Strategic guidelines for implementation of urban geofencing solutions

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BACKGROUND

This document is a strategic implementation guide for geofencing in traffic and transport management, and urban planning in cities. It is intended for all readers interested in geofencing, mainly targeting mobility planners and managers in local authorities. The aim is to share knowledge and recommendations on how cities can design and successfully implement geofencing solutions.

Most geofencing applications require the involvement of multiple stakeholders within and beyond the city authorities, to be designed and implemented in a satisfactory way.

The knowledge presented in this report is generated from the GeoSence project and related projects on geofencing.

PROJECT CONTEXT AND AMBITION

About GeoSence (April 2021 – June 2024)
The GeoSence project was a JPI Urban Europe project, funded under the ERA-NET Cofund Urban Accessibility and Connectivity call. The project was a collaboration between public authorities and researchers to design, trial and evaluate new geofence concepts and solutions for specific city use cases, and to propose new ways to deploy geofence applications. This was made possible by running tests, demonstrations and evaluations in participating cities. Research focused on user acceptance, stakeholder engagement, policy & regulation, governance and impact assessment.

Partners in the project include the City of Gothenburg, The City of Munich, The City of Stockholm, The Norwegian Public Roads Administration, Chalmers University of Technology, RISE, SINTEF, Technical University of Dresden, University of Westminster and CLOSER.

NATURE OF THIS GUIDELINE

This guide provides recommendations, considerations and questions to cities, that they should address internally and in cooperation with relevant stakeholders. Unless otherwise stated, this document is based on documents and deliverables produced in the GeoSence project. All public reports from the project can be accessed via the project website[1].

Examples from partner cities are given throughout the guideline. More information about these cities, and their path to and experience with geofencing can be found in the city-specific documents on the project website.

The document has four sections:

- **Section 1** provides an **overview and introduction to geofencing**, how it works and relevant applications for cities.
- **Section 2** provides **system perspective** insights such as to impact, acceptance, governance and regulation of geofencing.
- **Section 3** is a **step-by-step guide** for cities, where each chapter represents a specific phase in the suggested work process for deciding whether geofencing could be a relevant tool for the city.
- **Section 4** provides a **summary**, and includes **suggestions** as to how **non-city actors**, such as national or European authorities, technology providers and commercial road users, can aid the cities in the implementation of geofencing applications.

1 https://closer.lindholmen.se/en/geosence

1. INTRODUCTION TO GEOFENCING

1.1 WHAT IS GEOFENCING?

A simple answer is that geofencing is a virtual zone placed over a geographical area. Geofencing in itself is not of value. Instead, it is what geofencing can enable that is of value. In this guide, geofencing has a broader meaning, taking a system perspective on how geofencing can be successfully implemented in traffic and transport management, and indirectly in urban planning. Hence, the definition of geofencing as proposed by the GeoSence project is as follows:

"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".

This definition can be better explained by exploring the main building blocks of geofencing:

- **Design** – What data sources do I need, and where/when should the geofence be created?
- **Communicate** – How do I reach out with this information to the right recipients?
- **Locate** – Will the driver/vehicle be able to position themselves geographically?
- **Act** – What will the recipient do with the geofence and the information I have sent?
- **Follow up** – Is the system working? Is it triggering the desired actions?

These simplified blocks are not linear in the process but are rather iterative.

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A DESIGN

What data sources do I need, and where/when should the geofence be created?

Geofencing is essentially a digital tool for communication. The main question is what kind of information you want to share with traffic operators. Do you want them to follow speed limits or know where they can park?

To use geofencing effectively, you need reliable **geospatial** data that is accurate and easily accessible. Examples of this data include road information, speed limits, and weather updates. Most of this information can be found in national road databases or through other public institutions. Local authorities also provide data such as local traffic rules. Keep in mind that transport operators may use other/additional data sources in their systems.

It is worth mentioning that there are ongoing initiatives to develop standards for digitising traffic regulations and making them machine-readable.

In the GeoSence project, the City of Stockholm aimed to enhance its role as a reliable data producer and provider for geofencing applications and other location-based services. Key findings highlighted the need for a more defined strategy to develop the city's digital infrastructure, facilitating improved dissemination and communication of data. Additionally, establishing a systematic approach to enhance data quality across the entire process chain emerged as critical. This begins with ensuring accurate data input, such as verifying local traffic regulations and geo-referencing when applicable. Equally important is the correct installation and positioning of traffic signs. The city also expressed interest in implementing quality control measures for data output, such as conducting test drives to validate accuracy.

Parallel to this process, *consider the area you want to set boundaries around*. Is it the entire city or a specific street? Do you want the geofence to activate during specific events, like a festival or an accident?

Depending on different triggers, the geofence can be turned on or off. The simplest form of a geofence is **static**, meaning it rarely changes shape or purpose and is usually always active or within set times, like a speed limit zone during school hours.

A geofence can also be **dynamic**, meaning it changes based on various conditions or criteria. Dynamic geofences update in real-time or near real-time, are context-aware, and adjust automatically compared to static zones. Their complexity varies based on the number of zones, frequency of changes, and the data sources included.

Future geofences might become "**smarter**" by using more data sources and artificial intelligence (AI) to provide sophisticated, context-aware functions. Unlike static or dynamic geofences, smart geofences can adapt to complex conditions, making them more effective for various applications. Most current geofencing solutions are static or have some dynamic features.

Image ©: CLOSER at Lindholmen Science Park

Geofencing functionality implemented in Munich. With an average of nearly 13,500 e-scooters in the city and a rising number of complaints about improperly parked e-scooters, the city of Munich has introduced regulations to improve the parking situation for e-scooters and increase traffic safety. The city has used the GeoSence project to define and mark parking areas in the old town of Munich. The regulation is done by only allowing e-scooters to park within these marked areas. Geofencing technology is used to verify that e-scooters are parked within new physically marked and digitally geofenced parking areas at the end of the trip. In addition to permanent geofencing, the city has used temporary geofencing on e-scooters in two different ways during the Oktoberfest events in 2022 and 2023: 1) more parking and no parking zones in the event area and 2) no e-scooter rentals after 5 pm near the event area to prevent drunk driving. Finally, the City of Munich installed geofencing in 30 existing parking zones built in 2020 and 2021 and tested geofencing from October 2023 to March 2024 to better utilise the parking zones.

B COMMUNICATE

How do I reach out with this information to the right recipients? How often? If needed, how does the recipient communicate back to me?

Designing the geofence and the information it contains is one thing; the next challenge is to establish a way to communicate it. The communication chain can be **direct**, e.g., a transport operator can create geofence zones that are directly connected to their fleet. It can also **require several steps** with different stakeholders, e.g., a road authority creates a geofencing zone, sends it to a transport operator who sends it further to the vehicle manufacturer who connects the geofence to their existing fleet.

The communication of the geofenced zone can vary. In some trials, road authorities send the geofenced zone via email as a PDF file to the vehicle manufacturer. A higher level of **automation** is needed to be able to scale up the geofencing solution, especially in those cases that require a large number of zones and frequent updates.

In the GeoSence project, the micro-mobility use case in Munich utilised third-party GIS software to create and communicate geofenced parking and non-parking zones to mobility providers, specifically e-scooter operators. The operators agreed to share data with the city, enabling it to monitor the e-scooter parking situation in real-time using the same GIS software. This facilitated smoother communication between the city and the operators. However, operators used different systems to communicate these zones to their own fleets, meaning each operator had to interpret and manually create new geofenced zones in their own systems. The city of Munich observed that the new parking policy positively impacted the parking situation, but they also noticed irregularities between the zones they created and how the operators had drawn the zones on their apps. These discrepancies were partly due to manual errors and also because there are no universal standards for creating the zones.

Similar software is also used in the geofencing services offered by vehicle manufacturers, e.g., Volvo and Scania, to transport operators.

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C LOCATE

Will the driver or the vehicle be able to position themselves geographically?

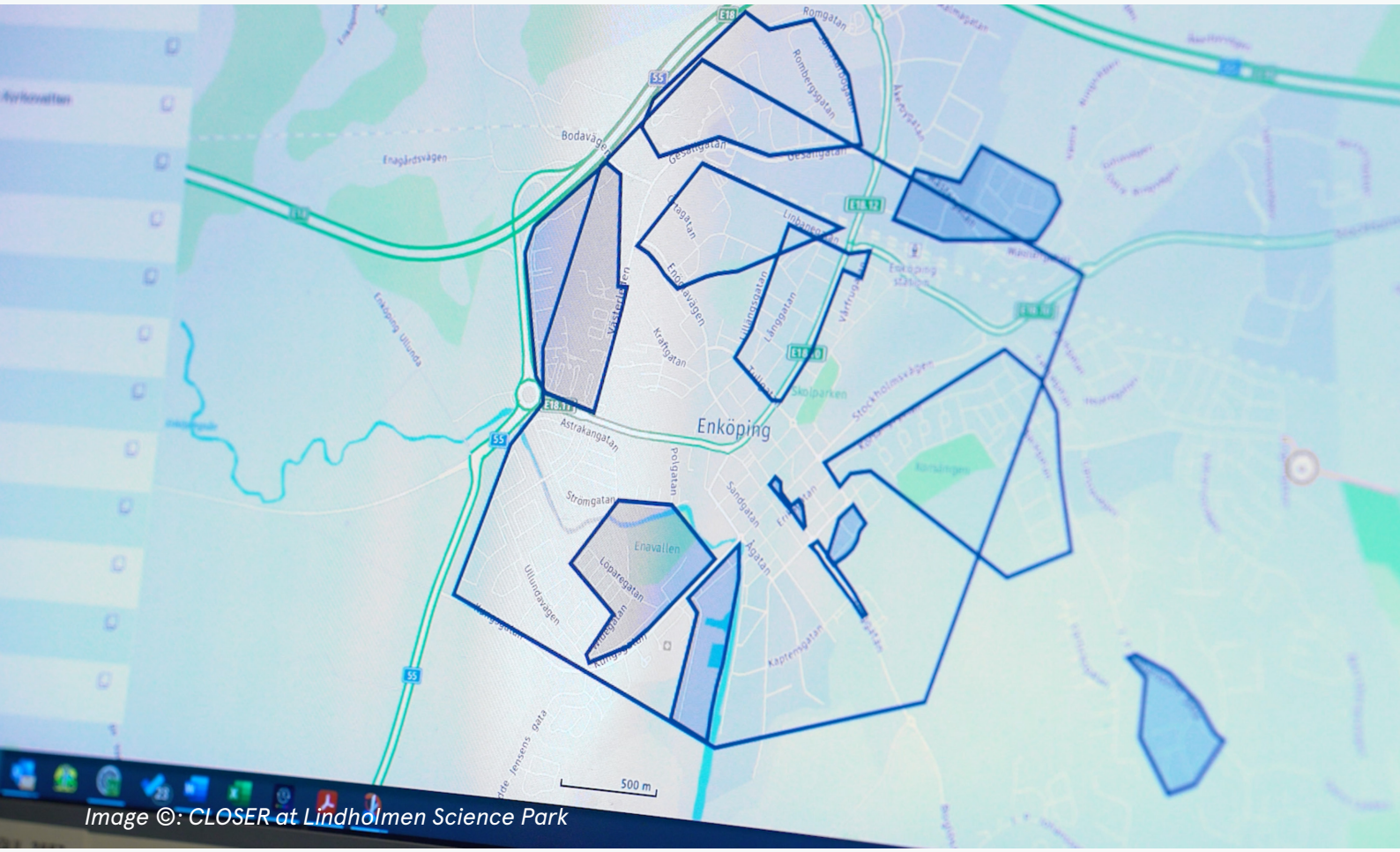
For the vehicle to use geofencing, the equipment must have the technical ability to understand whether it is outside or inside the geofencing zone. In general, the majority of **vehicles** on our roads can **position themselves geographically**, although the level of inaccuracy can vary widely depending on the combination of solutions used.

The ability to position oneself geographically in real-time is crucial for improving the quality of geofencing-based services. **Positioning technology is constantly being refined**, but challenges remain, such as in locations with poor coverage like tunnels, grade-separated intersections, and places with many crossing lanes where the vehicle cannot identify the exact lane it is in. Some application cases are more dependent than others on having reliable positioning, almost at centimetre-level accuracy.

Global Navigation Satellite Systems (GNSS), e.g., GPS, are a **widely used method for vehicle positioning**. Several factors can impact the quality of the method, such as the **quality of GNSS receivers** and other hardware, **latency** (the time delay between the actual occurrence of an event, such as a movement or a positional change, and the time it takes for the GNSS system to process and report this information to the user), **jamming** (the deliberate transmission of radio signals that interfere with the operation of GNSS receivers by overwhelming the receiver with noise or false signals), or **spoofing** (sending fake GNSS signals to deceive a GNSS receiver into calculating an incorrect position).

Other methods that can be used for positioning are **augmentation systems, ground-based navigation** GNSS signals such as EGNOS, **cellular** and **WiFi**, **Bluetooth**, and Inertial Navigation Systems such as **gyroscopes** and **accelerometers**.

In the GeoSence project, the micro-mobility use case in Munich recognised that GNSS (e.g., GPS) inaccuracies in the e-scooters were a factor in why some of the e-scooters were parked outside the parking zones. The city worked closely with the e-scooter operators to point out that this issue needs improvement. The city was also interested in investigating whether Bluetooth-based sensors could be installed at the designated parking areas to supplement the GNSS data and improve positioning.



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D ACT

What will the recipient do with the geofence and the information I have sent? How will the driver or the vehicle interact with it?

The way the vehicle/driver acts on and responds to the geofence is critical to the process. The level of interaction with the driver can vary from no/low interaction to high interaction. For instance, once the vehicle enters a geofenced zone, this could trigger the **tracking/collection of data**. The data is then shared between the vehicle and, for example, a mobility operator or a road authority. No interaction is being made with the driver. What data is being collected can vary, e.g., vehicle performance, speed, etc.

The Norwegian Public Roads Administration is interested in using geofencing to differentiate road user charging, with the ambition to create a fairer road pricing system based on distance, e.g., you pay more per km driven, and fuel, e.g., you pay less if you drive electric compared to fossil-based fuel. The solution is based on tracking and data collection, and trials have been/are being conducted in projects such as *GeoFlow* and *Tag4All* to develop the system, including a payment solution.

The next level of driver interaction is to **inform and/or warn the driver**. For instance, entering a geofenced zone can trigger the system to inform/warn and alert the driver about an accident nearby or roadworks. The interaction with the driver can be visual, e.g., the speed limit is shown on a screen, audio/acoustic, e.g., beeping sounds, or haptic, e.g., slight pedal resistance when exceeding speed limits, etc.

A high level of driver interaction often triggers **vehicle interventions**, enabling or disabling specific features such as speed control. For instance, e-scooters can automatically slow down when entering a slow-speed or no-go zone. This capability can also be applied to other vehicles like cars, buses, and trucks, but it is less common. Instead, speed control is typically managed by limiting the driver's ability to accelerate beyond a set speed limit.

Geofencing can also activate or deactivate a propulsion switch, such as triggering a hybrid vehicle to switch to electric-only mode. Other examples of interventions include enabling or disabling the parking mode in certain zones, granting vehicles access to specific areas or roads by giving traffic signal priority, or opening gates and barriers.

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Intelligent Speed Assistance (ISA) is an advanced driver assistance system (ADAS) designed to help drivers maintain appropriate speeds by providing feedback or automatically controlling the vehicle's speed. Starting in July 2022, ISA will be mandatory for new models and types of vehicles introduced to the market. By July 2024, it will be required for all new cars sold. The vehicle manufacturer can choose between different solutions: 1. cascaded acoustic warning, 2. cascaded vibrating warning, 3. haptic feedback through the acceleration pedal, and 4. speed control function[2]. The first two options can be considered as informative/provide warnings whilst the last two do intervene. The third option will push the driver's foot gently back to make the driver aware and help to slow down, and the fourth option the car speed will be automatically gently reduced. In both cases, the driver can choose to override the system.

Please note that while **geofencing and ISA are related and share many challenges, they are different from each other**. ISA focuses on speed assistance in vehicles and is typically always on, though drivers can temporarily override restrictive systems like options three and four mentioned above. ISA systems use various data sources, such as on-board cameras, data maps, and GNSS, to identify speed limits.

Geofencing, on the other hand, can be used for purposes beyond speed. It can be turned on or off and can trigger specific actions when a vehicle enters or leaves defined areas. Geofencing typically uses GNSS and other location-based technologies to define and monitor geographic zones.

Some **vehicle manufacturers offer geofencing-based services with** varying levels of driver interaction, usually available in newer vehicle models as **add-on subscriptions**. Scania Zone[3] and Volvo Zone Management[4] are two examples of such services. There are also **third-party solutions** that can be retrofitted to older vehicle models or used in new models. These solutions, often utilised by fleet managers, transportation companies, and individuals, enhance vehicle tracking, management, and safety. GeoTab[5] and V-tron[6] are two among many providers.

In the GeoSence project, the Gothenburg use case trialled third-party systems in their Special Transport service. Several geofencing zones were established around areas with vulnerable road users, featuring lower recommended speed limits compared to official traffic regulations (e.g., 30 km/h instead of 40 km/h). The trials included both an informative system and a speed control system. One key learning from the use case was the importance of early and ongoing communication with the technology provider before, during, and after the installation phase. For example, an issue arose where the vehicle's cruise control function overrode the third-party solution when activated. Other important aspects to consider include the positioning of the display screen, whether and how the driver needs to activate or log in to the third-party system, and similar operational details.

Image ©: CLOSER at Lindholmen Science Park

2 https://road-safety-charter.ec.europa.eu/resources-knowledge/media-and-press/intelligent-speed-assistance-isa-set-become-mandatory-across
3 https://www.scania.com/scania-zone.html
4 https://www.volvobuses.com/en/fleet-management-services/zone-management.html
5 https://www.geotab.com/
6 https://v-tron.nl/en/

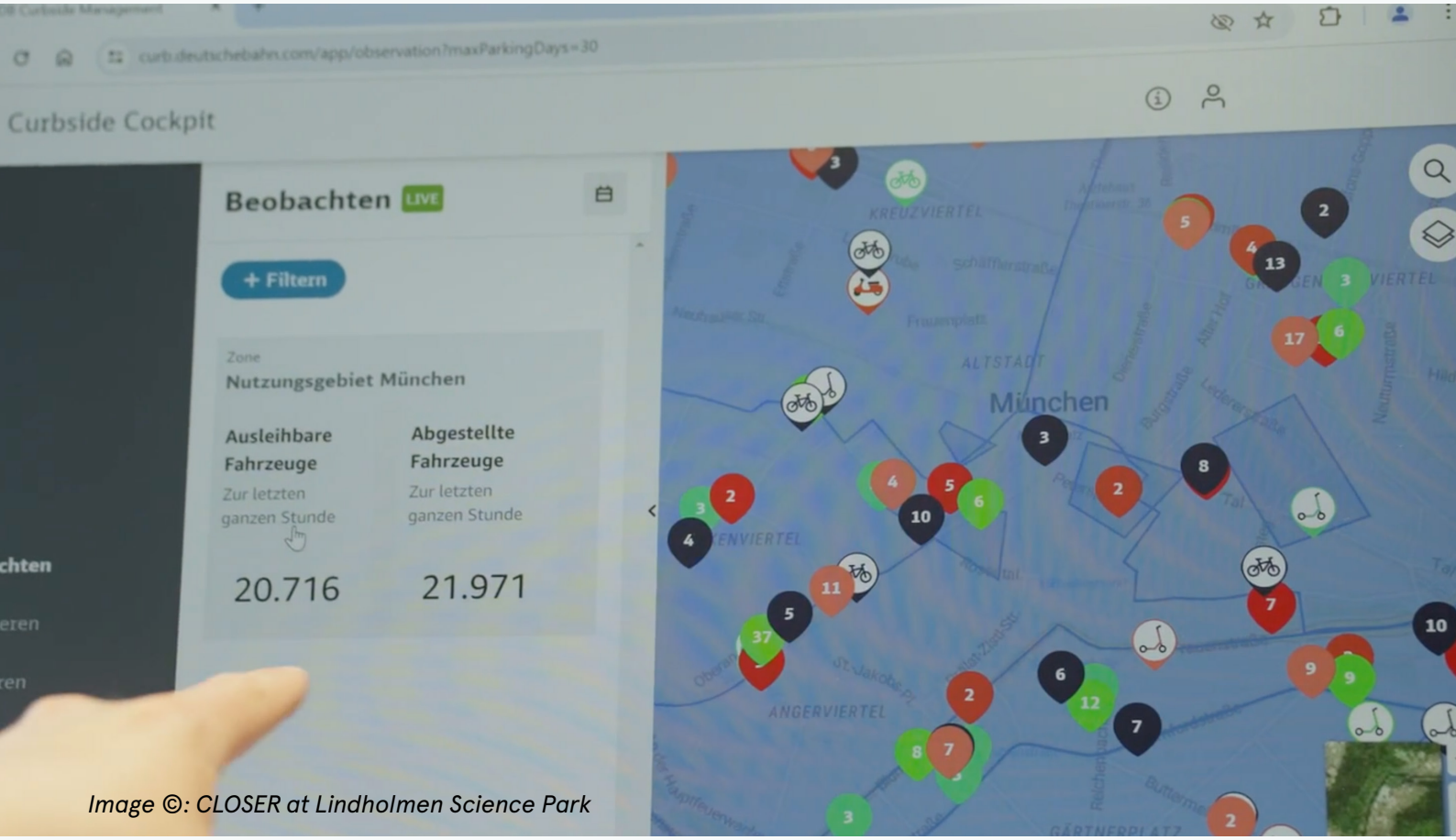
E FOLLOW UP

Is the system working? Is it triggering the desired actions? Is it in line with the agreement and regulations?

As demonstrated in the previous sections, **technological errors and human misinterpretations can occur at each stage**. It is crucial to continually assess and follow up to identify and address these issues. Without this ongoing attention, there is a risk that low-quality geofencing applications will fail to achieve the desired impact.

Understanding the possibilities and limitations of the technologies used is essential. Adopting standards and specifications is one way to mitigate these risks. **Automation and enabling digital communication between systems** can minimize human errors. Additionally, ongoing **communication with stakeholders**, including drivers and users, is vital in identifying and correcting errors and misinterpretations. **Establishing a system for monitoring** and follow-up early in the process is also important.

In the GeoSence project, the micro-mobility use case in Munich implemented GIS-based software with dashboard functionality. This enabled the city to monitor the impact of their policy measures. Specifically, the city monitored whether e-scooters were being parked correctly in designated parking zones. By maintaining effective communication with e-scooter operators, the city could investigate the causes of parking errors, leading to incremental improvements in the solution and enhanced compliance over time.



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1.2 WHY GEOFENCING?

Traffic and mobility-related challenges in cities vary depending on local contexts. The main challenge for cities and authorities is enabling mobility while limiting negative effects. This chapter presents some traffic and mobility challenges faced by cities, along with transport policies that can counteract these problems. It also explains how geofencing can be a tool to improve traffic and mobility in cities. The challenges covered include traffic safety, traffic system efficiency, optimised transport planning and operation, efficient use of parking and space, and reduced environmental impact. These challenges are interrelated; for example, speed compliance can lead to fewer accidents, better traffic flow, and lower noise levels and emissions.

IMPROVE TRAFFIC SAFETY

European cities strongly focus on preventing accidents, but ensuring traffic safety for all road users can be challenging. Addressing speeding vehicles is crucial for traffic safety. This concern affects both the vehicle's driver and vulnerable road users. Additionally, staff involved in road construction and maintenance are vulnerable to speeding vehicles. Geofencing can help mitigate these issues by alerting drivers to potential risks and automatically regulating speeds in designated zones. Furthermore, it can digitally restrict access to specific areas, potentially preventing vehicular terrorist attacks.

Geofencing for speed compliance
The City of Stockholm has implemented a range of traffic safety measures such as limiting speed to 30 km/h outside all schools (or car-free streets, if possible), 40 km/h instead of 50 km/h etc. Still, 78 % of the professional drivers are speeding. Geofencing has the potential to counteract this problem by alerting the driver or restricting the speed of the vehicle.

IMPROVE TRAFFIC SYSTEM EFFICIENCY

Effective management and utilisation of transportation networks will ensure a smooth flow of vehicles, minimise congestion, and optimise travel times.

Relevant traffic information for road users
Geofencing can be used to inform or warn road users about nearby roadworks, congestion, accidents, and other events. Better-informed and prepared road users can be more cautious and may choose alternative routes.

A fairer road pricing system
Geofencing applications can also be used to differentiate road pricing based on factors such as distance travelled and type of fuel used.

Limit negative impact on infrastructure
In scenarios where heavy vehicles encounter restrictions such as bridge closures due to weight limits, geofencing offers a potential solution by enabling controlled passage at reduced speeds.

The City of Stockholm is located on an island connected to the mainland by several bridges. Some of these bridges are old and sensitive to vibrations caused by high speed. To reduce the negative impact on one of the bridges, the city has imposed a regulated speed limit of 30 km/h and installed a traffic sign. Geofencing can help control speed for better compliance with regulations, extending the lifespan of the bridge, saving costs, and increasing traffic safety.

OPTIMISE TRANSPORT PLANNING & OPERATION

A more efficient traffic system can also enable transport operators to optimise their transport planning and operations.

Off-peak deliveries in Stockholm
In the City of Stockholm, most of the road network has a night-time ban on heavy transport from 10 pm to 6 am to reduce noise pollution. The city and local stakeholders have been testing quiet off-peak transport for some time. The results have been positive, improving transport efficiency by shortening delivery times and enhancing the quality of urban public spaces. During these tests, geofencing applications were used to ensure the switch to electric propulsion in hybrid vehicles. Due to these positive outcomes and the potential for off-peak transport to accelerate the electrification of heavy vehicles, the City of Stockholm is continuing to expand quiet off-peak transport through various approaches.

Efficient fleet management systems
Integrating geofencing into fleet management systems (FMS) can significantly enhance transport efficiency. It improves route optimisation and facilitates better allocation of vehicles for deliveries or pick-ups. By tracking vehicle positions and sending alerts when they enter or exit designated areas, geofencing helps adapt to changes in daily plans. This minimises travel distances and maximises vehicle utilisation, ultimately reducing operational costs.

EFFICIENT USE OF SPACE AND PARKING

Many cities have limited space and must manage it for different groups like pedestrians, cyclists, public transport, cars, delivery trucks, and more. These groups often have different needs that can conflict. Geofencing helps manage space better by creating specific areas where micro-mobility vehicles can park correctly in the designated parking spots. It can also guide drivers to nearby parking and drop-off areas, making urban travel smoother.

LOWER ENVIRONMENTAL IMPACT

Pollution and environmental issues are common concerns in cities. Geofencing technology can help encourage the use of cleaner vehicles by restricting access to certain areas. This could reduce noise and emissions from traffic. For example, geofencing can automatically switch hybrid vehicles to electric mode in specified zones or inform drivers about environmental rules. It can also support initiatives like low emission zones (LEZ), helping cities cut down on harmful emissions. The image below shows a geographical area of geofenced low emission zone (LEZ) in Trondheim, Norway

IMPROVE GOVERNANCE AND REGULATION

Digitalisation and geofencing applications can help cities improve their traffic and transport regulations, and urban planning. Geofencing allows cities to manage different types of road users more effectively, such as nudging them towards certain behaviors or enforcing mandatory speed limits. It also enhances regulatory compliance by ensuring that drivers adhere to speed limits and parking regulations in designated areas. This technology opens up new ways for cities to regulate and manage mobility, contributing to safer and more efficient urban environments.

In summary, the adoption of geofencing technology may contribute to multifaceted benefits across the transportation sector, addressing key challenges while promoting safety, efficiency, and environmental sustainability.

2. SYSTEM PERSPECTIVES

The first section introduced geofencing and its key technological components and processes. This section will cover important aspects to consider when implementing geofencing, such as impact assessment, user experience, and governance and regulation, including data for governance. Additional comments on stakeholder engagement will be made throughout the three chapters. These aspects were the main research focus of the GeoSence project. Note that other aspects, such as business models, are also part of a system perspective but are not covered in this section.

2.1 IMPACTS

The impact can be understood as the effects and benefits the solution provides for the stakeholders. This can be assessed along several dimensions, which should be chosen to reflect the objectives of the specific service to be implemented or the test to be performed. An impact study is a systematic tool for assessing how well the solution performs for the municipalities – how effective and efficient it is. It can also provide insight into its societal and external side effects and benefits.

ASPECTS TO INCLUDE IN IMPACT ASSESSMENT

For urban geofencing solutions, technology, financing, policy, and societal and behavioural aspects are all relevant dimensions to include in an impact study. Within each of these dimensions, more detailed topics can be specified to capture the specific assessment criteria relevant to the application being studied. Impact studies performed in GeoSence provide examples of aspects to include in an impact study and how they can be assessed.

The example given in Table 1 and Figure 1 is a simplified version of the impact assessment of the Gothenburg use case. Each aspect or assessment criterion has been assigned a score on a scale from zero to six. This score can be based on quantitative or qualitative assessments. The list of assessment criteria under each dimension should be expanded and adapted to fit the specific purpose of each application as well as the site and situation addressed.

Table 1. List of dimensions and criteria used to assess the impact of the Gothenburg use case in GeoSence.

Dimensions	Assesment criteria
Technology & operation	• Technology readiness • Reliability, bugs and errors • Integration with other IT systems • Efficiency of operation
Finance & management	• Public R&D investment in hardware • Public R&D investment in software • Maintenance costs for municipalities • Turnover for service provider • Profit margin for service provider
Policy	• Compatibility with existing local strategies • Integration within local procurement • Improved driver compliance • Improved traffic control/ police
Society & behaviour	• Acceptance from users • Improved safety • Privacy and confidentiality • Shifts in choice of travel mode

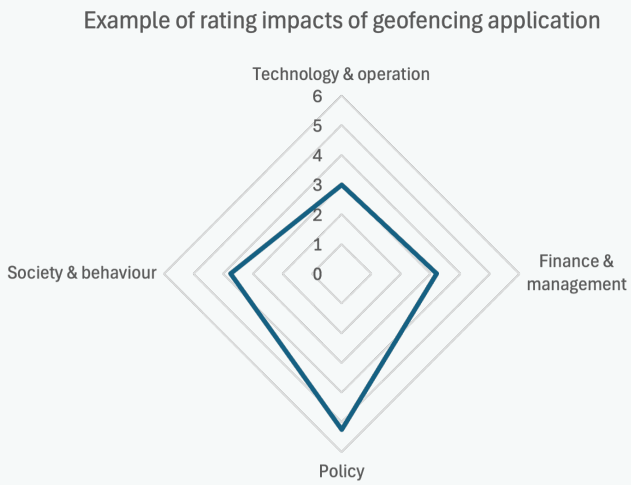

Figure 1. illustrates a simplified version of the scoreboard of indicators used to assess the Gothenburg use case, with zero as the lowest rating and six as the highest rating. It is divided into four main dimensions: Technology & operation, Finance & management, Policy, and Society & behaviour.

WHAT ARE THE IMPACTS AND CONCLUSIONS?

Even though there is ample evidence that geofence applications are now more widely implemented, there are still not sufficient findings and results to generalise upon. As the applications and solutions must be adapted to each unique site, circumstance, and purpose, much of the available evidence of impacts from geofencing solutions is still very fragmented. Thus, there is a need for continued gathering and dissemination of evidence and findings on the impact of future implementations and tests of geofencing applications.

The main conclusions from the GeoSence impact assessment are that there is a demonstrated potential for the future development of geofencing applications in parking management and shared micro-mobility in cities. Results about the potential use of geofencing for counteracting speeding are less convincing and will require more development and research before a definitive improvement can be evidenced with more certainty.

Findings from the Munich use case on shared e-scooters during the GeoSence project show that parking behaviour improved substantially after the geofenced parking areas were made available to e-scooter users via the app provided. At the same time, the mobility service providers (MSPs) renting out the e-scooters experienced an increase in the number of scooters and trips. The results also indicate a shift from private cars to shared micro-mobility. According to the MSPs and the municipality, these achievements would not have been possible without geofencing.

PREREQUISITES FOR SUSTAINABILITY IMPACTS FOR GEOFENCING

Generic, fundamental lessons learned from GeoSence regarding the beneficial impacts and effectiveness of using geofencing technologies in transport planning and applications, along with the prerequisites for obtaining these, are summarised in the following points.

Embeddedness: A geofencing application needs to be integrated into a general transport policy aimed at reducing congestion, improving safety, or making road traffic more fluid, greener, and more friendly to pedestrians and citizens. A geofencing application is never efficient or effective by itself. It is always part of a policy objective, contributing effectively, along with many other tools and working methods, to help achieve the targets.

Example from Munich
In the case of the parking zones in Munich, the solution of improving behaviour and increasing market share could not have been achieved without geofencing. However, demonstrating its unique usefulness was ultimately embedded into a vast web of coherent actions and investments.

Testing and development towards improvement: A geofencing application needs testing and development, adapted to the field and its improvement. It can hardly be neutral in contributing to maintaining the status quo. The aim should be an effective situation improvement, and the contribution of the geofencing application towards this should be made clear during tests and trials on a small scale.

Visibility: Geofencing requires more than a zone on a digital map. Successfully implementing a geofencing application goes beyond defining and entering the limits of a low emission zone or a pedestrian zone into a digital map in a navigation app or uploading speed limits for e-scooters to the vehicle. This should not be something a municipality or a transport service provider implements without additional specific actions or public information exchange to ensure visibility.

Scale-up: The geofencing application should be a candidate for scaling up. If it reaches its target on a small scale, the objective of the next step is to try reaching industry-scale implementation. How to do this extension successfully remains to be demonstrated in another possible project.

Details of the impact assessments for the GeoSence use cases in Gothenburg, Sweden, and Munich, Germany, are documented in Deliverable D4.4 and city-specific documents, all available on the project website.

Image ©: CLOSER at Lindholmen Science Park

2.2 ACCEPTANCE

WHY BE CONCERNED ABOUT ACCEPTANCE?

Whenever new and innovative technologies and measures are implemented and used in the field of traffic management and planning, there will be changes to the status quo and the functioning of the current traffic system. In some cases, this means that those affected by the measure must adapt and change their usual behaviour and travel habits. An acceptance analysis is therefore an important step to understand how a technology or measure works, how it is perceived and evaluated among affected groups, and how to be able to support it by measures to improve compliance.

CHALLENGES FOR EVALUATING THE ACCEPTANCE OF GEOFENCING

As described in the chapter "Why geofencing?" above, various application scenarios for geofencing in the field of traffic & transport management and planning can be envisioned. Due to this diversity, a general acceptance assessment for geofencing as a technology is not possible per se but depends on the context of use. In addition, the use of geofencing as specific functional aspects is usually not directly visible to the end-user or affected group, but can often only be experienced as part of the whole package (system/measure).

When evaluating acceptance of a measure it may be then more important to what extent the solution interferes and restricts users' behaviour and habits. For example, a system that actively and autonomously regulates the speed of a vehicle will certainly be rated as more intrusive and less acceptable than one that only supplies information on applicable speed limits, even if the geofencing-specific aspects used are the same in technological terms. Therefore, especially if acceptance problems arise, it may be critical that the acceptance evaluation has the potential to reveal which aspect of an implemented solution has caused an issue.

ACCEPTANCE ISSUES RELATED TO GEOFENCING

Presently, the implementation of geofencing often comes with challenges. The list summarises the main barriers associated with geofencing as experienced in our use cases and as derived from the literature:

- Perceived inconvenience
- Technological challenges
- Lack of knowledge/understanding
- Privacy concerns
- Lack of trust
- Regulatory hurdles (e.g. GDPR, liability, jurisdictional issues)
- Equity issues
- Cultural and social factors

The **perceived inconvenience** significantly impacted the acceptance of end users in the GeoSence use cases. This was linked to usability issues with user interfaces and perceived obstacles and usage infringements caused by the implemented geofencing solution.

Technological challenges, such as GNSS (e.g., GPS) inaccuracy, exacerbated these issues, resulting in unreliable system behaviour that did not meet user expectations. For example, in Munich, some e-scooter users reported being unable to return their scooters despite being within designated parking zones.

Lack of knowledge and understanding often stems from user and stakeholder perceptions, misperceptions, or a complete absence of understanding of what geofencing is, its capabilities in specific use cases, or the reasons for geofencing particular areas.

Privacy concerns are manifested in users' worries about the collection and analysis of location and position data without their explicit permission or consent. These concerns also relate to expectations of trustworthiness from stakeholders involved in data collection and processing.

Regulatory challenges pose barriers to stakeholders involved in the implementation process, including issues related to how data protection regulations like GDPR can be efficiently implemented and how the use of third-party technologies impacts liability, warranties, and other jurisdictional matters. Cultural differences also play a role, with some social groups viewing the technology as a privacy violation or security threat, while others are more receptive to sharing necessary information and data.

ACCEPTANCE FOR GEOFENCING – THE EVIDENCE

Although several projects used geofencing for traffic management and planning, findings related to acceptance were sparse when GeoSence was launched in 2021. Meanwhile, some evidence has been published.

Overall the findings suggest that acceptance for geofencing depends on the type of traffic regulation it supports (the automatic regulation of the drive mode of a hybrid electric vehicle in low emission zone is more accepted than the automatic speed regulation in school zones), that personal experience with a system is important to build trust and positive attitude toward such technology and that usability of and satisfaction with the human-machine-interface of the system also contribute acceptance levels.

Privacy concerns, as outlined in the previous paragraph, were included only in one study which found that they may pose a challenge to acceptance of a geofencing regulation. Taken together, more information and data are still needed to understand the conditions for acceptance in the context of geofencing to unlock its full potential.

The GeoSence use case in Munich illustrates behavioural aspects of acceptance. Here, geofencing was deployed to regulate e-scooter parking, allowing parking only in designated zones while prohibiting it in the Old Town area. Acceptance and compliance with this regulation were analysed behaviourally by comparing parking locations before and after its implementation.

In 2020, e-scooters (blue dots in Figure 2) were scattered across most streets in the Old Town area on maps. By 2023, however, the locations of returned e-scooters were notably clustered around the designated parking zones (larger black dots in Figure 3), indicating a significant improvement in compliance with regulations aimed at enhancing pedestrian safety.

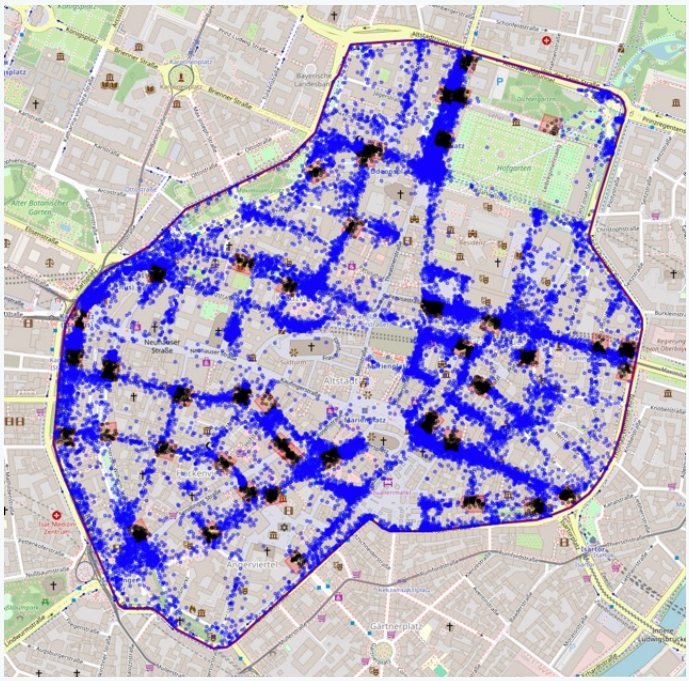

Figure 2: Map of e-scooter parking in Munich in 2020

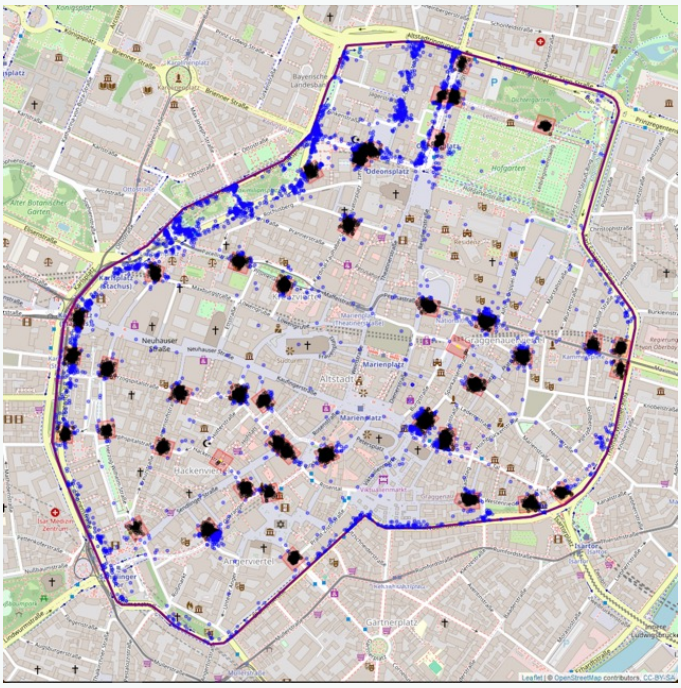

Figure 3: Map of e-scooter parking in Munich in 2023

A survey conducted among affected groups revealed that 53% of e-scooter users accepted the regulation, while 20% rejected it. In contrast, among pedestrians, acceptance was high, with 98% of respondents supporting the regulation. The lower acceptance rate among e-scooter users was largely attributed to perceived technical issues, including GNSS inaccuracy. Addressing these issues is crucial for future improvements and development.

ACCEPTANCE ON THE INSTITUTIONAL LEVEL

Acceptance at the institutional level is critical not only among end users and affected groups but also among all stakeholders involved in the implementation process, including authorities, municipalities, political actors, and private entities. During the testing or implementation of geofencing, it is essential to consider the perspectives and objectives of all stakeholders.

Introducing geofencing within organisations and institutions requires a willingness to undergo transformative processes, from individual employees' readiness to acquire new knowledge and skills to departmental and institutional support for resource provision and change management. At the governmental level, acceptance of geofencing determines whether, how, and when solutions are introduced, emphasizing the importance of national policies and legal frameworks.

A successful transformative process hinges on early identification and engagement of stakeholders to foster commitment and trust. This involves establishing clear objectives, expectations, roles, responsibilities, timelines, and potential challenges in implementing geofencing applications. It is also crucial to articulate the purpose of geofencing applications among stakeholders, aligning with their diverse values to minimize organisational and acceptance barriers. Such processes are extensive and resource-intensive, requiring diverse capabilities among involved employees.

Image ©: CLOSER at Lindholmen Science Park

2.3 GOVERNANCE AND REGULATION

Governance is a broad term used to describe the various ways in which organisations and societies are governed. It includes structures, processes, and mechanisms used to direct and manage collective activities. Governance encompasses both formal and informal arrangements that influence how public and private actors coordinate their actions and resources.

Meta-governance is an interdisciplinary perspective that examines how different actors, including government agencies, private companies, and civil society, interact to manage and solve collective problems. This can include everything from policy development and implementation to the monitoring and evaluation of outcomes. Meta-governance is not limited to political systems or corporate governance but extends to all types of organisational and social systems where there is a need for coordination and control to achieve desired goals and objectives

GOVERNANCE FROM A USE CASE PERSPECTIVE

Essential components in governance strategies for the implementation of urban geofence solutions include:

Framework: legislation and contracts
- Define governance goals
- Make a governance action plan

Observe and understand
- Collect data
- Understand how to interpret the data
- Analysis of patterns of use and impacts

Adapt and adjust
- Continuous data monitoring (e.g. dashboard)
- Stakeholder collaboration
- Data-driven adjustments
- Public feedback integration
- Regular policy reviews
- User feedback collection
- Adaptive measures implementation

GOVERNANCE SUMMARY AND CONCLUSION

The governance process must be updated based on continuous data analysis, stakeholder feedback, and the observed effectiveness of current policies. The following recommendations have been extracted from the GeoSence use cases:

Use visualisation as a tool: Digital dashboards for real-time monitoring (e.g. of e-scooter parking and movement patterns) can ensure compliance and the effectiveness of geofencing zones, strengthening the ability to conduct efficient governance.

Mobilise and engage for governance: Regular meetings with involved stakeholders and transport providers to discuss data trends and emerging issues are essential to ensure all parties are informed and collaborate effectively. Engaging stakeholders also ensures their objectives are taken into account, mitigating acceptance hindrances.

Focused data collection: Utilising collected data to make adjustments to geofencing zones and regulations is crucial. This includes modifying geofencing parameters and enforcement strategies in areas with high non-compliance or safety concerns. Additionally, integrating feedback from pedestrians and residents through surveys and public consultations will help refine the governance framework and address public concerns. Conducting regular reviews of regulations is necessary to ensure they remain relevant and effective, assessing the need for new regulations or modifications based on evolving data and stakeholder feedback.

Regular consultations with transport operators and technical suppliers should be held to interpret data and understand operational challenges, ensuring all stakeholders are aligned. Gathering feedback from user groups (e.g., drivers and passengers of special transport services) to identify practical issues with the geofencing implementation is crucial. This feedback should be used to refine the technology and its application.

Implementing adaptive measures based on data analysis and feedback, such as adjusting speed limits in geofenced zones and enhancing ISA system alerts to improve compliance and safety, is essential. For example, providing ongoing training for drivers to ensure they understand how to effectively use ISA systems and comply with geofenced speed limits will enhance overall compliance and safety

GOVERNANCE CHALLENGES

Implementing governance in the transition from the current state to the future state naturally offers some challenges. The two cities demonstrating geofence applications in GeoSence both encountered common challenges related to GNSS precision, technical issues, data protection, and operational constraints in their efforts to implement and maintain governance through geofencing technology. These challenges and constraints may be interlinked:

GNSS precision issues can lead to e-scooters not accurately registering their positions within geofenced parking zones, or impact the ability to accurately monitor and control speeds in geofenced zones. Data protection restrictions under GDPR can make it difficult to share and use personal data to enhance monitoring and enforcement.

Financial limitations can affect the scope of the project and the availability of resources to implement comprehensive geofencing measures. As a consequence, technical challenges may arise with the integration of geofencing technology and ensuring it functions as intended.

Operational challenges, such as managing and maintaining large amounts of real-time data, require significant resources and expertise.

Technical problems with installation and operation e.g. of ISA systems and geofencing technology in combination, can affect their effectiveness. Ensuring the accuracy of all input data, such as speed limits around schools and during roadworks, can be a significant challenge, and be affected by data management difficulties involving handling and analysing large volumes of real-time data and ensuring a constant and reliable data flow.

Regulatory hurdles include the need to continuously update and adjust policies to keep them relevant and effective as new technologies and insights emerge.

3. STEP-BY-STEP GUIDE FOR CITIES

This section of the guideline describes a step-by-step process in three phases, based on the experience and advice from cities, users, geofencing pilots and trials, and transport providers.

The suggested process and steps provide a large number of topics and questions for cities to discuss and decide on, and not so many specific answers. This reflects the character of urban geofencing applications: they need to be tailored to the specific issue, site and circumstance.

Phase 1: Get to know your current situation and options

- Then decide whether available solutions are sufficient to reach your goals, or if you need other tools.
- If the latter: move on to the next phase.

Phase 2: Explore geofence as a tool for your city

- Then decide whether geofencing applications can be a relevant and realistic tool for your city.
- If yes: move on to the next phase.

Phase 3: The implementation process

Throughout: Document the process, definitions and rules, findings and takeaways, and share your knowledge and experience!

3.1 KNOW YOUR CURRENT SITUATION AND OPTIONS

Before looking for solutions to a specific transport-related challenge, you need a precise description of the problem, what you want to achieve, and what resources and solutions you already have. Then you can decide whether the existing solutions will be sufficient or if you need to look for new or additional measures to reach your goals.

Geofencing can be used together with existing solutions, such as traffic signs, to improve current regulation efforts. For example, geofencing can be applied to taxis, school buses, and delivery vehicles in a school area with a 30 km/h speed limit sign to prevent them from speeding in this area.

The existing measures will still be necessary for communicating traffic regulations to all road users. There will be vehicles on the road without geofence capabilities for years to come.

IDENTIFY AND DESCRIBE THE CHALLENGE AND GOALS

Understanding the challenge and the goals is essential when improving urban traffic management.

Describe the traffic or mobility-related issue:

- What is the problem, and where is it? – Geography matters!
- What causes the problem, and why?
- Is it permanent or seasonal?
- Who are the affected stakeholders or road user groups, in what way, and what are the consequences?
- Are there any conflicting goals?
- How urgent is it to solve the problem? (This will show how much of a hurry you are in.)

Study existing available data

Existing data can help answer these questions, understand the properties and mechanisms of the problem, and suggest possible management goals and measures.

Develop the goals

Pre-assessment of goals and strategies is important when working with urban traffic management.

- What do we want to achieve, and what is the overarching strategy?
- Decide what/who, how, and when to regulate/manage (speeding, access, parking, emissions, etc.).
- Are there spatial issues to consider?

Review existing strategies

Once the challenge is identified and the goals are developed, ensure coherence with the existing strategies and policies by reviewing:

- The city's strategies regarding transport and digitalisation
- Relevant policies and Sustainable Urban Mobility Plans (SUMPs).

A thorough review of these documents is important to avoid incoherence and conflicts with stakeholders in other departments, divisions, etc.

WHAT ARE THE OPTIONS TO OBTAIN THE GOALS?

Once the challenges and goals are identified and described, the next step is to discuss and identify the alternatives and options to achieve the goals.

Build on the existing strategy for mobility and improve it. It is important to have this in place before starting with geofencing.

Explore your options

- How much time do I have?
- Are there any existing solutions that can be applied?
- Are these solutions good enough to solve the problem – fully or partly? If only partly, define what is missing.
- Is there a need for other/additional/ new solutions, and can they be combined with existing solutions and systems?
- What combination of techniques do I need to solve my challenge?

If existing solutions are not sufficient to solve the problem, it is time to consider other alternatives.

Get an overview of the alternatives

- What are the available solutions on the market?
- What are the experiences, and what are the costs?

Get an overview of the data needs

- What data do we already have?
- Does it already cover what we need?
- Do we need additional/new data?
- How do we manage the data?

Then, consider your possibilities carefully before deciding on the solution.

WHAT ARE YOUR PRIORITIES?

Discuss the larger vision and priorities regarding the cities' roles in governance and management of infrastructure and services:

- How to address conflicting goals.
- How to use in-house resources and capacity

Image ©: Lindholmen Science Park

3.2 EXPLORE GEOFENCE AS A TOOL FOR YOUR CITY

Once the decision has been made that existing available resources and solutions do not suffice to solve or mitigate the issues, the next step is to investigate whether geofencing applications can be a relevant and realistic tool. This consideration should be based on knowledge about what type of traffic management is already in place, and whether there is enough time and resources to implement new technology. Knowledge about geofencing can be gained by talking to other cities that have experience with geofencing.

It is crucial to ensure you have enough time to implement a test before deploying geofencing. If you do not have sufficient time to test the system, you may risk the acceptance of the measure.

This chapter provides recommended steps for the individual city to take when exploring whether geofencing can be a tool to solve the problem or improve the situation. The steps are illustrated by questions the city should discuss.

INITIAL STEPS AND WORK PROCESS

Consider the feasibility of geofencing, e.g. by asking these questions:

- What can a geofence application contribute to in our case?
- What is the goal of the geofence?
- Is geofencing the most efficient tool to obtain the goals we have agreed on?
- Is the aim to reduce speed, prevent speeding or control access to a certain geographical area?
- What data do I need to deploy geofencing?
- Who has the data, and how do I get it?
- How do I finance it?
- What can the business models look like?

Then, if the conclusion is that geofencing can obtain the goals, consider the feasibility:

- Can we reach the goal for this application within reasonable cost and time?
- Assess hindrances, e.g. useability; technology; collaboration; acceptance
- Define actors and stakeholders.
- Consider stakeholder engagement from departments, providers, and users.
- Talk with other stakeholders for consent on the geofencing objective.

If the answer to the questions points in the direction that geofence is considered a useful tool, you should establish a working process that is agile enough to take care of strategic learning. Ensure common understanding among the group members and that the entire organisation is moving together in the same direction.

NEXT STEPS TO TAKE AND QUESTIONS TO DISCUSS

In this section, several questions (Q1–11) are proposed, which may be read as a stepwise process for cities to take when considering geofencing as a solution to solve traffic and mobility issues. The steps presented do not necessarily have to be carried out in a certain sequence.

Q1 WHAT HAS ALREADY BEEN DONE, AND WHO CAN TEACH ME?

Acquire knowledge about what has already been done in this area.

- Do not reinvent everything. Look out for best practices in other cities and learn from their experiences with geofencing.
- Can you collaborate with other cities to increase the efficiency of the tender process?
- Can you collaborate with national or regional administration in your city?
- Can Mobility Data Specification "MDS" be relevant?

Successful implementation of technology, such as geofencing, in society, requires that different actor groups consider it valuable and practical. Listen to experts in the field, operators, technology providers, and the public.

Conduct comprehensive market studies and engage in roundtable discussions with technology providers:

- Where do they stand technically?
- What are their perspectives on the identified issue to be solved, and relevant solutions?

Involve external mobility service providers early, directly in the development of use cases to ensure a mutual understanding of obligations, responsibilities, and expectations.

- What experience and technical possibilities do they have?
- How can mobility providers enable or hinder the city's geofencing plans?

Q2 HOW CAN I CONSULT AND COORDINATE STRATEGIES?

Implementing geofence in cities implies the adaption of existing mobility strategies or the development of new mobility strategies.

Have a digital strategy first. Then go on to applications.

The City of Gothenburg has a digitalisation plan for 2023 – 2026 which is a precondition for the city to do the right things in the right way. The document specifies what committees/boards and administrations/companies must do, who must do it and how it must be done.

Q3 WHAT SKILLS DO I NEED?

A range of skills and capacities may be necessary:

- Knowledge of already existing data that can be used (e.g. traffic regulation data).
- Skills to visualise data and draw geofences
- Legal expertise
- Stakeholder management skills
- Procurement skills
- Project/process management

Once the necessary skills are identified, the next step is to find out what skills you already have in your organisation. If your organization does not have the essential skills, find out who can teach you, or where you can acquire the missing skills and techniques, for example through hiring.

Q4 STAKEHOLDERS – WHO NEEDS TO BE INVOLVED?

Involving stakeholders is important to ensure that the solution is effective and meets the needs of all parties involved. Stakeholder involvement can be crucial for the successful implementation of geofencing.

Establish continuous contact with stakeholders, to identify and overcome hindrances in the planning and implementation phase and to decrease knowledge gaps and increase acceptance.

Stakeholders can be found internally in their organisation as well as externally. Responsibilities and tasks related to geofencing must be communicated clearly to all stakeholders.

The type of stakeholders that should be involved is case-dependent but often involves four stakeholder types: *authorities, political decision-makers, businesses, and affected groups/users.*

Stakeholder involvement in Munich

In the Munich use case, city officials invited e-scooter providers to help identify suitable locations for geofencing e-scooter parking in the old town. The e-scooter providers shared usage data with the city authorities, which then suggested parking areas. The parking areas were inspected by the district committees and the building department to see which of the suggested areas were suitable. The process resulted in 43 parking spaces that meet the needs of all involved stakeholders.

Q5 HOW DO I MANAGE ZONES AND SPATIAL ISSUES?

Knowledge about the space where you consider applying geofencing is crucial when defining the geofence zone and the exact location of the geofence:

- What type of space is the geographical area?
- What is the use of the space?
- What type of road users are involved?
- Who will be affected by geofencing? (This is closely connected to stakeholder involvement).
- Are there already restrictions for some road users in the particular space where you consider applying geofence?

Heavy vehicles and taxis are examples of road users who may already be subject to regulations and boundaries. Be aware of this and how the existing boundaries will work together with the ones you plan to apply. This knowledge is crucial to link a new geofence zone to the ones that already exist and avoid overruling the different boundaries.

Involving territorial authorities can be helpful to get insights into spatial considerations.

Q6 HOW DO I INFORM AND COMMUNICATE WITH ROAD USERS?

Communication of information and instructions regarding geofence needs to be tailored to the specific road user categories involved. When planning the communication, think about:

- **Who** are the receivers? - road user categories
- **What** to communicate?
- **How** to communicate? - means and formats
- **When** to communicate?
- **What** is in our control, and what is not?

Q7 HOW DO I DEAL WITH COMMERCIAL ISSUES, BUSINESS MODELS AND FINANCING?

Ensuring financing is key for both the planning and the implementation phases related to geofencing. Questions about who will pay for planning, implementation etc. will most likely emerge. Who will benefit from geofencing is another important question to discuss.

For successful geofencing, it is crucial to establish a sustainable business model – from pilot to real operational operation.

Business models should encompass

- The solution to define and manage geofences for one or several mobility services
- Solution that helps to manage and analyse mobility data provided by some mobility service
- Retrofit driving assistance system (hardware) that are geofencing compatible
- Services that help to improve/overcome current GNSS (e.g., GPS) inaccuracy issues by using additional sensor technologies or Machine Learning/Key Intelligence-based data analyses

Further, financing involves identifying procurement requirements.

Public procurement and unproven technology

In your tender, you must describe what you want to buy.

- Use functional requirements
- Do market research
- Are there alternatives to geofencing?
- Identify risks

Start on a small scale, test and learn. Then scale up.

Q8 WHAT ARE THE DATA NEEDS AND ISSUES?

Deployment of technology such as geofencing in public spaces, generates questions and issues about data needs and data management. Due to privacy and data management regulations, data is one of the main issues related to geofencing.

- Find out what type of data is necessary
- Identify who can provide the specific data
- Make a plan for how to manage data

It is crucial that all aspects of data use, data access, and data quality are managed correctly and securely, under current legislation and regulations such as GDPR.

Use existing data if possible

Involved service providers and operators may be helpful to identify e.g. relevant zones/set up geofencing zones.

Operators (e.g. Taxi companies or providers of shared micro-mobility) can have data on where the vehicles are operating, the vehicle speed, and where the vehicles are parked.

If the available data do not cover your needs, you must look for ways to develop or create the required data.

Spatial precision of geofence definitions

The level of precision for the geofence boundary depends on the use case purpose:

- Speed zone/low emission zone may require a precision of **+/-1 meter**,
- Whilst parking zone definitions for e-scooters may require a precision of **+/-10 cm**

When high precision is required, the available map material and resolution may not be sufficient to define the outline of a geofence zone just by drawing it on a map. In this case, geofence locations may have to be measured with professional GNSS measurement technologies.

Location precision of GNSS signal from users/vehicles

GNSS accuracy varies with the systems and sensors it is measured with, and which functionalities they support.

- Older and low-budget systems and sensors are often less accurate
- GNSS accuracy is usually higher if the object is stationary compared to a moving objects

In the case of small geofence zones (e.g. parking areas for e-scooters), the dimension of the geofence may be smaller than the average error of a GNSS location. As a consequence, the estimate of whether an object is inside or outside the geofence will be very unreliable, making control of e-scooters parking within the geofence a challenge. To mediate this, a tolerance range needs to be applied before this issue is solved. For instance, the geofence dimension can be extended by a few meters in all directions.

Temporal requirements (latency)

Acceptable temporal delay of communicating geofence information depends on the use case:

- For speed regulation and information related to entering or leaving geofence zones only **minor delays (1 second)** can be accepted
- For providing more general traffic information within zones, longer delays may be acceptable

How often does geofence information need to be updated?

This depends on whether the geofence is spatially or temporally dynamic. The more dynamic the geofence, the higher the frequency of updates required:

- Emergency information (e.g. alert about an approaching emergency vehicle at a junction) or congestion information will be more dynamic than information related to parking zones or speed zones.

Legal basis for data sharing

Prepare data sharing agreement and ensure that the city will have access to the expected data

When considering data needs: make sure to develop future-proof solutions which allow for upscaling and for long-term use.

Q9 WHAT ARE THE TECHNOLOGICAL NEEDS AND ISSUES?

Technological needs and issues will depend on the zone where geofencing is deployed. Some technological needs and issues are generic regardless of case, while others are zone/case specific.

Get a good overview of what needs to be controlled, public transport? Private transport? Fleet management?

Retrofit or factory-ready in the vehicle?

Geofencing can be facilitated either by retrofitting equipment in a vehicle or by using factory-installed equipment. For each case, consider which method is most suitable. The two alternatives have different needs and issues.

In-vehicle or cloud-based system?

There are two typical system setups when deploying geofencing technology: in-vehicle systems and cloud-based solutions. Both systems have advantages and disadvantages.

In-vehicle systems

The object/vehicle has its IT system (hardware and software) where maps, geofences and regulations/policies are stored, and which can analyse the object's GNSS location in relation to that stored geofence information and provide feedback to the user or even control vehicles function.

If geofence and policy change, the information in the system needs to be updated e.g., by over-the-air updates on demand or in planned intervals. Continuous data connection to a service is not required, as all necessary functions can be provided by the system itself.

Current advantages of in-vehicle systems

- Can process GNSS geofence information faster than cloud-based solutions
- Well suited for situations where low temporal delays (1s or less) are required (speed control)
- No continuous mobile data connection required
- May also work in areas where mobile data connection is bad or not available

Current disadvantages with in-vehicle system

- Suited for static geofences only (geofences where information does not change often)
- Possibly higher requirements and costs for in-vehicle hardware

Cloud-based solutions

The object/vehicle needs hardware and software to transmit and receive information (e.g. over mobile data connection), and optionally also to display/ issue feedback to the end-user or for an interface to control vehicle functions. The vehicle's location information is sent to the cloud service, where it is analysed and the result of the evaluation is sent back to the vehicle via mobile data connection.

Current advantages of cloud-based solutions

- Somewhat lower requirements for in-vehicle hardware
- Suitable for temporal, dynamic and smart geofencing applications (i.e., spatially and temporally dynamic geofences, geofencing decisions that depend on the current situation of a traffic network and/ or depend on other road users)
- More complex data analysis can be performed
- Software solutions and algorithms in the cloud can be adapted more easily, with fewer demands for updating/ maintenance

Current disadvantages of cloud-based solutions

- A continuous and stable mobile data connection is required
- Sending data to cloud service and back takes time and introduces delays in the system
- The time delay may be variable
- The system will not work if the data connection is not available
- Additional cost for mobile data connection/ data transfer

Independent of which of the two alternatives fits your case the best, it may be a good idea to start with a review of the market for available solutions. If the market already offers solutions to fit your purpose, and it is possible to adopt the standards of such available solutions, this should be explored.

Q10 WHAT ARE THE GOVERNANCE ISSUES?

The city may approach several governance issues when considering deploying geofencing.

- One of the main governance issues is cities' lack of authority to process information on personal data.
- Data protection restrictions due to GDPR prevent tracking of individual journeys, while parking situations are not affected. This indicates that geofencing may be more challenging to deploy in certain areas or for certain purposes.

Geofence is hard to regulate

Geofencing applications can include many technologies and processes. Keep in mind that:

- At the moment, there is no law prohibiting the use of geofencing for users
- Because geofencing applications consist of many different things, it is also difficult to regulate
- There is not one specific standard for geofencing

This creates challenges if you want to do a public procurement.

Legislation: GDPR and enforcement

Geofencing and other connected solutions can be dependent on technical infrastructure, data availability and compatibility with existing systems. From a regulatory point of view, the implementation of geofencing must comply with all relevant laws and regulations, including data protection and privacy laws such as GDPR.

In the extension of data management, the city may approach legal and regulatory hurdles associated with the use of geofencing on the road, including privacy and data protection concerns.

Stakeholder opposition

Opposition from stakeholders such as (e.g., residents, mobility providers, and other government agencies is a potential issue. Residents may e.g., be hesitant to accept deployment of geofence in their neighbourhood due to fear of negative consequences.

The technology

Governance issues may also concern the technology:

- What is the accuracy and how reliable is it?
- Is the connectivity sufficient?

Financial constraints

Financial issues are prominent in city governance. The city may have ideas, strategies, and motivation to deploy geofencing, yet deployment needs to reflect the financial resources available. Financial constraints could limit the scope or size of the geofence project, as well as the availability of funding sources.

Q11 WHAT IS THE COST-BENEFIT, AND WHO BENEFITS?

For the cities, access to new types of data is beneficial.

- Are there any additional benefits for the city?
- Does anyone pay a cost in terms of loss of benefits or qualities by introducing geofence? – If so: who/what stakeholders?

Once these issues have been explored and discussed, you should be in a position to decide whether geofencing applications can be a relevant and realistic tool for your city. If that is the case, you should continue to the next phase, planning the implementation of the geofence solution.

Image ©: Lindholmen Science Park

3.3 THE IMPLEMENTATION PROCESS

Once the decision to implement geofencing for traffic management has been made, it is time to begin preparing for implementation. This involves working on details such as zone definition, stakeholder involvement, developing business models, and procurement. This chapter provides further elaboration on these and other important issues in the geofencing implementation process.

THE IMPLEMENTATION PHASE COMES WITH A RANGE OF CHALLENGES

The cities in the GeoSence project have encountered several challenges during geofence implementation. Here are some listed, not to warn but to provide insight into potential challenges, enabling better preparation and readiness to address them if they arise:

- Coordinating and collaborating with multiple external users
- Sharing information and data among multiple actors
- Awareness and acceptance among service providers and end users
- Technology and system affordability – equality of access
- Missing policies or strategies
- Legal bases and regulatory options – a political question
- Missing guidelines and standards – "silos" versus unifying solution
- GDPR, data protection or data security issues
- Insufficient/immature technical equipment or procedures – digital and physical infrastructure could be key
- Missing support by authorities
- Budget constraints
- Not enough knowledge or competence in own organisation
- Uncertainty about impacts and traffic effects of geofencing solutions

STAKEHOLDERS

To achieve successful implementation, involve stakeholders and secure their cooperation, despite potential differences in motivations and attitudes towards geofencing. This requires mutual respect and understanding of diverse perspectives on the technology.

Stakeholders must also grasp why geofencing is the optimal solution for addressing identified traffic issues. Alongside shared understanding, building mutual trust is crucial. Stakeholders are likely to inquire about personal or collective benefits, prompting discussions on fair distribution of costs and drawbacks.

HOW TO ACHIEVE ACCEPTANCE

Recommendations include arranging early physical meetings with all participants in the project. Use these meetings to clarify expectations, roles, and responsibilities for the city, other authorities, stakeholders, and equipment and solution providers. This ensures everyone is aligned from the outset:

- Start small when installing and testing the system, and keep a continuous dialogue with users and service providers.
- Have as close contact with end users as possible, and exclude middlemen with little or no interest in the geofencing pilot or implementation (as the middleman might not see the value of the technology).
- Communicate findings to the public and stakeholders.

ZONE DEFINITION AND SETTING UP ZONE RULES

The definition of a geofence zone includes:

Spatial definition
- What is the **size** of the zone, **how many** of them, etc.?

Temporal definition
- Is the zone **permanent**, and will be switched on-off depending on what time and day it is?
- Or is it **temporary**, for instance only lasting during an event?
- Will the zone change **dynamically** depending on a certain triggering event, e.g., an accident or challenging road conditions?

Data definition
- What data will the geofence be based on – e.g., road data, traffic regulations, weather conditions, etc.?

Decide on how to communicate the geofence and to whom

- **Who will receive** the created? Is it the transport operator, or will it be communicated directly to the vehicle manufacturer, or the road user, e.g., the driver?
- **In what format** will the geofence be sent, and what **software** can be used?
- **What tools** can be used to maintain good **communication** with relevant stakeholders?

Decide what the geofence should be doing

- **Collect/Track** data – e.g., information on how many vehicles enter a zone and how long they stay.
- **Inform/Warn** – e.g., recommend speed limits or warn if a vehicle enters an unauthorised zone
- **Restrict/Control** e.g., control speed, propulsion, or access to a zone

Decide on the level of enforcement

- Is it based on a **voluntary** agreement, or will it be **regulatory**, e.g., permits dependent on using geofencing applications?

Decide on how to monitor and follow up

- What **criteria** should be used to monitor and follow up, e.g., what is expected from the transport operator to report back?
- What **software** and **tools** can be used for monitoring and follow-up?
- What **measures** can be taken to improve the application design? For instance, it might be necessary to complement the geofence with physical signs to improve compliance.

You should only make rules if you know how to follow up and enforce them.

DATA REQUIREMENTS AND DATA MANAGEMENT

You need a specification and standards to communicate data. For example, the Mobility Data Specification (MDS)[7] is an open-source tool enabling two-way data communication between a city and mobility/transport providers. It allows cities to collect data and publish regulations on the same platform.

Keep in mind that real-time data sharing is usually more costly and generates a larger amount of data. If not necessary, consider using historical data, such as parking data based on the previous day, week, or month.

Also, be precise about what data should be shared with you. Raw data that has not been processed will require more work to process and analyse. Most often, aggregated data that has been summarised by the provider based on your criteria will be preferred.

BUSINESS MODELS AND FINANCING

Financing models for the city's costs must be tailored to the scope and potential of the geofencing:

- Users benefiting from improved operations due to the geofence can be subject to special user charges. For example, in Munich, e-scooter providers must pay a fee for every scooter parked in the city. Companies like Nivel[8] specialise in this.
- The city may also decide to cover the full cost. A successful implementation may result in indirect cost savings, such as reduced consequential accident costs.

PROCUREMENT

The procurement of geofencing solutions involves several steps to ensure the solution meets your business needs and is implemented effectively. Procurement can be divided into three main phases: 1) prepare procurement, 2) carry out procurement and 3) follow up on procurement.

7 https://www.openmobilityfoundation.org/
8 https://www.nivel.no/

Phase 1 – Prepare procurement

Define/remind yourself of your objectives

The first step in procurement is to define your objectives.

- What are you trying to achieve with your geofencing solution?
- What are the benefits you hope to gain?

By defining your objectives, you can ensure that you select the right technology and software, set the right parameters, and measure the success of your solution.

Establish a working group

Get an overview of what skills and resources are needed, then recruit staff from the relevant departments in the public administration.

In Gothenburg, a working group was established with staff representing:

- The traffic office department
- The service trips department
- The department of purchasing and procurement
- The department of data protection and law
- Traffic engineers

Survey the market

Market research is important to identify the different types of geofencing solutions available in the market, their features and functionalities, the cost, and the vendors offering them. This will help you determine the best solution that fits your needs.

Once the working group is in place, map and analyse the market regarding geofencing. Collect all available information on the market that the contracting entity can obtain and process at the planning stage. This can be done through dialogue with suppliers or by inviting suppliers to do a demonstration.

Determine Your Requirements

Once you have identified the different solutions available, the next step is to determine your requirements. Consider factors such as accuracy, battery life, cost, compatibility with existing systems, and support and maintenance.

Map and analyse risks

Installing third-party equipment in existing vehicles on the market may pose risks. The city needs to ensure that the additional technical solutions regarding geofencing would not affect the insurance or warranty of the vehicles.

Gothenburg's advice to other cities looking to procure and test geofencing solutions

1. Understand how vehicle types and engine specifications influence equipment selection and calibration. Initiate early discussions with suppliers to determine what suits your diverse fleet and aligns with your geofencing goals.
2. Test-drive the different variants offered by suppliers.
3. Ensure each vehicle variant undergoes testing in all zones before full installation to facilitate easy adjustments.
4. Ride along or drive yourself to experience firsthand the user interface and configuration of the vehicles.
5. Maintain direct communication with drivers throughout the process.
6. Ensure that trade union representatives at all levels are well-informed and supportive.
7. If conducting a research project, consider involving equipment contractors in the project application to secure external funding for their participation, reducing dependency on city funds.

User privacy and access to data

The city requires a solution to monitor data such as vehicle speed within geofencing zones without identifying individual drivers. This requirement may impact the implementation process.

Finances

The city needs to evaluate alternatives to geofencing to justify why it should invest in this technology.

Phase 2 – Carry out procurement

This phase involves producing procurement documents, advertising, examining and evaluating received tenders. Subsequently, the city must decide which supplier has won the procurement, and agreements must be signed. Afterwards, the city needs to purchase the geofencing equipment and gain access to the vehicles that require geofencing installation.

Munich's recommended steps in this phase of the procurement process

Develop a Request for Proposal (RFP)

- Create an RFP that clearly outlines your requirements and requests vendors to provide a detailed proposal that aligns with your needs.
- Include information about your business, operations, project scope, expected outcomes, and evaluation criteria in the RFP.

Evaluate proposals

- Review and assess proposals received from vendors based on your defined requirements and evaluation criteria.
- Consider factors such as the vendor's experience, track record, proposal quality, and pricing.

Select a vendor

- Choose a vendor that best meets your needs and offers the most value for your investment based on the evaluation process.

Negotiate the contract

- Once a vendor is selected, negotiate the contract terms to ensure all necessary conditions are included.
- Ensure the contract provides adequate protection for your business and clarifies expectations for both parties.

Phase 3 – Follow up of procurement

Munich's recommended steps in this phase of the procurement process

Implement and test
Once the contract is signed, collaborate with the vendor to implement the geofencing solution and conduct thorough testing to ensure it meets your requirements.

Train employees
Provide training to your employees on how to use the technology and interpret the data. This ensures informed decision-making based on the data and correct usage of the technology.

Monitor and optimise
Regularly monitor the implemented geofencing solution to ensure proper functionality. Make updates or adjustments as necessary to enhance effectiveness and efficiency. Continuous monitoring and optimisation maximize the return on your investment.

Evaluate and follow up on the public procurement – what has the city learned from the pilot about geofencing?

- Are the zones in the right place? Are there other routes to take to avoid the geofence?
- Does the vehicle react promptly when entering the zone, especially in terms of speed control?
- Does the vehicle accurately provide its position within the zone, such as for e-scooter parking?
- Are there variations for private cars, public cars, or other vehicle types based on model year and engine model?
- Are there differences for vehicles from different service providers, such as e-scooters?
- Is the in-vehicle equipment installed and calibrated correctly to ensure accurate geofencing functionality?
- Are there opportunities to upgrade the geofencing system based on lessons learned and feedback?

Procuring for city's vehicle fleets
If geofencing were already installed at the factory, such as part of Advanced Driver Assistance Systems (ADAS), it would simplify public procurement processes. However, geofencing is unlikely to become a standard feature in vehicles across all relevant segments, like special transport, in the near future unless driven by legal requirements or customer demand. For public procurement, it's essential for the city to have multiple manufacturers offering geofencing solutions to choose from. In the coming years, third-party solutions may complement this need.

Third-party solutions, such as retrofitting for speed control, still require significant effort, adjustments, and manual labour for installation and full functionality. Currently, there is no "Plug & Play" solution available for this purpose.

Example from Gothenburg and special transport
In Gothenburg, the city procures special transport services from various operators through public procurement. The vehicles are owned by these operators and are divided into two distinct pools. One pool comprises vehicles painted green, constituting approximately 70% of the fleet (around 260 vehicles). These green vehicles are exclusively reserved for meeting the city's specific transportation needs. The remaining 30% of the fleet consists of ordinary taxis. These taxis are available for use during peak hours when there are insufficient, green-painted vehicles available to meet demand. The image below shows an example of green-painted vehicles that do service trips for the city of Gothenburg.

Image ©: Peter Svensson

INSTALLATIONS

If retrofitting is necessary, it means third-party equipment needs to be installed in existing vehicle fleets. This can be complex, especially If the vehicle fleets consist of many different vehicle brands.

There is also a lack of knowledge about geofencing at car repair shops. This contributes to difficulties related to scaling up the technology as long as geofencing equipment needs to be retrofitted.

TESTING AND PILOTS

Installing geofencing through retrofitting requires fitting third-party equipment into existing vehicle fleets, which can be complex, especially when dealing with fleets comprising various vehicle brands. Additionally, there is a lack of geofencing knowledge among car repair shops, posing challenges to scaling up the technology through retrofits.

Testing and piloting are crucial before scaling up geofencing implementations:

- It is essential to ensure the geofence functions as intended during testing.
- Evaluate whether the impacts align with existing strategies, goals, and objectives.
- Assess the accuracy of vehicle positioning within geofence zones.
- Check for any temporal delays in geofence zone notifications.
- Evaluate usability and user experience, including features like displaying parking zones in e-scooter navigation apps.
- Verify compatibility with older smartphone devices.
- Confirm if the system effectively detects and provides feedback related to geofence zones.

Follow-up studies are crucial to observe and understand outcomes after implementation. Consulting with stakeholders one year later helps assess effectiveness and find areas to improve.

It's important to note that trials and pilots often occur under controlled conditions, and scaling up may introduce more complex issues not encountered during initial testing phases.

TRANSFERABILITY AND UPSCALING

Transferability involves ensuring that a digital system designed for a specific use case or location can be effectively deployed and used in other settings without significant modifications or loss of functionality.

Once a successful pilot has been established, transferability becomes relevant when considering implementation in different contexts. It encompasses adapting to varying geographical settings, operational contexts dictated by different modes of transport, regulatory frameworks, and technical infrastructures.

Upscaling, i.e. expanding the scope, size, and impact of a system that has been initially deployed in a limited, controlled environment, has a more limited scope, and possibly, is always the first way to consider when moving forward with geofencing. Even in this more limited scope, many aspects have to be taken into account to steer successful upscaling. An evaluation is needed of how the following aspects will affect a solution and, if necessary, which measures and steps need to be taken to mitigate and avoid expected challenges and problems:

- Increased geographical coverage
- Increased number of users
- Extended Infrastructure Integration
- Enhanced system complexity
- Improved performance and reliability
- Scalable (digital) architecture
- Broader stakeholder engagement
- Regulatory compliance at scale
- Financial and resource planning
- User education and training

STRUCTURE AND DOCUMENT FINDINGS AND EXPERIENCE

To accelerate real-world experience with geofencing in urban traffic management, it's essential to structure and document findings comprehensively. This includes detailing processes, definitions, rules, stakeholder perspectives, data management practices, impacts, acceptance levels, and enforcement experiences. Making this information accessible can support other cities considering geofencing as a traffic management tool.

4. RECOMMENDATIONS TO OTHER STAKEHOLDERS

Section 3 focuses primarily on local road authorities, transport planning departments, and public mobility/transport providers in cities. The guide consistently stresses the significance of stakeholder engagement and collaboration. Section 4 aims to outline recommendations and advice for other public and private entities involved in implementing and expanding geofencing applications for traffic and transport solutions. This list is not exhaustive but offers examples of how stakeholders can contribute to harnessing the potential benefits of geofencing.

TO OTHER MUNICIPAL/CITY DEPARTMENTS

Municipal and city structures can vary widely. Key responsibilities for this geofencing guideline include city management/executive roles, Information Technology (IT) departments, city planning departments, environmental departments, and others. These entities play crucial roles in implementing and overseeing geofencing applications in urban environments.

To City Management

Develop high-quality programs, strategies, and plans to establish a baseline ensuring that all city departments deliver excellent services. Utilise digitalisation and IT as tools to enhance service quality.

To IT

Digital and data strategies are essential for enabling geofencing services. Ensure active engagement with other departments on specifications, standards, privacy concerns, data collection, management, and spatial data including Geographic Information Systems (GIS).

To City Developers and Planners

Traffic and transport planning significantly influences the development and management of neighbourhoods and urban spaces. Thoughtful integration of digital solutions, such as geofencing applications, can enhance safety in areas with diverse transport modes and road users. It can also optimise land use, allowing spaces to serve multiple functions dynamically (e.g., accommodating deliveries and drop-offs while adapting to idle times).

Engage in testing and exploration of how digital solutions can complement physical planning processes.

To Environmental Management

Geofencing applications can enhance the monitoring and tracking of relevant environmental data within specific geographic areas. As mentioned in the guide, one example is using differentiated road pricing to incentivise environmentally friendly behaviour, such as reduced fees for vehicles using fossil-free fuels. Geofencing can also be employed to manage environmental zones.

Environmental factors like noise and emissions could trigger geofences, notifying road users of high emissions levels or establishing temporary no-go zones in areas with elevated particle and emission levels.

Engage in testing and exploring these solutions to enhance environmental conditions.

Furthermore, continue to enhance the quality of environmental data. Where possible, make this data accessible to others to enable the development of additional services that contribute to improved and healthier environments.

TO REGIONAL AND NATIONAL ROAD AUTHORITIES

The responsibilities of local, regional, and national road authorities vary depending on the country. The recommendations provided in section 3 are relevant for regional and national authorities as well.

Regional and national road authorities often have more resources for testing and innovation compared to smaller municipalities. You can lead by example and inspire other road authorities by sharing your initiatives with them.

You may also have greater resources and mandates to harmonise and make solutions interoperable. For example, national road databases are typically managed by national road authorities. There is significant potential to enhance the quality of road and traffic regulation data by collaborating with local road authorities and developing machine-readable solutions for reporting traffic regulations.

Explore how regional and national strategies for transport and digitalisation can be harmonised and optimally utilised. In some cases, additional digital infrastructure may be necessary to improve service quality. Digital solutions complement the physical infrastructure and offer efficient and cost-effective traffic solutions.

Regional and national road authorities can also allocate budgets to advance and develop digital solutions and services, including those based on geofencing technology.

National road authorities often engage in cross-border collaboration. Explore and test collaborations with neighbouring countries or other international partners. There are numerous funding opportunities available at the European level for such initiatives.

TO OTHER LOCAL, REGIONAL AND NATIONAL AUTHORITIES

To Supervisory Authorities

Authorities such as the Police Authority, the Transport Agency, and the Civil Contingencies Agency play a crucial role in law enforcement and ensuring the security of digital solutions.

Digital solutions can enhance law enforcement efficiency. For example, police speed controls and speed cameras could be complemented by increased use of speed controls in vehicles (ISA).

Engage in testing and exploration of digital solutions, including geofencing applications, to support law enforcement activities.

Collaborate closely with road authorities and other stakeholders to pilot new solutions. Early communication about potential safety and security challenges and strategies for mitigation is essential for conducting demonstrations in real-world environments.

To Emergency Services

Emergency services such as ambulances, police, and fire services are vital components of the transport system. Initiatives like the Emergency Vehicle Approaching (EVA) trial in the Nordic Way project have aimed to improve the accessibility of emergency vehicles on roads.

Dynamic geofences could potentially be established around emergency vehicles and accident sites to inform and alert nearby road users. Geofences can also trigger data collection and automatic information sharing.

Engage in testing and exploration of digital solutions, including geofencing applications, to enhance life-saving efforts and contribute to a safer society.

To Digital Government Agencies

In countries where a digital government agency exists, their role is pivotal in several key areas:

- Supporting the development and integration of digital infrastructure
- Promoting the establishment of common standards and protocols for geofencing
- Encouraging and facilitating the use of open data related to traffic and transport
- Guiding regulatory requirements and help navigate the legal landscape for implementing geofencing applications
- Ensuring that geofencing applications adhere to stringent data security and privacy standards
- Fostering collaboration among various stakeholders, including municipalities, transport operators, technology providers, and public authorities
- Facilitate funding opportunities and resource allocation for geofencing projects

This will and should be done in close collaboration with other stakeholders such as national road authorities.

TO POLITICIANS

You play a vital role locally, regionally, nationally, and at the European level. You can guide and encourage departments to try new digital solutions like geofencing. These innovations should aim to improve citizens' quality of life.

As a politician, you can support investigations into new technologies and propose laws or incentives to promote geofencing and similar advancements.
You also have the opportunity to inform citizens about digital solutions and secure funding for research and pilot projects. Your leadership can lead to safer, more efficient transportation and better urban development.

TO PRIVATE TRANSPORT AND MOBILITY SERVICE PROVIDERS

Transport and mobility service providers, such as bus operators, taxis, and hauliers, are crucial partners alongside public organisations in driving demand for geofencing applications. Here are some benefits they can leverage:

- **Efficient fleet management systems:** Geofencing allows real-time monitoring of vehicle locations, improving route planning, reducing fuel usage, and enhancing overall fleet efficiency.
- **Traffic safety and compliance:** Ensure compliance with local regulations by setting geofences around restricted or hazardous areas. Alerts can be triggered when vehicles enter these zones, helping prevent violations. Geofencing can also manage vehicle speed in sensitive areas like school zones for enhanced safety.
- **Environmental impact:** Geofencing can help manage vehicle emissions in specific zones, promoting the use of electric vehicles and supporting urban sustainability goals.

Transport providers should explore available solutions from vehicle manufacturers and service providers. Use purchasing power to request geofencing applications and consider testing these services.

Maintaining close relationships with unions and drivers is crucial. Involve them in discussions before implementing geofencing solutions and gather their feedback during trials and implementation.

Engage with customers to discuss the potential of digital solutions like geofencing and gather their input.

After implementing geofencing applications, evaluate their impact on operations and traffic safety. The initial cost of geofencing should be offset by savings in areas such as fuel costs and fewer accidents.

Embrace collaboration with stakeholders and learn from previous trials to continuously explore and test new digital solutions.

TO TECHNOLOGY PROVIDERS

As a cornerstone in technology development, introducing geofencing applications and services to the market requires proactive engagement with both public and private service providers, as well as authorities. Here's how you can enhance the geofencing ecosystem:

Knowledge sharing: Interact with stakeholders and provide detailed information about your products and services on your website. Transparency with product/service specifications facilitates market research and informs procurement decisions.

Collaboration on standards: Embrace collaboration on industry standards relevant to geofencing. Establishing common standards enhances interoperability and improves overall system effectiveness.

Enhancing the geofencing ecosystem: Focus on solutions that enhance the quality of the geofencing ecosystem, including:

- Design and creation of geofences.
- Ensuring high-quality geospatial data.
- Effective communication of geofences.
- Tools for stakeholder interaction and data sharing.
- Improvements in vehicle and road user positioning.
- Interaction with drivers and enhancing vehicle services like ADAS (Advanced Driver Assistance Systems).
- Tools for detecting system errors and ensuring quality.
- Feedback mechanisms for cities and follow-up activities.

Engagement and exploration: Collaborate closely with customers to trial and explore geofencing applications. This process aims to refine usability and drive cost efficiency, ensuring solutions meet user needs effectively.

By focusing on these strategies, you can foster innovation, improve operational efficiency, and advance the adoption of geofencing applications in both public and private sectors.

Additionally, here are some aspects that are worth highlighting:

To Hardware Manufacturers

Provide the physical devices needed for geofencing, such as GNSS units, sensors, and communication devices.

- **Ensure compatibility and support standardisation:** Design hardware that can seamlessly integrate with existing vehicle systems and infrastructure, and adhere to industry standards to ensure interoperability with other systems and technologies.
- **Provide comprehensive support:** Offer training and technical support to your customers to ensure smooth installation and operation of the hardware.

To Software Developers

Develop geofencing applications, algorithms, and user interfaces.

- **Focus on user experience:** Design user-friendly interfaces for both operators and end-users.
- **Collaborate with end-users:** Engage with city planners, transport operators, and drivers to gather feedback and continuously improve the software.

To Data Analytics Firms

Analyse data collected from geofencing systems to provide actionable insights for traffic management.

- **Develop analytic tools to aid governance:** Data analysis and being able to provide meaningful insights will be key to enabling governance, and courage for cities to create and follow up on policies.
- **Focus on visualisation:** Design clear and accessible data visualisations to help stakeholders understand complex data.

To Telecommunications Providers

Provide the digital communication infrastructure needed for real-time data transmission between vehicles and geofencing systems.

- **Ensure coverage:** Provide comprehensive network coverage, especially in urban areas where geofencing is implemented.
- **Prioritise low latency:** Develop and maintain low-latency networks to ensure real-time data transmission.
- **Enhance security:** Implement robust security measures to protect against cyber threats and data breaches. For instance, GNSS jamming and spoofing are two types of deliberate interference that can disrupt communication and navigation systems. This issue needs to be addressed by many stakeholders, including telecom providers.

To Consulting and Integration Firms

Provide expertise in implementing and integrating geofencing solutions within existing transport and city infrastructure.

- **Focus on training:** There is a need for training and educating relevant stakeholders on how they can effectively utilise digital solutions such as geofencing.
- **Understand local context:** There is also a need to gain an understanding of the local transport system, regulatory environment, and stakeholder needs.
- **Provide end-to-end solutions:** Offer comprehensive services from initial consultation and planning to implementation and ongoing support.

TO OTHERS

To shippers

Take an interest and explore potential market solutions that can enhance the safety, environmental friendliness, and efficiency of your operations.

Develop close relationships with your hauliers and discuss how you can support them. Consider investing in software and hardware to facilitate accurate and efficient implementation.

Clearly define goals for using geofencing, such as improving delivery times, enhancing security, or optimising routes. Hold hauliers accountable for improving their operations and conduct follow-ups. While digital services like geofencing may incur additional costs initially, they should create long-term value and cost savings.

To Worker Unions

Worker unions play a crucial role in ensuring that technological advancements, such as geofencing, benefit both workers and employers. Show interest in how geofencing can improve working conditions for drivers and other workers, like transport managers.

Organise workshops, seminars, and informational sessions to educate members about geofencing technology, its benefits, and its potential impact on their work. Provide accessible resources such as brochures, articles, and videos that explain geofencing in simple terms.

Ensure employers communicate transparently about how geofencing will be used, what data will be collected, and how it will benefit workers. Advocate for strong privacy safeguards to protect workers' data and ensure it is used only for its intended purposes.

Encourage employers to participate in trials and innovation projects, with a focus on improving user experience.

Promote openness and encourage collaboration and trials of new solutions aimed at addressing societal challenges and improving worker conditions.

To other Special Interest Groups

You may represent cities, road users, etc. Your members play a crucial role in enabling geofencing applications. If you represent road users such as pedestrians, cyclists, the elderly, or mobility-impaired individuals, explore how geofencing can enhance mobility conditions.

Future geofencing applications have significant potential to improve demand management, for example, by prioritising traffic signals for pedestrians and cyclists during adverse weather conditions.

Engage, educate, and communicate project and research outcomes to your members. Reach out to mobility service providers, technology firms, and other stakeholders to foster collaboration and promote trials focused on user needs.

To insurance companies

Insurance companies can play an important role in implementing geofencing. They can investigate, promote, and incentivise digital solutions that enhance traffic safety.

Explore new technologies and assess their potential to improve traffic safety and reduce vehicle damage.

Utilise and share your extensive data resources to provide research insights and inform commercial actors about the impact of geofencing applications.

Educate your customers on how adopting these solutions can enhance traffic safety and improve travel convenience.

To Citizens

As a citizen, you play various roles in the geofencing ecosystem, primarily as a road user. Here are some guidelines to navigate this role effectively:

Openness to innovation: Embrace new geofencing applications while being mindful of privacy policies and deciding what data you are comfortable sharing.

Awareness of technological limitations: Understand the capabilities and limitations of geofencing technology. Be prepared to disable functions that may not work as expected.

Engagement with service providers: Maintain communication with your service provider. Report any suspicious or faulty behaviour of geofencing applications promptly.

Advocacy for digital services: Advocate for digital services that can enhance your daily commute. Engage with service providers to request improvements that benefit road users.

Political advocacy: Pressure politicians to implement cost-effective solutions that improve traffic flow and mobility conditions through geofencing and other technologies.

Self-monitoring and evaluation: Monitor your own experiences with geofencing applications. Evaluate whether there are noticeable improvements in your daily commute or road safety.

By actively participating in the geofencing ecosystem with awareness and engagement, citizens can contribute to safer, more efficient transportation systems.

GEOFENCING TRIALS OVERVIEW

Table 2 presents a simplified overview of geofencing use cases tested in real traffic trials or implemented. These use cases include speed zones, low or zero-emission zones, parking zones, access zones, and scheduling and traffic management. The examples are drawn from the GeoSence project and other related initiatives.

Table 2: Geofence applications tested under real traffic conditions – an overview

Policy type	Geofence application	Vehicle type	Control type
Speed zones	Lower speed around schools	Private cars	• Automatic, voluntary overriding • Information
	Lower speed for special transport	Special transp. vehicles	• Automatic, voluntary overriding
	Speed limits for street segments, or area near a metro station	Rental e-scooters	• Automatic, no overriding
	Lower speed for buses	Public transport buses	• "Agreed lower speed" • Automatic, voluntary overriding
	Lower speeds for trucks and vans	Freight vehicles	• Control not yet applied in practice
	Speed control for heavy vehicles on bridges and vulnerable areas	Heavy/high capacity vehicles	• Develop intelligent access control
Low/zero emission zones	Switch from fossile to electric propulsion	Hybrid cars (diesel/el-battery)	• Information • Including monetary incentive
	Automatic switch from fossile to electric propulsion	Hybrid cars (diesel/el-battery)	• Automatic, voluntary overriding
	Automatic switch from fossile to electric propulsion	Public transport buses	• "Agreed switch to el" • Automatic
	Restricted (no-)access for non-compliant vehicles	Freight vehicles	• Camera and automated number plate recognition
Parking zones	Designated parking zones	Rental e-scooters	• Automatic • Enforced
Access zones	Access based on permits	Heavy/high capacity vehicles	• Develop intelligent access control
	No parking- and no go-zones	Rental e-scooters	• Automatic ban • Enforced • Prevention of drunk driving
Scheduling and traffic management	Tracking of access and arrival times in factory area	Company vehicles	• Automatic • Enforced
	Information to vehicles in port	Heavy vehicles	• Information

READ MORE

PROJECTS

More information, use case descriptions and project deliverables can be found on our project website: **GeoSence (2021-2024)**: https://closer.lindholmen.se/en/geosence

Below is a non-comprehensive list of other innovation projects relevant to geofencing:

- **GeoFlow (2020-2022):** https://www.sintef.no/prosjekter/2022/geoflow/ (Norwegian only); https://www.q-free.com/new-road-user-charging-system-piloted-in-norway-with-q-free-as-technology-provider/ (Norwegian only)
- **GeoSUM (2018-2021):** https://www.sintef.no/prosjekter/2018/geofencing-for-smart-bytransport/ (Norwegian only)
- **HasT – Speed-controlled traffic zone in urban environments (2023-2024):** https://closer.lindholmen.se/en/project/hast-speed-controlled-traffic-zone-urban-environments (Swedish and English)
- **NordicWay 2 and 3 (2017-2024)** https://www.nordicway.net/
- **Smart Urban Traffic Zones (2019-2025):** https://closer.lindholmen.se/en/project/smart-urban-traffic-zones (Swedish and English)
- **Swedish National Programme on Geofencing (2019-2022):** https://closer.lindholmen.se/en/project/geofencing (Swedish and English)
- **Tag4All (2023 – ongoing):** https://www.sintef.no/prosjekter/2023/tag4all-teknologi-for-veiprising/ (Norwegian only)

SCIENTIFIC ARTICLES

Below is a non-comprehensive list of scientific articles relevant to geofencing:

- Arnesen, Petter; Seter, Hanne; Tveit, Ørjan Mørner; Bjerke, Mats Myhrvold (2021): Geofencing to Enable Differentiated Road User Charging. Transportation Research Record. 2021, 10.1177/0361198121995510 (https://doi.org/10.1177/0361198121995510)
- Seter, Hanne; Hansen, Lillian; Arnesen, Petter (2021): Comparing user acceptance of integrated and retrofit driver assistance systems – A real-traffic study. Transportation Research Part F: Traffic Psychology and Behaviour, ISSN 1369-8478, e-ISSN 1873-5517. (https://doi.org/10.1016/j.trf.2021.04.012)
- Dahl, Erlend; Arnesen, Petter; Seter, Hanne (2020): Geofencing for smart urban mobility: Effects from a pilot with retrofit equipment. European Transport Conference past papers repository, ISSN 2313-1853. (https://aetransport.org/past-etc-papers/conference-papers-2020?abstractId=7066&state=b)
- Hansen, L., Graupner, S.T., Andersson, K., Fjällström, A., Leonardi, J. and Al Fahel, R. 2024. Geofencing to accelerate digital transitions in cities: Experiences and findings from the GeoSence project. Transport Research Arena Conference 2024. Dublin 15 - 18 Apr 2024 Springer. (https://westminsterresearch.westminster.ac.uk/item/w840x/geofencing-to-accelerate-digital-transitions-in-cities-experiences-and-findings-from-the-geosence-project)
- Lindkvist, H., Lind, F. and Melander, L. (2023), "Actor roles and public–private interaction in transitioning

networks: the case of geofencing for urban freight transport in Sweden", Journal of Business & Industrial Marketing, Vol. 38 No. 6, pp. 1376-1389. https://doi.org/10.1108/JBIM-10-2021-0494

- Salmi, AK., Hökars F. (2023) Smart urban traffic zones–demonstration of three smart zones in Sweden based on geofencing and sensor data. Transportation Research Procedia – 2023 Volume (https://www.sciencedirect.com/science/article/pii/S2352146523009092)

REPORTS AND OTHER PUBLICATIONS

Below is a non-comprehensive list of reports and other publications relevant to geofencing:

- Arnesen, P., Seter, H., Foss, T., Dahl, E., Lillestøl, P. J., & Jenssen, G. (2020). Geofencing for smart urban mobility. Summarizing the main findings of work package 2: Pilot Design and work package 3: Piloting. (https://sintef.brage.unit.no/sintef-xmlui/bitstream/handle/11250/2643877/2020-00100_Geofencing%2bfor%2bsmart%2burban%2bmobility.pdf?sequence=2&isAllowed=y

- CLOSER 2022. Report on market analysis – geofencing-based services in road transport. (https://closer.lindholmen.se/sites/default/files/2021-11/report_on_market_analysis_-_geofencing-based_services_in_road_transport_.pdf

- CLOSER 2022: Assessment of stakeholder needs regarding geofencing in the transport system. (https://closer.lindholmen.se/sites/default/files/2022-05/assessment-of-stakeholder-needs-regarding-geofencing-in-the-transport-system.pdf

- Foss, T., Seter. H., Arnesen. P. (2018). Geofencing for smart urban mobility. Summarizing the main findings of work package 1. (https://sintef.brage.unit.no/sintef-xmlui/bitstream/handle/11250/2585379/2019-00123_Geofencing+for+smart+urban+mobility.pdf?sequence=2)

- Hansen, L.; Arnesen, P. et al. 2021. Current state of the art and use case description on geofencing for traffic management. GeoSence WP1 Deliverable D1.1 (https://www.researchgate.net/publication/355681063_Current_state_of_the_art_and_use_case_description_on_geofencing_for_traffic_management)

- Hansen, L., Graupner, S. T., Leonardi, J., & Lindkvist, H. (2022). Challenges and needs of European cities in using geofencing for urban traffic management.
- (https://closer.lindholmen.se/sites/default/files/2022-10/geosence_2022.pdf)

- Kløvning, Olve Nes (2023) User acceptance of geofencing and ITS for urban traffic management of automobiles: a socio-technical perspective. Master thesis, NTNU. (https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3097346/no.ntnu%3ainspera%3a146714540%3a97386055.pdf?sequence=1&isAllowed=y)

- Svensson, N., Genell, A., Gustafsson, M., Olstam, J., Gebrehiwot, R., Bhattacharyya, K., & Sjöblom, J. (2024). Effects of Geofencing on Exhaust Emissions and Noise : A combined Test Track and Traffic Simulation Study. Proceedings of the 25th International Transport & Air Pollution (TAP) and the 3rd Shipping & Environment (S&E) Conference, 51–56. https://doi.org/10.2760/564701