50–69 years area bigger than 0–19. The Estonian Human Development Report⁶ considers two sets of policies necessary—one dealing with challenges connected with urban growth (the capital region) and the other for sustainable downsizing (all other municipalities) as the country is going through a Metropolisation whereas the rest of the local governments are shrinking. Between 2000 and 2018, the population of the capital region increased by 10% (438,000 in 2021), while the rest of the counties shrank by 4–25%.

Politically and historically, Estonia is a post-soviet country that regained its independence in 1991 and joined European Union (EU) and NATO in 2004 and OECD in 2010. 30 years ago, Estonia and its local governments used to be in a similar geopolitical situation as other post-Soviet countries, including Russia, Armenia, Azerbaijan, Belarus, Georgia, the Republic of Moldova and Ukraine. Initially, Estonia's GDP per capita was below average in the ex-soviet bloc and it was approximately 33% of EU average in 1995. However, now Estonia has the highest GDP per capita among post-soviet countries having already increased to approximately 80% of EU average in 2020. In terms of digital industry and electronic governance (including digital local governments), Estonia has effectively leap-frogged among top countries in this area globally.

The average size of a local government in Estonia is 16 750 residents. Data regarding mobility challenges of Estonian local governments were collected as part of the preparation for a large-scale research-based piloting program.

First, a google-form-based questionnaire was sent out in the Summer of 2020 to 35 local governments (out of 79 in total). The answers to the online questionnaire were given by 16 municipalities.

This was followed by online interviews, participated by several representatives from each municipality (e.g., head or deputy head of local government, experts in strategic planning, urban planning, transport, IT or international projects). 16 interviews took approximately one hour and were carried out in the late Summer of 2020. For validation, these pre-mapped challenges were sent back to all local governments in the sample (35) for ranking in the scale of 0–3 whereas 0 is not relevant and 3 very relevant, a total of 29 local governments participated in this step.

The last step included online urban challenge-based-workshops with the local governments that had rated challenges.

5 Results

5.1 Output of the surveying activities

The complete list of challenges as identified from the surveying activity is reported later in Table 1, while the mobility challenges that were considered in the validation (phase 3) are the following:

-
- C1: Insufficient public transport for comfortable living arrangements for the population
 - C2: The involvement of residents is resource-intensive and not user-friendly
 - C3: Lack of skills and capabilities for data collection; scarce data usage
 - C4: Inefficient and non-operational traffic management and road maintenance
 - C5: There are no fast and sufficient connections to attraction centres
 - C6: Traffic planning is not accurate because data cannot be used
 - C7: Transport arrangements do not take into account all modes of movement and their interaction
 - C8: Carbon emissions and inefficient energy use in transport
-

While this result is based on the situation of Estonian LDA municipalities, the surveying activity and the identification of the mobility challenges are a key step of the framework (Fig. 2) which allows to frame the challenges to be related to available SMS. The surveying activity should also pinpoint what are the hindering factors the challenges should be weighted against. In the Estonian case study, for example, the main items in the way of implementing SMS were: unsuitable infrastructure, lack of specific skillsets within the administrations, amount of policy support needed and level of governance involved.

While the first two are somewhat self-explanatory, it is worth defining clearly what is meant by policy support and level of governance. The former defines the need of “political will” from an administration, it may be the case of a somewhat unpopular choice or simply the need to

³ <https://www.worldometers.info/population/countries-in-the-eu-by-population/> [42].

⁴ <https://www.stat.ee/et/avasta-statistikat/valdkonnad/keskkond/mets> (Statistics Estonia Database [43]).

⁵ <https://www.stat.ee/en/avasta-statistikat/valdkonnad/rahvastik/population-figure> (Statistics Estonia Database [43]).

⁶ [https://inimareng.ee/en/index.html_\(Sooväli-Sepping & Roose \[44\]\)](https://inimareng.ee/en/index.html_(Sooväli-Sepping & Roose [44])).

Table 1 Challenges clustered in Social, Technology, Economic, Environmental and Policy components

STEEP Component	Challenges
Social	<p>Social inclusion (Organising transport according to social requirement, social & mobility impaired transport, transport for school and kindergarten)</p> <p>Mobility tracing (Social behaviour as input for development of social services, public transport, and better planning of the city's development, monitoring, municipality border crossing)</p> <p>Social change (Changing travel patterns, reducing car usage, increasing active mobility)</p> <p>Participatory planning (In governance and decision making, developing cooperation between the local governments, NGOs, and private enterprises)</p>
Technology	<p>Infrastructural improvement (Street infrastructure for V2X technologies, improving traffic signs, smart parking, traffic calming, adaptive lights, upgrading PT technology)</p> <p>Traffic management (Replacing the static with dynamic analysis tools, dynamic parking fee, adaptive traffic management)</p> <p>Security (Traffic data security, Cyber security)</p> <p>Information (Deployment of electronic and mobile services, smart integrated + e/governance, information processing capacity, data-based governance and cooperation, unsystematic information and its readability & transferability, Streamlining information system, big data for decision making, timely processing)</p> <p>Planning (Technology integration, uniform level of services provision, reorganizing & developing real time PT, improving traffic parking, automation, understanding travel patterns, Smart city transition management, surveying, Managing geographical information, introducing digital on-demand/ other services)</p>
Economic	<p>Transport systems cost (Meeting PT operation costs, Public transport system advancement cost, capacity development for traffic flow analysis, power supply costs, real time data monitoring costs, Maritime upgradation and airfield development, construction of transfer centres for public transport)</p> <p>Sustainability transition cost (Hydrogen fuel operation, charging infrastructure cost, transport system component advancement cost)</p> <p>Decision making (Economic decision making, shutting of long distance buses, PT investment prioritization, fuel transition)</p>
Environmental	<p>Motivation for adopting sustainable practices</p> <p>Implementation of environmentally-friendly PT services</p> <p>Pollution (Sustainable infrastructure and fuels)</p> <p>Planning/documenting for sustainable urban traffic</p>
Policy	<p>Revising Infrastructural development (cycling and pedestrian infrastructure in streets, rebuilding streets and squares, reducing parking, car-free zones, setting organisational hierarchy, developing public transport network, improving urban-rural connections, social/school transport)</p> <p>Information and governance (Access of information, Lack of disaggregated data, integrated administration of departments and institutions, inclusive governance, organisational reforms, aligning goals with decision making, collaboration with other municipalities)</p> <p>Planning (Sustainable development practices, reorganizing public transport, intermodality, distribution of mobility, road pricing, polycentric urban environment, revising city walking plan, enhancing public trust on PT, safety improvements for active mobility)</p> <p>Developing niches (Establishing multi-modal mobility services, Development of Smart Transport and Mobility Hub, Regulations for new novel transport services, difficulty in attracting companies to small municipalities)</p> <p>Decision making (Understanding the data usability, Adopting evidence-based nature of discretionary decisions, data-based governance and decisions initiatives, participatory planning for transport policy development)</p>

stay engaged through the whole process. The latter represents instead the need to get involved for public bodies other than the municipality, the higher the level the higher the hindrance (reflecting the loss of control for the LDA municipality). An example is the introduction of SMS that may need amendments to the current legislation (e.g., Automated Vehicles).

5.2 STEEP classification

To apply STEEP to the set of challenges currently faced by Estonian municipalities allows to broaden the scope of the analysis and to highlight trends that would be missed simply relating LDA-SMS to challenges. The clustering of challenges in STEEP classes is reported in Table 1.

STEPP highlighted that challenges such as tracing social behavior, changing travel pattern and social inclusion have been the upmost important Social challenges in Estonian municipalities. Implementation of technology has been identified as one of the key priorities as well as challenges for several municipalities (i.e. Tartu and Rakvere). In particular, the municipalities are focusing on improving information and communication systems, traffic management and improving planning practices. Clustering also highlighted the need of policy direction in implementing the niche mobility services, regulating the technology ecosystem, revising the infrastructural development direction and decision making.

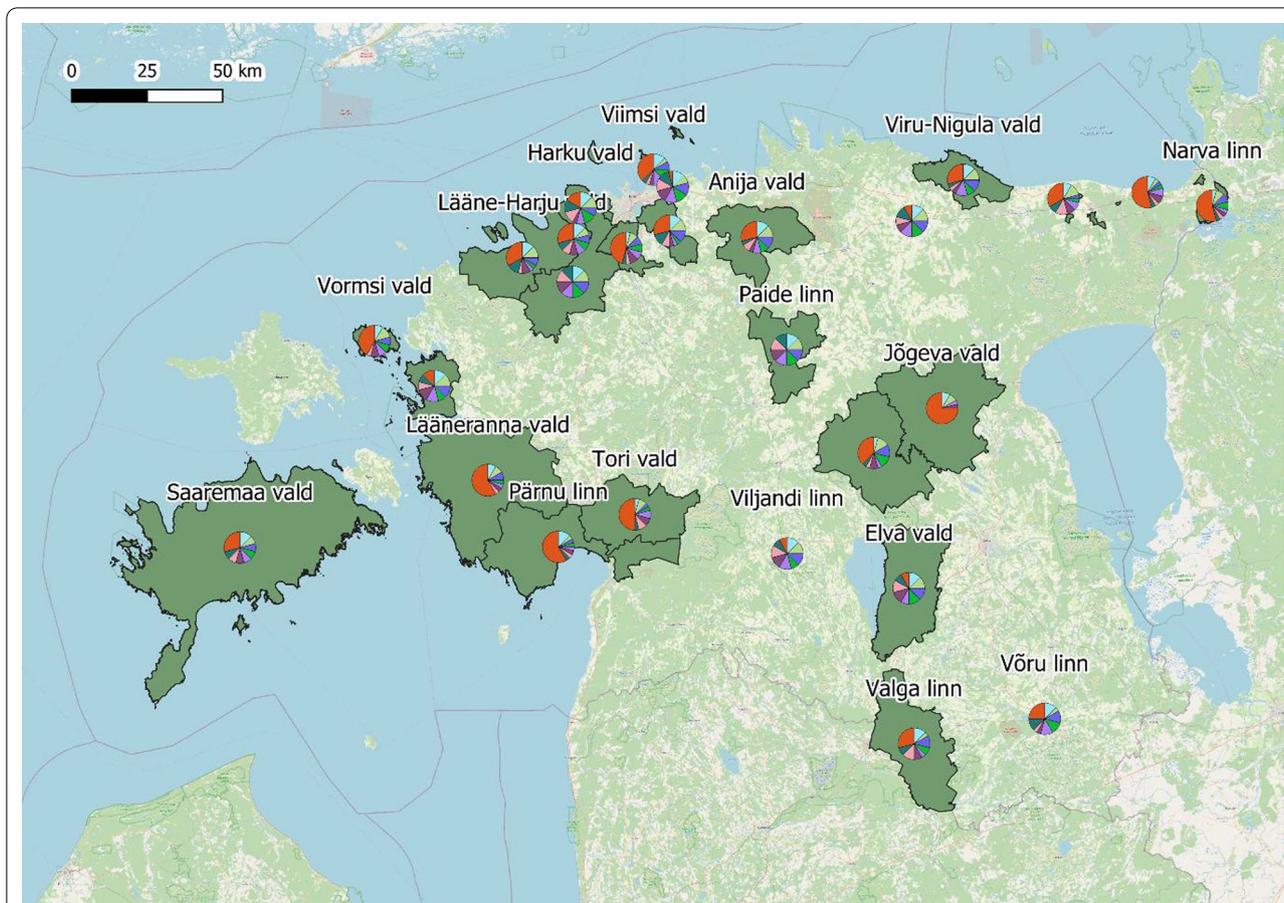


Fig. 5 Estonian municipalities and their challenge ratings (source:authors)

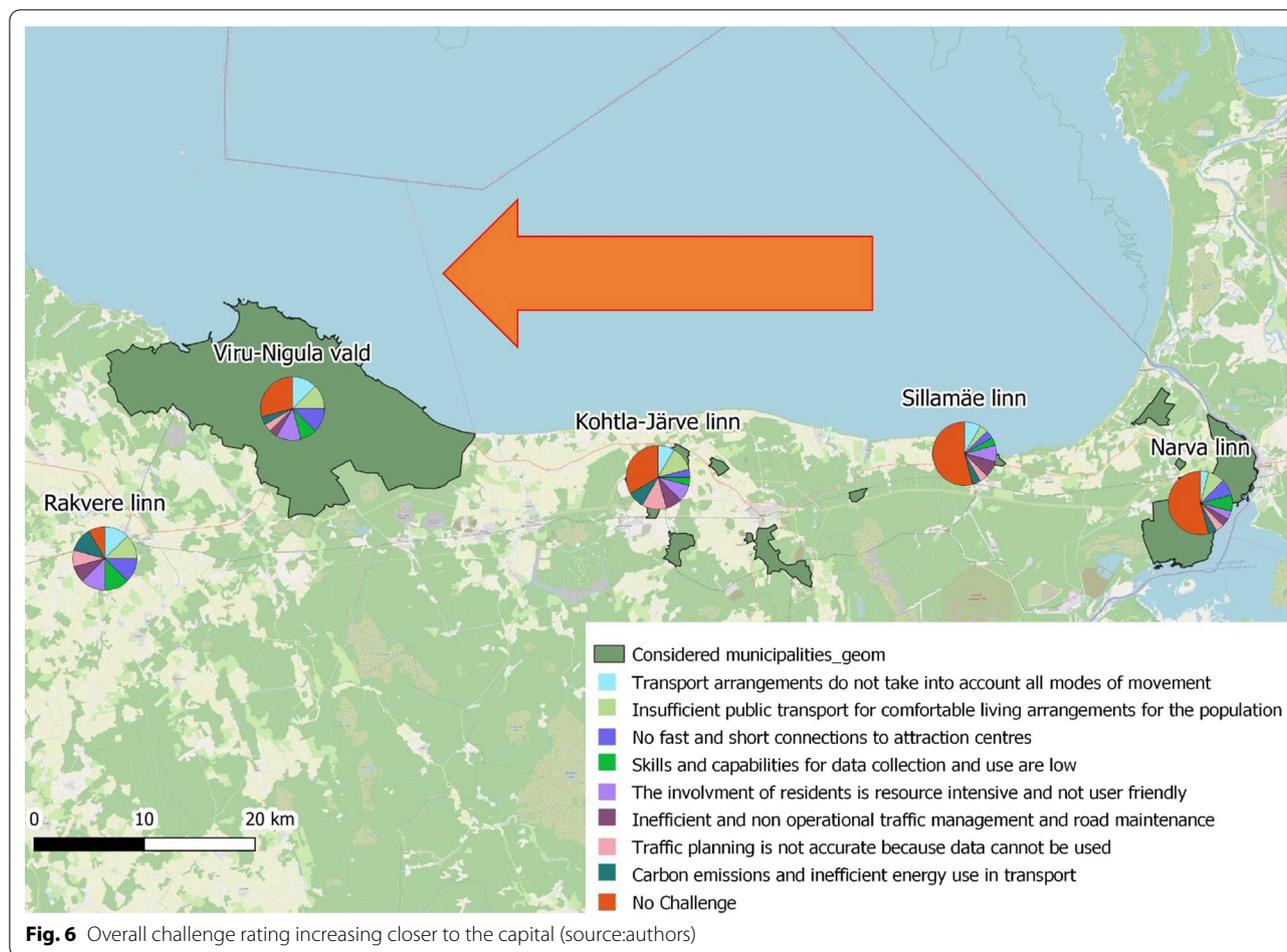
5.3 Spatial analysis

First, it is worth analyzing how the challenges have been scored between 0 and 3 by the municipalities. As detailed in 5.1, in this phase 8 challenges related to transport have been discussed. The results for each one of the considered municipalities are reported in the following map (Fig. 5).

Some interesting patterns arise. First, it is possible to note how the spatial dimension of the municipality reflects in how difficult the challenges are perceived. Smaller ones such as Viljandi or Rakvere (but also Haapsalu and Elva) score very little on the No Challenge item. This item was calculated by subtracting the sum of the challenge rating from the maximum challenge rate achievable ($8 \times 3 = 24$). This reflects how these centres differ strongly from a bit bigger centres such as Pärnu in which 7 of the 8 challenges are scored as 1. This result may reflect how generally all the presented items tend to become more challenging as the municipality becomes small and thus the means are reduced. On the other side, it may also reflect a cultural background such as in

Russian-speaking cities of Narva and Sillamäe in the east that are socio-economically a bit weaker than other cities in Estonia. These two municipalities scored very high in the No Challenge item, even though they are geographically less connected to the rest of the country. It is likely that, in these municipalities, the low connectivity is felt less acutely than in others, possibly due to alternative socioeconomical connections to the east. This, in turn, lowers the scores for items such as multimodality and lacking public transport connections. It is indeed interesting to notice how in this area the challenges are more keenly felt, the closer to the capital (Fig. 6).

The same effect does not arise in the southern part, where many challenges were reported with a scoring of 2 or higher. Both Valga and Võru, for example, report higher ratings for the arrangement of multimodality solutions, inefficient traffic management and difficulty of attracting people with the right skillsets. This comes somehow as a surprise, since these municipalities are better connected to a bigger centre (Tartu) and can also profit from a border vicinity with Latvia. However,



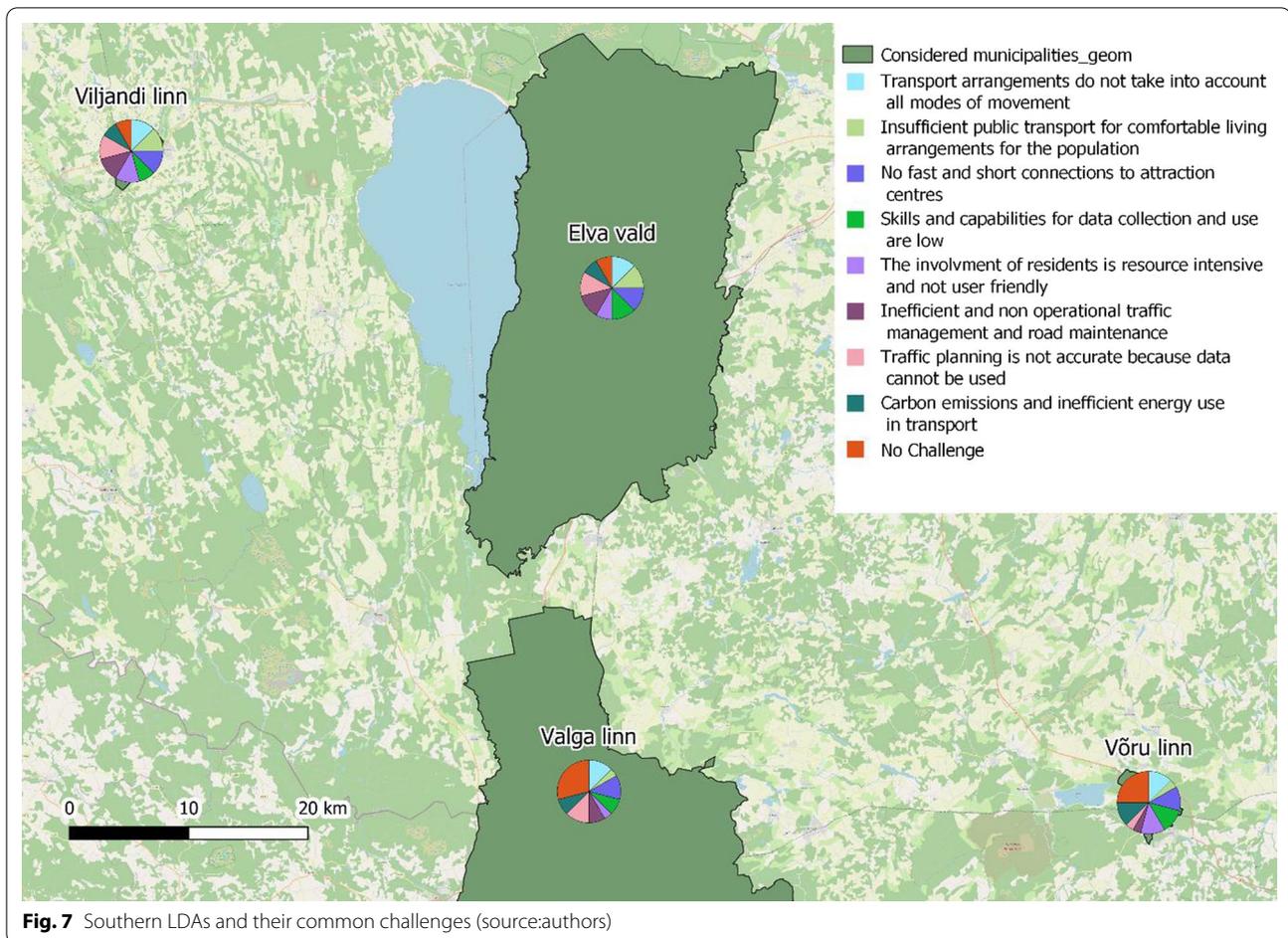
mainly due to language barriers (Estonian and Latvian languages are very different), the travel exchange and the mobility of skilled labor between Latvia and Estonia is relatively low. Indeed, the difficulty in attracting the right skillsets seems to be a moderate issue for all the considered southern LDAs (Fig. 7).

On the western side, instead, the main pattern concerns the islands (Vormsi and Saaremaa) in which almost all the challenges are felt at least moderately. It is also interesting to see how no pattern arises among Lääneranna, Pärnu and Tori (namely, how the scoring changes widely across the three). This was somehow unexpected due to the close geographic proximity of the three but may be explained by the different density levels. Indeed, Pärnu covers a wider area and has direct access to the sea while Tori is smaller and landlocked. Finally, Lääneranna is composed by three smaller municipalities and, with a population of 5343, has a very low density (which indeed is reflected on the focus on lacking connections and weak public transport). Pärnu faces challenges related to the management of multiple modes, while Tori feels more

keenly the challenges related to lacking skillsets and poor traffic management (Fig. 8).

The differing challenge ratings highlight how geographical proximity is not enough to predict different situations in LDAs and strengthen the argument for more focused studies concerning these use cases.

Finally, it is worth analyzing the LDAs surrounding the capital of Tallinn. Another unexpected result is the high rating of challenges related to connectivity and multimodality almost in all of these LDAs. The closeness to the capital is likely causing a bigger sensibility to these issues and this proximity is also likely raising the expectations and expected standards of both residents and policy makers. This hypothesis is also strengthened by the high rating of the challenge “no fast and short connection to attraction centres,” probably influenced by the fact that many people live in suburban municipalities and commute to Tallinn on regular basis. This is particularly interesting and reflects how the attitudes and expectations of the residents steer the focus of LDAs policymakers, while in more isolated LDAs a resignation effect might settle



in, further hindering the push towards a more integrated transport offer. Finally, another trend in the area arises from the higher rating of the challenge related to emissions, in this case it is legit as well to theorize an influence from the capital city (Fig. 9).

Table 2 presents an aggregated empirical insight into the eight foremost smart mobility challenges faced by Estonian municipalities. Grouping of the eight challenges into STEEP categorization presents a broad spectrum as well the intensity of the challenges. A wide overlook of the ranking highlights the Policy category is rated as the most rated challenge followed by the Economic, Social, Technology and Environment.

The highest scoring for the lack of modal diversity and interaction of existing modes highlights the need for support in planning and policy dimensions. Furthermore, infrastructural development tackling insufficient public transport and lack of fast connection to the activity centers are rated among the highest level of challenges by most of the municipalities. The need of policy and infrastructural support can be interpreted through the lens of economic challenges and seclusion faced by the

municipalities, especially those far from the major cities such as Tallin, Tartu and Narva. Among others, environmental challenges were least rated by municipalities.

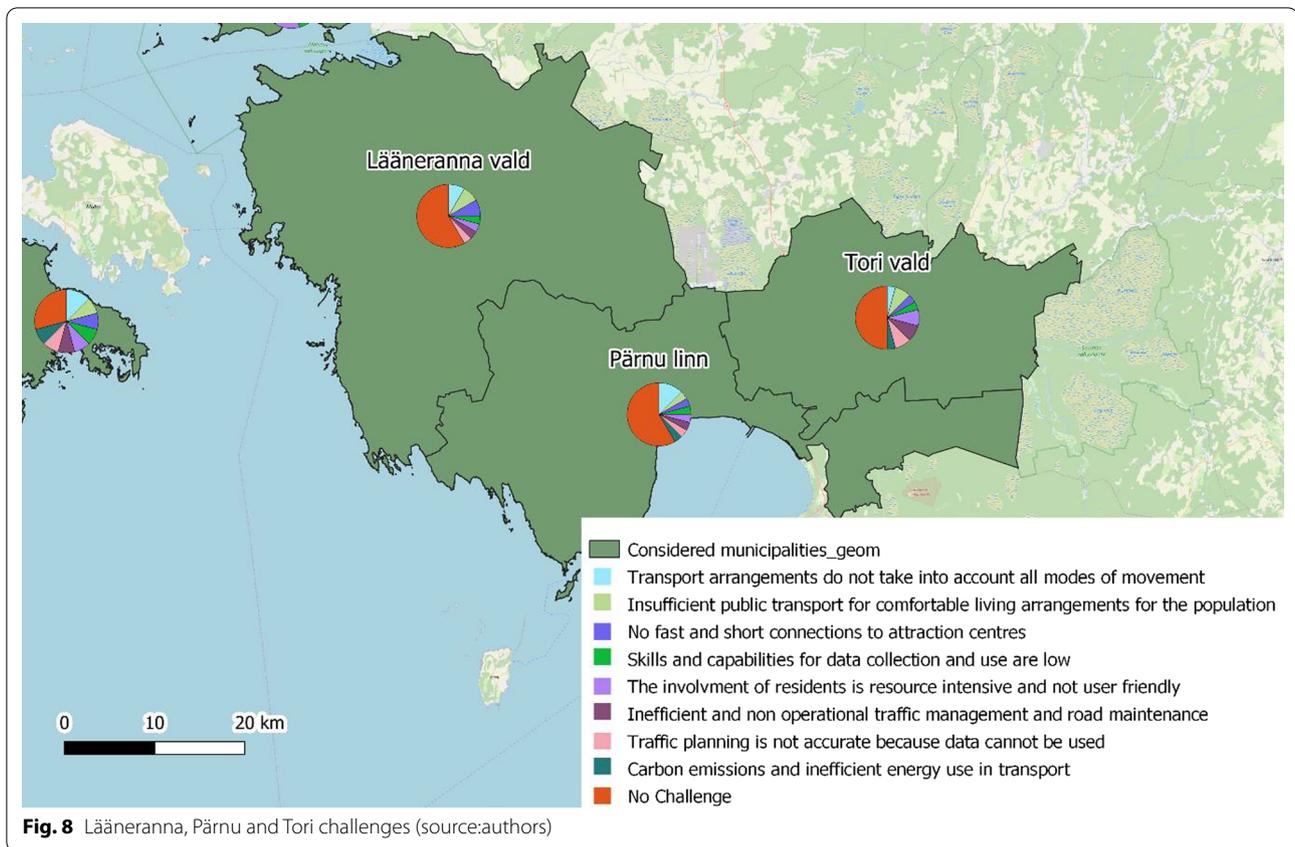
5.4 SMS and challenges cross-referencing

It should be highlighted from the start how the results are inherently qualitative, being based on the literature review and data collection approach that combined a questionnaire, individual interviews and several workshops with 35 Estonian municipalities.

Each SMS was assigned to existing challenges based on its ability to tackle it, as arisen from the literature review. This cross-referencing between SMS and existing challenges allows to identify STEEP clusters that are currently under-researched.

Table 3 reports the results of this cross-referencing activities, each cell being filled with the average challenge rate assigned by the Estonian municipalities.

In Table 3 it is possible, at a glance, to identify the SMS designed to tackle the most pressing challenges, as perceived by the Estonian municipalities. It is interesting to notice how the most pressing challenge's solutions do not



overlap with the SMS dedicated to the second and third worst rated challenges. This highlights how it is not possible to pinpoint one SMS as go-to solutions for LDA. Instead, it is paramount to identify the challenges afflicting each use case and choose the corresponding SMS accordingly. The spatial analysis in Sect. 5 proved indeed how different LDA may have different priorities and means, and how geographical proximity is not enough to cluster them. Table 3 tries to provide a quick mapping and to enable that kind of choice.

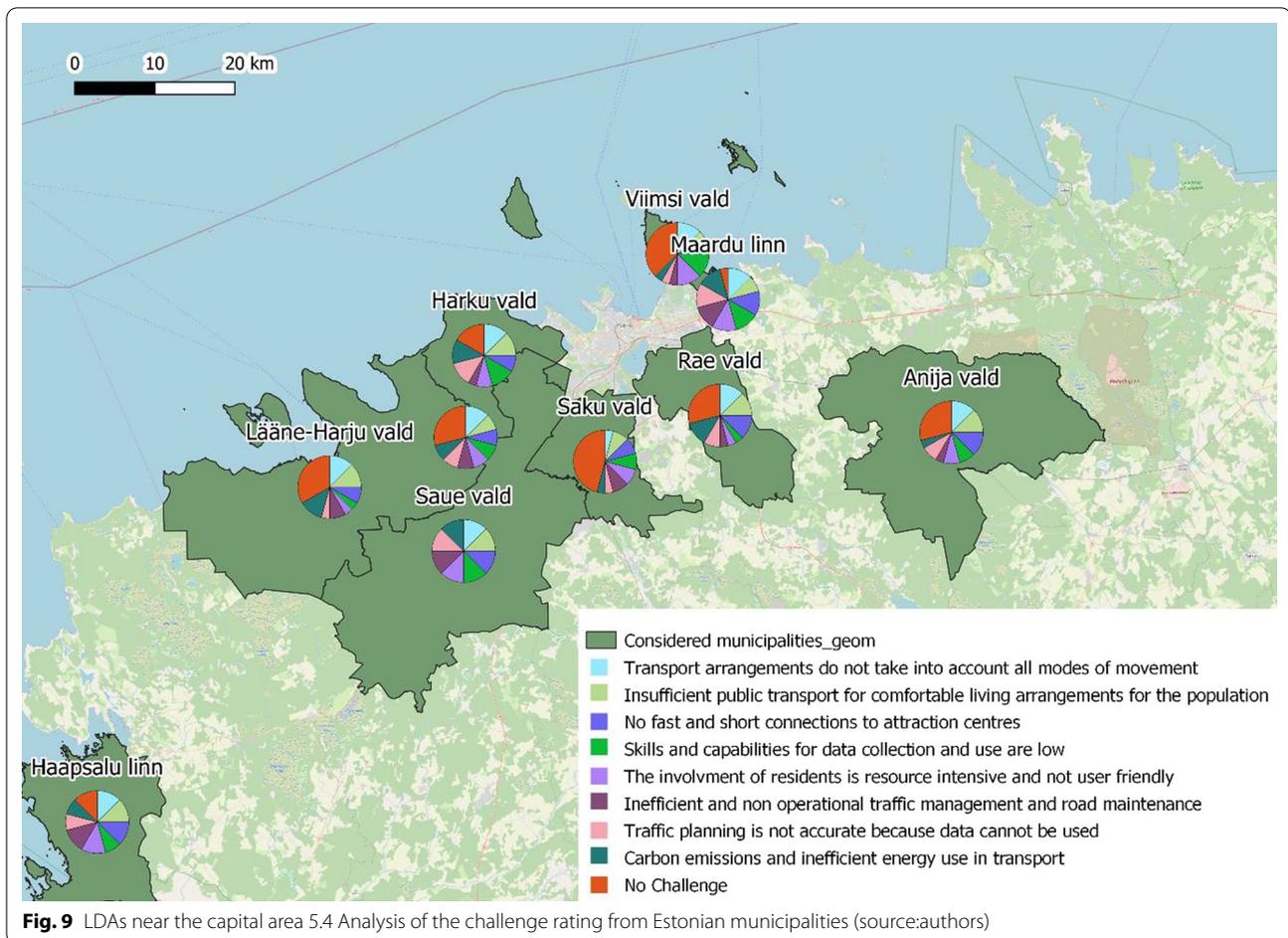
It is also worth reporting how each SMS fares against the four hindrance factors that arose from the surveying activities. This is done in Table 4.

From Table 4 it is possible to identify which challenge is harder to tackle with the current means. It is worth highlighting, for example, how inefficient energy use and emissions are hardly structurally tackled without facing at least 3 major hindrances. On the other side of the spectrum, the challenges related to multimodality emerge as the ones commonly facing the fewer hindrances. Another pattern relates to the number of challenges that each SMS tackles on its own. As it could be expected, the more challenges are tackled, the higher the number of hindrances involved (the most effective SMS being IoT

& info-mobility, tackling 6 of the eight challenges but being hindered by the need for a dedicated infrastructure and the need for both a skilled workforce and higher levels of governance, as detailed in Sect. 2.1). A more detailed table, (qualitatively) scoring each hindrance factor, is reported in Appendix 2. Overall, the main finding is that while bigger municipalities have most of the tools to address mobility issues, smaller municipalities have a more limited number, with no SMS explicitly tailored for LDA. This should foster more research on how to address the challenges characterized by high hindering factors also in LDA. Indeed, based on the presented analysis, one may argue that the responsibility for the lack of solutions lies more in the research environment than in the actions of municipalities.

6 Discussion

The paper reports an extensive surveying activity across Estonian municipalities, focusing on the rural and not connected areas. These results highlight the challenges faced by LDA and were analyzed through the STEEP lenses and the rating on a scale 0–3. The results suggest that the needs of LDA not only differ from the ones for bigger cities, but they also widely change based on factors



other than the spatial coordinates of each centre. By exploiting these results, the paper tries to assess through a qualitative analysis the transferability of SMS already tested in other rural scenarios. The limits of the current state of the art have been highlighted and the feasibility of each SMS has been assessed against the hindering factors reported by the Estonian LDA. The overall analysis was conceived to be transferable, by which it is meant that no structural barrier can be foreseen while following the described framework in other settings (the only input data needed being interviews and surveys with local LDA and macroscopic socioeconomic data).

Despite some good initiatives in introducing technological solutions in LDA, looking at the policy landscape provides a clear policy void lacking a dedicated integrated framework. Even in developed European areas where goals for rural settlements have been defined, these goals were merely limited to statements Mounce et al. [7, 8]. This policy void for rural mobilities affected the uplift of innovative solutions from and for local governments, partially because more policy focus has been directed toward urban mobility. While the attention on

the subject seems to have slightly increased recently, the scientific literature still focuses more into analyzing transport challenges in LDA or policy barriers and close to no paper designs innovative solutions tailor made for these settings instead. Almost all of the above papers analyze existing SMS, some of which are based on services designed decades ago (traditional DRT applications being a perfect example). It is indeed striking how so many of the subjects raised in the last decade are still relevant, which strengthen the point made in this paper, namely that research related to extra-urban areas and Smart Mobility is not progressing at the adequate pace. Very few papers apply the traditional research pipeline: drawing of research questions and hypotheses, defining a methodology, developing a solution or a service and measuring its impacts through KPIs. The only set of Smart Mobility Solutions that somehow go through this process in LDA seem to be the community-based ones, more rooted in social sciences. Finally, even for the already existing SMS such as DRT, sharing mobility or integrated transport, literature is lacking focus on very relevant outcomes in LDA such as impact assessment,

Table 2 Average of the eight most important mobility challenges faced by Estonian municipalities

STEEP Component		Challenge scores	Average STEEP component score
Social	Social inclusion (Organizing transport according to social requirement, social & mobility impaired transport, transport for school and kindergarten)	C1 (2.38) and C2 (2.08)	2.22
	Mobility tracing (Social behavior as input for development of social services, public transport, and better planning of the city’s development, monitoring, municipality border crossing)	C3 (2.13)	2.13
	Participatory planning (In governance and decision making, developing cooperation between the local governments, NGOs, and private enterprises)	C2 (2.08)	2.08
Technology	Traffic management (Replacing the static with dynamic analysis tools, dynamic parking fee, adaptive traffic management)	C4 (2.00)	2.00
	Information (Deployment of electronic and mobile services, smart integrated + e/ governance, information processing capacity, data-based governance and cooperation, unsystematic information and its readability & transferability, streamlining information system, big data for decision making, timely processing)	C4 (2.00)	2.00
	Planning (Technology integration, uniform level of services provision, reorganizing & developing real time PT, improving traffic security, automation, understanding travel patterns, Smart city transition management, surveying, managing geographical information, introducing digital on-demand/ other services)	C5 (2.33)	2.33
Economic	Transport systems cost (Meeting PT operation costs, public transport system advancement cost, capacity development for traffic flow analysis, power supply costs, real time data monitoring costs, Maritime upgradation and airfield development, construction of transfer centers for public transport)	C3 (2.13)	2.13
	Sustainability transition cost (Hydrogen fuel operation, charging infrastructure cost, transport system component advancement cost)	C8 (2.00)	2.00
	Decision making (Economic decision making, shutting of long-distance buses, PT investment prioritization, fuel transition)	C5 (2.33)	2.33
Environmental	Motivation for adopting sustainable practices	C8 (2.00)	2.00
	Implementation of environmentally friendly PT services	C8 (2.00)	2.00
	Pollution (Sustainable infrastructure and fuels)	C8 (2.00)	2.00
Policy	Revising Infrastructural development (Cycling and pedestrian infrastructure in streets, rebuilding streets and squares, reducing parking, car-free zones, setting organizational hierarchy, developing public transport network, improving urban–rural connections, social/school transport)	C1 (2.38), C5 (2.33) and C7 (2.50)	2.4
	Information and governance (Access of information, Lack of disaggregated data, integrated administration of departments and institutions, inclusive governance, organizational reforms, aligning goals with decision making, collaboration with other municipalities)	C3 (2.13) and C6 (1.92)	2.02
	Planning (Sustainable development practices, reorganizing public transport, intramodality, distribution of mobility, road pricing, polycentric urban environment, revising city walking plan, enhancing public trust on PT, safety improvements for active mobility)	C1 (2.38), C5 (2.33) and C7 (2.50)	2.4
	Decision making (Understanding the data usability, Adopting evidence-based nature of discretionary decisions, data-based governance and decisions initiatives, participatory planning for transport policy development)	C3 (2.13) and C2 (2.08)	2.1

economic indicators and quantifiable benefits. The existing indicators such as inclusion and accessibility are difficult to precisely convert into economic value. The innovation cycle of the SMS should proceed at the same pace as the adoption of new assessment methods incorporating both quantitative and qualitative (i.e. interviews and focus groups) evaluation. This vicious cycle translates into uncertainty and therefore risk aversion when it comes to both studies and trials of innovative solutions in LDA areas. Still, the literature review and the challenges

discussed in Sect. 5 answer the first research question: virtually no “tailored” SMS has been developed to answer the specific challenges of LDA, with the only exception being the Mitfahrbank described by Gross-Fengels & Fromhold-Eisebith [2].

Even though this is a case study of Estonian municipalities, the results can be also valuable for other municipalities in a similar socio-economical, socio-political, socio-demographical and socio-geographical context also considering that several mobility-related

Table 3 Cross-referencing the challenges with the SMS from literature

Clustering	STEEP	Social		Technology		Economic	Environment	Policy	
	Challenges	Insufficient public transport for comfortable living arrangements for the population	The involvement of residents is resource-intensive and not user-friendly	Skills and capabilities for data collection and low use	Inefficient and non-operational traffic management and road maintenance.	There are no fast and sufficient connections to attraction centres	Carbon emissions and inefficient energy use in transport	Transport arrangements do not take into account all modes of movement and their interaction.	Traffic planning is not accurate because data cannot be used
Car pooling/ sharing schemas	SMS						2	2.5	
Micro-mobility services								2.5	
Electric micro-mobility services							2	2.5	
MaaS social hubs		2.38					2.33		2.5
Electric buses				2.13			2		
Mitfahrbank (public bench)			2.08						
e-Hitchhiking services			2.08						
IoT & DRT		2.38	2.08	2.13		2.33			1.92
IoT & info-mobility			2.08	2.13	2	2.33		2.5	1.92
Autonomous vehicles & self driving buses				2.13		2.33			
MultiBus DRT service		2.38				2.33			
Hydrogen or natural gas propel-led buses				2.13			2		
Smart traffic lights				2.13	2				

challenges tend to be rather universal (e.g. car-dependency, quality of public transport service and infrastructure for bicycles). Thus, the results can be beneficial to other European municipalities with similar sociological macro-setting (e.g. land size, demographics, GDP etc.). Furthermore, this paper also emphasizes the value of understanding the local context, as universal challenges tend to have local nuances that are worth considering before making implementation plans.

6.1 Limitations and future research directions

The main limitation of this paper is that in-depth data collected on mobility challenges in one small European country, Estonia, can be too context-based and the results from this research are not automatically generalizable to other regions without a prior analysis of the challenges and specific socioeconomic features. As highlighted in Sect. 6, the spatial distribution of the LDA is not enough alone to define a pattern concerning challenges and/or hindering factors. Even in the case study, though there has been an extensive validation of mobility challenges with broad involvement of local government representatives of Estonia, the importance and hindrance factors and the cross-referencing with available SMS had to be based on literature and expert judgment. A future

research direction could be carrying out similar analyses in other countries, to highlight common patterns and define a broader transferability of the results.

Appendix 1: Sample

Local governments (population as of February 2019 in brackets according to the Ministry of Finance) involved to the sample: Kohtla-Järve (33,709), Viljandi (17,301), Saaremaa (31,453), Saue (22,139), Viimsi (20,142), Rae (18,951), Valga (15,625), Maardu (15,468), Rakvere (15,092), Harku (14,820), Elva (14,583), Jõgeva (13,523), Haapsalu (13,193), Sillamäe (12,842), Lääne-Harju (12,578), Võru (11,829), Tori (11,699), Tartu county (10,846), Paide (10,513), Saku (10,127), Keila (9975), Jõelähtme (6508), Põltsamaa (9756), Lügánuse (8631), Põhja-Sakala (7984), Mulgi (7525), Tõrva (6162), Viru-Nigula (5859), Peipsiääre (5587), Mustvee (5546), Narva-Jõesuu (4601), Loksa (2636).

Appendix 2: STEEP Table

See Table 5.

Table 4 SMS hindered by 1) Infrastructural requirements 2) High policy support needed 3) Skilled workforce needed 4) Higher level of governance involved

Clustering	STEEP	Social	Technology		Economic	Environment	Policy
			Insufficient public transport for comfortable living arrangements for the population	The involvement of residents is resource-intensive and not user-friendly			
Car pooling/sharing schemas	SMS						
Micro-mobility services							
Electric micro-mobility services					1		1
MaaS social hubs		1			1		1
Electric buses				1,2,3,4		1,2,3	
Mitfahrbank (public bench)							
e-Hitchhiking services							
IoT & DRT		1,2,3	1,2,3	1,2,3	1,2,3		1,2,3
IoT & info-mobility			1,3,4	1,3,4	1,3,4		1,3,4
Autonomous vehicles & self-driving buses			1,2,3,4	1,2,3,4	1,2,3,4		
MultiBus DRT service		2			2		
Hydrogen or natural gas propelled buses			1,2,3,4			1,2,3,4	
Smart traffic lights			1				1

Table 5 (continued)

Clustering	Car pooling/ sharing schemas	Micro- mobility services	Electric micro-mobility services	MaaS social hubs	Electric buses	Mitfahr- bank (public bench)	e-Hitchhiking services	Basic DRT	IoT & DRT
Steep	Challenges	Solutions							
Technology	<p>Infrastructural improvement (Street infrastructure for V2X technologies, improving traffic signs, smart parking, traffic calming, adaptive lights, upgrading PT technology)</p> <p>Traffic management (Replacing the static with dynamic analysis tools, dynamic parking fee, adaptive traffic management)</p> <p>Security (Traffic data security, Cyber security)</p> <p>Information (Deployment of electronic and mobile services, smart integrated + e/governance, information processing capacity, data-based governance and cooperation, unsystematic information and its readability & transferability, Streamlining information system, big data for decision making, timely processing)</p> <p>Planning (Technology integration, uniform level of services provision, reorganizing & developing real time PT, improving traffic security, automation, understanding travel patterns, Smart city transition management, surveying, Managing geographical information, introducing digital on-demand/ other services)</p>	<p>(C,C,B,C)</p> <p>(C,C,C,C)</p> <p>(C,C,C,C)</p>							

Table 5 (continued)

Clustering	Car pooling/ sharing schemas	Micro- mobility services	Electric micro-mobility services	MaaS social hubs	Electric buses	Mitfahr- bank (public bench)	e-Hitchhiking services	Basic DRT	IoT & DRT
Steep	Challenges	Solutions							
Policy	Revising Infrastructural development (cycling and pedestrian infrastructure in streets, rebuilding streets and squares, reducing parking, car-free zones, setting organisational hierarchy, developing public transport network, improving urban-rural connections, social/school transport) Information and governance (Access of information, Lack of disaggregated data, integrated administration of departments and institutions, inclusive governance, organisational reforms, aligning goals with decision making, collaboration with other municipalities)	(A,A,A,A)	(C,B,B,C)	(C,B,A,B)					(C,C,C,C)
	Planning (Sustainable development practices, reorganizing public transport, intermodality, distribution of mobility, road pricing, polycentric urban environment, revising city walking plan, enhancing public trust on PT, safety improvements for active mobility)	(A,A,A,A)	(C,B,B,C)	(C,B,A,C)					(C,C,C,C)
	Developing niches (Establishing multi-modal mobility services, Development of Smart Transport and Mobility Hub, Regulations for new novel transport services, difficulty in attracting companies to small municipalities) Decision making (Understanding the data usability, Adopting evidence-based nature of discretionary decisions, data-based governance and decisions initiatives, participatory planning for transport policy development)	(A,A,A,A)	(C,B,B,C)	(C,B,A,C)					(C,C,C,C)

Table 5 (continued)

Clustering		IoT & info-mobility	Autonom-ous vehicles & self driving buses	Multibus DRT service	Hydrogen or natural gas propelled buses	Smart traffic lights
STEEP	Challenges	Solutions				
Social	Social inclusion (Organising transport according to social requirement, social & mobility impaired transport, transport for school and kindergarten,) Mobility tracing (Social behaviour as input for development of social services, public transport, and better planning of the city's development, monitoring, municipality border crossing) Social change (Changing travel patterns, reducing car usage, increasing active mobility) Participatory planning (In governance and decision making, developing cooperation between the local governments, NGOs, and private enterprises)	(C,C,C,B)	(C,C,C,C)	(A,C,A,A)		
Technology	Infrastructural improvement (Street infrastructure for V2X technologies, improving traffic signs, smart parking, traffic calming, adaptive lights, upgrading PT technology) Traffic management (Replacing the static with dynamic analysis tools, dynamic parking fee, adaptive traffic management) Security (Traffic data security, Cyber security) Information (Deployment of electronic and mobile services, smart integrated + e/governance, information processing capacity, data-based governance and cooperation, unsystematic information and its readability & transferability, Streamlining information system, big data for decision making, timely processing) Planning (Technology integration, uniform level of services provision, reorganizing & developing real time PT, improving traffic security, automation, understanding travel patterns, Smart city transition management, surveying, Managing geographical information, introducing digital on-demand/ other services)	(C,C,C,C)	(C,C,C,C)		(C,C,C,C)	(C,B,B,A) (C,B,B,A)
Economic	Transport systems cost (Meeting PT operation costs, Public transport system advancement cost, capacity development for traffic flow analysis, power supply costs, real time data monitoring costs, Maritime upgradation and airfield development, construction of transfer centres for public transport) Sustainability transition cost (Hydrogen fuel operation, charging infrastructure cost, transport system component advancement cost) Decision making (Economic decision making, shutting of long distance buses, PT investment prioritization, fuel transition)	(C,C,C,C)	(C,C,C,C)	(A,C,A,B)	(C,C,C,C)	
Environmental	Motivation for adopting sustainable practices Implementation of environmentally-friendly PT services Pollution (Sustainable infrastructure and fuels) Planning/documenting for sustainable urban traffic	(C,C,C,C)	(C,C,C,C)	(A,C,A,C)	(C,C,C,C) (C,C,C,C)	(C,B,B,A)

Table 5 (continued)

Clustering	IoT & info-mobility	Autonom-ous vehicles & self driving buses	MultiBus DRT service	Hydrogen or natural gas propelled buses	Smart traffic lights
STEEP	Challenges	Solutions			
Policy	<p>Revising Infrastructural development (Cycling and pedestrian infrastructure in streets; rebuilding streets and squares, reducing parking. car-free zones, setting organisational hierarchy, developing public transport network, improving urban-rural connections, social/school transport)</p> <p>Information and governance (Access of information, Lack of disaggregated data, integrated administration of departments and institutions, inclusive governance, organisational reforms, aligning goals with decision making, collaboration with other municipalities)</p> <p>Planning (Sustainable development practices, reorganizing public transport, intermodality, distribution of mobility, road pricing, polycentric urban environment, revising city walking plan, enhancing public trust on PT, safety improvements for active mobility)</p> <p>Developing niches (Establishing multi-modal mobility services, Development of Smart Transport and Mobility Hub, Regulations for new novel transport services, difficulty in attracting companies to small municipalities)</p> <p>Decision making (Understanding the data usability, Adopting evidence-based nature of discretionary decisions, data-based governance and decisions initiatives, participatory planning for transport policy development)</p>	(C,C,C,C)			
		(C,C,C,C)			
				(C,C,C,C)	
					(C,C,C,C)

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Author's contributions

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Availability of data and material

The summary of the results from the surveying activities may be found at <https://taltech.ee/en/finstech-centre-for-smart-cities#p34631>.

Declarations

Competing interests

The authors declare that they have no competing interests.

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