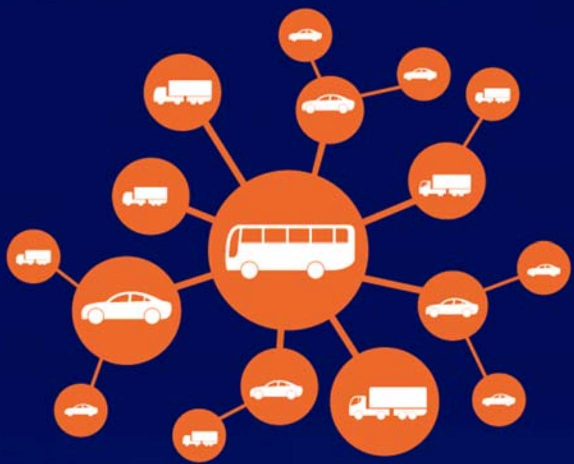
Strategic roadmap

WITHIN THE INITIATIVE STRATEGIC VEHICLE RESEARCH AND INNOVATION (FFI)

Efficient and Connected Transport Systems (EUTS)

03/11/2015



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1 Background and Objectives

This document describes in a comprehensive way the FFI programme's[1] link to the area of Efficient and Connected Transport Systems (EUTS). The document should be regarded as a strategic roadmap containing a description of the challenges, research and development needs, as well as the expected results.

The aim is to gradually contribute to an improved ability to jointly identify research and development activities and areas that contribute to increased transport efficiency. In addition, the roadmaps will be an instrument for monitoring and evaluating, and for increasing understanding of the FFI programme by illustrating the correlation between the funded activities and the expected effects within the programme's area. The document therefore primarily attempts to clarify what needs to be done to achieve the overall objectives of the programme, i.e. to contribute to:

- reducing the environmental impact of road traffic
- reducing the number of injuries and deaths in traffic
- strengthening international competitiveness.

It should also achieve the sub-programme's overall impact goals of addressing environmental and climate challenges, satisfying the requirements for mobility of people and goods, improving national and corporate finances, and increasing road safety. A system perspective is needed to satisfy the mobility requirements for people and goods, which in turn is highly dependent on what is being done in other FFI programmes.

Additionally, an attempt will be made to look further into the future, in some cases as far forward as 2050. For natural reasons, this description will be less detailed and uncertainty greater the farther forward we look.

2 FFI

FFI is a collaboration between the state (VINNOVA, the Swedish Transport Administration and the Swedish Energy Agency) and the motor vehicle industry (Scania CV AB, AB Volvo, Volvo Car Group and FKG) for joint financing of research, innovation and development efforts with a focus on the areas Climate & the Environment and Safety. The background to this effort is that developments within road transport and the Swedish automotive industry have great importance for Swedish growth. The initiative, which began in 2009, provides R&D efforts for approximately SEK 1 billion per year, of which public funding constitutes half.

The Government tasked VINNOVA with developing a strategic partnership programme with significance for the Swedish automotive industry which builds on the vehicle research programme from 2008-2010. Implementation of FFI is to take place in collaboration with industry and universities/colleges/institutes. The programme should have a focus on social objectives with regard to the environment, energy and transport safety, in combination with industrial competitiveness and employment in Sweden. The project portfolio should consist of two thirds climate and the environment and one third should be focused on safety. It may also include supporting projects within production technology, new technologies and materials.

Twenty-five per cent of FFI's resources are allocated through strategic initiatives, which means that the FFI's board of directors may choose to strengthen a current area with special funds for a limited period.

[1] *http://www.vinnova.se/sv/ffi/.*

The FFI programme is divided into five sub-programmes which receive 75 per cent of allocated funds:

- Energy and the environment
- Vehicle and road safety
- Electronics, software and communication
- Sustainable production
- Efficient and connected transport systems.

3 General Considerations

The General Considerations section has been divided into two parts, the approach and principle outline. The first section describes the aspects taken into account when developing the roadmap. The second section describes how the development of this roadmap has taken place.

3.1 Approach

It is possible to describe FFI activities in many ways and the perceived results are influenced by the approach taken. The programme committee has chosen to start from the following two aspects when drawing up the roadmap:

1. Description of milestones and possible concepts
2. FFI Efficient and connected transport systems programme areas (EUTS).

The first aspect tries to identify a number of transport-effective concepts that are fully possible to introduce on the market by 2030. The description stays at a generic level. The reasons for this is to simplify manufacturing (for example the same concept for passenger cars as for heavy goods vehicles) and to respect the needs of companies for confidentiality when it comes to technology and product plans. The concepts are linked to a “milestone", that is to say a time when the necessary research, testing and demonstration activities must be completed so that an industrialisation phase, outside the FFI, can begin.

The second aspect is based on priority research areas for EUTS:

- Vehicles
- Infrastructure
- Business models
- Regulatory framework
- Services
- People

The above areas partially overlap and a particular project may very well cover several programme areas. Regardless of the classifications that are chosen in a presentation like this, such overlaps and demarcation problems are bound to exist. In the presentation below there is both a technology focus and an approach to transport efficiency from a systems perspective. The presentation primarily describes aspects that the FFI programme can directly affect but other factors (such as the need for new standards or new legislation) are also identified.

3.2 Principle outline

A sustainable and systematic approach will be required if the desired results in the current milestones are to be achieved. At an overall level, this work can be regarded as a permanent interaction between research and preparatory development, testing and implementation.

The FFI permits a wide range in the types of results produced. For some of innovative or fundamental results, it may take decades before it is technically and economically feasible to take advantage of relevant knowledge. And because they often involve risky projects, some will never successfully be implemented in products and services. On the other hand, results produced using a scientific approach can immediately make an impact on product and service development. Combinations of both of these forms are common, e.g. a long-term project that incorporates lots of research elements where new knowledge is continually siphoned into companies' pre-development or product development departments or are introduced into research and education at universities and university colleges. This allows parts of the work needed to reach a specific milestone useful long before the intended market introduction of the finished concept.

When it comes to the results of the programme, FFI is part of the EU Commission initiative entitled “Innovation Union” and shares its ambition to “get more innovation from our research to catch up with our main competitors”. It is not just that more knowledge in general must be gained but also that research results need to be translated much faster into practical applications.

The board of FFI, alongside the programme committees, must fund pioneering initiatives directly. These would primarily be projects which, if they succeed, will lead to major leaps of technology or other crucial changes with relevance for the area. This type of project may also be run by the programme committee. The programme committee also supports projects that are best described as refining (the work of developing further an already used concept or approach) or enabling (activities of a knowledge-building or general nature).

4 The Area's Status and Potential for Development

The traffic situation in Sweden and Europe is becoming increasingly problematic, with congestion, degradation of the quality of life, productivity reduction and negative impact on the environment as a result. Goods transport in Europe is expected to increase by more than 50 per cent between 2000 and 2020[2]. In Sweden, road-based transport of goods is expected to increase by 1.9 per cent per year up to 2030[3]. This will lead to an even higher proportion of greenhouse gas emissions, increasing noise levels, congestion and worsening road safety. At the same, individuals increasingly demand more mobility.

Increases in urbanisation and expected regional expansions also lead to major transport challenges. One consequence is significant time lost during commuter travel. The governmental agency Transport Analysis calculated in a government project in 2011 that the total delay and environmental costs of commuting in Sweden’s three metropolitan regions amounts to SEK 11.5 billion per year. Estimates at the EU level indicate that time lost due to congestion and slow traffic in some metropolitan regions totals up to a couple of hours per commuter per day. Improved individual mobility can be achieved by effective optimisation of the transport system in several ways. For example, communication between the vehicle and the infrastructure and other vehicles (V2V, V2IN) can create an opportunity for new services, which can lead to more appropriate strategic and tactical decisions through different choices of routes. Studies of communication between vehicles, so-called Vehicle to Vehicle communication (VtV), a prerequisite for automation of vehicles, indicate significant benefits for traffic flows because vehicles cooperate and minimise stop times and optimise the interaction between vehicles.

The road network that is used by the transport system is unlikely to grow at the same pace, neither in quality nor scope. This means the capacity and efficiency of goods and passenger transport must be increased within the existing road network. Improving the efficiency of transports is central if mobility requirements are to be satisfied for people and goods, while minimising environmental impact and improving corporate and national finances. Improving efficiency is also a way of achieving political objectives for CO_2 reduction at both the national and the EU level. To achieve the best possible

[2] *Keep Europe moving, Mobility 2030.*
[3] *Swedish Transport Administration; Forecast of goods transport, 2030.*

efficiency in the transport system (passenger and freight), the complete system must be taken into account, including the impact of factors in its surroundings and from associated systems. Transports are affected by social factors (e.g. laws, rules and regulations), logistics requirements (mainly from transport buyers), mobility requirements (from travellers with different vehicles), technology development and infrastructure. At the same time, transports and transport systems drive the development of new laws and regulations, new technologies, new vehicle combinations, and new infrastructure. All this is done in an interaction that complicates the possibilities of influencing transports and transport systems in a certain direction.

Within FFI, we have defined and designated efficiency in the transport system to mean an efficient and sustainable use of time, vehicles and infrastructure for goods and passenger transports. Various stakeholders (car owners, vehicle manufacturers, transport buyers, hauliers and intermediaries and public actors) have similar but not identical views about the concept of efficiency. All stakeholders have stressed the various aspects of the concept “efficiency” in the transport system.

Efficiency for:

- society is to achieve transport policy objectives
- infrastructure managers is optimisation of use of functional and safe infrastructure
- vehicle manufacturers is development of efficient vehicles and services
- hauliers is development and provision of efficient transport solutions
- transport buyers is the achievement of the correct transport quality at the lowest cost
- private motorists and public transport passengers is to be able to arrive on time, at a reasonable cost and with experience of the good journey.

An efficient and connected transport system must be able to address all of the above perspectives.

To meet the challenges facing the transport system, the subprogramme Effective and Connected Transport Systems (EUTS) has chosen to focus on a number of different **arenas or areas** that have different problems, challenges and opportunities linked to the **development trends** we see.

The nature and conditions of urban areas will steer vehicles and regulatory frameworks in one direction, rural areas in another. There will be special requirements on infrastructure in the major freight corridors. Business models need to be developed in the hubs and terminals with the new development trends.

Effective, connected transport systems are developed by their components (vehicles, infrastructure etc.) being affected by development trends (automation etc.) in various ways, depending on where, in which arenas (urban areas, rural areas etc.) they exist. This pressure from development trends in the different arenas drives the changes in components of the transport system. In all, development trends, research needs and arenas are linked in the following manner.

RESEARCH NEEDS:

DEVELOPMENT TRENDS:

	Adapted vehicle concepts	Infrastructure	Business models	Regulations	Vehicle and mobility services	Users in the system
Automation						
Electrification						
Connected services/ digitalisation						
Customised transport solutions						

The focus within EUTS is the development of the components of the transport system in the light of the major development trends. Below follows a short description of the development trends that we see will dominate over the next few years, and how they will affect transport system components. Then follows a description of our view of how the transport system components need to be developed.

4.1 Development trends

There are many challenges in the transport system. Energy use is increasing, and thus the emissions of carbon dioxide, as long as we use fossil fuels. Figures for injured and killed in the transport system are still unacceptably high. The mobility of goods and people, and thus their availability, is inadequate. The Swedish-based automotive industry's competitiveness needs to be strengthened.

We have identified four trends that enable us to approach the objectives we established within these challenges:

- automation
- electrification
- connected services/digitalisation
- customised transport solutions.

These trends affect and change the transport system's components. In essence, we see that the transport system consists of: vehicles and vehicle services, infrastructure, regulations, business systems and people. We also see these transport system components as research and innovation objects that need to be developed to be able to manage the challenges.

Better use of vehicles and infrastructure through new services and business models. Improved utilisation of capacity and better flows on the road and in terminals. New solutions are created, e.g. automated driving, electric roads, electric vehicles, bus systems, High Capacity Transports, telecommuting, connected services etc. Common to these new solutions is that they have the potential for increasing transport efficiency. They have often been created for exactly that purpose. In turn, these solutions require changes to parts of the transport systems; on vehicles, to the infrastructure, to users, to regulations and to business models.

These development trends are general for all sub-programmes. For EUTS, the question is how these development trends can contribute to sustainable solutions at the system level.

4.1.1 Automation

Development of autonomous vehicles has already begun. Various forms of assistance systems for completely autonomous vehicles are already on the market, with adaptations in a number of different industries.

Autonomous driving is easiest to achieve in closed environments where processes are clearly defined. The challenges are greater on public roads and in open environments, and greatest in urban environments.

Automated vehicles offer a great number of opportunities:

- **Improved safety:** Research shows that up to 90 per cent of traffic accidents are caused by the driver.
- **Reduced environmental impact**: With the potential to reduce the number of vehicles and achieve more efficient fuel consumption, autonomous systems are optimised to minimise their environmental impact.
- **Higher efficiency and improved mobility**: Increased automation will allow traffic to flow faster and reduce congestion. Optimised driving can cut fuel costs and CO_2 emissions significantly.
- **Increased comfort:** The driver is a passenger in an autonomous vehicle. This turns autonomous vehicles into an attractive form of transport for the elderly, children and people with physical disabilities who do not have a driving license or have difficulties driving.

But there many challenges remain to be solved beyond the purely technical. These include laws and regulations, acceptance by users, ethical dilemmas and the question of liability in, for example, the event of accidents.

Automated driving will also bring new requirements to the design of both the physical and digital infrastructure.

4.1.2 Electrification

Electrification's obvious advantage is that it can break the link between mobility and fossil fuels because electricity can be generated from many different primary energy sources. Electrification means reduced energy use, because the efficiency of an electric motor is at least twice as high as that of an internal combustion engine. Electrification also means that vehicles can be driven in new environments where there are requirements for zero emissions and low noise levels, and also driven at night in sensitive residential environments.

Electrification of the road transport system follows two main approaches. It can be done partly through on-board energy storage.[4] Such technologies are relatively well proven and are mainly driven by car manufacturers. The second way to electrify road transport is by the energy supply being passed to the vehicle while it is driving (ERS – Electrical Road Systems). This technology is still in its infancy and is especially suited for trucks and buses, which do not have the capacity to carry the amount of energy storage that is required for their operation.

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[4] *EV- Electrical Vehicles, HEV Hybrid Electrical Vehicles, PHEV - Plug-in hybrid Electrical Vehicles, FCEV - Fuel Cell Electric Vehicles.*

Electrification means that vehicle development must go hand in hand with developing infrastructure for transmitting energy to the vehicles. This applies both to development lines and, even more so, to ERS, in which on-board energy storage is basically missing. Transmission technologies for electricity to vehicles in motion is largely untested in real world environments. Available systems are not yet fully developed and new ones are being introduced regularly. Development of interfaces and integration of transmission systems in vehicles is another area where development is incomplete.

To create a functioning infrastructure for charging vehicles, it is necessary to ensure that it is developed to address the needs, both in homes along the roads and in the cities. Important aspects are the availability of space for charging, access to charging systems, traceability for how charging takes place and payment models with good transparency for the vehicle owner/user. Furthermore, good integration must also be ensured between the vehicle and the power grid to achieve a balanced output in relation to access to electrical energy.

Electric roads are a phenomenon which are not regulated in current regulations. Regulations need to be developed based on the limitations and possibilities of the known technologies. Depending on how electric roads are designed, we will need to develop construction, maintenance and operating technologies. Financing and business models for electric roads are other areas that require both research and development. Finally, there is the issue of how electric roads will affect users and their ability to drive vehicles safely.

Limitations: Developing electrification by having on-board energy storage takes place within FFI's programme area Energy and the Environment since this sub-programme encompasses charging infrastructure.

4.1.3 Digitalisation

Digitalisation has previously been about transformation of information into digital form and the introduction of digital technology. In recent years, the concept has been broadened to include increased use of computers and the Internet. We are now facing another big step where the physical world is rapidly being connected to the digital world, called the development of the Internet of Things (IoT). The pace of development in this area has been exponential and is expected to continue to grow very rapidly in the foreseeable future.

The opportunities offered by digitalisation with laptops, tablets, mobile phones and connected vehicles with GPS positioning, together with wireless internet connection and cloud services, means that information is accessible and is expected to be available at virtually any time, anywhere. For the transport system, the digitalisation and new communications technologies offer opportunities for drivers, vehicles, loads and infrastructure to communicate with each other in real time.

Connected services increasingly require a systems perspective to be able to realise the benefits that could not be achieved by developing each component separately. Interfaces need defining and specifications must be established for vehicles and infrastructure to ensure reliable and standardised information exchange.

Digitisation has enabled, and will continue to enable, very rapid technology development. In the automotive industry, one of the more important areas of development will be automated driving. This will make new demands on the design of the physical infrastructure. When fully developed, it may result in different road designs and that certain highway equipment will become redundant, at the same time as other functions will be needed. The development of the technology also provides the opportunity for more automated data capture, analysis and use of information. For example, data about traffic, infrastructure and air quality will be collected via sensors in the vehicle and from infrastructure ("Internet of Things"), and from different "cloud" services, e.g. new traffic management systems.

As stakeholders, vehicles, infrastructure and surrounding systems are connected together, entirely new business models will be made possible. Existing companies will partly be able to develop their business models further, but it will also provide opportunities for new players to come in and challenge with new business models. One example of the latter is Uber, which in just five years has grown phenomenally and challenged the taxi industry in parts of the world.

Digitalisation will also present new challenges. When physical things are connected and can be controlled, there is a risk that people and property may suffer injury or damage when anything goes wrong. Safety is therefore becoming increasingly important in both an encroachment and a robustness perspective. Digitalisation has also meant that information has become increasingly more accessible, is deleted rarely and is becoming more and more detailed. This makes safeguarding privacy all the more important and has led to new and updated laws.

Another problem is that large amounts of data have a low quality or are incorrect. More monitoring, alarm systems, self-healing systems, and increased safety requirements for availability and management can be expected. A more connected transport system can lead to increased vulnerability to interference, and create security problems with new opportunities for terrorism and sabotage.

Limitations EUTS covers the development of connected transport systems, on-line services, associated business models and associated revision of laws and regulations, digital infrastructures and data analysis as a result of these being connected.

4.1.4 Adapted transport solutions

Transports in society have marginally been adapted to specific transport needs, whether discussion goods and passenger transports, vehicles, services or infrastructure. But a system, which in principle is open to all, is forced to make many compromises and the ability to meet special needs is limited. New specialised solutions can be offered to groups with specified requirements with the new technologies being developed (automation, electrification and digitalisation) and by adapting infrastructure and vehicles.

We see it, for example, in customised public transport solutions that combine high capacity buses (BRT) with smaller bus types for increased availability (proximity) in combination with park and ride schemes, new ownership forms for passenger cars in which mix car pooling, private leasing and private ownership, and a broader model range to meet consumer (users') needs. We are also seeing freight transport solutions in cities where the inner city needs for smaller vehicles are combined with larger lorries for transport to large common goods distribution centres (micro-terminals), specific harbour shuttles to reduce congestion and the environmental impact of container flows into and out of port towns, a differentiation of the road network in respect to bridges, load-bearing, safety and accessibility to meet environmental and efficiency requirements for long distance freight transport of both heavier and more bulky goods with new vehicle combinations. New services like Uber, intelligent maps, navigation and traffic information and new opportunities for access control are other examples.

Vehicles that are longer than 25.25 m and/or heavier than 60 tonnes (HCT - High Capacity Transports) may be allowed on the appropriate parts of the road network. This might reduce energy use per carried volume/weight by between 10 and 27 per cent. Much of the current road network is capable of this, allowing a more efficient use of the infrastructure. Limitations are mainly due to the low-traffic routes and some bridges. HCT provides opportunities to meet the expected demand for transport and lower energy use, environmental impact and costs with reasonable investment.

For logistics companies, forwarding agents and carriers, improved accessibility and increased opportunities for more efficient route planning are important for more efficient distribution of goods. It is generally agreed that optimisation of routes has substantially greater potential than optimisation of load capacity utilisation, especially for freight distribution in cities. The consequences of time slots for deliveries in cities needs to be examined as a way of avoiding increased vehicle traffic and lower degrees of load capacity utilisation. Problems and potential related to loading and unloading zones are often discussed when examining access. Increased management and control of regulatory compliance should considerably improve access. Additional examples of heavy transport in urban environments are traffic flows to and from the major ports. Flows are often concentrated to specific routes and frequently present major local environmental, traffic safety and urban development challenges.

Bus systems are also examples of adapted transport solutions. The core of the various systems are high-service level bus journeys. Service level is defined primarily by shorter journey times, higher frequency, good integration and access, and increased comfort. High service level is achieved through better (adapted) vehicles, better (adapted) infrastructure, higher frequency, fewer stops and more direct routes. “Think of tram or metro, but operate a bus” is a good summary of good bus systems.

Another commonly pointed to area is the ability to provide, in a controlled and customised way, dynamically used lanes for different types of transport needs. The industry seems open to meeting demands for increased transparency with authorities and agencies with some form of “monitoring” using modern ITS technology. This would help prevent improper use of these lanes and meet the requirements by the public transport services to avoid impacting the degree of service, punctuality and so on.

4.2 Research needs

Vehicle development will also continue to have a central role in delivering cost effect transport policy benefits. The individual components of the Swedish transport system are well developed, but there is a great potential for improving efficiency at the system level through increased cooperation between the different modes of transport and the use of the most energy-efficient transport chain for each situation.

As it integrated solutions between vehicles and between vehicles and the infrastructure become increasingly common, road safety improves, environmental and accessibility objectives are achieved, and the competitiveness of transport operators improves with new efficient and customised transportation schemes. However, this increases the complexity of development work, with more stakeholders having to work in close cooperation.

4.2.1 Adapted vehicle concepts

Complete vehicle combinations more adapted to their transport task can potentially provide significant increases in efficiency. A first step is more clearly designed combinations adapted to the transport task’s requirements. Designs for more efficient loading and unloading at terminals and for optimised aerodynamics are other important steps.

In addition to reducing fuel consumption and other operational costs, the vehicle combination’s productivity will increase over its lifetime. There is, however, a need for new methods to better understand the carrier’s comprehensive requirements and translate this into standard solutions (“blueprints”) that further optimise the entire combination’s design and operation. Future vehicle combinations and load carriers must also be more adaptable to each transport task and operating conditions (for example operating cycles and manoeuvrability requirements). Requirements for efficient inter-modal solutions will increase, requiring further development of both load carriers and vehicle architecture.

The effects of High Capacity Transports (HCT). These can mainly be found outside Sweden and have developed based on the existing conditions in each country). In Sweden, systematic development has been going on since 2009, especially with lumber transports. Factors for success have included the adoption and adaptation of international advances and verification in Swedish demonstrations. Unresolved issues involve vehicle characteristics and the most appropriate configuration for specific types of goods being shipped. It is also unclear the extent to which the infrastructure will be affected in the long term.

The effects of HCT also need to be reviewed. How do high capacity transports impact other traffic types? How do they impact competition, the environment and so on? The requirements and control systems for operating licenses are important factors for improving HCT safety compared to ordinary traffic. The Swedish system for gaining the right to operate needs developing, including the regulatory framework for the system.

Bus systems can be divided into different types, from priority bus systems to BRT systems with completely separate lanes and frequent direct line departures. Good bus systems require adapting route networks to the existing infrastructure. Planners need to develop their establishment principles, review the design and location of stations and stops, refine prioritisation principles based on surrounding traffic and specify vehicles adapted to the conditions of the bus system.

Passenger transit systems, including buses, cars, taxis and commuter trains, better adapted to variations in travel needs, routes, topography and environmental and safety requirements can reduce costs and increase availability/value of public transport while also improving choice, flexibility and sensitivity to disruptions.

Until now this area has not been so clearly defined for passenger vehicles. In the future, though, it could become more relevant as “mobility as a service” and level 4 autonomous vehicles entering the market.

4.2.2 Vehicle and mobility services

Service and maintenance services

Service and maintenance services are designed to improve the use of vehicles and reduce operating costs by developing technology and services that minimise unplanned stops and minimise the impact of planned maintenance.

Increased logging and follow-up of operating conditions, the status of vehicles and their components intended to anticipate service needs and prevent downtime, are key to improving transport efficiency. This, in turn, requires management and analysis of transport and vehicle data based on data logged during operation, how vehicles are driven, which errors occur and when they occur, whether vehicles are properly configured for the transport tasks and so on. This is resulting a rapidly growing need for logged vehicle data and other data that can give a complete picture of the impact of the driver's actions, data about the transport assignment (weight, speed, topography, climate and so on) and the vehicle's status. It also makes demands on the utilised methods, models and systems approach. The possibility of remote diagnosis, predicting remaining lifespan of components and providing new, more customised and dynamic maintenance services will be crucial in increasing the reliability of the transport system, increasing the use of transport resources and reducing total costs to society and the economy.

Driver support services

Driver behaviour and how transports are conducted has a major impact on efficiency and safety. New opportunities for linking together information from many sources, collecting and analysing large amounts of data and presenting and following up results of driver behaviour with respect to surrounding factors, will drive development of next generation driver support systems. This includes driver training, coaching both in the vehicle and back-office, and various forms of behavioural services intended to develop a stronger safety and fuel savings culture within the organisation. Although navigation, traffic information, fuel efficiency and safety have traditionally been key focus areas, these should also be extended to support, e.g. appropriate driving for reducing wear, increasing productivity, compliance, freight safety and an attractive driver environment.

Services for automation and electrical mobility

The development of technologies, such as automated vehicles, convoy driving (platooning) and other functions for increased vehicle automation, will require parallel development of services that can use these new features to increase traveller and customer benefit and transport efficiency. This requires a greater understanding of when, where, how and with which supporting business model these technologies will be able to create value in the transport system. Similarly, electrical mobility will drive the development needs of new services for the design and monitoring of batteries and their status for hybrid and fully electric vehicles. New models and service contracts that support electrical mobility, charging strategies and services related to planning of charging infrastructure, installation and operation must also be developed. Advanced real-time route planning and optimisation that takes into account the transport task, route, topography range and charging options will be needed to speed up the introduction of electric cars, buses and distribution vehicles and maximise their use. Dimensioning tools for electric bus and distribution fleets for optimising “system benefits” is another service area that is driven by electrical mobility.

Other traffic and mobility services

As vehicles go online, entirely new ways of influencing traffic, freight and passenger flows become possible. There will be opportunities to measure and affect traffic flows in real time using sensors in vehicles and then controlling the digital road infrastructure and, in the long term, even autonomous vehicles. Optimisation of the various components in the transport chain for both freight and passenger traffic make possible time optimisation for door-to-door commuting using multiple modes of transportation. It will also make possible coordinating optimisation of goods and passenger transport together.

New mobility services will emerge. For example, new opportunities will emerge for shared ownership of vehicles and selling mobility as a service instead of the vehicle as a product. As data from vehicles, infrastructure and personal devices can be linked together with data from other industries, new types of services and the ecosystem will also emerge, such as customised insurance policies based on driving style. Other examples of services that the connected vehicle will potentially provide include:

- *Functions for increased road safety (e.g. for autonomous vehicles, connected safety features that warn of future danger, augmented reality)*
- *Reduced environmental impact (e.g. optimisation of control systems for cruise control, reduced emissions within the selected areas via geofencing)*
- *More efficient navigation systems (e.g. dynamic updating of map data, finding available parking, charge station location)*
- *More efficient use of time in the car (e.g. predictive digital assistants, access to the world around via streaming video/audio).*

4.2.3 Transport infrastructure

Road infrastructure

Transport efficiency is, to a large extent, about using roads and infrastructure in a more resource-efficient manner. Both freight and passenger transport is expected to continue to have strong growth through 2030, while major capacity investments in new road or railway are unlikely. The development trends visible to us will affect infrastructure, which needs to be adapted to different transport concepts. The questions are in which ways, to what extent and how it will be possible to integrate the new concepts with regular traffic.

Traditionally, all roads in Sweden in principle have been open for all types of traffic and all kinds of vehicles. Modern technology allows dedicating some roads to certain vehicles under certain conditions (speeds, weights, lengths, dates, equipment, monitoring, safety and environmental characteristics and so on). In this way, opportunities are created to adapt and maintain a road or a road network's quality and increase its capacity. The development trends that we see in automation, electrification and other adapted solutions allow regular traffic to share parts of the transport infrastructure. Therefore, these systems can be considered as step 2 and 3 solutions to a 4-step principle for investment, i.e. adaptation and extension of existing infrastructure. For more advanced bus systems, the infrastructure is exclusive to these systems and thus involves extension or construction of infrastructure — step 3 or 4 solutions.

As autonomous driving develops, it will also offer new opportunities. The road space can be used more optimally, traffic can be packed more densely and lanes may be made narrower. This likely benefits large urban areas most where traffic congestion and more densely built up areas endanger the values that attract people to cities (green lungs for example).

Electrifying roads are another way of safeguarding infrastructure investments that have already been made and using them in an energy-efficient way. Electric roads can meet future demand for transport at a low cost and relatively quickly. This makes them a good complement to existing infrastructure.

The strategic initiative FIFFI (Vehicles and Infrastructure within FFI) is exploring possibilities of developing concepts that adapt vehicles and infrastructure to each other. High Capacity Transports (HCT) build on the fact that the larger a vehicle is, the lower the energy use per carried unit of goods. Up to 30 per cent less if standard European semi-trailer rigs (40 tonnes gross weight) are replaced by double trailer road trains of up to 80 tonnes gross weight.

In cities in particular there is a need to upgrade transport systems and adapt them to urban conditions and the demand residents make for a city that offers quality of life. Both bus and freight systems within cities can take advantage of such new technologies as electric vehicles and electric roads connected to modern logistics systems reduce traffic volumes and emissions. But this requires developing and installing the infrastructure for rapid charging of electric and hybrid vehicles.

It also requires research into how developed areas and infrastructure affect the energy use in the transport system. It also requires demonstration of how communities can be planned to allow for more energy-efficient and sustainable transport patterns while maintaining accessibility. Knowledge about these related connections exists but considerable research is needed to translate this knowledge into practice. We need to analyse whether there are organisational, political, technical or other problems that prevent the building of transport-efficient societies and to study how successful processes have been attained.

EUTS development of infrastructure refers to the functional requirements specification needed to ensure efficient interaction between infrastructure, new vehicle concepts and adapted transport solutions. It does not include physical conversion for the adaptation of road infrastructure, for example, to cope with new vehicles or transport concepts. Infrastructure includes more than just road design. It also covers how road equipment beside and on the road is affected (both digital and analogue), such as metal signs, VMS signs, signals and motorway control systems. Development of interfaces between traffic management systems and vehicle-based systems, including cloud-based information, is also included.

This is the only sub-programme in FFI that is working at system level where the road infrastructure is included.

IT infrastructure

Stakeholders, vehicles, physical infrastructure and surrounding systems will be linked via an IT infrastructure in the connected transport system. The design will be affected by the overall objectives, laws and regulations, surrounding systems, standards, and the specific services it is to support. These functional and non-functional requirements will form the basis for both its architecture and detailed technical solutions and properties. The design will then, in turn, also impose requirements on how the constituent parts of the transport system should be designed. A systematically developed requirements list does not currently exist, and therefore nor do the prerequisites for what this IT infrastructure will look like.

Some other dimensioning issues are:

- The extent to which it should be decentralised/centralised, for example, which components will be used in the vehicle, the vehicle manufacturer's cloud, industry-specific clouds or service provider clouds?
- To what extent should it be open/proprietary?
- To what level of QoS should it be developed (e.g. real-time aspects, reliability, availability, bandwidth)?
- Which APIs should be provided for integration with surrounding systems? (e.g. data and meta-data)
- How long should data be stored for later use?
- Which business models should it support?
- To what extent should it be able to manage information about and control of traffic and physical road infrastructure?
- The right to available information, who owns it and how will it be used?

IT infrastructure should also allow for the collection of data in real time and analysis of large amounts of data (Big Data) in both real time and as historical data. These will be central issues for many service areas. It will also require development of methods, models and analysis tools that can industrially process the data into information and services that can contribute to increased transport efficiency.

Limitations: EUTS focuses on developing an IT architecture that supports connected vehicles, transport infrastructure and their connection to surrounding ecosystems.

4.2.4 Regulations, standardisation and the law

Regulatory control is strong, making it potentially important for increasing the efficiency of the transport system. Regulations are basically agreements for how and in what form the transport system and its components may be used. This means that the regulatory framework must be adapted as technology, services and human circumstances develop. New circumstances create new conditions for regulations.

But it is also possible to reverse this argument. Changed regulations both open and close doors on opportunities for new technologies and new services. In this respect, regulations act as standards;

they both create and restrict renewal opportunities. This means that regulations can be treated in the same way as the other parts of the transport system. Their functionality and suitability can be considered and developed from a transport efficiency perspective.

Current regulations in the area of transport reflect all aspects of safety and the environment, in combination with the ability for people to comply with the regulations. So, developing regulations on the basis of transport efficiency is a development area in itself. It is highly complex, with many stakeholders involved, such as vehicle manufacturers, suppliers, authorities, legislators, academia, freight forwarders, hauliers and operators. They all have views on how the regulatory framework should be designed, compliance should be checked and sanctions imposed.

A number of regulations are affected and need to be reviewed. Traffic regulations, vehicle regulations and road marking regulations are considered the most important. The regulatory framework governing infrastructure design is also important in the form of RSD (road and street design). RSD sets parameters for the Transport Agency but is also applied by local authorities, it contains geometric design but also traffic signals and certain types of road equipment. “TRAST” is another document (Traffic in an attractive city that regulates the traffic in built-up areas). Municipal transport strategies can also be interesting where they control how street space should be used and for what purposes. In addition, PUL, the Personal Data Act, is also affected. The impact of the regulatory framework at EU level is discussed in another document.

In automation, liability in the event of any accident has not been regulated. Should the driver or the developer of the algorithms for automated driving be held responsible? Electric roads do not yet exist as a phenomenon in any regulatory framework and issues of safety and liability are largely unregulated. Within High Capacity Transport, a full development programme is being conducted with the aim of acquiring the knowledge necessary that will allow the development of regulations, so that HCT can be used on parts of the Swedish Road Network. Connected services require regulations to be able to handle privacy aspects. What information about road users is essential for the development of new services and under what conditions may this information be used? The relationship regulations have to transport efficiency is uncharted and there are a lot of questions.

Civil law and administrative law

Many new services and products may be developed, used and marketed by several operators. These may be subject to different forms of legislation and/or have conflicting commercial purposes. Uncertainty about legislation can inhibit service and product development and business development within the area.

Potential research areas include:

- Knowledge and development of models and structures for the easy establishment of agreements between multiple parties.
- Studies of liability and contract law questions related to complex products which may be implemented in safety-critical vehicle and traffic applications.
- The right to access, use and dissemination of information linked to drivers and vehicles by public authorities and other parties. These issues are interesting for both Swedish and EU legislation.

4.2.5 Business models

To put it simply, business models can be explained as how organisations create, capture and distribute value. Some models are addressed more at explaining which stakeholders are involved and what transactions occur, while others focus on how value is created and how to organise it.

Currently, business models linked to new innovative technology are a popular topic. Business models often need to be revised for innovative new technology to have a lasting impact on the market. It may be unclear how value is created and captured, as well as which stakeholders are involved. This makes it important to examine the impact on the business model early and in parallel with ongoing development of the technology.

All of the stated areas of development (automation, electrification, connected services and adapted solutions for transport) are areas in which business models need to be examined, demonstrated and developed. Digitalisation creates increasing complexity as more and more stakeholders, such as OEMs, suppliers, authorities, legislators, academia, freight forwarders, hauliers and operators) will need to interact in a completely different way than today. This has been a limiting factor in the introduction of new services.

The benefit/potential from research reports has been verified far too rarely in practical demonstration testing. Business models are often not possible to verify before late in the process, which means that commercial operators wait until a very late stage to take financial ownership for a new service. As the automotive industry is relatively mature, exposed to competition and involves considerable long-term investment, it intrinsically cautious about adopting new business models that initially usually involve increased risks.

4.2.6 Users in the system

Technological developments are rapidly taking place. Automation, electrification, digitalisation and adapted transport solutions are seeing particularly fast development. Changes at the system level bring with them new demands on users. New technologies must work and must be adapted to drivers' possibilities, wishes and expectations and to societal requirements if they are to be successful. With the new types of vehicles and their possible introduction on a large scale, a number of questions arise about how people can and cannot use them. Operation of the actual vehicle changes. People have different attitudes toward technological changes and to computers, digitalisation and social media. This shows how different we are and how differently we assess and adopt new technologies.

Automation, platooning and driver support services need to be studied from a user perspective. The starting point could be organisational or behavioural aspects and how they affect possible implementation.

Over the next ten years, increasing numbers of heavy goods vehicle and bus drivers need to be recruited, and the availability of trained drivers will be a crucial question to solve. Professional drivers have many different jobs, requiring many specific skills. New solutions — electrical, autonomous, HCT vehicles and platooning — will result in completely new roles for drivers, but also completely new situations. In addition to improved traffic solutions, connected vehicles will result in of new services. In future, most traffic information will be digitalised and made available in real time. ICT solutions will create opportunities for drivers, in conjunction with others, to be able to create additional value for transports.

Increased productivity in the transport system is necessary. Is it possible to create value through new tasks during the journey? Analysis and research are needed about where and which tasks should be carried out, among other things, as a result of the new technology. How can new tasks be allocated between drivers and traffic management, and how can they be supported in the system, including through the use of planning tools and traffic control. How does this affect productivity of new information, new technologies, new equipment and more collaborative partners that provide an opportunity for new services?

Increased digitalisation opens up opportunities for new services that can increase productivity. But online registering information exchanges and positioning of connected objects creates new opportunities for follow-up and monitoring. At the same time as the information becomes important for the individual and for companies, it may be perceived as being negative for employees and can reduce the appeal of the driver profession by increasing stress on the parties involved. If privacy aspects cannot be handled in a socially acceptable way, this may delay introduction of the connected transport system. At the same time, legislation has difficulty in keeping up with digital developments.

Driver behaviour is affected by and impacts many areas, such as working environment, responsibility, safety and the environment. It is important to understand how the connected vehicle benefits the drive in the form of information about new destinations, intelligent routing, speed adjustment and vehicle operating condition, among other things. What are the benefits, do they lead to less stress, increased safety and does this lead to better fuel economy and reduced environmental impact? Can the next generation of apps be used for future improvements, such as traffic management, queuing systems, parking routing and providing the vehicle access to the different parts of the transport system (QTS – Qualification Transport System)?

Safety in and around the vehicle is an important area and more knowledge about this is needed, both to protect drivers and goods. Each year there are many work-related accidents, some fatal. Driver behaviour is largely the cause of these accidents. Many factors affect driving and create stress, e.g. delivery schedules and traffic situations. Research is also needed on how to support drivers when faced with threats and threat scenarios and on how changing behaviours and using new technologies can impact safety. How does this, in turn, affect the working environment of the entire system (individuals – vehicle – roads – loading – unloading)?

5 Future Milestones

FFI will contribute to reducing deaths and injuries in traffic and reducing the environmental impact of road transports. Since FFI in Swedish stands for “vehicle strategic research, development and innovation”, it is natural that FFI’s efforts are essentially *about vehicle-relevant activities in early phases of development*. The results will be used by the participating companies in their development of new or improved products and services. In projects involving academia, the new findings will be utilised in graduate-level research and as new instructional material. With the EUTS sub-programme, the transport system is considered from an overall perspective, in which policy issues and the opportunities for inter-modal transport are also of great importance.

To illustrate what FFI-supported development can lead to, three different future milestones have been defined based on when the anticipated market introduction of new technologies or new services will occur. These milestones are based on the expected market introduction of new technologies or new services. The three milestones in FFI EUTS are:

- Milestone 1: 2020 – The connected transport system
- Milestone 2: 2025 – The integrated transport system
- Milestone 3: 2030 – The automated (digitalised) and electrified transport system.

The different steps are described in more detail in the following sections and for each concept.

An overall road safety objective is specified for each concept. There is a theoretical measure and a rough estimate of the effect if all vehicles and all infrastructure take full advantage of the technology found in each milestone and if all of society actively develops the area.

By speaking of overall objectives, in this roadmap we mean objectives that FFI aims to achieve. These objectives are written at the societal level and require more factors or stakeholders than those at FFI’s disposal and working in the same direction. The overall objectives also assume that the technology is used in its intended manner and that the vehicles and road transport system are used in accordance with the intentions of current provisions.

Figure 2 shows the steps of the development chain of a new product or service from concept to market introduction. These are used in the following to show an overview of the time periods that the different steps dominate for each milestone and area.

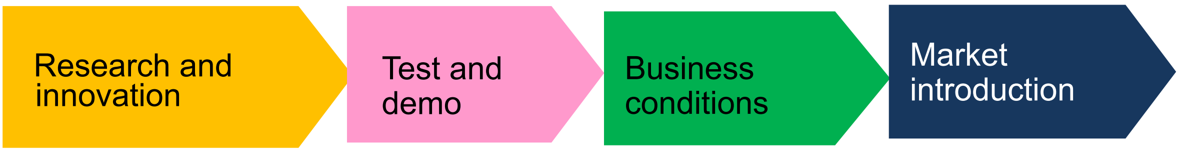

Figure 3. *The different steps within FFI.*

*** Business conditions are understood to mean regulations, legislation, standardisation, industrialisation (suppliers, production, after sales), business models, business partners/ecosystems, market channels.*

We have highlighted challenges and examples of relevant research areas within the identified sub-areas. In certain cases, the sub-areas are broken down into a further step. Table 1 provides a general description of what is required to achieve the various overall concepts and milestones.

5.1 Roadmap milestones

5.1.1 Automation

Milestone 2020 *The connected transport system*	**Milestone 2025** *The integrated transport system*	**Milestone 2030** *The automated and digitalised transport system*
1. The pilot project with lorry platoons in scheduled traffic with partially adapted infrastructure and first-generation support services, business models, standards, regulations and driver requirements. **2.** Pilot projects for autonomous marshalling and operation of lorries and construction machinery within demarcated terminals and mines (quarries) with supporting local IT infrastructure. **3.** Automatic guidance of buses towards bus stops **4.** Technology and services for passenger cars, tested and demonstrated in traffic	**1.** Platooning in varying traffic conditions, services for formations and payment flows commercialised. National (EU) standards and regulatory frameworks **2.** Driverless transport within mines and quarries. **3.** Pilot projects with partially automated buses on appropriate infrastructure. **4.** Automated passenger vehicle traffic on semi-urban, dual carriageways (commuter areas). Stretches of Gothenburg – Malmö – Stockholm adapted for autonomous driving (level 4)	**1.** Fully built-out platooning between large freight nodes with adapted infrastructure, advanced services and functioning business models and established international standards and regulations. **2.** Fully automatic terminal marshalling and mine transport **3.** Highly automated vehicles (level 4) in general traffic. Driverless passenger cars and buses on selected routes with the support of optimised traffic management systems in urban areas

5.1.1 Electrification

Milestone 2020 *The connected transport system*	**Milestone 2025** *The integrated transport system*	**Milestone 2030** *The automated and digitalised transport system*
1. Standardised payment systems for "electrical tank filling" of passenger cars. **2.** Fully electrical commercial bus system available in multiple cities **3.** Needs and requirements for the charging infrastructure. **4.** Demonstration of electric roads 2.0 **5.** The basis for implementation strategies for electric roads is available.	**1.** Closed "point to point" systems (corridors) for totally or partially electrified heavy traffic demonstrated **2.** Basis for planning the first major electric road is available.	**1.** An electric road connection between two large communities is in operation. **4.** Commercially viable systems for dynamic charging during driving are demonstrated and evaluated on a large scale on public road, which has provided the necessary knowledge used for decisions about further investment.

5.1.2 Connected services (digitalisation)

Milestone 2020 *The connected transport system*	**Milestone 2025** *The integrated transport system*	**Milestone 2030** *The automated and digitalised transport system*
1. Logistics Services for increased capacity utilisation, fewer empty transports, better adapted frequency, routes and bus sizes suited to the flow of passengers are demonstrated. Better use of distribution vehicles over the day with off-peak deliveries demonstrated. **2. Vehicle control** Reliable and rapid communication between vehicles and the control technology is developed and tested. **3. Road traffic management (RTM) for cooperative and self-driven vehicles** Requirements analysis RTM for road trains and autonomous vehicles is produced. **4. Mobility services** Control of access to transport routes with specific conditions developed and tested. **5. Booking services for loading/unloading, slot times/parking and waiting sites** Solutions for control of access to sensitive urban areas (geofencing) tested. Safe and bookable drive and ride car parks tested. Structured collection and utilisation of sensor data for traffic conditions, air-quality, speeds, infrastructure quality, roaming delivery/delivery directly to the vehicle. **7. Access control** (geofencing) tested in sensitive urban settings, e.g. for transition to electric operation. **9. Traffic management** Fast and reliable communication between vehicles and the infrastructure demonstrated, enabling autonomous vehicles. **10. Prediction** Pilot project for personal digital assistants in vehicles.	**3.** Demonstration projects for road traffic management for autonomous vehicles on selected stretches of road. **4.** Control of access to tunnels/roads/bridges on limited sections. **5.** Individually adjusted tax/insurance tested. **7.** Access control is used on a small-scale for selected areas. **8.** Connected cars as standard enable a wide use of vehicle data for the analysis of, e.g. traffic data, traffic safety, weather data and road maintenance requirements. **9.** Demonstration projects for traffic management by autonomous vehicles on selected road stretches. **10.** Personal digital assistants as an option in all vehicles. **11.** Pilot project for the technology to ensure privacy.	**9.** Traffic management and flow control of autonomous vehicles on selected routes and in selected areas.

11. Privacy. Demonstration of technology to ensure personal privacy of connected cars.		

5.1.1 Adapted transport solutions

Milestone 2020 *The connected transport system*	**Milestone 2025** *The integrated transport system*	**Milestone 2030** *The automated and digitalised transport system*
1. HCT demonstration phase completed and a basis for the new regulatory framework in place. New load class intended for 74 tonnes. Swedish PBS system accepted and adapted and safe vehicle combinations are tested on the road and evaluated. **2.** BRT/bus system (vehicles, infrastructure, services) as a complement to other local/regional public transport solutions demonstrated. **3.** The first corridor (port, dedicated commuter train etc.) with partially separated lanes and shuttles for heavy transport demonstrated. **4.** The demonstration of business models and IT support that stimulate coordination and reloading of goods transport.	**1.** HCT introduced on small parts of the Swedish road network. Volume and weight-optimised vehicle combinations for parts of the road network with support of PBS regulations and intelligent access-control. **2.** Adapted terminals for more efficient transfer of goods and people in and around urban areas. **3.** Stretches of Gothenburg - Malmö - Stockholm routes adapted for autonomous lorries (level 4) **4.** Goods transports use energy-efficient transport systems and the majority of all cargo carriers, vehicles and vessels are designed for use in intermodal transport chains without special adjustments or extra investment.	**1.** Fully introduced PBS regulations for many specialised combinations on major parts of the road network with a fully developed and automatic access control. **2.** Partial payment-controlled systems for multimodal transport in cities that use public transport, car-pooling, bicycles and so on to most effectively resolve the city's mobility needs. **3.** Control tower traffic management of all heavy traffic around ports and other urban logistics centres with slot-times and fully synchronised with the available capacity of transport systems and terminals

6 The Project Portfolio and Priorities

The diagram below shows the budget distribution between the roadmaps programme area today and the priority set by the programme committee for achieving the EUTS milestones.

Distribution of the budget between the programme areas (%).
Outcome and the desired position 2030.