Comprehensive action plan: Joint mobilization on digitalization for secure and smart urban environments

GOVERNMENT ASSIGNMENT – TEST AND DEMONSTRATION PROJECT USING GEOFENCING IN URBAN ENVIRONMENTS

Foreword

This action plan details the efforts and activities that need to be initiated and developed if geofencing will be implemented on a larger scale in our cities. The action plan highlights the steps from demonstration and pilot phase to actual implementation and scalability.

The action plan is a result of the government assignment "Test and demonstration project using geofencing in urban environments" [Test- och demoprojekt med geostaket i urbana miljöer] that was sealed with a handshake between Volvo Cars, AB Volvo, Scania, the City of Stockholm, the City of Gothenburg and the Swedish Transport Administration in the spring of 2017. Veoneer is also included in the project, as it is a key partner in this project. CLOSER has served as a neutral project manager for the assignment.

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Summary

Following the terrorist attack on Drottninggatan in 2017, the Swedish Transport Administration was tasked by the Government to test geofencing in demonstration projects in urban environments. This work was carried out in close collaboration with the automotive industry as well as the City of Stockholm and the City of Gothenburg. The assignment resulted in a demonstration of a concept for geofencing and in this comprehensive action plan, which will enable the implementation of the geofencing digital tool on a larger scale.

Geofencing is a collective name that includes the application of technical solutions in combination with suitable digital and organizational processes, and procedures to obstruct or control vehicles in specific geographical areas. Geofencing is considered to be an important instrument for creating a secure road transport system for vulnerable road users in today's complex traffic environments. It is also considered important if we are to meet both current and future demand for secure, fossil-independent and quieter transportation.

Geofencing enables a number of different functions. This was demonstrated in Stockholm in May 2018. The demonstration included functions to enforce a safe maximum speed limit, powertrain control and access to a specific area for connected vehicles, in a densely populated zone in Stockholm. The aim of the demonstration was to visualize the potential of geofencing to create a road transport system where vulnerable road users and vehicles can coexist in complex environments with a high level of safety and security.

Today, two key conditions are lacking for the large-scale introduction of geofencing in our cities – functioning digital infrastructure and enforceable regulations. This is why the project has drawn up an action plan, together with the business community and authorities, comprising a list of seven points intended to pave the way for the implementation of the geofencing concept.

The seven points in the action plan are founded on the challenge arising from the local preconditions for achieving the desired societal impact, particularly in terms of security and the environment in cities, and at the same time facilitate for national and international interoperability. The most important requirement for implementing the entire action plan is therefore the creation of a collaboration platform with a clear innovation agenda. The action plan focuses on both implementing pilot studies based on existing conditions, and also initiating a review of legal circumstances and the necessary digital interfaces.

The seven points in the action plan are:

1. Set up a research and innovation (R&I) program with targeted research and innovation projects to prepare the required documentation for work with all points of the action plan.
2. Encourage legislation and regulations that support the implementation of geofencing.
3. Develop organizational and digital processes as well as data for geofencing zones.
4. Develop systems, procedures and processes for self-regulating systems and control in smart zones.
5. Investigate the socioeconomic and business potential.
6. Encourage national and international harmonization.

7. Support and pursue demonstration and pilot projects.

1 Background

On May 18, 2017, Scania AB, AB Volvo, Volvo Personvagnar AB, the City of Stockholm, the City of Gothenburg, the Swedish Transport Administration and the Swedish government shook hands to jointly coordinate how the opportunities offered by digitalization can be harnessed in the field of transportation. At an early stage, Veoneer was seen as a key partner and was therefore included in the group. CLOSER was engaged as a neutral project manager for the assignment.

The hand shake was formalized in a government assignment to the Swedish Transport Administration to test geofencing in a demonstration project in an urban environment, and to develop relevant research and innovation programs that incorporate geofencing. The government assignment was given in connection with the terrorist attack on Drottninggatan in Stockholm in 2017.

A first step was to conduct geofencing demonstrations in 2018. The parties also assented to follow up the hand shake with a comprehensive action plan to enable the implementation of geofencing. The main purpose of the measures and R&I activities proposed in the plan is initially to develop geofencing systems that enable driver assistance that facilitates regulatory compliance primarily with regard to speed, urban environments (air and noise) and access to designated zones.

Geofencing – digital control of connected vehicles

Geofencing entails the creation of geographical areas on a digital map and assign rules for vehicle properties in the area. For example, it is possible to designate that only authorized vehicles may be driven in the area, to guarantee that speeds are limited or to modify the vehicle’s powertrain in a manner to ensure that it is only possible to drive the vehicle using electric power within the zone. However, this requires the vehicle to be connected. It also requires agreement between the authorities and automotive industry concerning regulations on limitations and opportunities in the geographical area, and the communication of applicable regulations.

Geofencing is considered one of many effective measures to create a safer and more sustainable urban environment. It also has the potential to impede terrorist attacks using road vehicles. However, several complementary measures are required in addition to geofencing to prevent terrorist attacks using vehicles, as detailed in Figure 1. Transport Analysis has a parallel government assignment concerning terrorism prevention measures[1]. Geofencing is seen as an important complement in this context.

[1] *Measures to reduce risk of vehicular terrorist attacks*, Transport Analysis. Report 2018:5

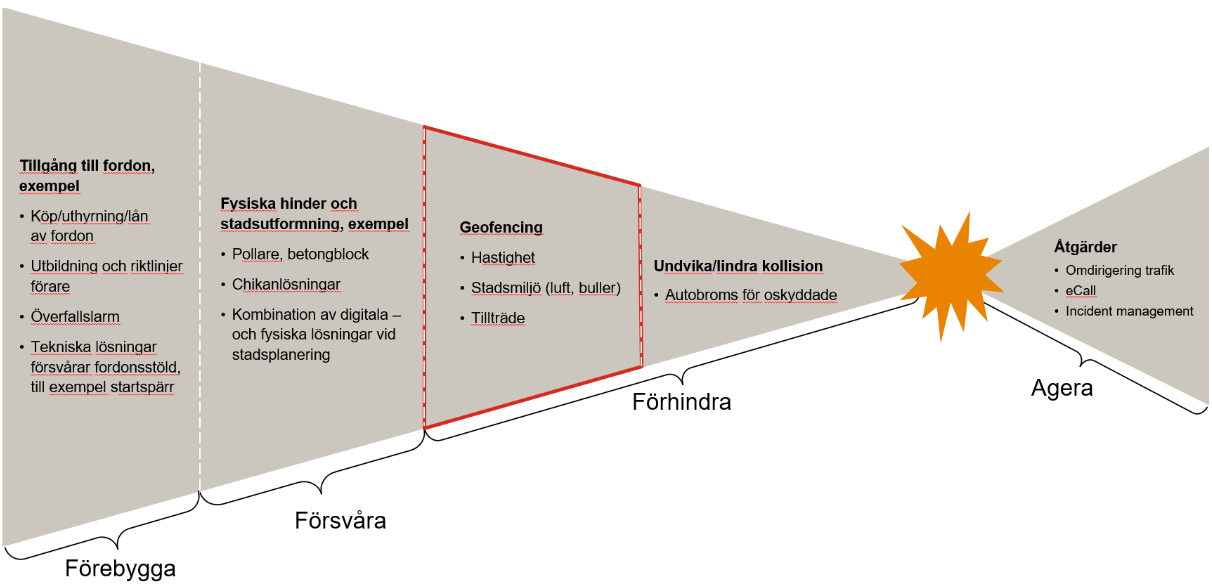

Figure 1 Measures to reduce risk of vehicular terrorist attacks, with geofencing as part of a preventive sequence of events.

Geofencing technology is already used to a limited extent today. For example, it is used on bus routes 16 and 55 in Gothenburg, where the vehicle's speed is automatically reduced on certain sections of the route. These tests are being conducted as part of the ElectriCity project. Similarly, the technology was tested in the Off-Peak project in Stockholm, when distribution trucks automatically switch to electric drive in emission-sensitive areas. In both cases, the parameters are programmed in the vehicles by the automotive manufacturers.

A system perspective is required if connected vehicles instead are to receive signals directly from the road manager, which stipulates the local conditions, and the building blocks available at the location must be linked together. Processes that are conditional upon digital and organizational systems and that enable the establishment of geofencing do not exist at present, and these need to be created to achieve the desired effect. The technology is also at present immature, for example, there is a sensitivity to external factors and disruptions, which affects the reliability of the technology.

Additional research and development is required to create a robust system that meets the challenges above. Accordingly, it is concluded that action is needed to strive toward a complete system that respond to and enables the implementation of geofencing in large, designated city zones. This development can also be seen as an important stage in preparing cities for autonomous transportation. Furthermore, the initiative is an important piece of the puzzle in work toward Vision Zero in cities.

1.1 Focus of the action plan

The starting point for the action plan was to coordinate studies, developments and the implementation of innovative solutions using opportunities offered by digitalization, to contribute towards secure, smart and sustainable urban environments. It is about linking existing technology in the vehicle's digital system with the road manager's handling of geodata at a system level. A system for this information exchange must be designed and built. Digitalized and, where possible, automated processes are required and supporting policies in transport planning, traffic management, vehicle operators, vehicle systems and eventually blue light emergency services. Specifications are also needed for the design of and responsibility for the infrastructure that stores and transfers appropriate data. This includes regulations for standardized and secure interfaces detailing the content, frequency and format of the data to be exchanged. As far as possible, the harmonization should be achieved through international initiatives and projects.

The challenge is to act from the local conditions to achieve the desired societal impact in terms of security and the environment and at the same time facilitate for national and international system solutions. The large-scale implementation of geofencing is a complex process with a large number of relevant stakeholders, and this must be pursued from several directions to maintain momentum. The action plan therefore focuses on implementing pilot studies based on existing conditions and also initiating a review of legal circumstances and the digital interfaces required for efficient communication between vehicles, infrastructure and road managers. If road managers are to implement a system to control vehicles using geofencing, changes are required to regulations at a central level. There is also every reason to begin testing geofencing on a more voluntary basis before regulations are in place. Conditions and incentives must be created to allow operators to secure their transportation, if they so wish, by offering support to initiate this work, for example by providing access to digital map data and available technology.

1.2 Guiding objectives, relevant roadmaps and guideline documents

The development of geofencing is dependent on a number of national and international objectives, for example:

- Agenda 2030, particularly the goal for Sustainable cities and communities
- transport policy objectives
- Vision Zero.

It is equally affected by national and international roadmaps, initiatives, studies and guidelines documents, such as:

- The path to automated driving – market introduction
- Measures to reduce risk of vehicular terrorist attacks – report by Transport Analysis.
- Efficient, high-capacity and sustainable freight transport – a national freight transport strategy
- Environmental zones for light-duty vehicles
- System of Systems for Smart Urban Mobility
- FFI – Efficient and Connected Transport Systems
- C-ITS platform Phase II final report 2017

- On the road to automated mobility: an EU strategy for mobility of the future (May 17, 2018)

The above are only examples of initiatives from transport policy to strategies and tactical plans to create more secure environments and improved quality of life in densely populated areas.

1.3 Objective

The objective for the government assignment has been to encourage the implementation of one or more demonstration projects with geofencing. The project also aims to contribute toward a secure road transport system for vulnerable road users in today's complex traffic environments as demand increases for fossil-independent and quieter transportation.

Collaboration between authorities and industry is currently preparing for innovative implementation solutions to transform cities as a platform for new, digital vehicle technology. Cities must provide quality of life that means vehicle movement is on the terms of vulnerable road users, while retaining service and transport quality.

Project partners jointly defined vision for 2030 is to use a combination of technology, digital infrastructure and smart design of urban environments to promote sustainable, safe and secure densely populated environments. The first steps have been taken with this government assignment, but joint mobilization is required. In 2019, the partners wish to create a collaboration platform concerning geofencing with an associated agenda for innovation. More specifically, the following goals are proposed for the next phase, between 2019 and 2022:

- Establish basic procedures and processes to enable cities to implement local geofencing.
- Create incentives for connected vehicles and infrastructure.
- Establish national digital infrastructure, harmonized with European standards, that makes geofencing possible.
- Conduct geofencing pilot studies in designated zones.

1.4 Fields of application

The action plan's approach is comprehensive and far-reaching: to utilize the opportunities offered by digitalization to create safe and secure cities. This is why the project partners have chosen to prioritize three practical applications of the technology:

- speed
- urban environment
- access.

1.4.1 Speed

At present, the methods used to reduce vehicle speed are traditional physical barriers, such as chicanes and road humps. Geofencing and digital solutions can complement and, in the long term, even replace physical barriers by digitally checking that vehicles comply with rules and by controlling speeds in designated zones. This could involve, for example, driver assistance (meaning a reminder of the applicable speed in the current zone), automatic compliance controls of speed and dynamic speed control based on the prevailing traffic situation.

1.4.2 Urban environment (air and noise)

To improve air quality in certain areas, municipalities can decide to exclude some heavy vehicles (trucks and buses) from city centers and other environmentally sensitive areas, by using environmental zones. Geofencing can act as an enabler in this respect.

Geofencing could shift vehicles from combustion engines to electric powertrains and be utilized for automated compliance with local traffic rules (such as rules for environmental zones, noise, studded tires, length and weight limitations). Geofencing could be a method to create quiet zones near residential areas, recreation areas or hospitals. It is also interesting to use geofencing in work with incentives where connected vehicles through conditional guidelines have the opportunity to conduct off-peak transportation and thereby better utilize the system with more traffic at night. Another example would be to review requirements that vehicles must have systems that enable compliance with prevailing traffic rules by using geofencing, when conducting procurements

1.4.3 Access

Today, vehicles are restricted from driving in certain city areas, depending, for example, on the vehicles length and weight and the time of day, through the use of local traffic rules and physical barriers. Digital solutions may ultimately be utilized to regulate access to targeted zones or some parts of infrastructure based on set requirements.

One initial step could be to control one-way streets as a zero zone, meaning setting the speed limit to almost zero. Work with incentives for access to targeted zones is another interesting field, for example, for carriers that connect their vehicles and that can thereby demonstrate compliance with set conditions for the zone (such as speed compliance and zero emissions).

Figure 2 links the fields of application (vertical) with identified conditions that must be in place (horizontal) if geofencing is to be implemented. This forms the basis for activities in the R&I program as proposed by the assignment, presented in Chapter 2.

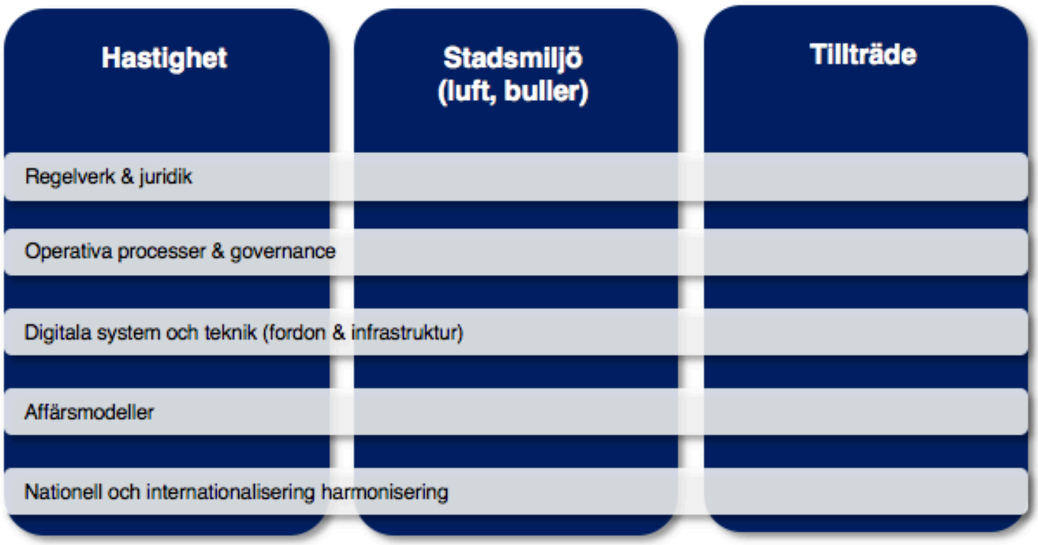

Figure 2 Fields of application (vertical) and enablers or conditions (horizontal).

2 Comprehensive action plan 2019–2022

In the activities described in this action plan, the implementation of geofencing remains dependent on political decisions at national and municipal level together with a broader representation of the business sector (such as carriers and the automotive industry).

Given the above, and the collaboration conducted within the scope of the assignment, the following seven points are proposed during an initial phase (2019–2022) to achieve the goals.

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5. Investigate the socioeconomic and business potential.
6. Encourage national and international harmonization.
7. Support and pursue demonstration and pilot projects.

2.1 Establish an R&I program

To enable the large-scale implementation of geofencing, continuing collaboration is proposed with the R&I program as base. The structure of the program is proposed to include work package where strategic concepts for necessary technologies, processes, regulations, transactions etc. are created, validated and verified. See Figure 3 below.

Figure 3 Proposed structure for R&I program for geofencing.

A R&I program provides a comprehensive approach. This makes it possible to drive developments forward with a system perspective and successively toward the strategic objectives. Concept development is proposed to be conducted gradually according to a technology and system ability perspective all the way from idea and concept generation (T/SRL 2[2]), to concept validation (T/SRL 5), verification of concept in a real-world environment (T/SRL 8) and finally implementation (T/SRL 9) (see Figure 4).

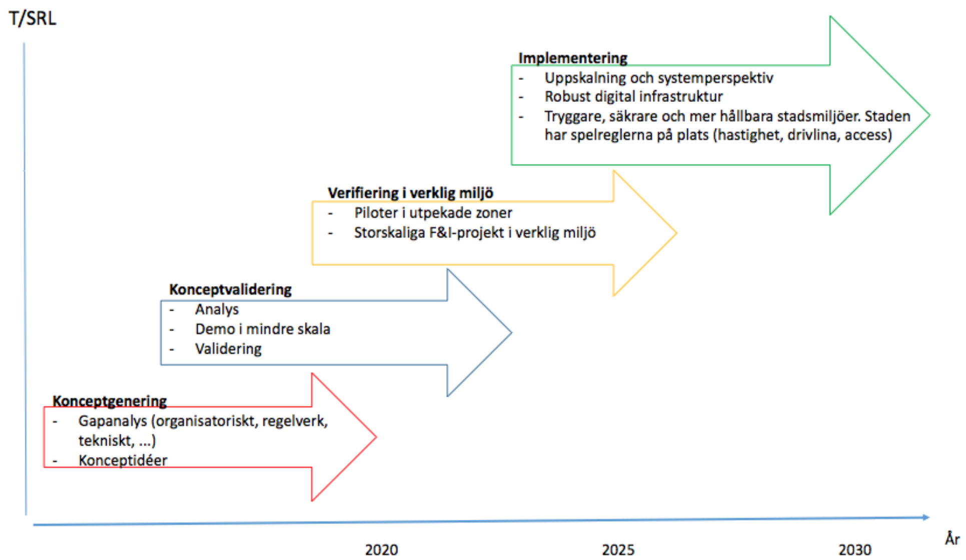

Figure 4 Gradual process for research and innovation concerning relevant concepts.

[2] Technology Readiness Level (TRL) is a designation for the degree of maturity of a technology where low TRL (1-2) entails concept generation and basic research and higher TRL levels are striving toward testing and demonstration and onward to full-scale implementation in daily operations (TRL 9). The implementation of geofencing requires a functioning digital system that includes organizational processes and functions, which is why the System Readiness Level (SRL), meaning development, testing and implementation of these systems, is also mentioned here.

2.2 Work with legislation and regulations

Prevailing regulations at both national and international levels must be reviewed if geofencing is to be implemented on a large scale. This is necessary to ensure a safe coexistence between vulnerable road users and all types of vehicles. Any discussions about regulatory change will mainly focus on three areas. These three areas together create the necessary conditions to implement geofencing:

- the right to make special demands on vehicles
- the right to make demands on vehicle driving
- the type of functional demands that can be made on vehicles.

Work must also begin to interpret and define prevailing traffic rules, primarily the traffic rules that currently lack a distinct policy definition. This includes speed limitations in pedestrian zones or on stretches of road with a recommended speed. To guarantee the quality of traffic rules and data quality, an examination is needed into the possibility to legislate the quality assurance of prevailing traffic rules so these are correct in space and time.

A study should also be conducted to identify who is responsible for specified zones, and how the process should take place when deciding policies for the specified zones. It must be established which authority or road manager has the authorization to introduce static or temporary traffic rules in a zone to meet requirements for a swift decision-making process and to enable self-regulating solutions. Well-grounded documentation must be created to accomplish these tasks. It must also be considered whether international cooperation is possible in these efforts – not least as the international regulations in the field must be considered and may need revising.

The first step toward implementation is to work with incentives, for example by including geofencing in the public procurement of transportation to help carriers comply with prevailing traffic rules. An investigation is needed into how geofencing can be included within the framework of public procurement and the follow-up processes of these procurements, and the potential to make special demands on vehicles and how they are driven.

2.3 Organizational and digitalized processes as well as data for geofencing zones

If zones with geofencing are to work properly, well-developed processes, effective procedures and suitable technology are important. These provide key components in a system for collaboration between relevant stakeholders.

Geofencing can be designed and applied with differing degrees of complexity. The most basic form of geofencing can be described as static traffic rules in a certain zone, which can be communicated to vehicles driving there. Such static traffic rules may be, for example, speed, mandatory actions, bans, etc.

A more advanced form of geofencing is known as dynamic geofencing. This means the vehicle receives prevailing traffic rules within a zone down to the minute level, and the zone's size and traffic rules are changed depending on the current traffic situation. Zones are decided using regulations that define the conditions for when a zone should be established and the traffic rules that should then come into effect. The zone may, for example, be influenced by information about an ongoing event, critical traffic situation, high levels of particles, roadworks, temporary road closures, temporary speed limit restrictions, etc. and where the information is used for active traffic control by communicating with vehicles in the zone.

The aim is to set up well-developed concepts and harmonized processes for geofencing in dynamic zones that will be available for implementation not later than 2022. To achieve this, responsible organizations must be identified or established that can ensure that information enabling the creation of both static and dynamic geofencing zones is made available digitally and is quality assured. These organizations must establish organizational and digital processes and procedures for data management to attain the desired level of accessibility. Dynamic geofenced zones require organizations that can operate around the clock.

Another precondition for establishing geofenced zones is access to supporting digital infrastructure, with the development of the following digitalized process stages:

- Establish a digital platform for voluntary affiliation with a geofenced zone.
- Decision to establish geofenced zones – procedures for the decision-making process need to be devised and may differ between different road managers and cities.
- Describe zones and applicable traffic rules for both static and dynamic geofencing.
- Collect data in real time, with the aim of obtaining decision guidance documentation for whether the conditions are met to establish a zone (exclusively for dynamic zones).
- Transfer the zone’s traffic rules to the vehicles.
    - for static zones, publication, meaning making data available for digital download, would be possible today using the National Road Database (NVDB), which is affiliated with the Swedish traffic regulation register (STFS). One requirement is that the process does not entail major delays in transferring approved zones but that this can take place automatically.
    - no digital infrastructure exists currently for dynamic zones that meets requirements, but within a few years a Swedish “traffic cloud” could be one solution.
    - all types of zones and traffic rules reach the vehicle via the vehicle supplier’s or vehicle fleet’s digital system.
- Implement zones and traffic rules in vehicles.
- Recover data from vehicles and infrastructure to assess and quality assure the effects of established zones and traffic rules and conditions set for the establishment. This enables continuous optimization of the geofenced zones.

Figure 5, below, shows a proposal for digital infrastructure that may facilitate static and dynamic geofencing. Data from many different sources (fixed sensors, open data, commercial suppliers) make it possible to obtain a snapshot of traffic and the environment. The conditions for when a geofenced zone may be created are then compared with the snapshot. When the conditions for creating a zone are fulfilled, the zone and associated traffic rules come into force. These are then sent to vehicles in accordance with the dataflow in the diagram.

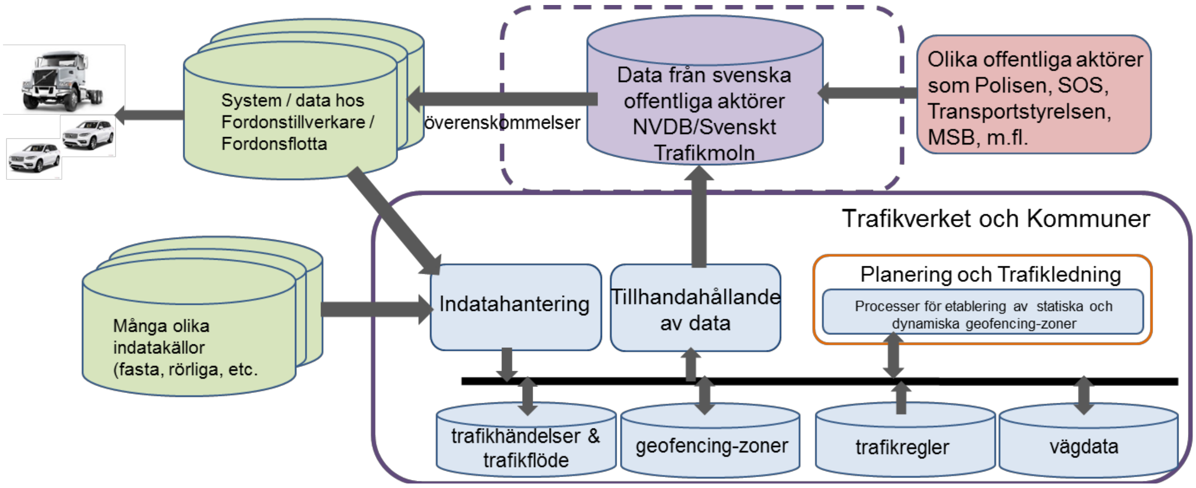

Figure 5 Digital system that enables static and dynamic geofencing.

2.4 Self-regulating systems and control in smart zones

Through the use of connected infrastructure and connected vehicles, the possibility is opened up for a future implementation of smart zones that allow feedback and traffic control, and that enable self-regulating systems with the vehicles involved. Digital connectivity to enable feedback concerning infringements would encourage drivers to comply with applicable regulations and transport operators and consignees to monitor and control their own operations. Any infringements can periodically be reported to the supervisory authorities. In the long term, regulatory compliance and access can automatically be digitally controlled.

To enable self-regulating systems and control in smart cities, processes and procedures for compliance controls and feedback to the responsible authority or transport purchaser must be developed in the years ahead. In addition, a study is required concerning which party should receive feedback concerning infringements, which data is relevant and what form the digital and organizational processes should take and how these should be developed. In parallel, solutions must be developed and integrated to complement the digital system for self-regulating zones, for example physical solutions such as bollards and road humps. One interesting possibility for further work is granting connected vehicles access to parts of the city’s road network when they prove that they follow the regulations.

2.5 Socioeconomic and business potential

One part of the government assignment was an initial analysis of the impact of geofencing on speed and emissions in major cities. The analysis was based on assessment models for a decrease in average speed. A separate report of the results of the analysis will be published at year-end 2018, but a short summary is presented as part of this action plan.

More extensive analysis will be needed in the future of systemic impact, socioeconomic potential and the use of more advanced methods. For example, the impact of a reduction in average speed is a simplification. Geofencing prevents vehicles from exceeding the speed limit that impacts speed distribution, but driving patterns are, presumably, also changed – which is not visible in this analysis. It is difficult to predict how motorists would adapt their driving patterns if speeding became impossible. This requires an analysis of real studies. The effect is illustrated in Figure 6 below, based on the assumption that the restricted vehicles will maintain a speed just under the speed limit.

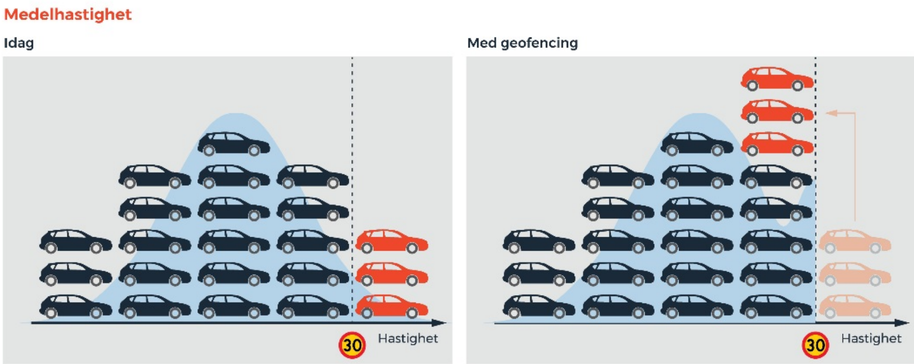

Figure 6 Illustration of the effect based on the assumption that the restricted vehicles will maintain a speed just under the speed limit.

The analysis estimated the impact on average speed from the use of geofencing based on speed measurements on streets in a number of major city centers. On streets with a speed limit of 40 km/h, the average speed would decrease by 2–3 km/h. Speeding is more prevalent on streets with 30 km/h, and the effect would therefore be greater, at about 4–5 km/h. It is unusual to speed on 50 km/h streets in city centers due to congestion, and the impact on average speed would therefore not be affected significantly.

Speed varies between vehicle types, but also varies along streets for each individual vehicle. This variation can be described as a *driving pattern*. Driving patterns describe speed variations, acceleration and braking. The driving pattern for vehicles that previously exceeded speed limits will be affected by geofencing (see Figure 7).

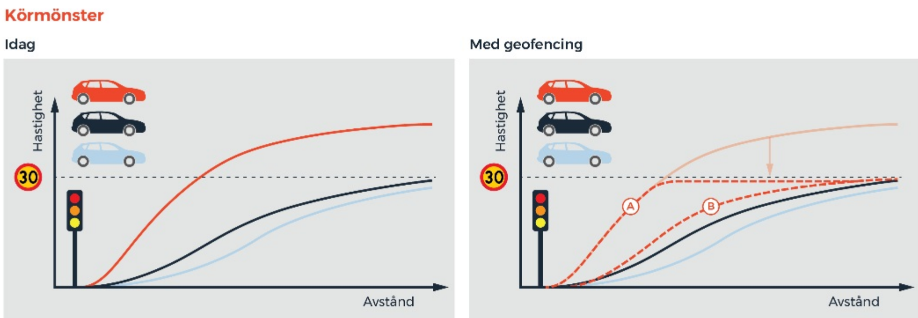

Figure 7 Driving patterns with geofencing for vehicles that previously exceeded the speed limit.

It is difficult to predict in detail how motorists would adapt their driving patterns if speeding became impossible. If we assume that only speeds exceeding the speed limit are impacted, then we obtain a driving pattern following line A (in the figure to the right above). However, in reality speeding motorists are also expected to adapt their speeds on other stretches of road (for example following line B).

Anticipated effects

- Geofencing would only influence the fastest cars through speed compliance. On most city center streets, the majority of vehicles would therefore remain unaffected.
- The average speed on inner city streets is expected to be reduced by a few km/h through the use of geofencing. The greatest reduction will be noted on streets with low speed limits.
- Given that the reduction in the fastest speeds is expected to have a particularly marked effect (see subsequent section), the net effect may be greater than those achieved by the equivalent general changes to speed limits.
- Driving patterns are also impacted if geofencing is used to ensure speed compliance – the restrictions on the fastest speeds will likely also result in fewer accelerations and less braking.

The project has calculated the impact of geofencing in Sweden's ten largest cities, in city center areas. The estimate is based on accident data from all cities and speed measurements from several inner-city streets in five of the cities. The calculation of the effect on road safety used the Power Model.

Many accidents occur in inner city areas, despite the generally low speeds. This is due to the larger exposure when many road users must share a small area. One study focused on accidents that occur in the central areas of Sweden's ten largest cities. According to STRADA,[3] more than 150 people are moderately or seriously injured every year in these environments in relevant accidents[4]. Just under five people are killed per year in similar types of accidents. The estimates indicate that geofencing in these environments could reduce the number of moderately or seriously injured people by about 16 every year, and the number of fatalities by 2 over three years.

It is currently difficult to determine the effect geofencing may have on air quality. Lower average speeds generally mean high emission factors but the link between speed and emissions is more complex than this. Restricting speed through the use of geofencing would probably entail a more even driving pattern with less braking and fewer accelerations, which would produce lower emissions and thereby better air quality. A more exact answer cannot be provided without further studies of the impact of geofencing on driving patterns. However, the greatest potential with geofencing is to gradually create fossil-free zones.

In addition to the need for more advanced and detailed analyses to assess the effect of geofencing from a broader perspective, incentives or demands are also needed for the implementation of geofenced functionality. A commercial potential must be created for relevant stakeholders to develop, provide and utilize the geofencing system on a commercial basis, for example as incentives including exemptions for night deliveries or access to certain zones. Additional benefits highlighted include the opportunity to demonstrate regulatory compliance and transport quality to customers and public-sector stakeholders, for example through safe speeds, zero-emissions and quiet transportation.

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[3] STRADA: Swedish Traffic Accident Data Acquisition

[4] The analysis was restricted to accidents that involved motor vehicles: S (single–motor vehicle), O (over-taking–motor vehicle), U (rear-end collision–motor vehicle), A (turning motor vehicle), K (crossing–motor vehicle), M (head-on–motor vehicle), C (cycle/moped–motor vehicle), F (pedestrian–motor vehicle)

2.6 National and international harmonization

To achieve large-scale implementation at both national and international levels, future work must encourage national harmonization and international interconnection. The interface to exchange data and message types must then be harmonized. Work is already underway to a certain degree to develop and test this within the scope of the EU's NordicWay 2 project, linked to C-Roads.

The technology needs to be scalable and widely implemented to maximize its benefits. The idea is therefore to include more road managers and authorities in Sweden to harmonize legal issues, digital technology and processes for geofencing. The aim is also to include more users. Broad support is an advantage, as is the use of similar digital processes and tools in order to take full advantage of opportunities for rationalization.

The method for making available and receiving different types of data must also be solved effectively, for example through the use of the digital system presented in section 2.3. A number of European forums exist today that discuss some of these issues, such as the Smart Cities Communities. Active stakeholders in Sweden have an opportunity to take the lead here in terms of strategic issues and to steer work toward common goals.

2.7 Demonstration and pilot projects

Development and innovation projects contribute to continuous knowledge and system development, which is often crucial when implementing new services and innovations. Future work should therefore stimulate demonstration and pilot projects of geofencing to test and verify the functionality and efficacy of geofencing. The R&I program proposed in section 2.1 is designed to hold together work and ensure communication between ongoing and new initiatives and to pursue development efforts.

The R&I program has been structured using the TRL method, see Figure 4, which describes the **concept generation**, **concept validation**, **verification** and **implementation** stages for the functions and processes to be introduced. Each function and process is needed in developing concepts that may lead to the implementation of the system elements, standardized architectures, types and format of data exchanged and included interfaces. In addition, proposals must be drawn up for stakeholder responsibility and processes for the collection, generation, storage and provision of data.

One key focus for the program is to drive developments in areas with serious and identifiable challenges, that lead to the creation of processes and technology for establishing new functions in **static**, **dynamic** and **smart zones** (see Chapters 2.3 and 2.4). Figure 8 below illustrates the stages from idea and concept generation to implementation. The figure shows that static, dynamic and self-regulating zones are at different stages of technical maturity. This means more progress has been made in geofencing to enable static regulatory compliance, and large-scale pilot projects with a number of vehicles could be initiated as a first program phase. Dynamic and self-regulating zones is a more distant prospect, both for technology and issues related to organization, legality and control. The initial projects here are rather at a concept and analysis phase.

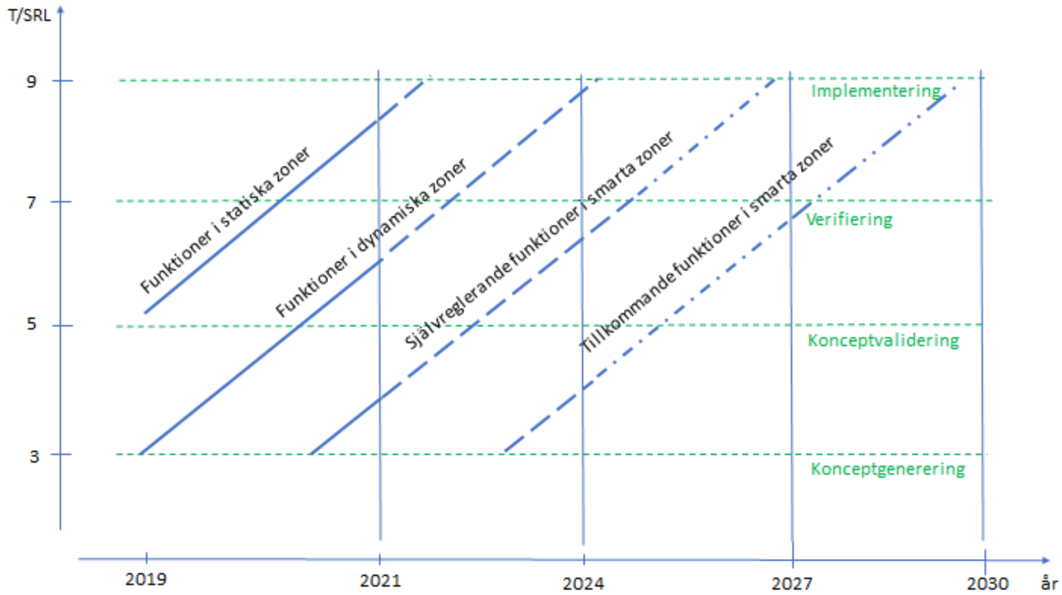

Figure 8 Stages from idea and concept generation to implementation, where, for example, static, dynamic and self-regulating zones are at varying phases, as they are at different stages of technical maturity.

Initial demonstration and pilot projects could include:

- Demonstration projects and pilots to develop effective processes to establish, store and distribute quality-assured static geofenced zones and utilize these for the desired function, for example speed compliance. Responsible road managers (municipalities and the Swedish Transport Administration), transport operators, map suppliers and the automotive industry are involved in this work.
- Develop and validate the process concept to set up dynamic zones for various fields of application. The police and road manager authorities are examples of stakeholders that make decisions, which the operational traffic management then communicates. The transfer to vehicles must use internationally agreed procedures, which could utilize a Swedish transport cloud and the digital systems from vehicle suppliers and vehicle fleets.
- Design concepts for feedback by using data that can be captured via vehicles and infrastructure. This enables feedback to the system, so the regulations communicated reflect the quality-assured needs of the current situation and has the desired effect. The international link is an important component to take full advantage of the opportunities for R&I collaboration and to harmonize the supporting documentation for standardization.