Challenges and needs of European cities in using geofencing for urban traffic management

GeoSence

The project GeoSence elaborates on geofencing solutions aiming at improving urban traffic management and planning.

Authors: Lillian Hansen, SINTEF, Sven-Thomas Graupner, Technische Universität Dresden, Jacques Leonardi, University of Westminster and Hannes Lindkvist, Chalmers University of Technology.

This project is supported by the European Commission and funded under the Horizon 2020 ERA-NET Cofund scheme under grant agreement N° 875022

ISBN: 978-82-14-07576-2

Summary

This report presents the results and analysis of exploratory interviews and a questionnaire survey among transport experts and professionals in Europe dealing with geofencing in urban transport management. As part of the European collaboration project GeoSence - "Geofencing strategies for implementation in urban traffic management and planning", the report contributes to a first step of solving the problems by identifying and exploring the challenges and needs of transport authorities. Starting from the cities' biggest traffic challenges, as experienced by municipalities and cities, but also from the perspective of regional and national authorities, the report focuses mainly on geofencing and its following unresolved implementation issues, such as lack of regulation, an issue prevalent across both experienced and less experienced users of geofencing, GNSS accuracy and infrastructure, user acceptance, costs, knowledge and various practicalities. In the discussion section we synthesise how to overcome some of the barriers and how to tackle those needs suggested by the informants, as well as presenting risks and possible mitigation options, and a transferability analysis for cities that do not use geofencing yet. While findings show the applications of geofencing for micro-mobility and parking as the most transferable use case, the case also is an example of how regulation and the legal framework would need to keep pace with the development of the practical solutions. In conclusion, several recommendations are derived, including the need for investing in digital infrastructure in European cities, and further developments matching digital and physical infrastructure to achieve the potential for geofencing. Further, increasing municipalities capacity for knowledge building- and sharing, starting new geofencing real traffic trials, as well as scaling up and transferring existing and good functioning solutions will be key.

Table of contents

1. Introduction

This report, as part of the European collaboration project GeoSence – "Geofencing strategies for implementation in urban traffic management and planning", focuses on the challenges and needs when using geofencing in urban traffic management. The report is based on interviews and a questionnaire survey asking transport authorities in European cities mainly, but also regions and national authorities to identify specific mobility-related challenges in the urban areas, cities in particular, to describe ongoing experiences with and activities related to geofencing, and the challenges faced when implementing these use cases. The report considers what local, but also regional and national authorities see as the main purposes for using various geofencing solutions in cities, what they consider the main challenges in using geofencing for regulation and implementing it, what could be potential new use cases, and allows a comparative analysis between European cities. Our ambition is to provide an overview of the most pressing questions and challenges to be tackled in the next steps of the various geofencing projects in Europe, identifying the needs of different types of transport experts, and try to discover and derive a European convergence of views and priorities for actions among them. This report also serves internally to be better prepared and have a clearer understanding for the next steps of GeoSence.

In the report, the following **definition of geofencing** is used, which is based on the "working definition" within the project: *Creation of a geofence for monitoring, informing, and controlling traffic (mobile objects/vehicles) located within, entering or exiting the geofence, using electronic communication technologies or pre-defined geofences embedded into the mobile objects/vehicles, where a geofence is defined as: a virtual geographically located boundary, statically or dynamically defined*.

Considering this report as a building block for the GeoSence project, its main objectives are to deliver an analysis of lessons learnt on geofencing so far, showing the point of view of the practical and strategic transport experts dealing with this technology solution in Europe, and also to contribute towards the next steps of GeoSence, for assisting cities in setting-up of pilot tests, and prepare the future guide for implementation. The focus on challenges and needs for transport authorities has the objective to provide inspiration for many future points of action, and possibly allow us to hint at priorities to the biggest challenges and area that would need to be improved the most.

The report is structured as follows: In section two we go through the used method regarding first the interviews and then the questionnaire survey. In section 3 the results are presented before they are discussed in section 4. The report concludes with the main findings followed by recommendations for cities and authorities and the next step of the GeoSence project.

2. Method

The research design of this study was exploratory in nature, with data collection consisting of two studies, (1) an interview study with partner cities and national authorities of the participating countries in GeoSence, and (2) an online survey with participants from city and regional authorities across Europe. The interviews with participating countries have been key to understand the use of geofencing, to better describe in which areas the various solutions can and have been used, what potential challenges have been faced, and what the current and future needs for this technology are. After a first set of initial interviews were conducted, the findings led to creating and phrasing the questions for the survey questionnaire that followed.

In the following chapter we provide more details about the background of the data collection and the research design using both semi-structured interviews and a questionnaire survey.

2.1. Semi-structured interviews

2.1.1. Background and interviewees - city, region - and national authorities of European partner cities and countries

As a starting point for learning about the main challenges and needs of European cities, we completed interviews of the city partners of the project in Spring-Summer 2021. We also used networking and direct email contacts with authorities and experts in European cities, regions and national authorities, via partners in the GeoSence project and via the supporting transport expert networks of POLIS and ALICE. Some of the interviews were also done in connection with the Swedish geofencing programme. The total number of informants was 15, where some participated in group interviews, and some received follow up questions on email afterwards. These are described in table 1. The informants were project managers, traffic strategists, ITS-coordinators, researchers, head of engineering, real estate developers, regulation authorities etc., working with transport questions in their daily work, and as such transport experts in different ways and/or at different levels in their respective organisations.

Table 1. Informants/interviewees

Country	*Organization*	*Number of respondents*
Sweden	Stockholm transport administration	1
	Gothenburg transport administration	2
	Swedish Transport Administration	1
Norway	Trondheim municipality, Ownership unit	1
	Oslo, Mobility division	1
	Viken county, Mobility department	2
	Trøndelag county, Mobility unit	1
	Norwegian Public Roads Administration	2
Germany	City of Munich, Mobility Department	1
	Bavaria State Building Directorate	1
	BASt, Bundesanstalt für Straßenwesen (Federal Highway Research Institute, acting in the domain of the Federal Ministry for Digital and Transport (BMDV))	1
United Kingdom	City of London, Transport for London engineering	1
In total		**15**

2.1.2. Development of interview guide

The purpose of the interview guide with semi-structured questions was to base ourselves on some guiding main topics, drawing inspiration from results from the first report of the project "Current state of the art and use case description on geofencing for traffic management" (Hansen et al. 2021), as well as an approach leaning on user needs assessment – collecting structured data to be able to solve a problem (Rossett, 1982). The interview guide followed a warming up, main section, and cooling off curve according to the following main topics: (1) role of respondent, (2) experienced challenges of the city/cities in the region/cities of the country (depending on level of authority), (3) understanding of and experience with geofencing for traffic management, (4) in what context and with which actors and use cases they had experience with geofencing, (5) evaluation of their own experience, (6) challenges with geofencing for regulation for different types of uses, and (7) regulation, future use- and knowledge needs. The questions were adjusted according to experience, as we expected not all experts to have applied it or tried it in their cities. For the more abstract situations, we rephrased the questions somewhat, to be focused on what interview partners could imagine using it for, and what they thought could be a challenge.

2.1.3. Analysis approach and software

Interviews were transcribed, either by the project's researchers themselves or an assistant. To secure validity, the interviewers coded and analysed the transcriptions of the other interviewer's cities. Quotes and paraphrasings from interviews were also sent back and affirmed or new details added. The initial analysis round was completed using NVivo (QSR International 2022), an analysis tool for qualitative data. The overall analysis approach was deductive-inductive (Tjora 2013) in the sense of using both our own main categories, and the views of the interviewees as a point of departure. This implies starting both from previous empirical findings and a user needs assessment approach (section 2.1.2) but also applying a "text-close" coding approach, using the interviewees own experience and wording as a point of departure. The three researchers' coding were then merged – and codes that were similar, categorised together under an overarching main topic. After the first round of analysis of the interview data we had two meetings where we discussed the findings from the reading and initial coding of the interviews. From this discussion we noted and agreed on the most relevant topics to be included as questions and answer categories for the different questions in the following survey.

2.2. Survey questionnaire

2.2.1 Development of the Online Survey

The online survey was developed based on three sources of information. Firstly, the questions used in the interview guide, secondly, the results from the subsequent interview analysis, and thirdly the aims related to WP5 in the GeoSence project "Development of a strategic implementation guide for cities". The starting point for the development were the topics from the questionnaire guide. A first draft of questions for the survey was then further refined based on the interview analysis and several rounds of discussions and input between the project partners. Interview respondents' answers on the different questions guided us towards the most relevant questions and answer options for the survey questionnaire. Based on the interview analysis it also came apparent that the survey had to be formulated and structured in a way to both accommodate the potential needs and challenges for respondents with high and low degree of experience with geofencing.

2.2.2 Structure and content of the online survey

The questionnaire started with a short introduction of the topic geofencing, the main objectives of the data collection and the expected answers from respondents. The first three items in the survey were used to collect descriptive information, including the city/region and country the informant worked at and the professional role within the organisation the informant was working for. This section was followed by one question on the most relevant traffic related challenges and problems in cities/regions and then continued with questions and topics about geofencing. Table 1 (in the appendix) summarises topics of the questions and the answer formats used. The questionnaire had two slightly different paths, depending on the experience of geofencing the respondent had. Altogether the questionnaire covered a maximum of 14 questions, with less experienced informants asked only 12 questions.

2.2.3 Implementation and dissemination of the survey

The questionnaire was implemented as an online survey with the LimeSurvey Tool (Limesurvey GmbH). The LimeSurvey tool and the database were hosted at the Saxony education portal in Germany. Answering the questionnaire was assumed to take 10 minutes. According to the LimeSurvey questionnaire log, respondents took between 4 and 25 minutes to fill the survey. The survey was made accessible online on 2nd February 2022 and was closed on 31st March 2022. It was first published through the POLIS website and network newsletter and a few other channels of European project initiatives (JPI Urban Europe, Eurocities, Nordisk Vegforum, ALICE). It aimed at respondents working for administrations and authorities of European cities and regions in the field of ITS and/or traffic management and planning. The invitation was framed in a way to address both respondents with and without previous experiences on geofencing and geofencing implementation. Since the initial response rate was low, a second round of activities was started to promote the survey including posting the invitation on the social media channels of GeoSence partners and supporting institutions, and sending it by mail to contacts in professional and scientific networks, with the request to participate or spread the survey invitation.

2.2.4 Data processing and result grouping approach

The questionnaire responses data were downloaded as a CSV file and analysed using the software RStudio Microsoft R version 1.4. Data processing was performed question wise. For each question we calculated either the number of nominations for a questions' option, or the percentage of nomination for an option (relative to size of the reported group). The latter was necessary to compare the response patterns between the two experience subgroups (less and more experience), as the number of respondents in each group was slightly different. Some questions were analysed based on the differentiation between less and more experienced respondents with geofencing.

2.2.5 Respondents: description of the survey sample

About 57 potential respondents visited the survey site and 30 of them completed the survey. Two respondents did not complete the survey but gave answers at least up to question 5 and their responses were included in the analysis. Another 6 respondents left the survey with only answering (part of) the descriptive questions. The descriptive information on the geographical distribution of the cities, and on the professional role of respondents is shown in Table 2. Responses came from many different cities and regions across Europe (25 cities/regions: 14 countries). Most responses (each N=5) came from Denmark and the UK (4 from London area). In the reported data, there is a slight overrepresentation of cities and countries from Central and Northern parts of Europe. The professional role question was answered in an open text format. Therefore, the received answers varied in level of detail. Table 2 (right column) shows descriptions that have been obtained by recoding the answers into broader role categories. These roles were clustered into two broader categories, related to either more executive (E) vs. more strategic (S) functions/roles for a project implementation. More than half of respondents can be classified as belonging to the executive level (e.g., planner, project managers, engineers, data analyst). For all other respondents their role has a more strategic value, even naming team-lead, financial or department lead functions. This suggests that responses came not only from people that (will need to) work with geofencing on a daily basis but also from people whose task it is to suggest or decide on developments in a more strategic manner. Altogether, we assume that our respondents are a representative sample of persons who are involved (presently or in future) in the development of geofencing related projects in the field of traffic/mobility/transport planning and management in Europe.

Table 2: Sample of cities and roles of online survey's respondents

Countries	n	Cities/Region	Roles	n	E/S
Austria	2	Region Austria	Project Manager	7	E
		City of Vienna	Planning (Transport/	6	E
Germany	4	Dresden	Mobility/ Urban/Strategic)		
		Hamburg	Head/Lead	5	S
		Freiburg	Expert/Advisor/Consultant	4	S
Turkey	1	Izmir	(Mobility/Policy)		
Greece	1	Trikala	Engineers	3	E
Norway	3	Fredrikstad/Sarpsborg	(Traffic/Transport)		
		Trondheim	Innovation Expert	2	S
		Oslo	GIS Analyst	1	E
Sweden	2	North Sweden	Science	1	S
		Skåne	Safety Officer	1	E
Finland	1	City of Turku	Financing	1	S
Denmark	5	Capital Region of DK	Unspecified Traffic	1	E
		City of Copenhagen			
United Kingdom, UK	5	West Midlands			
		London			
		Kingston upon Thames			
		London Borough of Redbridge			
Belgium	1	Bruxelles			
Italy	3	Bologna			
		Padova			
		Rome			
Spain	2	Vitoria-Gasteiz			
		Bilbao			
Netherlands	1	Helmond			
Iceland	1	Reykjavík			

Note: E= Executive function, S = Strategic function

In the survey, the respondents were asked "What experience do you have with geofencing?" giving 8 answer options defining the belonging of the respondents to a more or less experienced group. We then used the terms "Less" and "More" to classify the experience level and this impacted the progressing to the next questions. For example, for the answer option "never heard of it", the following question on geofencing projects was supplemented by a definition of the term geofencing, and phrasing the questions referred to a potential implementation of projects with geofencing in the future.

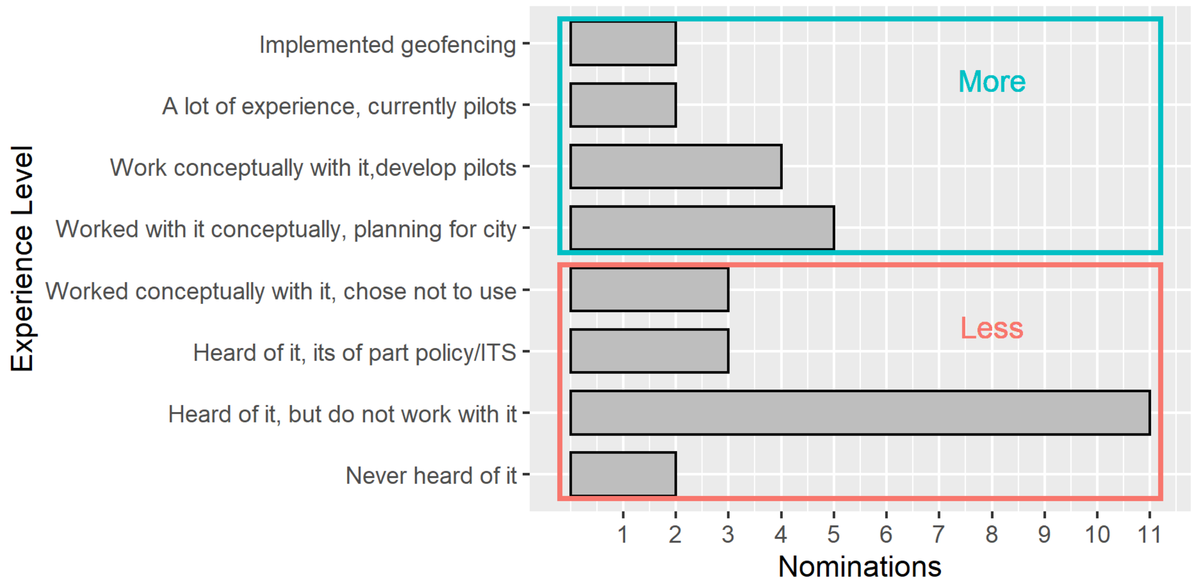

Figure 1. Reported experience level with geofencing technology in the online survey

In Figure 1, those respondents who answered one of the lower four answer options were assigned to the experience level "*Less*" and those who selected the upper four statements were subsequently grouped to the level "*More*" experienced. As shown in Figure 1, there is a clear dominance for the answer options *"Heard of it, but do not work with it"* (n = 11), with more than a third of the participants selecting this option. The second and third most nominated options belonged to the *More* experienced group. According to our classification scheme, n=19 responses belonged to the *Less* experienced group and n=13 belonged to the group with *More* experience.

3. Results– Challenges and needs of cities

This section presents the results and statements of the qualitative interviews performed in the period Spring-Summer 2021 in Europe, and the online survey performed in early 2022, including categorisation of interview data and analyses of the survey data. The responses were structured along the main concepts around challenges and needs, from the more fundamental to the more practical and detailed problems. Original interview statements are paraphrased or presented in "word by word citations", with some clarifying text added by us in brackets. The section starts with the more general challenges of cities, before turning to experience with geofence use cases, followed by the main section on challenges with implementing geofencing for regulation.

3.1 Traffic and mobility related challenges of cities

Before looking at the specifics of geofencing applications, one of the first questions to the informants was about traffic and mobility related challenges of cities, and this question was asked to public sector experts performing at the municipal, regional and national level. The German representative of the Federal Highway Research Institute (BASt) made an observation on the challenges faced by the administration on their fundamental objectives which could be of relevance for other countries as well:

How to “enable mobility and at the same time limit its [negative] effects”. While the biggest impacts such as congestion, accidents, speeding, parking and mobility restrictions, and various other issues are responsible for societal, local and political tensions, the sub-sections below present the challenges mentioned during the interviews.

3.1.1 Space allocation and competition

Space is often mentioned as an issue for several types of mobility by the partner cities. For buses: “Space is always a problem, especially when you drive buses. No one wants a bus or a bus depot located outside their window” (Trøndelag county). For urban logistics: Urban logistics require space, and that space is limited. Further, freight traffic comes in conflict with other drivers, and it influences how roads are used. Roads are built mostly in a wide size and are dimensioned for rush hour: “you save billions a year by stopping expanding our roads” (Trondheim). This statement is in line with the issues in Munich, Germany, mentioning the creation of cycle lanes: “we would have to take space away from someone to make room for someone else, so a new cycle path often means one less car lane, and now the difficult budget situation comes on top of it”.

3.1.2 Congestion and access, and how to improve this

In Sweden and Norway, informants argue that congestion is one of biggest issues in the cities, and it is often mentioned in relation to access, where congestion is hindering reliable or easy access into the cities. Some suggest a potential travel ban at some times of the day could be introduced (Trøndelag county). This is in line with arguments from the Mobility Department in Munich, where they see that the share of motorized private transport is not decreasing, and even increasing some places. Further, it was argued for a need of information on how to drive detours, and a need to prioritize public transport over other modes (Viken county). Another issue related to that is how infrastructure projects are restricting access. Many large infrastructure projects going on at the same time restrict access in several different places, and that makes the entire transport system very sensitive to disturbances (Gothenburg).

3.1.3 Decreased use of public transport, and how to tackle it

Regarding the need to prioritize public transport, this is due to the observed decreased use of public transport, especially during the last couple of years due to COVID-19. Issues here were funding, limited budget and capacity. Gothenburg also mentioned the challenge of getting travellers back to use public transport after the pandemic as many travellers shifted to car during the pandemic. This also relates to the general challenge of how to reduce the high amount of individualised traffic. One of the informants pointed out how to manage the shift from motorized vehicles, e.g., how to strengthen cycling and pedestrian traffic, creating better cycle paths, and walking and [opportunity] for micro-mobility (Munich). In London, the interviewee referred to these as the solutions “supporting active travel”.

3.1.4 Pollution and environmental challenges, and mitigating strategies

In the interviews, issues of climate, sustainable travel, emissions or pollution were prevalent. Many statements were made on how to contribute to a zero-carbon or ambitious climate goals, not only for passenger transport, but also for goods delivery (Oslo). As a direct cause, COVID-19 restrictions led to even more use of private cars (as also mentioned in 3.1.3), at the expense of public transport (Munich). Related to sustainable travel specifically, COVID-traffic was a topic or rather "how should we return [get away] from "COVID-traffic?". As stated by Gothenburg:

> "Many people have become accustomed to driving their own car, perhaps alone, to different places, to work, and so on, and [how] to [come] back [to] the lost work of making sustainable travel choices, when the pandemic is more under control, and hopefully over"

Some also see the future potential to tackle pollution and environmental challenges and mitigate them with appropriate strategies that include geofencing, as stated by one respondent:

> "You can think in terms of what you want in the city, it's clean, quiet, safe, accessible and stuff like that. And then I think that you can work with freight and distribution traffic in it. For example, with silence, the more we electrify, the better, and if we can control it on a powertrain, [using geofencing] for example, it would have been good" (Gothenburg).

3.1.5 Digitalisation is a challenge for infrastructure upgrades

Digitalisation was an issue brought up in the interviews. While this is ongoing work in for example Sweden, where in the Swedish Traffic Administration (STA) there is a program currently working for digitalizing of the transport system, it was discussed as a challenge in Germany how they can conjoin all the different transport offers in the future:

> "The digitalisation of the transport infrastructure is a major challenge that we are facing. Automated and connected driving is a point that we will have to deal with. Getting all the different transport offers, with the complexity of for example micro-mobility, sharing offer and mobility as a service together under one umbrella, this will be a great challenge for road operators" (Bavaria).

3.1.7 Road safety - geofencing as possible solution

Road safety was mentioned as a main challenge by several of the informants (e.g., Stockholm), and specifically in relation to badly injured people (NPRA). Further the advantage of geofencing as a possible solution was mentioned, as it can be used for introducing mandatory lower speed inside cities, as a safety measure, but also to contribute to less wear and tear of the vehicles (Gothenburg).

3.1.8 Micro-mobility related issues and a lack of regulation

Some of the issues brought up about micro-mobility is how it is getting out of hand with shared e-scooters regarding parking and having no overview of how many rules are disregarded (Munich). It was also pointed out that since it is a new type of mobility, there is a lack of regulations (Oslo). It was pointed out how there are too many e-scooters in the city of Oslo, so the municipality wants to put a ceiling on the maximum number of e-scooters in the city (and use geofencing for that). Since this interview, the city of Oslo, Bergen and Trondheim have gotten increased possibility to regulate operators. More on this in 3.4.6. Until now e-scooters have been regulated as bicycles in Norway, so being able to go on the pavements. But this recently changed during last writing of this report. Now e-scooters are regulated as motor vehicles in Norway, however, one can still follow many of the same rules as before, such as being allowed to still drive on the pavement, given certain conditions (NPRA 2022).

3.1.9 The main challenges are confirmed in the online survey

The survey question on traffic related challenges of cities/regions confirms many of the challenges mentioned by the respondents in the interviews. *Congestion*, *pollution, a high amount of individualised car traffic* and *parking* were the most often nominated challenges, while the topics *speeding*, *micro-mobility related issues* and *maintaining and transformation of traffic infrastructure* received the fewest nominations. The fact that *micro-mobility related issues* were comparably seldom perceived as a challenge is somewhat surprising, given the often-negative press coverage and public opinion associated with this scheme of mobility in the recent years (Gössling, 2020). An explanation for this might be that micro-mobility is often seen as part of a solution to the actual predominant problems like pollution and congestion. So, it could be associated with an opportunity for a solution rather than a challenge. Evidence for this comes from a study with stakeholders, extending from decision-makers to transport planners, engineers and prospective users, that was performed in preparation of e-scooter trials in the UK, suggesting that stakeholders generally are in favour of e-scooter use and implementation (Packar, 2020).

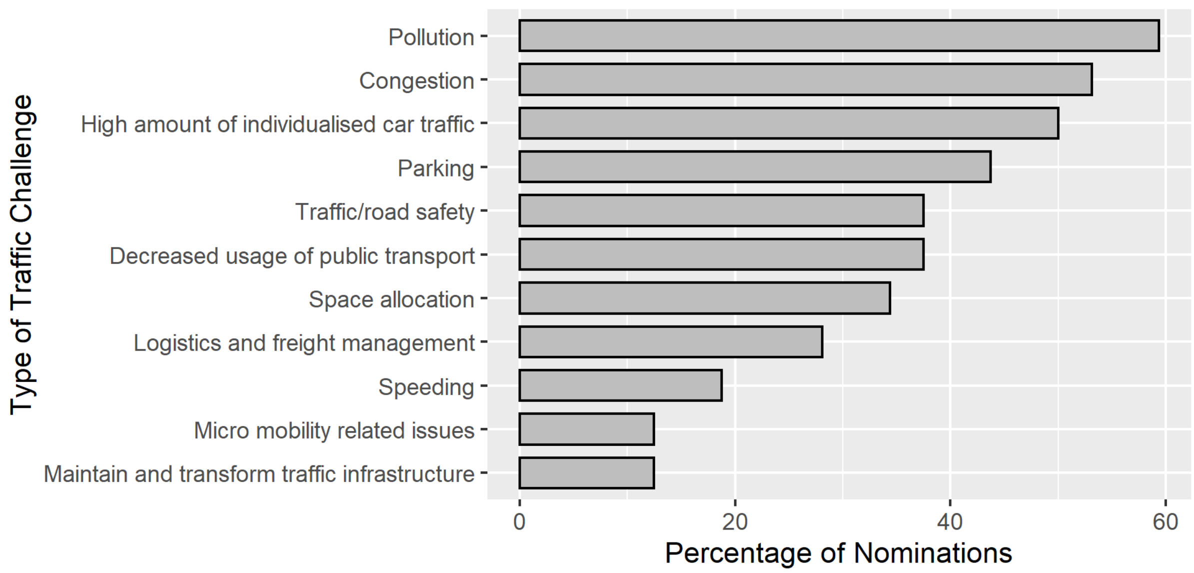

Figure 2. Traffic-related challenges for cities/regions

Note: Minimum 3 and up to 5 answers per response

3.2. A variety of geofencing solutions and use cases

As found in the interviews and the online survey, geofencing is a technology with multiple applications that differ in their context but all correspond to using a mapping to fence off digitally some area for quite a lot of different traffic management purposes and aims, such as improve parking, limit speed, enable access, lower pollution, enable cooperation, ease enforcement, speed up information exchange, process data, automate traffic information update, and communicate with users.

The most common transport modes where geofencing is currently used are e-scooters and buses, corresponding to the mobility types of micro-mobility, active travel, and public transport. Summarised, based on the interviews and survey results, which are also in line with our initial definition in the introduction, a geofencing application consists of having a digital map designed, created and run by a for example a Municipality Mobility agency, and serving as reference for geographical limits and exact positioning of where the rules apply, for example speed limits for certain street portions, or an area near a metro station and areas reserved for parking of e-scooters. The key element of an application is that the map is downloaded into vehicles and connected with information systems and transmission of data with central servers of transport operators. In some cases, the client using the vehicle can see the map directly in the application. What remains invisible is the whole set-up of the geofencing system involving the communication platform and data exchanges between Municipality services, operators, vehicles and end-users, and the set of rules that were the subject of contracting agreements between the main actors.

There was some diversity among the respondents in what constitutes a geofencing solution. However, in accordance with the responses, the essential elements of a geofencing solution are a set of technology elements, regulatory agreements, management practices and practical user procedures. Put simple: with a geofencing solution in place and functioning, the mobility user can drive or ride onboard a vehicle with a pollution level authorised for the area, avoiding parking in the wrong place, being guided around fenced off street portions (or in ideal cases directed towards a free parking spot), respecting the speed limit set for that exact place and time, avoiding uncertainties and contributing to a safer and more sustainable transport system.

Applications and solutions mentioned by the interviewees are presented in the following.

3.2.1 Boundaries to e-scooter parking

Munich is testing the application of parking spots reserved for e-scooter, with restricted access to the area surrounding the parking spot, making it difficult for users to leave the scooter outside the designated parking zone. “We want to introduce no-parking areas around these physically established parking zones” (Munich).

In Norway, geofencing for parking zones is already in place in some cities like Bergen, or soon to be geofenced for e-scooters in other town centres. [This might have changed since interviews]. “We want that, only places where you can start and stop the e-scooters; [geofenced] parking zones" (Trondheim). Such parking zones are complemented by so-called geofenced “no-go” zones: “The engine power of the scooter will turn off if you drive into an area where you are not supposed to ride" (Trondheim). This could have educational benefits: "Once you have a parking zone and someone has parked correctly inside, it has a very educational effect. So, you get a kind of gain then, from the fact that there have already been someone who have parked there and done well" (Trondheim).

3.2.2 Limits to e-scooter or shared vehicle access of certain streets, times and speed

"We have a dialogue with the electric scooter companies about what to geofence, but then it is up to them to do so" (Gothenburg). "Geofence for electric scooters are also going well" (Gothenburg). "We simply block certain zones with the help of geofences. For private (e-scooters), the question is whether that is possible. But for shared micro-mobility, this is definitely our first main area of application in the field of traffic management (Munich). In Trondheim, no-access zones are being used in the sense that it is not allowed to park e-scooters at the cemetery or outside certain buildings. Further in Trondheim, operators of shared e-scooters have to use a speed zone with geofence in certain areas. E.g., the vehicles automatically switch to 6 km/h across the main square of the city.

3.2.3 Bus lanes with connected traffic lights system

"We use geofencing [with a] Softprio-system that we have in public transport. And it's about priority in signals, traffic signals." (Gothenburg). Softprio is a software that enables and triggers the signals to give priority for busses at crossings, modifying the traffic signals when the bus is at a certain distance, and this distance is corresponding to a geofence.

3.2.4 Urban logistics applications

There are existing logistics applications for geofencing, but these are not in use on a daily basis: "I know that [not named colleague] works with the fact that they have a freight [operator] connected. And then a little bit with Volvo and Scania and also then transport operators" (Gothenburg).

3.2.5 Speed limits for taxis

One of the GeoSence trials in Gothenburg will include several geofenced areas with speed limits for urban taxis. Stockholm have also had discussions on how to make sure that taxis follow the set speed limits in the city with help of geofencing or Intelligent Speed Assistance (ISA).

3.2.6 Geofencing of speed for transport buyers

A potential application currently under development is the improved control of speed for transport buyers.

> "In terms of speed compliance, the technology is interesting. We have this "call/announcement for sustainable speed" (Swedish initiative "Upprop Hållbara Hastigheter"), it is a project where we work with Sweden's largest transport buyer and the ambition is to eventually be able to get geofencing of speed" (STA).

3.2.7 Geofencing for validation of traffic information

In Germany, a project has been carried out by the Bavaria State Building Directorate using geofences to filter and validate location information of roadwork/maintenance warning trailers which are operating on motorways or rural roads before feeding these signals to regional and national traffic information networks. Geofences are used to demarcate the premises of the motorway maintenance authorities which are often located close to motorways. If a warning trailer is located on the premises of the motorway maintenance authorities, so not on the motorway itself (e.g., for maintenance, work-breaks, etc.), a geofence is used to make sure the data of this vehicle/carrier is filtered out and not forwarded, thereby improving the validity of information related to warning trailer's location in the traffic information network.

3.2.8 Road charging with geofencing

In Trondheim, there is an ongoing pilot using geofencing for road charging, as an alternative to tolling stations. The focus is on privacy / GDPR and testing a technological solution that is close to implementation. This pilot also includes user experience and user acceptance through surveys etc.

3.3 Perspective on problems and solutions differ slightly according to level of geofencing experiences

3.3.1. A variety of geofencing solutions for different mobility types and mobility problems in the online survey

Respondents of the survey described in an open-ended question currently implemented, developed, or envisioned potential ideas for geofencing projects. In order to pre-structure the answers, there were three text boxes in which the participants were asked to name the *mobility type*, the *mobility problem* it addressed and the *function* it implemented. Respondents from the experienced group were also asked about the *implementation status*. The questionnaire provided an exemplary project description and various anchor terms to focus the answers – see Figure 3[1]. Figure 3 shows the modes of transport, vehicle used and mobility types that geofencing projects or use cases are developed or envisioned for. The dominant category named for the mobility types was *private cars* (including road/motorized/combustion engine vehicles). The second most frequent category was *micro-mobility* (including e-scooter or similar terms). Both (*private cars* and *micro-mobility*) make up for almost 50 percent of the named mobility types. *Goods transport and logistics* and *public transport* were the categories that followed with a roughly equal share of nominations, but already only half as often as the first two.

When comparing the experience level groups, the most apparent finding is that *goods and logistics* was named far more often by less experienced respondents and *emergency vehicles* were named only by experienced respondents. As is depicted in Figure 3, a few other categories received singular mention.

[1] Data processing consisted of that each respondent provided at least one and, in many cases, several records for geofencing projects or ideas. Due to the open answer format, the received answers were heterogenous in wording and structured by us into general categories. In two cases the terms given were too unspecific to be classified and were therefore removed from the data set.

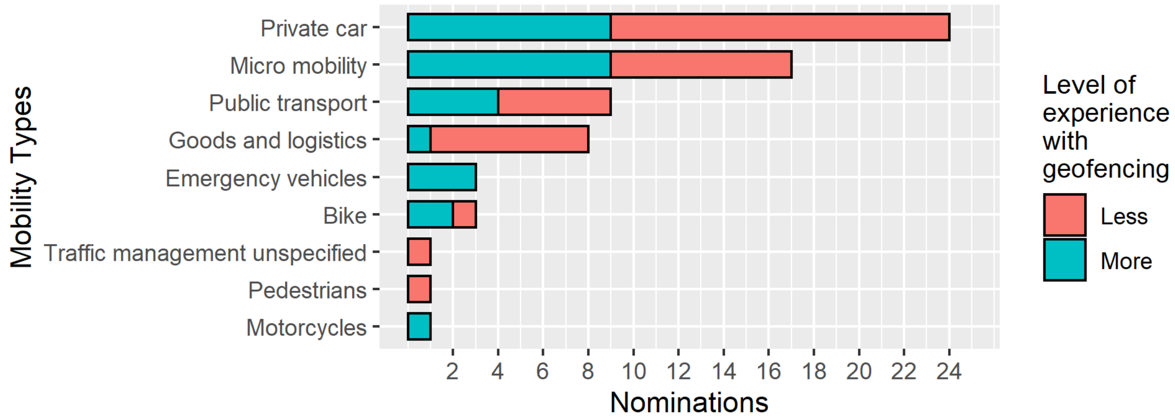

Figure 3. Mobility types for current and envisioned geofencing projects, by experience level

The free text answers about mobility problems are structured into thirteen categories (Figure 4). *Access* and *Parking* are the two most commonly nominated problems that are or are to be targeted with geofencing technology. *Speed*, *Safety, Pollution* and *Congestion* were other more often named problem areas. A few differences can be observed between the experience level groups. However, the interpretation of these differences is difficult. It might be related to the fact that there were more respondents in the *Less* experience group which proposed a larger number of possible geofencing implementations. Furthermore, the *Less* experienced respondents might have more often suggested more abstract problem classes (e.g., *Pollution, Congestion, Capacity*), on one hand because these were framed in the question as anchors for answering, on the other side also because there is no experience with concrete implementations yet. In contrast to that, the *More* experienced group has a higher level of expertise with the implementation process resulting in nominating more often practical problem fields, (e.g., see distribution for Prioritisation).

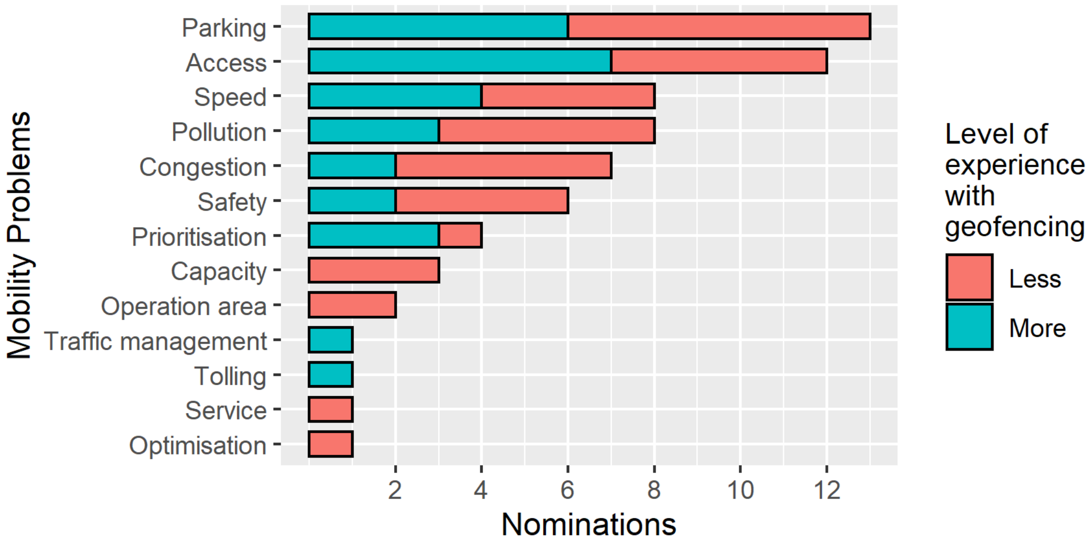

Figure 4. Mobility problems to be tackled by current and envisioned geofencing projects, by experience level

3.4 Challenges with implementing geofencing for traffic management – experienced users' perspective

In this section, experienced users express their views on practical challenges and problems to be tackled to implement geofencing solutions for regulation or traffic management

3.4.1 Struggle to coordinate and collaborate with many external actors:

One of the challenges with geofencing is that some cities experience that there is lots of working steps, and actors needing to collaborate. One example Gothenburg points out, is to get reliable traffic regulation data to be coherent with the physical infrastructure (also presented in section 3.4.9): "This urge collaboration between many actors, all the way from contractors who set up the road signs, to municipalities and further on to various navigation service providers".

In Munich, the free-floating e-scooter rental operators linked with the geofencing tool are allowed to run on the streets of Central Munich by the municipality services, and following a set of traffic rules but not mentioning parking in 2021. “Regarding the parking areas, they [the city] don’t have “hard contracts” with [the e-scooter rental operators] so they cannot force them to do it [to use geofencing].” However, the city does have some leverage: “If you don’t cooperate, then we’ll treat it as a special use, as it’s already done in some cities, and then they’re out [of the contract], or have to [re]apply” (Munich). However, in Trondheim, Bergen and Oslo there has been a problem with one company – that operates on the side of the rest, not following the guidelines of the city, which created competition problems for the other operators. Operators have shown to be interpreting drawn zones differently than the city (Trondheim). As the informant from Trondheim pointed out: “There is a need for a setting rules and guidelines when new things appear (e.g., within micro-mobility) so that “one doesn't have to start from scratch every time” (Trondheim). Relevant and new laws and regulations regarding micro-mobility are briefly presented in section 3.4.6.

3.4.2 Challenges in information and data sharing among multiple actors

Data sharing is another topic related to these difficulties in coordination of multiple actors: In Oslo, there was noted scepticism by the municipality about sharing data. But this has improved with the realisation that the data can be used for a good cause. When geofencing is posted in the system of the municipality, it goes out to the different micro-mobility operators – but they still have to accept it in their system, it is not automatic (Gothenburg).

Related to the data sharing topic, some cooperation difficulties occur in different practical contexts, such as the lack of a platform for collaboration/data sharing, for example in Gothenburg. However, they state that various platforms are being tested in different small-scale projects. For geofencing applications within micro-mobility there have been some recent changes in the final writing of this report - platforms have been tested and a full-scale solution is now in the process of being procured by Gothenburg city. However, they state that for more advanced geofencing solution there is no unified solution for data sharing.

This is an issue in progress in C-Roads (C-Roads.eu 2022), where the programme experts work on improving communications between transport actors in new data platforms through standardisation of a joint European platform, regarding e.g., signatures and message formats, among others. “This opens up for these regulations to work across national borders” (NPRA). Linking with other types of data was also brought up:

> “There are probably some developments there I also think that no one really knows where it is going, but this thing with IoT platforms in cities, that you create much better knowledge about what is happening through sensor data and also crowdsourced data from vehicles and the like. That information should, of course, be collected on one platform and linked to the different geofencing functionalities” (STA).

Germany is working on a new data exchange platform for mobility, with the purpose of obtaining a better cooperation among actors for ITS in general (BMDV, 2021). The "old" MDM [Mobility Data Marketplace] will be integrated in a new mobility data platform, "which is intended to enable the collaboration of data-driven services from the private sector, and to all data provisions that have a regulatory basis, such as the ITS Directive and the Delegated Regulation on safety-related traffic information, real-time traffic information and multimodal traffic information. All of this is now to come together in the so-called Mobilithek. We have a big role there.” (BASt). The Mobilithek is a platform for mobility providers, infrastructure managers, transport authorities and information providers to share digital information (BMDV 2021). However, the MDM covers ITS in general and does not explicitly, nor necessarily, cover data sharing for enabling geofencing applications – although it could. Furthermore, commercial use cases will be explored by the emerging Mobility Data Space (https://mobility-dataspace.eu/).

3.4.3 Awareness and acceptance among users and end users

One of the informants mentioned how they think people [end users] are not so aware (yet) of what geofencing is, and that it is the responsibility of the providers to be clearer in their apps/channels, as well as the responsibility of the municipality to give more information (Munich). Awareness and acceptance of those employed in Bavaria came up related to the infrastructure, or rather operational vehicles in Bavaria (see 3.2.7. for explanations on the use case of validation of traffic information). "Where we already have an acceptance issue is in the localisation of operational vehicles such as warning trailers. We have to make the employees of the Free State of Bavaria aware that it is important to pass on this data and that it does not somehow serve to control their work, but that it is used to set up services" (Bavaria State Building Directorate).

In the city of Trondheim, as well as Gothenburg, acceptance was an issue in the sense that the e-scooter operators have voluntary agreements with municipalities, which give them the possibility to choose not to follow a regulation. They have to "accept" the regulation sent through the system by the municipality, it is not automatic: "If there were to be mandatory rules, then perhaps it would work in a different way technically as well. That [the rule] is actually only received when we say that it should take effect" (Gothenburg).

In Stockholm, the importance of the drivers' understanding and acceptance was mentioned regarding speed. They further comment regarding geofencing for buses – "it can actually be positive for the work environment that it is less of a stress factor if it is an external factor that determines how fast you can drive".

Regarding private vehicle users, the NPRA commented that it depends on what the geofencing will be used for in Norway, "if it gives disadvantage to the user then I think you can meet a lot of resistance. But if it helps the user to make good choices or use means of transportation in a good way, then I think it will go well". Related to that, reluctance to being controlled was brought up: Reluctance to accept the technology itself depends on how strong the regulation is, according to the interviewee in London; "If it's a privately owned vehicle, I would estimate that, if it's being used for enforcement or being used for control, I think the public will be reluctant to adopt it, but [for] anything that hire, hire bikes, hire cars [it would be different]".

3.4.4 Technology and system affordability - Equality of access

Some interviewees are speaking about the topic of equality of access to technology and IT systems in that it gives some access to certain areas only for some, for example if you have the resources or the technology: "One of the issues could be that one can buy one's way of access in the transport system" (Gothenburg). This implies, that if we put criteria's for being able to drive in certain areas, like having a technology, it will exclude others. Equality of access can also be an issue when it comes to pilots. E.g., in London, a pilot with geofencing and e-scooters, they have not included certain Boroughs in the participation of the trail, meaning they are "geofenced out" (London). This means you cannot access these areas with the e-scooters, which will affect the end consumer.

3.4.5 Missing policies or strategies

This was an overarching topic in the interviews, when interviewees were asked directly if the cities have some overarching policy or guide in place for geofencing. In general, it was reported to be no action plan or strategy designed specifically for framing or developing geofencing. One interviewee reported that various IT support and functions are included in the road safety plan. But there is a budget for interacting with industry and work for geofencing of speed in Stockholm's inner city. (Stockholm). In Gothenburg they say: "We have a strategy that was decided by the Transport Board in April last year, a strategic plan for electrification, automation and digitalisation. It mentions geofencing as one of the areas on which we should work more with, but it is not a concrete plan for how [to use it], rather something that we need to focus on and continue to be active in".

One opinion from the Swedish Transport Administration is that it would be better to let the market decide/develop instead of making laws and regulations – as this would demand resources to follow up on. From most informants in Norway, it was reported that there are no strategies or policies targeted for geofencing. But as pointed out by Viken county, it is promoted to seek new technologies or use technology in new areas, as a guide in the transport strategy, and thinking about implementing an ITS strategy.

3.4.6. Legal bases and regulatory options – A political question

A recurring topic was what opportunity municipalities have to ban or give local regulations for e-scooter operators (NPRA and Trondheim). Further, the classification of e-scooters is critical, as argued by STA: "That the Swedish Transport Agency has chosen to classify the electric scooters as bicycles makes it more difficult for us to regulate them tightly, compared to how they have been regulated in some other countries" (STA). In Norway it is the opposite: e-scooters were, during the end of writing of this report, just reregulated as vehicles, not bicycles (NPRA, 2022). Regarding legislation for e-scooters, the issue in Munich is that they [are] not able to go slow enough, to be allowed in the pedestrian zones. A new law in Norway on rental of small electric vehicles in public space, effective from Summer 2021, gives municipalities the possibility to put down a local legal regulation on rental and use of e-scooters (Lov om utleie av små elektriske kjøretøy på offentlig grunn, 2021, §3). Another regulation in Trondheim, is that parking companies can fine wrongly parked e-scooters, sending the bill to the operators but also private citizens (Toftaker and Kringstad 2021). These laws, to an increasing degree, put micro-mobility operators and users under stronger regulation.

Driver responsibility is also an issue, believes the STA, if geofencing were to be used. Questions regarding who is responsible for certain actions or system failures etcetera needs to be considered.

For private vehicles, a point from the county of Viken is that a lot of the limitations of the technology and legislation are about political choices.

Sharing of data is another critical issue in general. BASt, Germany, comments on the need for a legal basis for being able to take up data from vehicles, which would be a prerequisite for geofencing. They have come up with a new data protection concept: "yes, this is actually a good and sustainable concept, but you still need a legal basis. This has now been created with the latest amendment to the Road Traffic Act[2]".

3.4.7. Missing guidelines and standards – Silos versus unifying solution

In general, a “ready-made” recipe on how to apply geofencing is not available. This is confirmed by the informant in Munich. Standardisation of data transfer, [has the aim] to transfer data in a uniform format. But [it was] not done so regarding geofencing in Germany (State Building Directorate). Standardisation can also relate to the user certificates and the type of data security. The project C-Roads work on standardisations related to this (NPRA). In Germany, the Traffic Centre Hesse has set up a central data storage system for the data of the warning trailers for the whole of Germany. All federal states can join and submit data. The issue of standardisation and simplification seems to work very well here, because it is now operated by one national authority - the Autobahn GmbH and Verkehrszentrale Deutschland (Bavaria State Building Directorate). BASt in Germany makes the comment that cities (but also federal states or nation states) in Europe, have a suitable solution for themselves, a bit like a silo that satisfies their needs. The question is then how to make it compatible with the neighbour, other regions etc. On the other hand, in one of the Norwegian cities, the issue of guidelines and the possibility of the municipality to impose power and demands on e-scooters, has gone all the way to the Supreme court in Norway (Trondheim– they lost however). Further they comment “think we have to try to put in place one, a set of rules then. Guidelines that can also be used when new things appear, so we do not start from scratch every time, because I think this can develop quickly”.

3.4.8. GDPR, data protection or data security issues.

The NPRA comments that the technical side regarding positioning for geofencing, seems quite solvable– but that there is a bigger issue with how to convey the [geofenced] zones. This is related to user certificates (with reference to standardisation above) and data security. GDPR and data privacy are one of the biggest issues. In Germany, BASt have come up with data protection concepts that have been coordinated at the federal level and with the relevant state commissioners. Integrity is another security issue. Jamming can be a challenge, but GNSS combined with IMU [Inertial Measurement Unit[3]] is pretty good at holding position when GNSS coverage disappears / is disturbed. Further the representative of NPRA argues from own experience tests, that spoofing is demanding to do and probably not a real threat from "amateurs".

3.4.9 Insufficient/immature technical equipment or procedures – Digital and physical infrastructure could be key

As mentioned above by the NPRA, but also in Munich, the software side is not the biggest issue – if the car is compatible. The bigger issue regarding the technical side, are the older vehicles that are not developed enough/not geofencing compatible (among others mentioned by Viken county and NPRA

[2] https://www.gesetze-im-internet.de/stvg/index.html See the latest amendement to the Road Traffic Act. A corresponding paragraph 63e has been added, which contains a legal authorization and processing basis for the purposes of traffic safety and traffic management

[3] Can contain gyroscopes, accelerometers, and sometimes magnetometers.

regarding regulation possibilities). However, as mentioned by STA, the sale of new cars [with such compatibility] is increasing, BMW for example, has introduced a geofencing solution for switching between electric and conventional powertrain in Stockholm and Gothenburg. This solution has also been trialled in cites in Norway through the NordicWay3 project.

Another issue is inaccurate maps and source quality. If this is not matched with the physical infrastructure it can hamper geofence solutions. For example, there is a need for the speed available digitally to match the signs. This is currently not completely the case. The format is also an issue (STA). But they [the national authorities] are currently working on this:

> "So, I would say that perhaps the most important thing we are doing at the moment is actually addressing the data quality problem at source. Because even if we make sure that all the information that is in NVDB today is correct and consistent with what is in the STFS database where the regulations are located, it does not matter so much if it constantly fills up with information that is not true later, it will not take many years before it is as bad again." (STA).

The barriers with maps and matching between physical and digital infrastructure is also commented on in Gothenburg: "Where road signs are located and how roads are formed need to match with how they are distributed digitally with a geofence". The informant also points out that updated maps are a prerequisite for both traffic information, route planning and geofencing information to be correct.

GNSS challenges were a recurring issue among several county informants. But this issue was reported especially for micro-mobility. While this could naturally be because there were more micro-mobility geofence cases, the informants provided some important nuances. In London, it was noted that there are different deploying approaches to geofencing depending on the supplier. Either onboard telemetry and real time global positioning – interrogating the map instantaneously, and the other cloud-based system that communicate the global position with the cloud every 3-5 seconds. The issue with the latter is that it creates lag. "They are working with suppliers around this (commercial value so he could not be specific), but it is related to the urban environment, because of the signal bouncing off adjacent buildings as well as GNSS signal issues". Operators need to have a "slow zone": "This requires that the GNSS in the e-scooter sends the signal back to the server relatively often" (Trondheim). But there are already ongoing developments to work around GNSS issues, where physical infrastructure might be key. Although it remains to be seen to what degree it can. On-street infrastructure was commented on by London, as a way to improve inaccuracies generated by GNSS signal failures through high inner-city buildings. But expenditure for maintenance would be too expensive for the trial they were working on at the time of the interview. In Munich, the informant commenting on the GNSS challenges states they will have to work with a buffer zone for e-scooters, as the GNSS can be inaccurate, and that additional sensors could work here. Another issue is the problem with "verticality" when using speed control by maps – as sometimes the vehicle doesn't know where it is, when you have crossed roads (STA).

3.4.10 Missing support by authorities

One issue coming up among interviewees is that there is a lack of interest or rather de-prioritisation in municipalities/regions, as there are many other issues that need attention first and foremost. Also, vehicle manufacturers focused on low emission/fossil free vehicles (Stockholm). The NPRA (department of Authority and Regulation) argues that a challenge to geofencing is lack of use cases where this gives value/societal benefits. They also commented how they have weak instruments/or lack of the means to use geofencing for regulation in traffic, as long as there is a mixture of vehicles with and without steering using positioning equipment in traffic.

3.4.11 Budget as an issue

Limited budget was a recurring issue for the city/municipalities. Munich reports this to be catastrophic, and a very difficult situation with drop in trade tax for example. Oslo, reports on the limited economy as a municipality "And there are probably many who experience that the type of technology development that we are doing now is not in a way a natural part of our tasks". Further it is commented that the digital capacity is not taken fully advantage of across municipalities in Norway which is argued to depend on a lack of prioritisation [and thus of budget/funding]. London comments that funding is always an issue but does not see it as a barrier for going forward, but rather to mean one has to prioritize better.

3.4.12 Not enough knowledge or competence in our organisation

In city units dealing with geofencing, a lack of "internal agreement" seems to be an issue. A challenge partly relating to this is that, as argued in Gothenburg, [geofencing] is not in the everyday vocabulary of everyone: "So, it demands a pedagogy [effort] in explaining what we do and why it is important. [We] can't say we face any resistance really, but the thing with understanding what it is, is probably a bit of a challenge, and how it connects to our normal activities". Another issue, and somewhat related to prioritisation, is that it could be harder for municipalities with smaller professional environments (Viken county). Furthermore, there is a need to get new work processes in place and tools to support them in order to implement geofencing solutions (Gothenburg).

3.4.13 Uncertainty about impacts and traffic effects of geofencing solutions

Like other innovative and exploratory trials for new digital technologies in transportation, many actors mention the lack of knowledge about the consequences and impacts. "What are the consequences on traffic flows if a certain number of vehicles are geofenced at a lower speed?" (Gothenburg). In Trondheim, it is argued that it is sufficient with the positioning data and historical data for e-scooters, but for overall mobility planning, they see it could be an advantage with more or other data as well.

3.4.14 Online survey responses on challenges in implementation

The survey respondents were also asked about their perception of the main challenges when working with geofencing. Figure 5 summarizes the findings. The most frequently mentioned challenges can be identified in three areas. One topic is that respondents felt that their work was not enough supported through policies, strategies, guidelines and standards and was also hindered by current laws and legal bases. A second group of challenging topics refers to technical aspect for implementation of geofencing. Both the accuracy of GNSS signals but also insufficient quality of maps or other necessary sources of (geo-)information and insufficient/immature technical equipment and procedures are perceived as common obstacles for implementation. A third point refers to problems that arise within the work with external actors. More specifically, missing regulations of operators and vendors were nominated as a challenge. This supports the statements found also in the interviews, that a common problem for cities is to create and enforce regulations with micro-mobility providers, due to missing legal possibilities.

Affordability and accessibility of technologies and access to collaboration and data sharing platforms were not perceived as an important challenge. The latter might simply be a consequence of COVID-19, which forced many authorities and administrations in cities and region to establish new digital ways of working and collaboration during the pandemic. Interestingly also acceptability problems or privacy concerns are not seen as a major challenge for implementation. The question here is, whether problems with acceptance were not evident so far, or whether this is the case because acceptance is not in the foreground when implementing some geofenced supported traffic measure (including especially technical details and operational procedures) but rather is a topic that comes up later during subsequent evaluation stages. Furthermore, funding and financing was also not perceived as a challenging factor.

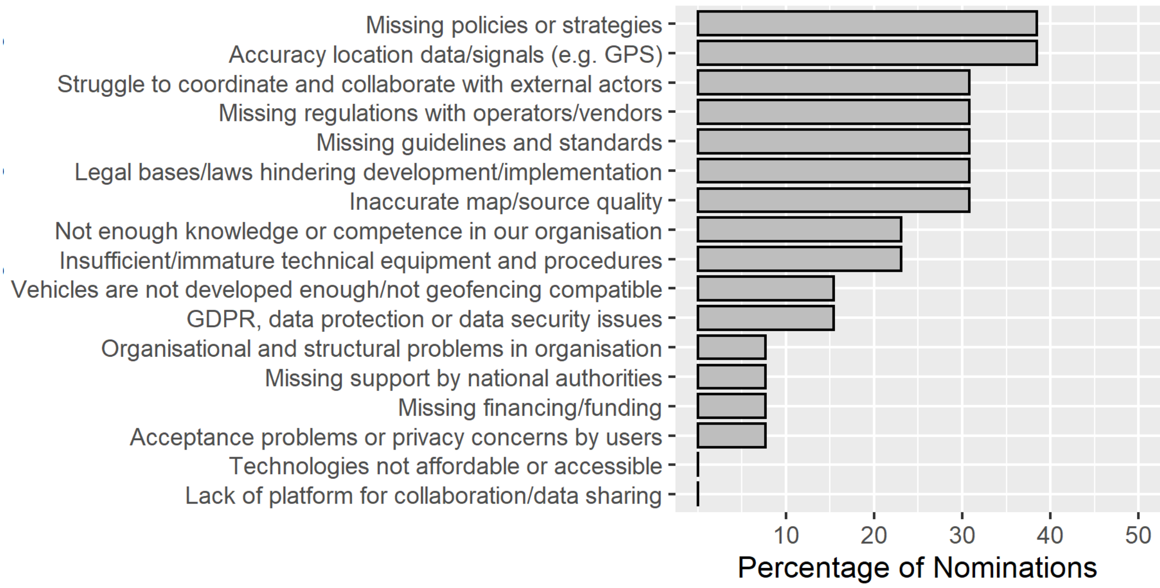

Figure 5: Challenges when implementing Geofencing technology for *More* experienced survey respondents

We also asked the less experienced respondents what they consider factors which would need improvement or particular consideration in order to use geofencing technologies in the future (Figure 6). It is interesting to review these results especially in comparison to the similar question (Figure 5) given to experienced respondents. Although the answer categories were somewhat different for the experienced and less experienced groups, altogether both groups considered laws and regulation a major challenge. Also, there is some agreement between both groups concerning the importance of challenges related to accuracy problems of geolocation data and other technical infrastructure in general.

An important difference is, however, that topics such as *user acceptance, funding and financing*, *data protection and privacy*, as well as *human resources/competence* are given much more priority by less experienced respondents. This result might also reflect on the fact that finding appropriate resources (financial or human) is often one of the first steps when starting a project in a new work domain. Projects related to geofencing do not replace other traffic related projects within the responsible authorities and administration but demand extra work and efforts to also acquire additional resources. Topics as *acceptance, data protection* and *privacy* do not fall in the primary work domain of traffic engineers and planners. Although there is now a general understanding that taking these issues into account is important for the success of a traffic-related measure, we suspect having to deal with these issues is associated with a high degree of uncertainty and unease, as there is a lack of concrete knowledge and experience on how to adequately address these problems. Once an authority has succeeded in implementing a geofencing project, experience, knowledge and solutions to deal with these problems may be available, making them less prominent, hence resulting in fewer nominations of these topics in the *More* experienced group. Furthermore, the degree to which acceptance is seen as a challenge might also depend on the type of traffic related problem geofencing is planned to be used for and how much concerns or reluctance might be expected to be raised by influenced groups and actors. Comparing these results with the data shown in Figure 5, it seems that the topics suggested to be targeted with geofencing by less experienced respondents often might result in restrictions for traffic users which in turn is expected to create acceptancy issues.

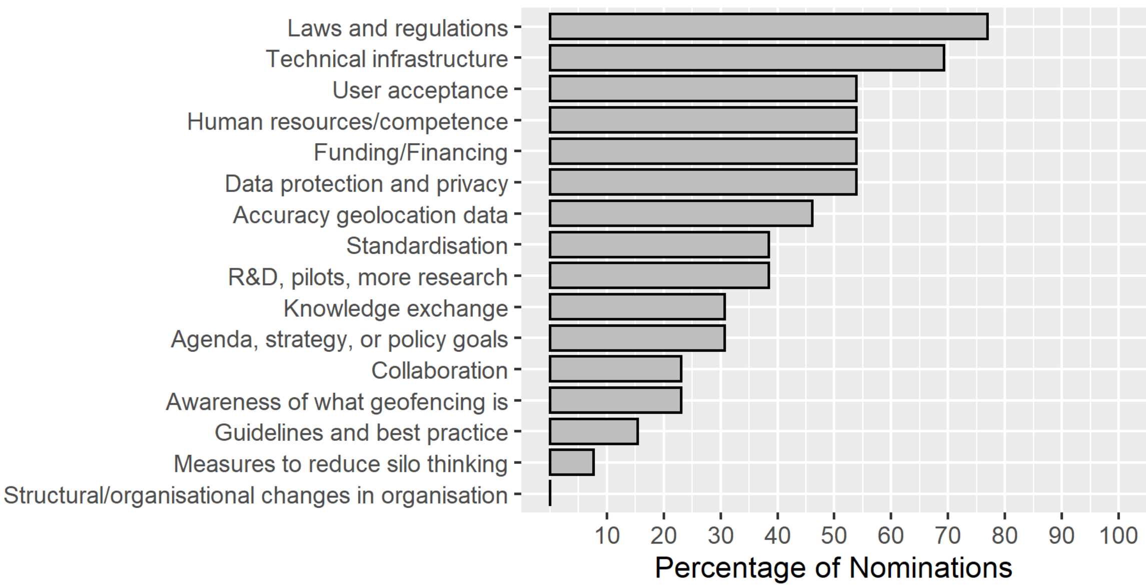

Figure 6: Factors to be improved/considered to use Geofencing in future, as named by *Less* experienced survey respondents

3.7 Needs for using geofencing in the future

One important aim of this report is to focus on cities and regions' needs when implementing geofencing projects and technologies. To learn about it and to be able to focus on the topic in the online survey, we analysed the answers of the interviews regarding current challenges and barriers with geofencing implementation and about expected needs and challenges for implementing geofencing in the future. One guiding reasoning for this analysis, was that specific technical information and procedural know how could provide an important aid and assistance for a planned implementation approach for geofencing. The analysis of the interviews revealed eight thematic topics, that describe relevant sources of knowledge, know-how and expertise (in theoretical, procedural or practical terms). These were used as answer categories in the question in the online survey. We asked the survey participants to evaluate which of them they consider important for the implementation process with the question: What type of knowledge, /know-how, /expertise or /experience respondents would currently be needed the most to implement and evaluate a geofencing project? Tick all that apply. The responses to the question are shown in Figure 7.

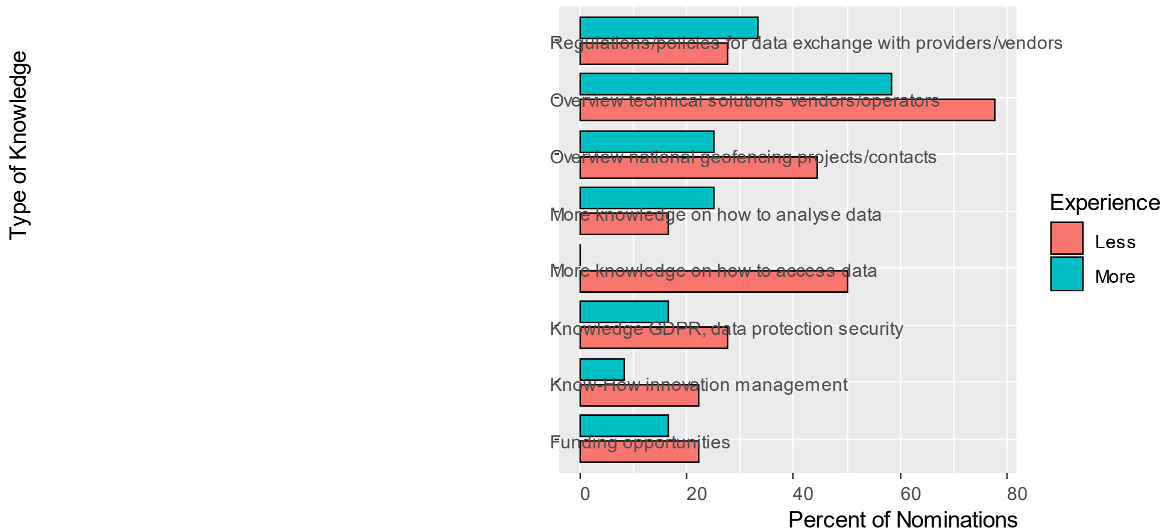

Figure 7: Survey findings on needs for knowledge/know-how/expertise/experiences to implement and evaluated geofencing

Respondents from both experience groups most often chose an *overview on technical solutions of vendors and operators* (almost 80% of participants in the *Less* experienced group selected this option). This seems to suggest that to find appropriate technology providers and solutions is an important task to be solved along the way to implement geofencing. Since technologies develop, this is something that turns up again and again in projects with every new solution to be developed. Municipal and city authorities or administrations could therefore benefit from receiving updated lists of information with the newest developments and technological key stakeholders. Similarly, *information of other national geofencing projects* was selected to be a source to retrieve information, know-how and expertise from.

One important difference between the experience level groups in this question was, that 50 % of *Less* experienced respondents chose *More knowledge on how to access data*, while none of the *More* experienced respondents selected this option. Once more, this might hint to the fact, that problems and tasks to be mastered at an early stage of geofencing project development are different from those needed to be considered once it is running.

This suggests that different types of information are needed at different stages of planning to implement geofencing projects which need to be considered in the future aims of the GeoSence project, when developing a strategic implementation guide. Providing sufficient information on certain aspect of the implementation, might help to allay fears associated with perceived technical hurdles.

4. Discussion and lessons learnt - Synthesis of cities' challenges and needs for implementing geofencing solutions

In this section we discuss the interviews and the online survey and what they imply by summarising and go further with the understanding and explanations of causalities. In the following, we explain and link challenges with ideas on how to remedy the diagnosed difficulties. The aim of this section 4 is to derive possible solutions stemming from a consensus among actors about the main difficulties, the causalities, and the systematic understanding of consequences of past use cases and trials. Possible solutions are also derived from the survey question on needs for implementing geofencing in the future, with one of the fundamental needs being to tackle the key issues with adequate actions and decisions. We base this section on ‘consensus of actors’ which implies statements were told independently by at least two interviewees. An even stronger consensus was observed for example on regulation, or lack thereof, where expert responses to the questionnaire corroborate the oral statement of several interviewees. "Solutions" are here understood as a feasible way to overcome the barriers and challenges, not only of transport and traffic management in general, but very specific through actions and decisions adapted to the deployment of the geofencing technologies. This is including management practices and regulatory design. Last but not least, this section also has the secondary objectives to support the design of current GeoSence project use cases, and to contribute to GeoSence expert recommendations in WP5 of the project. However, we do give some recommendation in the concluding sections.

4.1 Economic, technology and policy barriers for implementation

In the interviews and in the questionnaire, there is a whole set of barriers that were identified as causes hampering the effectful implementation of geofencing solutions for cars, e-scooters or traffic management, and can be considered for now as major hindrances for large scale deployment of the various technology solutions in European cities. As can be seen in section 3, some major barriers are fundamental, others more specific, and can be summarised as follow, ranked from the more fundamental to the more detailed:

Lack of regulation: As long as there is no established regulation, like for e-scooters operating on city roads prior to the development of specific e-scooter legislation, the geofencing technology solutions are operated in a legislative vacuum where the market is let to develop on its own. To overcome this barrier, there is a need to develop regulatory changes stepwise and in coherence with the technology and traffic management trials, and in collaboration with authorities (Hansen et al., 2022). This has to some degree happened for example in Norway, where municipalities are given regulatory room to regulate e-scooter operators.

Selective vehicle upgrading: Some vehicles are equipped while others are not, so a rule change cannot be universal and reaching all mobility and traffic agents for all transport modes. To overcome this barrier, like for emissions standards, a progressive approach, leaving either a long period or a stepwise approach to preparation time for the entry into force of the new legislation, seems to be adequate (Lurkin et al. 2021). As an example of a stepwise approach to vehicle upgrading, retrofitted solutions using only assisting/supporting geofencing through an app (Dahl et al., 2020) could be an important step on the way, although it is dependent on the use case.

Lack of market overview: The market of geofencing technology solutions is split into a high number of providers, either of geofencing service providers and the vehicles able to apply them, which creates a lack of clarity for cities, about which product is offering what kind of feature and service, at what price. To overcome it, market studies were initiated, notably in Sweden (e.g., CLOSER, 2021).

High price: As long as the technology is under development in most mobility sectors, and still use prototypes, the costs of R&D are high and running against a market profitability or rendering a wider uptake and upscale not feasible. In most cases, if a product is so expensive that its costs doesn't allow a profitable business model, and would oblige a company to go bankrupt, it cannot be considered a feasible solution. The solution here, like for emissions reduction, is to try a progressive approach in time. Most projects are expected to continue relying on external research funding, as long as the development needs are rather high.

Weakness in the core technology: GNSS signal is essential for geofences, and they are inaccurate in some cases and some urban areas. The solution to overcome this barrier would be for the technology companies to work together with cities and engineering experts to develop complementary options together with GNSS for those areas with high rise building, where it is well known that the GNSS signal failure renders the whole geofencing technology unusable for enforcement or regulatory purpose. This needs to be worked on in parallel with keeping accurate maps to base the regulations on.

Lack of knowledge on impacts and effects: Due to the limited budget and the small scale of some trials, the data collection most often doesn't deliver good, quantified information on traffic effects such as contribution to speed reduction, increased active travel or reduction in car trip when using geofencing in trials. The solution to overcome this barrier would be to include impact assessment measurements into trial data collection, and report in several cities, for several technologies and traffic management options.

4.2 Less and more experienced groups of actors

There was an initial hypothesis of differences between perceived challenges faced by the two groups of less and more experienced cities. We were interested to see if there were any clear differences between area/regions, and between level of experience of two hypothetic groups, but this set of hypotheses could not be verified. The tests with geofencing were taking place in pioneering cities, which are pretty typical cities in terms of traffic problems, if compared with most other European cities, and those pioneer cities do not really have different needs regarding geofencing technologies.

However, we did see one clear difference of less experienced cities in comparison to the more experienced cities, and that is the need for more knowledge on how to access data. One apparent similarity between these two groups regarding challenges they had when comparing the survey results is that those with less experience ranked laws and regulations as the biggest issue, while missing policies and strategies were the biggest issue for those with more experience. It is clear that more overarching regulation is a cross cutting issue independent on experience level.

4.3 Mobility problems by mobility type – how does it vary for geofencing projects?

To further investigate the priorities to be set for various mobility types and which traffic problems are or can be tackled by geofencing, we created a cross table. Table 3 is providing the frequencies, showing how often a named problem was associated with a mobility type in the online survey. Clearly *Parking* stands out in the table as it is mentioned most often (together with access though) and also because it is currently seen as a problem to be solved or solved for *micro-mobility* related geofencing projects mainly, affirming issues on this brought up by the interviewees. Furthermore, the results suggest that *access* related problems need or are being solved with geofencing especially for the mobility types *private cars, goods and logistics* and *micro- mobility*. *Pollution, congestion* and *speed* one the other side are seen as problems that need to or are being solved for *private cars* mostly. Moreover, providing *prioritisation* for *public transport* is another topic that cities are interested to solve by means of geofencing technology.

Table 3: Frequency of co-appearances between mobility types and mobility problems as found in the reports for current and envisioned geofencing projects

		Mobility types						
		Bike	Emergency vehicles	Goods and logistics	Micro-mobility	Private car	Public transport	Sum
	Access		1	3	4	3	1	12
Mobility problems	Capacity			2		1		3
	Congestion		1			4	1	6
	Operation area				2			2
	Parking			1	8	3		12
	Pollution			1		5	2	8
	Prioritisation		1				3	4
	Safety	2		1		2		5
	Speed	1			2	4	1	8
	Sum	3	3	8	17	24	9	

Note: Mobility types or Mobility problems that were just named once per column or row were omitted to increase readability.

This is important, as it gives a hint at key geofencing use cases that are currently being worked on for different cities, and within the different types of mobility, and not least expected use cases. Parking for micro-mobility is currently the most applied and envisioned use case where geofencing could be a solution. Further we see the biggest diversity in use cases for private cars. This makes sense, as private cars are a main contributor to the challenges for traffic in cities (see figure 2 above). Following this, a lot of potential is seen by cities in developing geofencing use cases for this mobility mode. Conversely developing uses cases that could enhance efficiency and experience for other modes of transport like public transportation is important.

4.4 Risk and possible mitigation options

Continuing from 4.1., there are several risks associated with the aim of tackling the barriers and challenges to the adoption of geofencing applications. Table 3 summarises the central risks and proposes some mitigation options.

Table 3: Risks of adoption of geofencing applications, and possible mitigation options

Risk	Description	Possible mitigation option
High development **costs**	Cities and businesses testing and developing new technologies need funding earmarked for product development. This includes the testing and trial stage of geofencing applications in real business conditions and real traffic.	Research funding and collaborative international and EU projects.
Lack of **knowledge** and experts	Data collection and reporting for geofencing projects mentions, like the respondents for this survey, a lack of knowledge in cities and few experts available.	Enable transport innovation experts and digitalisation experts to work more together on geofencing.
GNSS remains **inaccurate**	Despite R&D, principal accuracy problem for geo-localisation of vehicles will continue.	Develop other geo-localisation technologies or infrastructure complementing the GNSS
Lack of **acceptance**	Acceptance highly dependent on type of user and type of use case: e.g., operators of e-scooters accepting or rejecting use of geofencing, anticipation of low acceptance of control technology for end-users (private cars) as e.g., speed control for end users requires special mix of carrot and stick strategies. Acceptance by city authorities as a core user is also important.	Marketing campaigns and legal obligation for the manufacturers, like for the adoption of emission reduction techniques in vehicles. Encourage openness to sharing certain data to and from cities/municipalities.

Source: GeoSence interviews and online survey Europe, 2022; authors.

4.5 Transferability analysis

Transferability is understood to be the key condition that allows a new technology to be adopted by other businesses, other cities and other fields of application. The analysis, based on the interview and survey results showing a rather high level of similarities in the challenges and needs, tend to suggest that, once a successful solution using geofencing has been developed in one city, it can be transferred to many other cities later.

The number one in transferability at this stage seems to be the geofencing use case for shared e-scooters, which is either implemented or far along towards implementation in many cities. Parking has been and still is a major issue in some cities when it comes to micro-mobility, which makes it an issue solved by or hoping to be solved with geofencing, along with other issues of people leaving the e-scooters in inappropriate places. But even if a solution for e-scooter parking purely based on geofencing is not always working optimally, the technology itself is already an important tool or part of the solution to master the challenges. This is also to an increasing degree followed by regulatory changes and digital solutions, at least in some cities. As found in other studies (as summarised in e.g., Hansen et al., 2021), improving GNSS positioning for the geofencing zones are unlikely to solve issues and enable a higher transferability alone. Complementary solutions such as the use of additional geo-localisation techniques or physical infrastructure (e.g., to mark parking areas, sensors) could be part of the implementation. However, other concerns with use of space, land and city planning will then need to be considered.

To enable a wider take-up and to scale-up the adoption of the geofencing applications, other public transport modes such as buses need to be more included in future developments, testing and regulatory changes for municipalities. For this, the encouraging progress of shared e-scooters developments and applications can serve as model. The use of geofencing for private vehicles is to a larger extent a political question where privacy plays an important role, although implemented low-emission geofences in Gothenburg, or ongoing trials, such as the pilot in Norway on road charging, could show the vast potential of the technology for tracking and charging in an efficient manner.

5. Conclusion

With the aim of informing on geofence implementation, through learning from both experienced users of geofence technologies in different types of mobility, we can conclude with a summary of the main findings so far. The challenges can be summarised as 1) A lack of regulation in new forms of mobility, leading to a legislative vacuum for geofencing solutions. 2) Not all vehicles are able to equip geofencing solutions, which can lead to social inequity where some operators and end-users have access and others do not. 3) Not having a good market overview, either of geofencing service providers and the vehicles able to apply them, and 4) High costs for R&D and for including necessary dimensions and improvements to make the geofencing solutions viable. 5) Weaknesses in the GNSS technology, 6) Lack of knowledge on impacts and effects due to lack of budget and/or competence, especially in smaller municipalities/cities.

Findings of this report, as suggested by both the informants interviewed and the online survey leads us towards risks but also mitigation options. The risks of high development costs for those use cases not yet fully implemented, should be met by more research funding but also suggest that cities need access to more resources to collaborate in such projects. A lack of knowledge points to the need of transport innovation experts to work more with digitalisation experts. The GNSS inaccuracies need to be solved by complementing physical infrastructure. And the lack of acceptance, which is highly depending on use case and type of user, could be partly solved by marketing campaigns, legal obligations for manufacturers and operators, and spreading awareness to encourage data sharing, while excluding sensitive personal data. This report is a humble confirmation that geofence use cases can be transferred from one city to another, and for which shared e-scooters are the best example of application thus far. As can be seen in the long list of challenges and needs, there are issues to be solved, and it remains to learn from other ongoing trials in other types of mobility and modes of traffic.

Based on this report's analysis and synthesis we can give some early recommendations for European cities and national authorities for the use of geofencing for urban traffic management:
- Increase municipalities and government actions and **investments for digital infrastructure**, including coordination of geofencing projects

- **Start new trials of new solutions**, trying to tackle some of the key challenges and mitigating the main risks mentioned above, while addressing also the main needs identified
- Scale up, **expand, and transfer existing** good functioning **solutions** through expansion strategies within cities, for new businesses and new transport modes, and for new cities in Europe
- Collect higher quality **impact data** on the various solutions tested
- Consolidate and expand a **knowledge network** of municipality and other transport authority experts
- Increase access to national and international **research funding** for geofencing projects for industry, local authorities and academia
- Focus on **complementing GNSS-positioning** to achieve full potential of geofences

Abbreviations and definitions

BASt - Bundesanstalt für Straßenwesen ((Federal Highway Research Institute)
BMDV – Federal Ministry for Digital and Transport
E - Executive
GDPR – General Data Protection Regulation
GNSS – Global Navigation Satellite Systems
GPS – Global Positioning System
IoT – Internet of Things
IT – Information Technology
ISA – Intelligent Speed Assistance
MDM - Mobility Data Marketplace
MDM Platform – the National Access Point for Mobility Data (in Germany)
n – in statistics, the number of observations in a sample
NPRA – Norwegian Public Road Administration
NVDB - National Road Database (in Sweden and Norway)
R&D – Research and Development
S - Strategic
STFS – Swedish Database for Traffic Regulations
STA – Swedish Transport Administration

References

BMDV – Federal Ministry for Digital and Transport, 2021: Mobilithek – Germany platform for data that keep things moving. 13 Oct 2021, Berlin, https://www.bmvi.de/EN/Topics/Digital-Matters/Mobilithek/mobilithek.html

CLOSER, 2021. Report on market analysis – geofencing-based services in road transport. Geofencing | https://closer.lindholmen.se/projekt/geofencing. Accessed 25th of May 2022

C-Roads, 2022. https://www.c-roads.eu/platform/about/. Accessed 15th of May 2022.

Dahl, E., Arnesen, P., & Seter, H. 2020. Geofencing for Smart Urban Mobility: Effects from a pilot with retrofit equipment. In *European Transport Conference 2020*.

Gössling, S. 2020. Integrating e-scooters in urban transportation: problems, policies, and the prospect of system change. Transportation Research Part D: Transport and Environment, 79, https://doi.org/10.1016/j.trd.2020.102230

Hansen, L., Arnesen, P., Graupner, S-T., Lindkvist, H., Leonardi, J., Al Fahel, R., & Andersson, K., 2021. GeoSence. Current state of the art and use case description on geofencing for traffic management.

Hansen, L., Seter, H., & Tveit, Ø. M. 2022. Regulating connected and automated vehicles: How do drivers experience being automatically regulated by digital traffic rules?. *Transportation Research Interdisciplinary Perspectives*, *14*, 100611.

Limesurvey, 2022. An Open Source survey tool /LimeSurvey GmbH, Hamburg, Germany. URL http://www.limesurvey.org

Lov om utleie av små elektriske kjøretøy på offentlig grunn. (2021). Lov om utleie av små elektriske kjøretøy på offentlig grunn (LOV-2021-06-18-139). https://lovdata.no/dokument/NL/lov/2021-06-18-139 Accessed 24th of May 2022

Lurkin V., Hambuckers J., van Woensel T., 2021. Urban low emissions zones: A behavioral operations management perspective. Transportation Research Part A, 144 (2021), p. 222-240.

NPRA, 2022. Trafikkregler for elsparkesykler https://www.vegvesen.no/trafikkinformasjon/trafikksikkerhet/sikker-pa-sma-elektriske-kjoretoy/regler-for-elsparkesykkel/ Accessed 24th of May 2022.

Packar, G. 2020. The changing use of e-scooters in London: Stakeholder perspectives and future scenario pathways https://open-education-repository.ucl.ac.uk//663. Accessed 17th of May 2022.

QSR International, 2022. https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home. Accessed 15th of May 2022.

Rossett, A., 1982. A typology for generating needs assessments, Journal of instructional development, Vol 6, 28. https://doi.org/10.1007/BF02905113

Tjora, A. 2013. *Kvalitative forskningsmetoder i praksis.* 2. edition. Oslo: Gyldendal akademisk.

Toftaker, J. and Kringstad, K. (2021). "Her kan du nå få 900 kroner i gebyr for å parkere elsparkesykkelen feil". https://www.nrk.no/trondelag/feil-parkering-av-elsparkesykkel-kan-gi-deg-gebyr-i-trondheim-1.15656673 Accessed 24th of May 2022

Appendix

Table 1. Topics for the survey questions and the used answer format and path through the survey

Question topic	**Answer format**	**More experienced**	**Less experienced**
4. Traffic related challenges in the city	11 options and an editable *Other* option 3 to 5 selections	X	X
5. Experience with geofencing	8 options	X	X
6. Geofencing projects run/developed	3 text boxes for free entries to describe mobility type, mobility problem, functionality Four separate lines to describe projects	X (additional field for implementation status)	X (reframed as ideas for geofencing projects)
7. Future use for geofencing	Free text entry (with a suggested structure for the answer)	X	-
8. Challenges for geofencing implementation	17 options and an editable *Other* option 3 to 5 selections	X	-
8_1. Foreseen future challenges for geofencing implementation	16 options and an editable *Other* option 3 to 5 selections	-	X
9. Type of knowledge needed for implementation	16 options and an editable *Other* option Tick all that apply	X	X (Knowledge they would need)
10. Preferred knowledge transfer formats	16 options and an editable *Other* option Tick all that apply	X	X
11. Use of instruments (policies, strategies, … 12. and the instruments perceived usefulness	Yes/no [extremely useful- useful-no opinion-useless-completely useless]	X	-
13. Plan for implementation in the near future	[definitely-probably-possibly-probably not-definitely not]	X	X
14. Additional topics important for GF but not covered by the survey	Free text entry	X	X

Note: The three descriptive questions are not included int the table.

GeoSence, led by CLOSER, elaborates on geofencing solutions aiming at improving urban traffic management and planning.

The overall objective of the project is to design, trial and evaluate geofencing concepts and solutions for specific cases in cities, within the project and from other previous and ongoing geofencing initiatives, and to propose new ways of successfully deploying geofencing technologies. Tools for implementation, as well as approaches to scale-up and spread the innovation further in Europe will be proposed including e.g. ways of integrating geofencing functionalities in the decision making, built environment and traffic management in cities.

The project is a Joint programme initiative (JPI) Urban Europe project funded by European Union´s Horizon 2020 and gather project partners from Germany, Norway, Sweden and UK. GeoSence project period is April 2021 to March 2024 with a budget of approx 1,6 million euros.

Partnership: Göteborgs Stad, City of Munich, Stockholm stad, Norwegian Public Roads Administration (NPRA), Chalmers University of Technology, RISE, SINTEF, Technical University of Dresden, University of Westminster & CLOSER.

Support partners: ALICE, City of Helmond, City of London, City of Madrid, London European Partnership for Transport (LEPT), POLIS, Swedish Transport Administration, Volvo Group.