Automated Transport Systems – a Strategic Research and Innovation Agenda

Summary

We define an automated transport system as a system where the driver of the vehicle is partially or fully replaced by an advanced system consisting of computers, sensors, communication devices etc. in the infrastructure as well as in the vehicles. Transport automation is in a formative stage and there is a very high potential for proactive nations to reach and benefit from a leading position. We develop this agenda envisioning that Sweden is positioned and recognised as a leader in automated transport systems.

Transport automation contributes to the transport policy goals as well as the fulfilment of visions such as “Den goda staden”, “Det goda livet” and “Liveable Cities” for the city environment, Vision Zero for traffic safety and zero dependency on fossil fuels for the environment. The main goals of this agenda for 2025 are an integrated innovation system including all key actors and competencies needed for a successful development of products, processes and services for an automated transport system, a high degree of action, and a central role in European R&D programmes as well as policy groups setting the standards for the automated transport system.

Our agenda forwards an approach linking four transport automation levels (individual, city, transport system, and technology and products) and four priority areas (virtual and applied development approaches, harmonisation and standardisation, legislation and business models, and impact of transport automation). The proposed innovation programme coordinates or even integrates existing and future initiatives thus creating a strategic approach leveraging the investments in transport automation.

What is an automated transport system?

In this agenda, we define an automated transport system as a system where the driver of the vehicle (airplane, train, ship, bus, car or wheel-loader, to mention a few examples) is partially or fully replaced by an advanced system consisting of computers, sensors, communication devices etc. in the infrastructure as well as in the vehicles. Transport automation entails a development of the physical and digital environment, involvement and education of end users, technological solutions such as cloud computing and connected vehicles and much more. One challenging feature of transport automation is that it requires intense and trustful collaboration between several disciplines and actors.

Linked to the need for collaborations between people and organisations to move this area rapidly forward, there is also a technological dimension that calls for connections and communication between large numbers of different entities, see Figure 1.

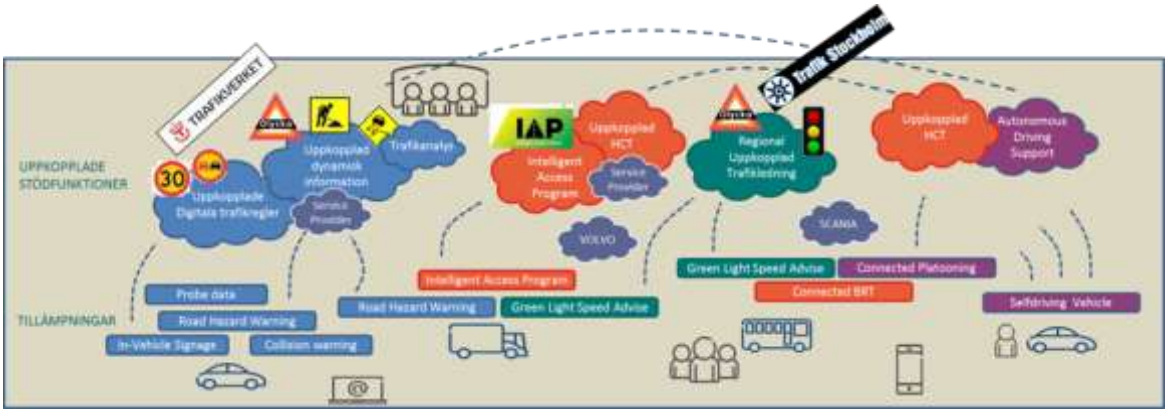

Figure 1: Interlinked functions in the automated road transport system (Source: Summary of roadmap for connected and collaborative transports, September 2014, page 6)

Driverless cars are devoted much attention and almost all studies available focus on car traffic. However, it should be noted that the potential is larger for logistics for goods and people in a broader perspective, particularly given the profile of the Swedish automotive industry with a dominance of commercial vehicles.

Several terms are used to describe transport automation, such as autonomous, automated or driverless vehicles. In this agenda, we mainly use automated, partly as the agenda targets the whole system, not only the vehicles.

Why create a new programme for automated transport systems?

It is seldom questioned that transport automation has a very high potential to bring several benefits to society. This will be described more in detail below. What is questioned, and rightly so, is if there is a need for a specific programme. Large existing programmes, in particular FFI, are forwarded as platforms to use also for transport automation.

We argue that the only efficient method to drive transport automation is through a broad programme incorporating all main stakeholders. FFI has already and will probably even more in the future support transport automation from the automaker's perspective. This is important but not enough. The success of this programme depends on a broad and open approach with IT, telecom and the automotive industries collaborating on a level playing field together with universities and public administrations and agencies. FFI is not open and as the automotive industry is in the driver's seat, it does not provide a level playing field.

Who is supporting this research and innovation agenda?

The following organisations have supported and support the development and realisation of this agenda for automated transport systems (in alphabetical order): AB Volvo, Artic Falls, ASTAZero, ATM, Autoliv, Chalmers University of Technology, Ericsson AB, Forum för innovationer i transportsektorn, Göteborgs Stad, Lindholmen Science Park, Linköping University, SAAB AB, Safer, Scania, SP, Stockholm Stad, Trafikverket, Transportstyrelsen, VGR, VICTA, Viktoria Swedish ICT AB, Volvo Cars and VTI.

Visionary context

In society at large there are several existing visions linking to automated transport systems. Examples include "Den goda staden", "Det goda livet" and "Liveable Cities" for the city environment, Vision Zero for traffic safety and zero dependency on fossil fuels for the environment. Together they can be seen to envision *an attractive, safe, clean and efficient (automated) transport system for people and goods.* Of critical importance is the efficiency, which includes a reduction of the land use for transport through a better use of the existing infrastructure and improved opportunities for public transport and other solutions.

Automation of the transport system has the potential to contribute substantially to all these aspects in the visions, and this is the starting point for our agenda.

A window of opportunity

A fully automated transport system is probably decades away but it is relatively safe to say that the transport system of tomorrow will be more automated than the one of today, see Figure 2. This trend has been stable for a number of years already and the benefits associated with increased automation appear substantial. However, it is for several reasons difficult to forecast the level of automation achieved by 2025 as technological shifts of this dignity almost always are quite unpredictable. Several factors apart from the technology influence the speed of development such as legislation, customer acceptance and cost of energy.

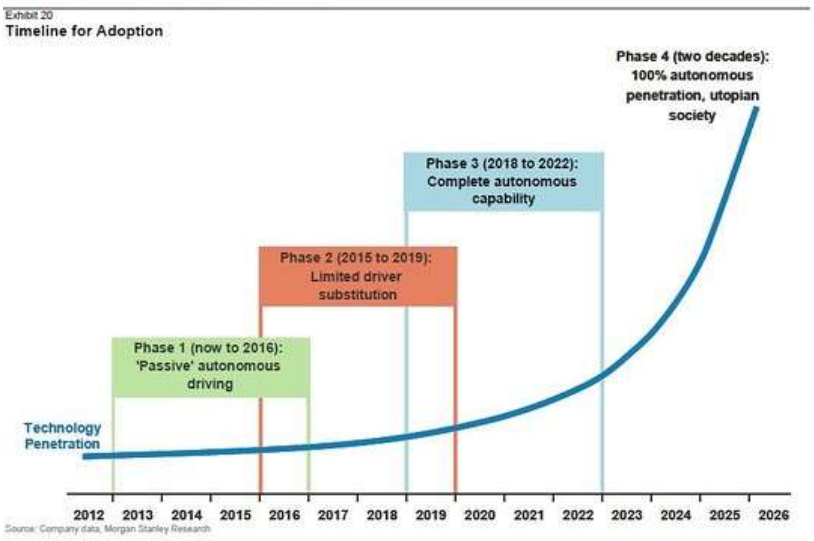

Figure 2: One introduction scenario (Morgan Stanley, 2014)

Having stated this, it appears as if there is a strong momentum building up right now in several parts of the world in the area of transport automation. Pilot projects, adaptions of the legislative frameworks, demonstration activities and high attention in media all contribute to this

momentum. However, this new setting is still in a very formative stage and there are thus substantial opportunities for actors being proactive. Among others, there is a high likelihood that the European Union will set aside large funds for transport automation activities for the coming years.

One very recent report from the Swedish Transport Agency confirms the opportunities and challenges related to transport automation:

> "Utvecklingen av självkörande fordon går mycket snabbt och system som under vissa förutsättningar stödjer autonom körning kommer snart att vara redo för en marknadsintroduktion. I dagsläget saknas dock en tydlig struktur i utvecklingen. Olika aktörer med tillgång till olika styrmedel agerar ofta var för sig. Det kan vara lätt att tro att utmaningen främst är av teknisk art som t.ex. att säkerställa tillförlitligheten hos dessa system. Dagens vägtrafiksystem är dock mycket komplext med en samverkan mellan dess olika delar som ofta är svår att förutsäga och styra. Det betyder att utvecklingen på området kan få en genomgripande påverkan på hela vägtrafiksystemet och dess funktion i samhället. Utvecklingen kommer därigenom sannolikt även att få effekter på en övergripande samhällsnivå när det gäller exempelvis samhälls- och stadsplanering, bosättningsmönster, resmönster och resvanor, trafikarbete, former för bilägande m.m." [1]

Today Sweden has a good position in the automation of transport systems. We have a strong innovation system for the development of new generations of ICT systems. The automotive industry is also well equipped with in-house and external sources of knowledge, components and systems. Finally, there is a relatively ambitious national agenda relating to safety and environment, which most likely will benefit a lot from increased automation.

Vision for this agenda

Against this background we develop this agenda envisioning that Sweden is positioned and recognised as a leader in automated transport systems. To be a bit more specific, this means that we need to strive for forefront positions in three related areas:

- Knowledge and competencies supporting a sustained leadership in key areas for the further introduction of transport automation.
- Innovation and development of products and services related to automated transport systems for a global market.
- Implementation of automated transport systems in Sweden.

A leading position in implementation serves as a tool to make Sweden more attractive for people and businesses as it contributes to reduced negative consequences of transportation (energy, environment, efficiency, safety…). It is also a platform for Swedish firms involved in the transport system to test and develop new automation products and services.

Goals and strategy

In line with the vision, the main goals for 2025 are

- An integrated innovation system including all key actors and competencies needed for a successful development of products, processes and services for an automated transport system. This includes not least the infrastructure, the city environment and the end users of the mobility services.
- A high degree of action in terms of demonstration and deployment of automated transport system features in Sweden.

[1] Swedish Transport Agency/Transportstyrelsen (2014) Autonom körning – Förstudie. Rapport Dnr TSG 2014-1316. August 2014. (page 7)

- A central role in Europe in the R&D programmes targeting transport automation as well as in the policy groups setting the standards for the automated transport system.

Examples of quantitative indicators reflecting the development and the value of this initiative are:

- Number of research and demonstration projects in Sweden and elsewhere with Swedish participation addressing transport automation.
- Numbers of academic courses, PhDs and publications focusing on transport automation issues.
- Volumes of public (Swedish as well as European) and private investment in transport automation.
- Numbers of operating vehicles on each level of transport automation (using the five level automation scale forwarded by NHTSA in USA[2] or another definition).

On the more qualitative side, the development of the innovation system and potential spin-offs from the integration of all mentioned actors and developing paradigms has potentially even more important implications but they are more challenging to measure.

On another level, it could be argued that transport automation primarily is a tool to reach transport policy goals, as mentioned in the Visionary context section. There is a good review of how transport automation relates to these goals in the report from the Swedish Transport Agency (pages 41-43) [1]. However, it has to be acknowledged that the impact of transport automation is still unknown to a large extent and there is thus an urgent need for research enhancing the understanding of the impact of various potential automation initiatives as early as possible. Some examples: How is traffic safety impacted? Which are the business opportunities? Which is the impact on the city of tomorrow?

The strategy to reach the goals is simple in its idea but potentially challenging in its realisation: Through an open innovation programme creating, developing, using and implementing knowledge, the already strong momentum towards transport automation is sustained and directed towards the goals. Critical for success is the involvement of all main actors. In line with this, the involvement of users, commercial as well as private, is important to make sure that there is a market demand.

Relevance for Sweden

In a global and national perspective, transport automation promises important benefits to the environment, to traffic safety and to the economy:

Environment. An automated car is 20 - 30 per cent more energy efficient and it contributes to reduced congestion and thereby to further reductions of the energy use.[3,4] Automated road transport might reduce pollution by enabling use of alternative fuels. Lighter vehicles reduce range problems and the vehicle can go by itself for recharging or refuelling.[5]

[2] National Highway Traffic Safety Administration (2013) Preliminary Statement of Policy Concerning Automated Vehicles, see www.nhtsa.org
[3] iMobility Forum (2013) Roadmap Automation in Road Transport, Version 1.4, May 2013
[4] Morgan Stanley (2013) Autonomous Cars: Self-Driving the New Auto Industry Paradigm
[5] Anderson JM, Kalra N, Stanley KD, Sorensen P, Samaras C, Oluwatola OA (2014) Autonomous Vehicle Technology: A Guide for Policymakers, RAND Corporation

Safety. The socio-economic cost of road traffic accidents are estimated to amount to about 2% of the annual EU GDP[6]. Human errors cause approximately 90 - 95 per cent of all crashes. Automated driving has the potential to eliminate the human error.[3,7] In the Strategic Research and Innovation Agenda "Safe Future" automated vehicles and driving are mentioned as enablers to increase traffic safety.[8]

Economy and time savings. Congestion costs the EU economy more than 1 per cent of GDP[3]. Automated transports may both reduce the congestion and the cost of congestion, as the time spent in transport can be productive[5]. A longer-term benefit of transport automation is reduced land use requirements. Parking spaces can be moved to less attractive areas and thanks to the precision of automated vehicles, two lanes of today might easily allow for an additional separate bicycle lane tomorrow.[9] Most of the already operating solutions bring savings through lower salary costs. In almost all commercial applications on road or off-road, the cost for the driver is a substantial part of the total cost.

Together, the IT, telecom and automotive industries generate one third of Sweden's export incomes, they employ roughly 250,000 persons in Sweden and they invest more than SEK 30 billion in research and development[10].

Finally, it should be mentioned that even though there are some examples of successful collaboration between the two main industries involved, there is a huge potential for further improved collaboration with large synergies relating to transport automation as well as other cross-cutting application areas. A broad support within and around this research and innovation agenda might thus lead to a nationally changed approach to innovation.

Global Trends

Automation started early in the aviation and maritime sectors. A high degree of automation in combination with an extensive use of simulators in the training of pilots has led to a situation with required minimum hours of manual operation to maintain the skills. In other areas, such as workshops, storages, terminals and ports, a rapid development towards automated vehicles has taken place driven by commercial factors. People movers at airports and new subway lines, e.g. the metro in Copenhagen, are frequently designed to operate without a driver. Automated solutions are more cost efficient. Finally, there are locations such as mines and other areas with unattractive or even dangerous conditions for people which require automation. In some of these examples of early implementation of automated solutions, there is also a need for low or zero emissions, which thus leads to electrified modes of transportation.

Road transportation is not yet fully automated but there is a wide range of features in the vehicles interacting and supporting the driver that have been introduced on the market in large scale. Main objective has been enhanced safety with systems such as forward collision warning, automated emergency braking and lane keeping assistants. In parallel, and partly for other reasons, there is also a trend towards more connected vehicles. There are several joint areas of

[6] http://europa.eu/rapid/press-release_MEMO-13-232_en.htm
[7] USDOT National Highway Traffic Safety Administration, NHTSA (2008) National Motor Vehicle Crash Causation Survey
[8] SAFER (2013) Säker framtid i samhälle och affär: Forsknings- och innovationsagenda för trafik- och fordonssäkerhet
[9] c.f. https://www.youtube.com/watch?v=3PRzHqeBorA
[10] Bilsweden.se; fkg.se; scb.se; Giertz E, Levén P, Sörensson R, Lougui M (2013) Företag inom informations- och kommunikationsteknik i Sverige 2007 – 2011, VINNOVA VA 2013:07

interest between transport automation and a more (digitally) connected transport system, e.g. high capacity and extremely reliable communication methods and cloud computing.

The USA is more active than Europe in road automation with several large projects and changed legislation in a couple of states. Google has since 2010 tested self-driving cars and until the beginning of 2014 accumulated more than one million kilometres without major accident. One experience of the tests is that people become lazy and unwilling to take the control back of the vehicle towards the end of the distance driven autonomously. Partly for this reason, the second dedicated generation of Google cars were initially considered to have no steering wheel.[11] Another example is the 3,000 vehicle field-test in Michigan with vehicle-to-vehicle communications technology.[12]

The interest for automated driving enjoys a positive trend in the USA. During the years 2012 – 2014, the willingness to pay USD 3,000 for autonomous driving features in the vehicle has increased from 20 to 24 per cent.[13] Another study made by Cisco reported a high trust in driverless vehicles, on average 57 per cent, see Figure 3.[14]

Figure 3: Trust in driverless cars (Cisco, 2014)

"The revolution, when it comes, will be engendered by the advent of autonomous or 'self-driving' vehicles. And the timing may be sooner than you think."[15]

IHS Automotive forecasts total worldwide sales of self-driving cars will grow from nearly 230 thousand in 2025 to 11.8 million in 2035 – 7 million SDCs with both driver control and autonomous control and 4.8 million that have only autonomous control. In all, there should be nearly 54 million self-driving cars in use globally by 2035. The study anticipates that nearly all of the vehicles in use are likely to be self-driving cars or self-driving commercial vehicles sometime after 2050.[16]

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[11] Simonite T (2014) Lazy Humans Shaped Google's New Autonomous Car, MIT Technology Review, 2014-05-30
[12] See http://www.safercar.gov/v2v/v2v.html
[13] J.D. Power (2014) J.D. Power Reports: Vehicle Owners Willing to Pay for Smartphone Functionality, but Not Connectivity 2014-05-01
[14] CISCO (2013) Consumers Desire More Automated Automobiles, According to Cisco Study, 2013-05-14
[15] KPMG and CAR (2012) Self-driving cars: The next revolution
[16] IHS (2014) Self-Driving Cars Moving into the Industry's Driver's Seat, 2014-01-02

Japan has long been leading in robotics and there is a good organizational setup for the development of transport automation. However, automakers such as Toyota have a low profile stressing that automation of today primarily serves to assist the driver to enhance the safety. Hyundai in Korea has some activities. Focus in Japan and Korea is on technology.

Australia is deeply involved in transport automation, both below and on the ground. More than 70 automated trucks from Komatsu and Caterpillar are operating in mines. Automated trucks are also operating in mines in Chile.

Opportunities and challenges for Sweden

In order to determine a research and innovation agenda for automated transport systems that fits the needs of Sweden, a classical SWOT analysis is made (strengths, weaknesses, opportunities and threats). Probably needless to say, this SWOT is just a very brief highlight of some particularly relevant aspects to consider.

Among the *strengths*, it has already been mentioned that we have highly competitive knowledge, products and services in core areas for transport automation, among them telecommunication systems, vehicles, systems engineering, big data management and traffic safety. Apart from strong firms with substantial research located in Sweden, the universities and institutes have also been generating and accumulating knowledge over a long period of time.

Another strength is the ability to make and handle complex systems. The systems approach is claimed to be a Swedish speciality and it is a veritable strength in the area of transport automation, which indeed will be based on a large and complex system. Potentially even more promising is the tradition of collaboration in triple helix type constellations. To succeed in the implementation of transport automation, a trustful and productive collaboration between local, regional and national authorities and agencies, industrial actors and the academy is of great importance. The transport system is indeed very large and complex as it among others encompasses city planning, digital and physical infrastructures, all transportation modes and carriers and the operators and end users of the mobility services.

Sweden's high profile in environmental matters is a strength, as the environment will most likely be one increasingly important driver of transport automation. Similarly, it is a strength that we have a leading position in traffic safety. This strength includes knowledge and competencies relating to almost all aspects of traffic safety. It has also to be mentioned that there is also some goodwill in the environmental and safety aspects, which means that Swedish automation solutions incorporate some credibility in these dimensions.

Other strengths are a good network in the EU policy and R&D networks and a, according to international comparisons, world-class innovation system. The Swedish Transport Agency is involved in the EU policy discussions about regulations, Volvo has had an important role in the development of the first road map targeting this area and there is a continuous dialogue with the commission in these matters.

Most of the *weaknesses* relate to the small size of Sweden. In some cases, such as the need for firms to think and act globally in order to find a sufficiently large market, this is also a strength. But lack of scale, a high dependency on foreign resources, and a small national market reduce the possibilities for Swedish actors to select and follow a path that differs substantially from what is taking place abroad. Newcomers and start-ups in the field of transport automation might in particular be affected by this.

Given that the involved established industries are mature and highly international, the impact of a small home market is limited but there exists a need to avoid fragmented approaches. Moreover, the possibilities to nurture a high variety in the approaches to vehicle automation are limited. Resources, size and scale are also of some importance when it comes to standardisation issues.

A final weakness to be mentioned is the tendency to investigate rather than act, which sometimes leads to the loss of a leading position. As transport automation is in a stage when experimentation is of great importance, there is a need to act powerfully (without running too far in the wrong direction).

Among the *opportunities*, there is a good chance that Sweden can secure a leading position in transport automation. Leadership in knowledge, development and implementation is also envisioned in the strategic innovation programme. Partly linked to this and probably also a necessary precondition is that a strong position in the EU system can be obtained, leading to good co-funding opportunities and direct access to policy makers shaping the framework for future transportation systems.

Another opportunity is a merge or combination of parallel technological paths, among them 'internet of things', transport electrification and, of course, transport automation. This combined approach can lead to synergies and lead to a rapidly improving transport system.

An intensified collaboration between all actors involved in transport automation brings also great opportunities in terms of spill-overs to other areas benefitting from cross-sector multidisciplinary approaches. One example is city logistics, which requires a productive collaboration involving approximately the same set of actors.

The *threats* associated with a strong and strategic involvement in transport automation are limited as the trend in this direction is relatively stable and incremental approaches are possible to a high extent. Still there is a threat that the timing of the Swedish initiative does not match the global development. As discussed above, the risk that we start too early is far smaller than vice versa. If we start too late or too slowly, a leadership will not materialise.

Further threats to bear in mind are the choice of wrong technologies, lack of relevant development criteria ensuring adequate levels of safety and incompatibility with global standards (to be decided). Linked to the dependence on valid business models, there is also a threat that potential lead users in Sweden do not demand the initial solutions sufficiently.

Finally, but of great importance for this agenda is the threat that a lack of knowledge and competence in Sweden hinders the development and limits the possibilities for Sweden to benefit from the growth potential that transport automation promises.

Priority areas

Based on the SWOT, a number of recommendations emanate for how to work towards the agenda's vision and goals;

- Ensure a broadly supported leadership and create strategic national **alliances** to fully make use of the potential in a joint Swedish approach involving leading industries, academia and public organisations. Add international alliances to define the global standards
- Build knowledge and competence of a relatively **generic** nature and prioritise an open approach not locking in to very specific development paths

- Allow for **incremental** innovations steadily increasing the degree of automation and generating positive cash-flow
- Involve **lead users** from the very beginning
- Foster an **action-oriented** approach with learning-by-doing and a short period from idea to first implementation
- Nurture **synergies** between evolving paradigms such as automation, electrification and internet of things.

These recommendations serve as a kind of check-list when identifying the priority areas to address. There are two recent and to a large extent independent initiatives considering transport automation:

Roadmap for connected and collaborative transports. One national initiative aiming at strengthening the innovation system in this area is the Forum for Innovation in the Transport Sector. It gathers several important actors around areas of common interest. For several such areas, roadmaps are being developed. The roadmap for connected and collaborative transports, which currently is in the stage of finalisation, underlines the nationwide interest in transport automation. The following areas are highlighted as prioritised; architecture for a digital infrastructure (read standardisation), efficient solutions for communication between vehicles, passengers, goods and transport infrastructure, business models including payment solutions, and the establishment of a pilot test area in Sweden. The latter is forwarded as the most urgent action. The roadmap stresses that automated transports need to be connected in real time to surrounding local as well as central systems. Moreover, it forwards the need for national coordination as a first step followed by the launch of connected support functions in the traffic system (e.g. digital traffic regulations and support for heavy vehicles). The board of the forum firmly supports this endeavour and considers the formation of this strategic innovation programme the way forward.[17]

ARV – Boundary conditions for vehicle automation. This project led by SAFER with funding from FFI, Autoliv, Scania, Volvo Cars and Volvo Group recommends Sweden to take the lead in the following areas; impact assessment of transport automation, pilot areas for automated vehicles, simulations of mixed traffic environments, methods for verification and validation, experimental studies of business models and business eco systems.[18]

Another input relating to vehicle automation is that following a review of on-going research and other activities related to vehicle automation, Habibovic et al (2014) forward the following challenges; a) transfer of control between the vehicle and driver and vice versa, b) behaviour of vehicles in relation to other road users, c) communication of system reliability status to the driver and d) clarification of the impact on societal values.[19]

Driverless cars are devoted much attention but it should be noted that the potential is larger for logistics for goods and people in a broader perspective, particularly given the profile of the Swedish automotive industry with a dominance of commercial vehicles.

[17] Forum för innovation inom transportsektorn (forthcoming) Färdplan för Uppkopplade och samverkande transporter, draft version September 2014

[18] Wedlin J (2014) White paper: Automatiseringens randvillkor. En avsiktsförklaring för den svenska samverkansplattformen inom forskning kring automatiserade fordon, SAFER Report: Project A45 dated 2014-05-07

[19] Habibovic A, Englund C, Wedlin J (2014) CURRENT GAPS, CHALLENGES AND OPPORTUNITIES IN THE FIELD OF ROAD VEHICLE AUTOMATION, presented at FISITA 2014

Based on the input received during all workshops and meetings carried out within this project and the recommendations in the mentioned studies, we forward four priority areas, see Table 1.

Table 1: Priority areas

SWOT recommendations→ ↓Priority areas↓	Generic	Incremental	Strategic alliances	Lead users	Synergies	Action-oriented
Virtual and applied development approaches	X	(x)	(x)	X	(x)	X
Harmonisation and standardisation	X		X		(x)	(x)
Legislation and business models	X	X	(x)	(x)	(x)	(x)
Impact of transport automation	X	(x)			(x)	
X = Directly targeted, (x) = Addressed/used to some extent						

The priority areas are purposely selected to be generic and thus relevant for all main actors involved in the agenda project. Below follows a brief description of each priority area.

Virtual and applied development approaches

Automated transport systems accentuate the classical dilemma when technologies with different life cycles are combined. In this case, the renewal of IT hardware and software in the vehicles as well as the surrounding infrastructure is typically much faster than the renewal of other parts of the system. Given the different speed of technological development, the methods to bring solutions from idea to market are sometimes also quite different. Whereas developers of IT products and services often can afford a launch of a not 100% tested and debugged new software as it can be updated later, a bus developer is not supposed to launch a new type of safety-critical system without being very close to 100% sure that it will work for several years without problems. The possibilities to involve the user in the development of the solution are typically greater in the IT area, thus allowing for open innovation to a larger extent.

As automated transport systems to a large extent depend on a successful integration of technologies from the telecommunication and the automotive industries, there is a great need to find efficient methods to develop, test and demonstrate new systems. Simulation methods of different kinds are particularly useful but they need to be complemented by more hands-on approaches.

Harmonisation and standardisation

In all emerging areas there is a struggle to find a globally accepted standard. The electricity business with national monopolies over a long period of time illustrates perfectly how each country has developed its own standards on all levels from the plug design and above. This has been an issue to address when trying to introduce plug-in vehicles. In the transport area, the railway systems have also been relatively incompatible with different types of electricity supply and even different rail gauge.

To some extent, local adaptations will remain, but a lot would be gained if vehicles use the same ‘language’ from Japan via Europe to the USA. Sweden is small and has thus limited

chances to set the standard. Success in this priority area calls for a careful mix of active participation in standardisation committees, international alliances, good relations with important policy makers and a qualified analysis of trends. It is also necessary to have concrete demonstrations to refer to when advocating a certain solution.

The need for international alliances and collaborations is related to the size of the Swedish market. A natural starting point is the EU programmes, which not only allow for the establishment of valuable networks between various stakeholders in transport automation, it also offers co-funding possibilities.

Legislation and business models

Legal and regulatory frameworks in Europe state the driver always must be in full control of the vehicle (iMobility Forum, 2013). Small but significant changes must be made in the legislative area in order to manage a controlled transition towards driverless vehicles. One critical issue is the division of responsibility between the captain of the vehicle and the providers of the systems allowing it to move without an active driver, not least the vehicle manufacturer. It is possible that the manufacturer's liability may increase and it is important to avoid that this leads to unnecessary delays of the introduction of automated transports. Approaches to reduce this potential problem could be to change the business model to deliver a mobility service rather than a product or monitor the driver's behaviour more closely.[5]

One very common trap in the ITS area is to be too technology-oriented and 'forget' that there must be a clear business case. Almost everything appears possible but several interesting potential innovations never reach the market as one or several parts of the business concept do not work in practice. On the roads, transport automation has so far mainly been gradually introduced in the form of various safety services through an interesting mix of policy interventions and voluntary initiatives. In the coming phases, when the environmental and economic aspects will have a more important role, other introduction methods will be needed. Last but not least, it remains a very critical discussion whether and how much the buyer and user of the vehicle are willing to pay for the driverless option.

As mentioned above, a gradual introduction with a focus on areas with lower barriers and shorter payoff time periods appears to be one guiding principle. However, in some cases it will probably be important to demonstrate a step change, not least to influence international standards. A crucial and over a long time period difficult issue is to manage the mix of automated and not automated vehicles as well as the transition phases from manual to automated driving and, even more important, from automated to manual driving.

In some aspects the electrification of the transport system is linked to the automation and there are thus some possibilities to make joint or combined approaches in order to create synergies.

Impact of transport automation

Even though automated transport systems have been on the agenda over a long period of years, there is still a great uncertainty about the benefits and weaknesses linked to it. For various reasons, it is of interest to study how automation impacts critical issues such as environment, safety and economy, both directly and indirectly. Having a leading position in this area increases the likelihood of making good decisions when trying to navigate towards globally competitive solutions. Moreover, even if the best alternative from a technological standpoint

seldom wins (cf. qwerty[20]), knowledge and competence in this area supports the acceptance of all stakeholders directly or indirectly involved in the development.

Commercial buyers and users of vehicles tend to make relatively rational choices and it is therefore possible to identify cost-benefit ratios that should lead to an adaptation of automated features. Given that some applications already are automated to a large extent, there are also experiences to use when expanding the number of applications. Private users of cars are less predictable as the choice of vehicle is influenced by several personal priorities. The trend towards car pools and other types of car sharing might be reinforced by automation features, as automation shifts the focus to other aspects of the transportation mode and it also encompasses functions that allow for drastically improved (free-floating) car sharing services.

In a larger context, automated transport systems might lead to a change of how cities should and could be developed and designed. Automated vehicles typically require less space as they navigate with very high precision. Parking in attractive areas can be avoided and parking areas can be designed differently as the passengers can exit the car before it is parked.

Strategic Innovation Programme for Automated Transport Systems

We develop this agenda envisioning that Sweden is positioned and recognised as a leader in automated transport systems. Given that there already are on-going substantial programmes targeting several of the aspects mentioned in the agenda, there is a need for a dedicated programme that coordinates the efforts and ensures focus on initiatives that really make a difference.

This programme:

- forwards a leadership in the area of automated transport systems specifically. All transport modes are covered, even though the focus will be on surface transport. A systemic approach is emphasised, thereby trying to enjoy synergies and avoid dead ends.
- involves all types of actors being relevant for the advancement of automated transport systems. Stakeholders such as city and regional planning authorities, Trafikverket, Transportstyrelsen, the automotive and the ICT industries are involved as well as universities, institutes and consultants. The programme is open for new actors to join and the management will carefully try to balance all stakeholders' interests.
- takes its stance in the needs of the individual and the city of tomorrow and the corresponding (currently to a large extent unknown) opportunities to develop radically different mobility solutions.
- combines technological and regulatory dimensions in a unique way. Even though this is a challenge it appears as this is the most efficient path forward. As other initiatives globally seldom include this type of partnership, it is a strength to foster and benefit from.
- encompasses issues from relatively basic research all the way to test and demonstration. This is as explained previously important as hands-on experiences not least serve as a playground for rewarding research.

The programme thus complements and adds new dimensions being weakly promoted in on-going initiative on the national or EU levels.

[20] David PA (1985) Clio and the Economics of QWERTY, *American Economic Review* (American Economic Association) 75 (2): 332–337

Among the initiatives with public support relating to transport automation we find Internet of Things, FFI, the Drive Me project, SAFER, Closer, Vehicle ICT Arena, K2 and many others on the national or international/EU level, the development of 5G mobile network technology being one example.[21] They are important components in this Strategic Innovation Programme for Automated Transport Systems and they will to some extent form the body of activities.

The largest programme encompassing vehicle automation is FFI. A rough estimation of the investments made in the FFI programme over the period 2010 – 2017 is that 600 MSEK have been devoted to topics directly relevant for automation, see Figure 4. Outside FFI is Volvo Cars's Drive Me project, which, if it is carried out in line with the plans, is an investment in car automation of approximately 400 MSEK.

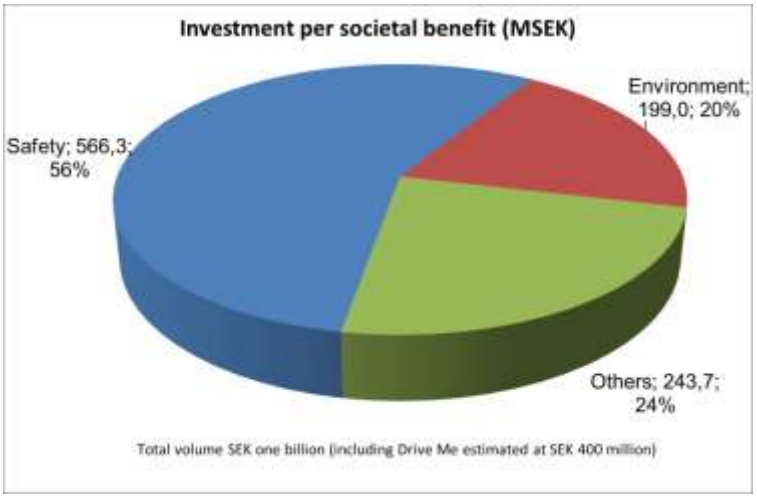

Figure 4: R&D investments with public co-funding 2010-2017

Outline of the strategic innovation programme

All priority areas mentioned in previous section require a mix of education, research and development, and test and demonstration to prosper and put Sweden into the driver's seat (even if there is no driver anymore). The concept for the strategic innovation programme is based on the four priority areas outlined above. However, in order to link the activities in the programme to the needs of the end users, we have developed a 'cake model', see Figure 5. The most important aspect in this cake model is that there is a strong and bidirectional communication between the different elements of the cake from the centre and out to the periphery (see the red arrow). Through this interaction, relevant knowledge and solutions are developed on all levels through education, research, development and demonstration.

[21] See http://www.ericsson.com/res/docs/whitepapers/wp-5g.pdf

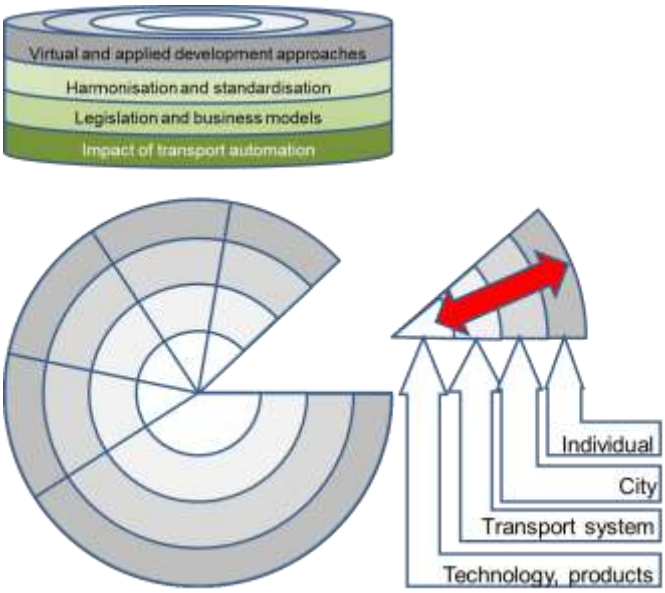

Figure 5: The transport automation cake

The vertical layers of the cake have already been outlined. In Table 2, the radial direction is explained briefly.

Table 2: Levels of transport automation

Label	Explanation	Typical actors
Individual	The end user of all transport solutions has multifaceted needs and behaviours but considers mainly transport and mobility as a means to fulfil other qualities of life.	Just a few examples: Cecilia commuter, Eric eBay shopper, Torkel trucker and Rut mobility service customer.
City/state	Develop an attractive city by offering mobility at the same time as greenhouse gases, noise and air pollutions are limited, accidents are avoided and the available land is used smartly.	Local, regional and national administrations of transport related issues.
Transport system	Physical and digital infrastructures, legislation and regulation, vehicles, operators…	City, region, road and rail administrations, telecom and automotive industry, public transport operators, suppliers of logistics services, academy and institutes.
Technology, products	Transport automation requires a series of new or developed technologies and products, among them: sensors, extremely reliable and high speed communication systems, cloud computing services, positioning systems …	IT, telecom and automotive industry, academy and institutes.

As indicated in Figure 5, the cake can be divided into a number of pieces, each targeting a specific need or service in the transport system. Among the candidates receiving strong support from all insofar involved actors are the following:

- Public transport
- Transport services in closed areas
- City logistics
- Port logistics
- Parking solutions
- Mobility services
- Long-distance heavy freight.

Even though these ‘pieces of cake’ have very transport-oriented names, the actual activities incorporate a large number of actors and ICT development is probably the most important contributor to an automated future transport system.

Gaining momentum

This research and innovation agenda has been strongly supported on all levels from the ministries and the governmental agencies via the industries involved and the higher education system down to potential users and benefactors of an automated transport system. Since the initiation of this project in October 2013, several dozens of meetings in smaller and larger settings have taken place to discuss this agenda or particular aspects relating to it. In Appendix 1, a brief description of the project and the workshops organised are given.

In the initial phase of the implementation of the agenda, three key activities are planned for:

- Setup of a programme management organisation
- Detailed investigation of current activities related to the automation of transport systems in education, research and development and test and demonstration
- Start of projects in line with the priorities mentioned above.

Each key activity is described briefly below.

Organisation

The suggested organisation of the innovation programme can be viewed in two phases.

For both phases Lindholmen Science Park AB, a national innovation node located in Gothenburg is suggested to be and act as a host. As this is a true national (with international ambitions) programme, Lindholmen’s heritage and proven track record of hosting national efforts is valued by all partners.

Phase 1, Sep 23rd 2014 – April 21st 2015, constitutes the formation and definition process. We believe it is essential to already during this period act with a strong leadership as the theme of the innovation programme is complex and involves a broad spectrum of organisations and people.

During this phase we will strive to engage a senior leader with experience of collaborative efforts across academy, industry, society and politics. To his/her support we will form a working group of people representing the different dimensions we believe are important to finalise the formation of this programme. As ICT and infrastructure/city planning are key areas, we will carefully select resources accordingly.

During this phase a lot of attention will be required to line-out how this programme will interact and be positioned in the existing Swedish framework. Examples of entities to explore relations with are; FFI, Forum för innovationer i transportområdet, Safer, Closer, VICTA, Test Site Sweden, ASTAZero, K2, CTS, Internet of things. Lindholmen Science Park is well positioned as many relations already exist.

Phase 2, starting when this innovation programme application has been evaluated and approved.

As described earlier this programme intends to focus on automation of the transport system. Bearing in mind the complexity and the large amount of existing initiatives in Sweden, the leadership of the programme will be important. We therefore suggest a strong leadership with a true collaborative approach. The development will require collaborations and support with

organisations nationally and internationally. We foresee a growing number of global connections and projects, which also indicates that the leadership must be adequate and trustworthy from a national perspective.

Having Lindholmen Science Park AB as a neutral national host will generate the possibility to form a leadership that encompasses the relevant organisations in order to drive the process.

Suggested structure:

Chairman (neutral, senior, skilled in collaborations, biased towards ICT and/or infrastructure)

Board, consisting of representatives from agencies (Trafikverket, Transportstyrelsen), cities (Gothenburg, Stockholm from start), regions (Västra Götalandsregionen from start), industry (Ericsson, SAAB AB, Telenor, ICT companies representatives, vehicle manufacturing representative, construction companies representative), academy and institutes representative.

Connected to the board of the program we suggest to form a scientific board, where universities and institutes that are involved will be represented. So far in the process LiU, Chalmers, VTI, SP, Viktoria Institute have participated directly, while KTH, LU, RISE are most likely to join the program.

Through the board our ambition is to involve existing technical and organisational infrastructures in Sweden. Examples are Asta, SIM-4, winter test region, ICT labs in different sites, and strive for developing test environments in real environments. Both Stockholm and Gothenburg as cities have expressed interest to find ways in order to utilize the cities as "test arenas".

As described in the appendix, the organisations involved so far represent a broad mix of what we see as essential. However, there is still a need to add further stakeholders and a process targeting a structured involvement will be developed. International collaborations and alliances are necessary to add.

<u>Detailed investigation</u>

A detailed investigation of current activities related to the automation of transport systems in education, research and development, and test and demonstration is made to create a stable platform for decisions and to ensure that the future strategic innovation programme invites all relevant actors.

One starting point is the database created with all transport automation related projects within FFI. Together, the actors involved in the programme have a good knowledge base and the main challenge is to find a format and a process allowing for comparisons and the identification of activities to invest in.

Potentially the most delicate and critical task is to manage in the next step is to map all existing and planned initiatives (projects, programmes, centres etc.) and develop collaborations or even integrations in order to reach a coordinated and strategic approach to transport automation. It could be argued that this organisation of the resources is the single most important objective of this strategic innovation programme. If successful, it can leverage the investments in transport automation substantially and contribute to the positioning of Sweden as a leading nation.

Not least in relation to the goal to use the EU system to leverage our activities, it is also commendable to investigate and further develop the network to EU policy and funding systems.

As mentioned previously, the network is strong and there is an interest from the Commission for Swedish initiatives in transport automation.

Project start

Even though activities sponsored by the programme will have to wait until the proposal is approved, there is a need to continue and further develop the collaboration immediately. Several projects and other initiatives are already running and it is important to link these activities to the programme. Moreover, as the approaches outlined above need to involve a large number of different actors, it takes a couple of months from the first concept to a funded and started project.

APPENDIX 1: Involvement of stakeholders

This initiative has had a very fortunate and easy first year as the interest and support from all stakeholders has been overwhelming. The only cloud in the sky has been that some people initially considered the initiative superfluous, as many other activities were already going on. However, as soon as the ambitions were communicated, full support has been given.

An alliance with the project developing a roadmap for Connected and collaborative transport systems within the Forum for Innovations in the Transport Sector was created at an early stage for two reasons. One reason was to get a flying start through the use of the resources included in this working group, their network and the already relatively complete road map. The other reason was to ensure that there is no risk for parallel and competing initiatives trying to foster the development of an automated transport system.

Together, two workshops were organised. The first workshop in May 2014 had a broad approach with presentations detailing the development in EU, USA and Asia and plenty of time for an analysis and discussion of what to prioritise in Sweden.

The second workshop in early September focused on the proposed research and innovation agenda and how to land the positive intentions in productive projects.

In addition, approximately 50 meetings were carried out with people from all stakeholder groups including the Swedish government and its agencies via regional and local authorities to academy, institutes and industry to discuss various aspects of transport automation. These meetings included both the top management level of the organisations (chairman, state secretary, vice-chancellor, director general, executive director) and more operative resources. The spirit of all meetings has been very supportive and enthusiastic.

Below in Table 1Table 3 the participants at each workshop are listed.

Table 3: Participating organisations and people at the workshops

Workshop 1			**Workshop 2**	
AB Volvo	Anders Ekblad		AB Volvo	Lars-Göran Rosengren
AB Volvo	Janne Hellåker		AB Volvo	Lars Bjelkeflo
AB Volvo	Christian Grante		AB Volvo	Urban Wass
AB Volvo	Peter Kronberg		AB Volvo	Anders Berger
Artic Falls	Jonas Jalar		Asta	Peter Wallin
ASTAZero	Peter Janevik		Autoliv	Torbjörn Andersson
ATM	Magnus Hillerborn		Chalmers	Anna Dubois
Autoliv	Torbjörn Andersson		Ericsson	Torbjörn Lundmark
Chalmers	Anna Dubois		Ericsson	Anders Fagerholt
Chalmers/Safer	Ingrid Skogsmo		Göteborgs Stad SBK	Anna Svensson
Ericsson	Anders Fagerholt		Lindholmen	Maria Hedlund
Ericsson	Stefan Myhrberg		Lindholmen	Leif Axelsson
ERTICO	Maxime Flament		Näringsdepartementet	Niklas Nilsson
Göteborgs Stad	Annelie Kjellberg		SAAB AB	Jan Törnqvist
Göteborgs Stad	Anna Svensson		Safer	Ingrid Skogsmo
Göteborgs Stad	Anders Svensson		SP	Magnus Olsson
Lindholmen	Niklas Wahlberg		Trafikverket	Torbjörn Biding
Lindholmen/TSS	Leif Axelsson		Trafikverket	Anders Lie
LiU / VTI	Andreas Tapani		Viktoria	Hans Pohl
Näringsdepartementet	Hans G Pettersson		Viktoria	Azra Habibovic
Näringsdepartementet	Håkan Jansson		Vinnova	Ove Pettersson
Näringsdepartementet	Niklas Nilsson		Volvo Cars	Kalle Runnberg
SAAB AB	Jan Törnqvist		VTI/LiU	Andreas Tapani
Scania	Gunnar Tornmalm			
SP	Magnus Olsson			
SP	Anders Johnsson			
Stockholm Stad	Lars-Göran Jansson			
Trafikverket	Hamid Zarghampour			
Transportstyrelsen	Per Öhgren			
Transportstyrelsen	Jonas Malmstig			
VGR	Hans Fogelberg			
Viktoria	Hans Pohl			
Viktoria	Azra Habibovic			
Viktoria	Johan Wedlin			
Viktoria/VICTA	Kent-Eric Lång			
Vinnova	Ove Pettersson			
Vinnova/FFI	Eva Schelin			
Vinnova/Forum	Filip Kjellgren			
Volvo Cars	Anders Eugensson			
Volvo Cars	Marcus Rothoff			