Business models and financing for the development of electric roads in Sweden

Final report

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SUMMARY

The impact on the climate of road transport is significant, and one of the major challenges to reducing the overall negative effects on the environment and the climate is to reduce the impact of road transport. One of several solutions to achieve this is the electrification of roads. To introduce systems for electric roads requires an analysis of the electric road market, its participants, as well as possible business models, financing solutions and organisational solutions that can be used as a basis for future decisions on development.

Since electric roads for heavy vehicles are still a relatively new type of installation, there is still no established market, which makes it difficult to draw complete conclusions about the business conditions. The proposals for business packages that have been drawn up appear to provide suitable methods for analysing the market and have gradually proved reasonable based on the interviews, meetings and workshops that have been conducted. There is considerable interest in the market for electric roads, and it can be noted that there are private parties interested in different parts of the electric road system, i.e. the various business packages.

During a transitional period, and at an early stage of a future development, government support could be appropriate, e.g. by guaranteeing a certain volume of traffic on the section of electric road or by subsidising the purchase or leasing by carriers of vehicles adapted for electric roads.

EY's assessment is that there are good prospects for the development of electric roads in Sweden, although a lot of work will be required in the form of tests, pilot projects and inquiries before a fully developed large-scale electric road system can become a reality. By means of a declared interest and ongoing inquiries and investments by the government there are good conditions for encouraging and promoting private development as well, which will be required to realise the development of electric roads.

The report is a final report from EY, which was awarded the assignment by the Swedish Transport Administration in February 2018 to analyse possible business models for the development of electric roads, mainly for heavy transport.

Introduction to electric roads

Electric roads can be described as roads with infrastructure for electricity transmission that can supply a vehicle with electricity while moving (so-called dynamic charging. Incorporating the technology into road infrastructure means that the roads can be made available both to vehicles that use electricity transmission as well as to vehicles powered by other fuels. There are three main technologies for dynamic electricity transmission:

- Conductive transmission through overhead lines
- Conductive transmission via some form of rail or conductor in or on the road
- Inductive transmission through electromagnetic fields from equipment in the road body

The electric road system can be described in four parts:

1. Existing electricity grid infrastructure - current structure for electricity grid, connection point and electricity grid along the road that supply the electric road with energy
2. Electric road – the technology for power transmission to the vehicle including utilisation measurement system
3. Related services – road fee service, information management, access control
4. Areas of responsibility – maintenance, operation, financing and ownership

Market participants and roles
Several different participants need to interact in a functioning electric road system. The different roles in an electric road system consist of transport purchasers, carriers, vehicle manufacturers, electricity suppliers, electric road operators, electricity grid companies and managers of road infrastructure. All roles, apart from the electric road operator, are already represented through participants in the market.

A description of the dependency between the roles can be a transport purchaser engaging a carrier to drive a product from A to B. In order to use the electric road, the carrier needs a vehicle adapted to the electric road, which is provided by a vehicle manufacturer as well as an electric road, which is provided by an electric road operator that may be same as the manager of the infrastructure or a separate participant. In order for the electric road infrastructure to work, the electric road operator must be connected to the electricity grid through a distribution system operator as well as have access to electricity through an electricity supplier.

Overall costs
The costs associated with the development and operation of an electric road system are uncertain because the technology is relatively new and has not yet been tested on a larger scale. The development of electric roads drives investment in both electric road infrastructure and electricity grid infrastructure. In addition, the vehicles need to be adapted to the electric road, and a cost for electric power and electricity grids when using the electric road is charged, which also affects the cost structure. The investment required in infrastructure for power transmission amounts to between 9-35 MSEK/km depending on the choice of technology and interpretations of what is included in the investment.

The investment cost for developing the electricity grid amounts to approx. 4-8 MSEK/km depending on the length of the section of road electrified, the number of transformer substations required and the capacity the grid needs to be able to handle. The additional cost of vehicle adaptation amounts to approx. 0.5-0.8 MSEK/vehicle, and the charges for electric power and electricity grids when using the electric road are estimated at 0.7-1.6 SEK/km driven.

Payment model and pricing
The payment model for an electric road system needs to include payment for the use of the electric road infrastructure, the consumption of electricity and the connection to the electricity grid, as well as vehicles and pick-ups. There are several possible payment models for each stage of the business, which is affected to some extent by laws and regulations such as the Electricity Act and the Eurovignette Directive. One possible payment model is that the carrier pays an electric road fee to an electric road operator who, in turn, pays the distribution system operator and electricity supplier for distribution and electric power. Payment for vehicles and pick-up is assumed to take place separately.

The price using the electric road may or may not be regulated. At a market price, it is reasonable that the price for using the electric road, including electricity consumption, approaches but does not exceed the effective price per kilometre for an alternative fuel including the additional cost for the vehicle.

Possible business packages
Based on the overall size of the electric road system, four business packages have been drawn up, where the different physical components and services have been packaged with the aim of developing commercially viable businesses. The four business packages are:

- **Business package 1: Electricity grid extension**, which consists of the connection point for the electric road and electricity grid along the road
- **Business package 2: Electric road infrastructure**, which consists of the technology for the transmission of electricity

- **Business package 3: Vehicle adapted for the electric road**, which consists of the vehicle, pick-up and utilisation measurement system
- **Business package 4: Metering and payment system**, which consists of system for metering usage, payment service, information management and access control

These business packages should be seen as a first step towards future businesses and may well have a different appearance when it comes to the actual development, both in terms of content and implementation.

Financing

The development of electric roads requires extensive investments that are not necessarily part of the public sector's responsibility. The government has traditionally had responsibility for road infrastructure while private market operators take care of fuels. Electric roads can be said to combine these two systems and there is therefore no party that should obviously take overall responsibility. There is a declared interest in investing in an electric road development from parties such as pension fund managers based on the meetings and reference group meetings held during the investigation.

Traffic volume is considered to be the most important parameter for creating an economically sustainable business estimation for such an investment. At an early stage, some form of subsidy, guarantee or similar will probably be needed from the Swedish Transport Administration or the government in order to increase interest for external parties to invest in electric road technology. Examples are volume guarantees, i.e. that the government covers revenue up to a certain volume of traffic if the outcome is lower when the electric road has been developed, or provide support for the purchase of vehicles such as in Germany, where subsidies of EUR 40 000 are granted for the purchase of trucks powered by electricity or fuel cells.

For the sections of the electric road that qualify for government involvement, alternative financing solutions may be appropriate with a private financing component. Private funding should then be primarily seen as a way of distributing risks between different parties, and the often higher capital cost than when funding via the Swedish National Debt Office can be seen as a risk premium for the government to set a clear limitation on its cost outcome with electric road investments.

Concession or public procurement

For the sections of the electric road that the government may take responsibility for, either concession or public procurement can be considered as a form of procurement. Of the four business packages, it is mainly Package 2, Electric road infrastructure, where a public principal appears to be suitable, e.g. the Swedish Transport Administration, and in such a case it may be procured as a concession or through public procurement.

In a pilot phase, both concession and public procurement may be appropriate, while concession with transferred commercial risk should be most appropriate in the long term in a large-scale development. At an overall level, it can be concluded that procurement procedures appropriate for a higher level of uncertainty and innovation potential should be considered for procurement of the electric road infrastructure. However, the choice of procedure needs to be preceded by an in-depth feasibility study, which is not included in this investigation.

Innovation procurement described in the report could be tested for the development of electric roads since the market has great development potential and it is important that the solution procured supports further development, in particular during a pilot phase but also at a later stage.

Recommendations for further work

During the investigation, a number of areas have been identified where further examination is needed to assess whether, and if so how, the development of electric roads may be affected. Above all, a supplementary and in-depth feasibility study is recommended for the construction of the future pilot facility to answer questions in more depth about technology choices, costs, risks and their distribution, as well as funding and procurement. A subdivision of the pilot facility according to the business packaging drawn up is suggested although it needs to be evaluated during the feasibility study, as it is not necessarily appropriate in practice, even though it has been found to be plausible in this investigation.

Other recommendations for further investigation are:

- Continue to carry out demonstration projects and pilot projects
- Test a suitable form of connection to the electricity grid for the electric road
- Continue to investigate future development of electricity taxes
- Continue to investigate legal aspects
- Pursue the issue of standardisation of electric road technologies

EXPLANATION OF TERMS

Term	Explanation
Carrier	The user of the electric road, road transport supplier
Pick-up	Component on vehicles that picks up electricity
Consortium	Association of several parties
Demonstration section	Section of road intended for testing electric road technology
Dynamic charging	Charging the vehicle while moving
Electric road installation	The electric road with associated components (but not necessarily including the road infrastructure)
Electric road operator	Party that operates the electric road (but not necessarily including the road infrastructure)
Electric road provider	Suppliers of electric road technology
Electric road technology	Technology for how electricity transmission takes place
Electric road fee	Fee from carrier to electric road operator to utilise the electric road infrastructure
Distrib. system operator	Owner of electricity grids
Electricity supplier	Electricity supplier, seller of electricity
Pilot section	Section of public road intended for testing of the electric road
TRL	Technology Readiness Level, scale of how well-developed a technology is, between 1-9

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1 INTRODUCTION

1.1 BACKGROUND

The impact on the climate of road transport is significant, and one of the major challenges to reducing the overall negative effects on the environment and the climate is to reduce the impact of road transport [1]. By 2030, transport assignments in Sweden are expected to increase by 25% compared with 2010 [2], while Sweden has a target to reduce emissions of greenhouse gases from domestic transport (excluding aviation) by at least 70% by 2030 [3]. By 2045, Sweden should not have any net greenhouse gas emissions. One step towards achieving Sweden's ambitious climate target is therefore the electrification of road transport by means of electric roads.

Sweden, Germany and the USA are currently at the forefront regarding the demonstration of and research into electrified roads [4]. In Germany, three pilot sections have been decided on that will be built in the coming years [4, 5, 6]. In Sweden, there are two demonstration sections to date based on different technologies, one on the E16 with Region Gävleborg as principal and one in Rosersberg outside Arlanda Airport with a consortium as principal [7].

The Swedish Transport Administration is currently procuring additional demonstration sections and in the Government's decision in the National Infrastructure Plan for 2018-2029, the Swedish Transport Administration has been commissioned to develop an electric road and put it into operation as a pilot section by 2021 [8]. The government funding of the pilot section requires significant co-financing from business by limiting government funding to a maximum of 50% of the total investment needs and a maximum of SEK 300 million.

The Swedish Transport Administration's work on electric roads is organised within an Electric Road Programme that, in addition to the ongoing test sections of road, is also investigating a number of areas such as environmental impact, power supply, operation, maintenance and regulations in order to build an overall profile of the conditions for electric roads in Sweden [7]. Since 2016, research has been conducted through a research platform for electric roads that is aimed, amongst other things, at clarifying the conditions and benefits as well as to draw up proposals for implementation strategies, regulations and success factors for high acceptance [9]. The focus in the Electric Road Programme and in this investigation is on heavy transport, which accounts for about 20% of greenhouse gas emissions from road vehicles [10].

In November 2017, the Swedish Transport Administration submitted a roadmap for electric roads to the Government [11]. The report highlights how different factors such as the choice of technical solutions, ownership models, financing models and cooperation between private and public parties will play a crucial role in how successfully electric roads can be introduced in Sweden on a large scale. The report also highlights challenges of being too dependent on getting bogged down in previous structures, which may tend to divert attention away from new innovations.

Therefore, for Sweden to achieve its ambitious climate targets, despite increasing road transport, requires in-depth analyses of the electric road market, its participants and possible business models, financing solutions and organisational solutions that can form the basis for future decisions. In February 2018, the Swedish Transport Administration commissioned EY to analyse possible business models for the development of electric roads in Sweden.

1.2 Purpose and scope

The purpose of the assignment is to investigate and propose possible organisational and financing solutions for the development of electric roads for heavy transport and what the management implications are for the Swedish Transport Administration and the government.

The assignment also includes:

- Identify and describe the participants that may be included in a future electric road market
- Analyse and propose possible organisational models for providing an electric road system
- Analyse and propose financing and business models for the development of electric roads
- Consider how types of procurement such as innovation procurement, innovation partnerships, and concessions with different elements of technology development and innovation can be used to promote the development of business models for electric roads
- Add international experience into the work above

An important prerequisite for the investigation work has been to not only assume a traditional government undertaking for the transport infrastructure but also to conduct an open-ended investigation into how an electric road system could be developed in Sweden. One starting point has been to find solutions where private parties continue to take a significant responsibility for the supply of fuels such as today.

In terms of timescale, the investigative efforts focus on the development of electric roads in a phase between the first demonstration projects and a large-scale development in a mature market. In the cases where the time perspective is assumed to influence conclusions and reasoning, there is an account of in what way and what conclusions apply to what perspective.

Overall, the starting point has been an open competition-neutral electric road system on a large scale and, to a certain extent, in a pilot phase taking into account existing laws and regulations, including EU law on transport infrastructure and government aid rules. Open system means that it is open to different participants in the market, as opposed to internal systems that exclusively provide for predetermined participants, e.g. within a larger logistics centre. Internal systems can be important both from an emissions perspective and to test technology. However, they have not been specifically investigated during the assignment.

1.3 Definitions

In this investigation, electric roads are defined as dynamic transmission of electricity for propulsion and charging while travelling, i.e. charging of the vehicle while travelling and non-stationary charging through different types of fixed charging infrastructure. In the assignment, the starting point consists of electric roads intended for heavy transport mainly outside cities. The different electric road technologies can also be applied in cities and some even for passenger cars, but this has not specifically been taken into account during this investigation.

The assignment does not include an investigation of regulatory aspects for electric road systems, which is investigated separately by the Swedish Transport Administration. During the investigation, a number of different regulations and laws have proved to be of significance in terms of how the development can be organised and financed regarding, amongst other things, electricity grids (e.g. Electricity Act, the IKN Regulation[1]), legislation in the planning area (e.g. Road Act, Planning and

[1] A government regulation allowing for exemptions from the electricity legislation's requirement of electricity grids to be based on concessions.

Building Act and Environmental Code) and EU legislation (e.g. road charges). In some cases, current regulations have been briefly described without more in-depth assessments or interpretations of their content.

Despite the many ongoing efforts to develop and expand electric roads, they are still relatively new, the market is immature and there is a great deal of uncertainty about future developments. To investigate and propose appropriate business models may therefore be considered as early at this stage, in particular since access to data and experience is limited. However, several important principles for the continued development can be established, which is what this investigation has focused on.

1.4 Method description

The assignment was conducted in February - June 2018 and has been carried out in five overall phases:

1. Project establishment
2. Definition of technical solutions and identification of market participants
3. Analysis of business models, financing and organisational solutions including the following analyses
    - Costs
    - Payment model
    - Overall models
    - Risk analysis
    - Alternative funding
4. Consideration of appropriate procurement types
5. Reporting of results

The work has been carried out by means of studies of previous investigations, around 15 interviews and meetings with different market participants and experts in different areas, two workshops, two large reference group meetings with the Swedish Transport Administration and external participants, as well as meetings and exchanges with researchers in the field. During all interactions with market participants and others, knowledge, experience and interests have been accumulated which have formed the basis for the analyses. The work has been carried out in close cooperation with the Swedish Transport Administration and weekly work and status meetings have been held throughout the duration of the assignment in order to continuously report status and discuss ongoing activities.

1.5 Report orientation

The results of the investigation are reproduced in this report and the contents of each chapter are described in detail below. Chapters 2 and 4 and parts of the contents of Chapters 3 and 5 are based on previous research and studies, while Chapters 6-11 are based on new findings that have been made during the investigation.

2. Introduction to electric roads – Initial introduction to what electric roads are, the different technologies available, and international experience. An overall description of the electric road system as a whole has then been drawn up in order to create consistent terminology for the system's components and services.

3. Market participants and stakeholders for electric roads - Potential participants in an electric road system are identified and described and a proposal for how different roles can be defined in an electric road system have been drawn up.

4. Overall costs for the development and operation of an electric road system - Overall costs for investment and maintenance costs have been identified based on available sources and, to some extent, information from manufacturers.*5. Payment models* - Possible payment models are described based on previous studies, and a number of criteria for the appropriate design of payment models for an electric road system have been drawn up.

6. Possible business packages for the development of electric roads - Proposals for possible organisation of the development are described through a number of business packages into which the electric road system can be logically subdivided. Each business package is described on the basis of components, potential supplier, customer, risk exposure, payment model and any other considerations.

7. Risks and areas of responsibility concerning electric roads – A comprehensive risk analysis has been conducted through a valuation of risk categories and an assessment of how the different technologies affect the risk profile. An allocation in principle of risks and responsibilities has been developed based on the risk categories that should be divided between the government and private market participants.

8. Financing of electric roads - The possibilities for financing solutions for the extension are described in an overall manner, including the conditions for private investments in a Swedish electric road development.

9. Consideration whether public procurement or concession is appropriate for the development of electric roads – Consideration whether public procurement, concession or other solutions are plausible for the development of electric roads is made for each business package. Innovation procurement and a number of procedures are identified as plausible for the cases where procurement or concession appears appropriate for parts of the electric road system for which the government or the Swedish Transport Administration may be assumed to be responsible.

10. Conclusions – The conclusions of the investigation are summarised with regard to organisation and financing, as well as other considerations that have appeared as decisive for continued development.

11. Recommendations for further investigations and the next steps – In conclusion, brief recommendations are given regarding further investigations and the work to realise the development plans for electric roads for heavy transport in Sweden.

2 INTRODUCTION TO ELECTRIC ROADS

Electric roads can be described as roads with infrastructure for electricity transmission that can supply a vehicle with electricity while moving, also known as Electric Road System, ERS. Since today's technology for batteries does not have the capacity to power heavy vehicles over longer distances whilst maintaining load-carrying capacity, other solutions are needed to enable heavy vehicles to be powered by electricity [12].

In previous studies, the electric road is described by means of four main components: a vehicle, a road, an electricity grid infrastructure and as well as technology for electricity transmission, see Figure 1 [13] or as five subsystems: power supply, road, electricity transmission, operation of the electric road and electric road vehicles [14]. The concept of an electric road means that a vehicle being driven on an electric road can be charged by means of dynamic electricity transmission while moving. The electricity grid infrastructure in the vicinity of the road is adapted to run along the road and the final stage consists of electricity transmission technology built into the road area for the transmission of electricity to the vehicle. By building the technology into the road infrastructure, these roads will therefore be available to both electrified vehicles and other vehicles.

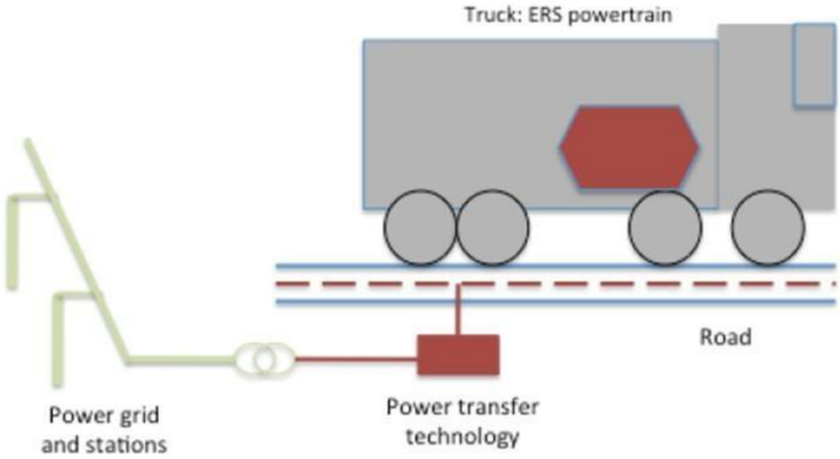

Figure 1: Overview of the four components, according to Tongur and Engwall [15]

2.1 Description of different technical solutions for electric roads

There are currently three main technologies for how the dynamic transmission of electricity from road to vehicle can take place and on which this investigation is based. These are based on conductive technology, also known as CPT (conductive power transfer), which involves transmission by means of direct physical contact, as well as inductive technology, also known as IPT (inductive power transfer), transmission through electromagnetic fields without physical contact. The three technologies are [11, 16]:

- Conductive transmission through overhead lines
- Conductive transmission via some form of rail or conductor in or on the road
- Inductive transmission through electromagnetic fields from the road body

Figure 2: Example illustrations of the three transmission technologies, from left: transmission via overhead power lines [17], transmission via a rail in the road [12], transmission via electromagnetic fields [18]

In addition to the three technologies above, there is also a technology using conductive transmission from the side developed by Honda in Japan. Until further notice, this is equated with conductive technology in or on the road.

In addition to the difference between the methods for the transmission of electricity, the technologies have different degrees of maturity, which can be defined using Technology Readiness Level, TRL, on a scale of 1-9, where 9 means a system that has been tested operationally and is working [19]. The different technologies also have different advantages and disadvantages [11, 13, 20]:

- The overhead power lines are the most tested and where technology development has advanced furthest. The disadvantages of the technology are that it cannot be applied to passenger cars due to the distance between vehicle and overhead power line, as well as the visual and other impacts that the power lines have on nature and the environment. One advantage is that the technology does not have any impact on the road body.
- Transmission via a rail is less tested and there is still uncertainty about the functioning of the technology. There is also friction between roadway and vehicle that can affect safety and also cause particle generation (as in the case of overhead power lines). It is also unclear how well the technology can cope with difficult climates. However, the technology can be applied to all vehicles and has no obvious visual effects.
- For the inductive transmission, much development is still in progress. There are discussions as to whether the electromagnetic radiation may involve risks for human health as well as cause interference in other electronic equipment. Inductive technology is also the most expensive of the three technologies to build. However, it does not have any obvious visual impact and there is no friction between roadway and vehicle either, and it can also be used by all types of vehicle.

In Sweden, the conductive technologies are currently being tested at different installations. The overhead technology is being tested on a 2 km long section of road outside Sandviken on the E16 in a project with Scania and Siemens. Conductive transmission via a rail is being tested at two installations in Sweden, one on a 2 km long section of public road outside Arlanda, and one at Volvo's internal test facility in Hällered in collaboration with Alstom. Conductive transmission from conductors on the road is being tested by Elonroad on a test section of road outside Lund as well as on an internal section of road.

Different types of technologies are being tested internationally in different stages, which affects the degree of maturity. There are different types of tests and pilot projects that are described by Tongur [13], amongst others, and in this report the following terms are used which are in line with what the Swedish Transport Administration uses in the national roadmap for electric roads [11]:

- Demonstration project – time-limited test of electric road technology on public roads where only one or a few selected carriers use the electric road
- Pilot project-testing of the electric road system in its entirety on public roads which is open to several parties and operated with commercial input
- Large-scale development - permanent development of an open system for market participants on commercial grounds

2.2 INTERNATIONAL OUTLOOK

Sweden currently has a leading role in testing electric road technology and demonstrators in electrified roads and introduced the world's first electric road on public roads outside Sandviken in 2016. However, several other countries are engaged in research and development within the field. Previous studies highlight several countries, including Germany, the United States, South Korea, Israel and Spain [11, 16].

Germany

Germany is at the forefront in the development of electric roads. Projects are being conducted in several of the aforementioned technologies:

- Bombardier is researching into inductive power transmission and has developed a system integrated into a Scania truck that they are testing on an 80-metre test track in

Mannheim.
- Germany has three upcoming projects in overhead transmission. Amongst other things, the government has financed three projects where the technology shall be installed on three sections of public road in 2018 and 2019 [21, 5, 22].

South Korea
KAIST University has been conducting research and development in inductive power transmission through the OLEV company since 2008. A solution for buses on public roads is being tested there with two buses in operation, powered by an inductive electric road.

Israel
The Israeli company Electreon has a 30-metre long test track for inductive transmission in Caesarea, and there are plans to test the technology in Tel Aviv on an 800-metre long public transport route during 2018.

USA
During the summer of 2017 a test facility was started, similar to the Siemens facility outside Sandviken, with conductive transmission via overhead power lines. The test section of road was 1.6 km and located outside Los Angeles. Five universities are conducting joint research into inductive transmission in a so-called SELECT centre.

Spain
In Malaga, an EU project in inductive power transmission project has been conducted. The project was based on a self-driving electric bus that was charged on a 100-metre section of road using inductive power transmission. The work comprises collaboration between the CIRCE and Gulliver companies.

Japan
Electric road technology is being developed and tested in Japan based on conductive transmission from the side. Honda is driving the development and is testing the technology at speeds of up to 150 km/h with a power output of 450 kW, supplied from a large-scale battery system [23].

2.3 Approach of business models for electric roads

Factors related to the different components in an electric road, see Figure 1, are added to a ready business model, including financing, ownership and payment flows. A general review of previous studies has been performed, in which primarily two have been found to be relevant: Stefan Tongur's thesis *Preparing for takeoff* [13] and RISE Viktoria's *Feasibility study of business ecosystems for electric roads* [24]. These are explained briefly in this section.

In *Preparing for Takeoff* [13], as well as in references to more studies in the area, Tongur describes the problem that arises from an investment regarding alternative infrastructure. Alternative infrastructure, which in this case is electric roads, is considered to be prone to risk by Tongur due to several aspects. The investment in the infrastructure is extensive, while initially it risks being characterised by a low utilisation rate. In addition to this, there is also the risk that the new technology chosen at an early stage can quickly become obsolete due to rapid improvements in the field.

In order to handle these investment risks, projects can be financed in different ways, where the funding can come from the public sector, the private sector, or a combination of both.

Tongur [13] further notes that so far there are no obvious business models on how to commercialise electric roads but highlights that there will probably not be a single party making the investment, but an interaction between parties is likely to be needed. Furthermore, Tongur mentions that pilot sections may be an important step in testing and evaluating business models.

RISE Viktoria also addresses possible business models for a future electric road system in *Feasibility study of business ecosystems for electric roads* [24]. RISE Viktoria focuses on the problem of a so-called two-sided market, which means that the value of investing on one side (in the infrastructure) depends on the number of parties investing on the other side (in compatible vehicles). In such a problem, the party controlling the revenue from the system is likely to need to subsidise the other party for a user network to grow, which in this case would mean that the party controlling the electric road needs to create incentives for potential users.

Since subsidies from the electric road operator would entail a significant risk of longer repayment on its investment, it would be less likely that a private operator would take on this role in the market.

RISE Viktoria also discusses three possible scenarios in an electric road system regarding the involvement of public and private parties respectively:

- Private, closed road
- Open road, owned and operated by a public party
- Open road, owned and operated by a private party

In the national roadmap for electric roads [11], the Swedish Transport Administration also mentions different distributions between private and public sector parties in several possible scenarios for financing and organisational models.

In summary, there is limited experience and studies regarding business models, and no concrete proposals for an appropriate business model have been found in previous studies that have been reviewed. However, this is not unexpected, since the area is still at an early stage of development.

2.4 Description of the electric road system

Based on previous studies, the interviews and meetings held during the investigation, an overview of the electric road system in its entirety has been developed as a starting point for developing possible business models, see Figure 3.

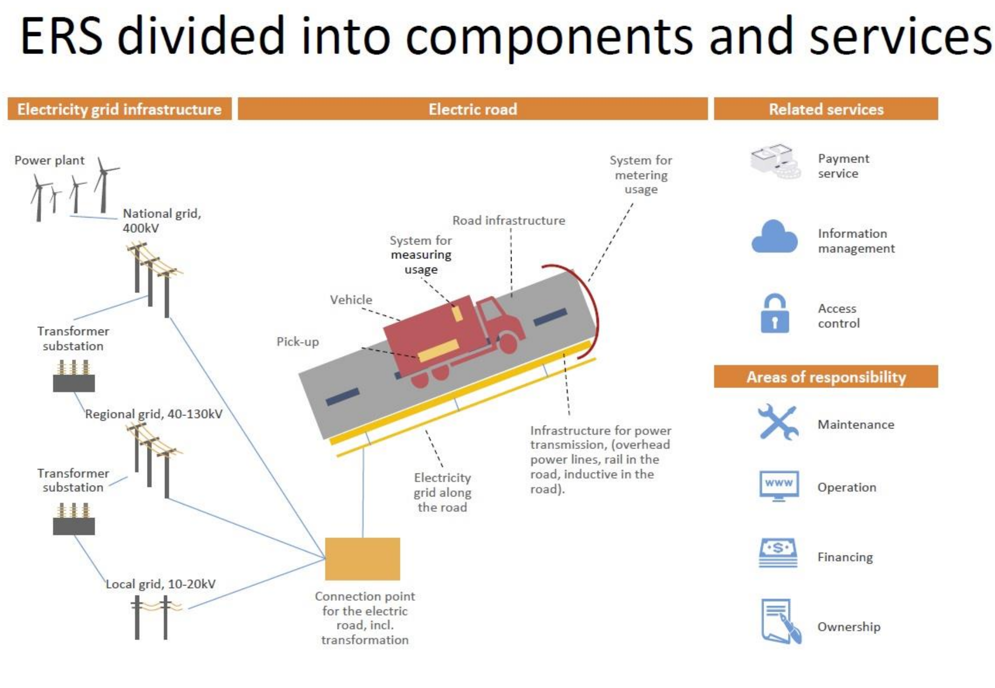

Figure 3: Overview of the electric road system

The figure illustrates four parts:

- Existing electricity grid infrastructure
- Electric road
- Related services
- Areas of responsibility

The electricity grid infrastructure consists of the existing structure for national grid, regional grid and local grid networks that supply the electric road with energy. It is technically possible to connect the electric road to different functional levels in the electricity grid infrastructure [25]. At the so-called connection point, after the existing electricity grid, the electricity needs to be transformed to the correct voltage for the electric road, after which it is transmitted via a new local electricity grid along the road to the power transmission infrastructure, i.e. electric road technology. The electric power is then transmitted to the vehicle by means of a pick-up or inductively, depending on the type of electric road technology used.

In the baseline scenario, it can be assumed that electrification will be added to an existing road. It is therefore possible to develop electric road infrastructure by expanding an existing road with a new lane incorporating electric road technology. Electric road infrastructure can also be a functionality that is integrated into new road construction.

To enable debiting of usage, an utilisation measurement system is required that measures electricity consumption and identifies the vehicles. In Figure 3, this system is fitted in the vehicle. A system for metering usage is also required to collect information from the vehicles, to check that the electric road users have permission and to minimise unauthorised use.

The electric road's related services consist of payment service, information management and access control, which are linked to the systems for measuring usage, and metering of usage in the centre section of Figure 3. The payment service needs to process the debiting of electricity consumption, electricity grid charges and measuring the usage of the electric road. The information generated in the system, such as vehicle identity and position, also needs to be processed and checked to determine which vehicles are using the electric road.

An additional dimension consists of areas of responsibility, such as maintenance, operation, financing and ownership, where some party needs to be responsible for one or more of these.

2.5 Factors that affect a business model

In order to draw up proposals for business models for electric roads, the investigation work has been based on a number of different factors that can jointly be described as being prerequisites for a business model for the market. The different factors are illustrated in puzzle format in Figure 4. These puzzle pieces, or factors, are the basis from which the overall assignment has originated and which are included in the method description in section 1.4. Within the framework of a business model, several different so-called value offerings by different participants are provided based on a coherent business concept, in this case, the electric road development.

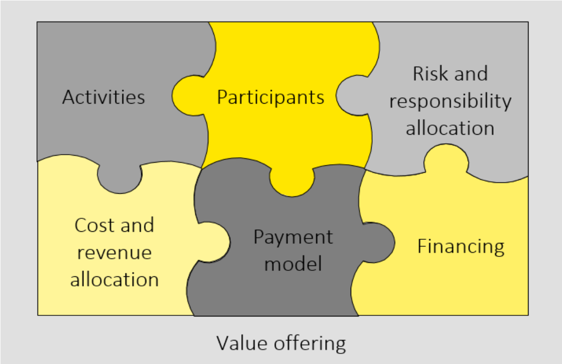

Figure 4: Factors that affect a business model

3 Market participants and stakeholders for electric roads

An electric road system consists of several components and services, which means that several different participants need to interact in different roles for the system to work as a whole. Figure 5 schematically describes the roles that the electric road system may comprise and how they can be structured. Apart from the role of electric road operator, all of the roles are already represented by companies in the market today, meaning that there are already active participants that are likely to have a role in a future electric road business. However, the current business models of these participants do not need to be directly transferable to the electric road but may need to be modified to differing extents.

Any horizontal and/or vertical integration between different roles is possible, which would create new business models with new value offerings. One example from Figure 5 may be that a distribution system operator fully or partly adopts the role of electric road operator. In addition, if the electric road operator is not a distribution system operator, it could be able to act as an electricity supplier by purchasing electric power and brokering it on to the carrier. In this case, it is also possible to change the value offering by selling time-limited access to the electric road instead of electricity, for example.

There is currently no obvious party to take on the role of electric road operator to provide infrastructure for power transmission. Something under discussion is the Swedish Transport Administration's role in an electric road system. Some of the participants interviewed name the Swedish Transport Administration as a natural party to take on the role of electric road operator. Amongst other things, it is therefore important to define which roles the Swedish Transport Administration could take responsibility for. The Swedish Transport Administration currently has the role of manager of road infrastructure, but it is not clear whether logical connections between the electric road infrastructure and road infrastructure are sufficiently strong to justify a government-owned electric road [11]. Traditionally, as noted above, the government has not been responsible for providing road vehicles with fuel, which is what the dynamic supply of electricity can be seen as.

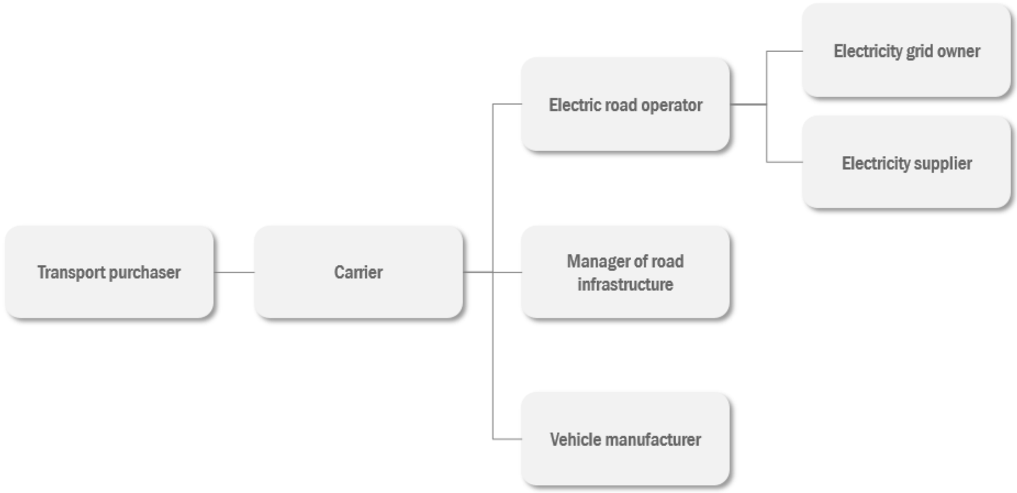

Figure 5: Roles in an electric road system

The structure of the roles in the electric road system is based from the start on the fact that a purchaser of transport services chooses to transport its goods by road. Then it is up to the carrier to transport the goods from location A to location B. If the carrier chooses to use the electric road, this requires a vehicle adapted to the electric road, an electric road infrastructure to use, and a road to drive on. For the electric road infrastructure to work requires a connection to the electricity grid and the supply of electric power.

The structure described above and in Figure 5 may differ in appearance. In a closed system, e.g. when transporting within a private industrial area, the transport purchaser can provide its own transport and therefore also be a carrier. In a closed system, the transport purchaser can also be an important driver for establishing an electric road and could play a role in the development as well as the operation of the electric road [26]. The system may also differ in appearance depending on point in time. The network in Figure 5 is based on a fully developed electric road system on public roads.

There are currently many stakeholders for electric roads in the market. These can be divided into direct and indirect stakeholders, where direct stakeholders may have a future role to play in the electric road system, and indirect stakeholders may be affected by the electric road without holding a role in the electric road system. The distribution between these may differ in appearance depending on point in time and in different projects. Since the stakeholders will be involved in different ways, they will also have different driving forces for electric roads. In turn, the driving forces will affect the willingness to take on different roles in the development of electric roads. Table 1 briefly presents potential driving forces for the direct stakeholders to become engaged in electric roads.

Table 1. Driving forces for electric road stakeholders

Direct stakeholders	**Potential driving forces for electric roads**
Transport purchaser	Lower transport costs Sustainability as a competitive advantage
Carrier	Lower fuel costs and maintenance costs Sustainability as a competitive advantage at an early stage
Vehicle manufacturer	New business opportunity At an initial stage, the opportunity to influence technology choices and thus take market share at an early stage Sustainability as a competitive advantage

	Increased proportion of environmentally friendly vehicles
Electric road provider	Sale of electric road infrastructure In an initial stage, it is possible to influence the choice of technology and thus take market share at an early stage
Electric road operator	New business opportunity
Manager of road infrastructure	Reduce the proportion of transport assignments using fossil fuels Increased energy efficiency Reduced vehicle noise and emissions
Electricity supplier	Increased sales of electricity
Distribution system operator	Growth through expanded network activities
Investor	Long-term investment with stable cash flow over time Green investments

Transport purchaser and carrier

For both transport purchasers, i.e. the owners of the goods to be transported, and for the carriers, e.g. a forwarding agent, an essential driving force is to reduce costs. Fuel is currently the carrier's second largest cost after the cost of the driver [27]. If carrier costs are reduced by using the electric road, it is reasonable to assume that they will use it. In turn, this would lead to the possibility of offering lower prices to customers, i.e. transport purchasers. Electrified vehicles are also reported in a longer perspective to be less maintenance-intensive than vehicles with combustion engine.

Apart from costs, a driving force for transport purchasers is also operational reliability. If the goods do not arrive in a reasonable time, transport costs play a smaller role. Assuming that operational reliability is unchanged when introducing electric roads, transport purchasers should choose the carriers that can deliver the transport service at the lowest cost. Hybrid operation with electricity and diesel will probably be dominant, at least during an early stage, in order to use the truck on other sections of road when required. This is positive for operational reliability because the truck can then be powered using diesel if the electricity supply does not work, even if the complexity of the vehicle increases. Increasing the sustainability of the transport service can be seen as an added advantage, because customer awareness as well as political demands and incentives to reduce environmental impact are increasing.

Vehicle manufacturers

Thanks to the electric road, vehicle manufacturers have the opportunity to sell a new type of vehicle. In addition, there is the opportunity to participate and establish the new electric road market at an early stage, which electric road technology will become standard, and then potentially draw competitive advantages from it. Sustainability can also be an important driving force for vehicle manufacturers.

Electric road providers

Electric road providers, the parties that develop electric road infrastructure, are driven by being able to sell this infrastructure, it is reasonable to assume, and by being able to influence which electric road technology constitutes a future standard.

In addition, the opportunity to sell services linked to the electric road may arise, e.g. service and some of the operation.

Electric road operator
For a future electric road operator, the establishment of electric roads means a new business opportunity with opportunities for profitable operations and investments.

Managers of road infrastructure
The government is manager of road infrastructure for public roads through the Swedish Transport Administration, or in some cases municipalities. Their driving force for electric roads is to reduce the proportion of transport assignments with fossil fuels, as part of achieving the set climate targets, but also to increase energy efficiency. In addition, noise from the traffic may decrease through electrification.

Electricity suppliers and electricity grid companies
For both electricity suppliers and electricity grid companies, the electric road creates opportunities for growth in a new market area and thus new customers with new demand patterns.

Investors
Investors, such as infrastructure funds, may be interested in electric roads since there is potential for long-term investments with stable cash flows over time. The opportunity to invest sustainably may also be of interest to some parties. The conditions for financing are described in Chapter 8.

Indirect stakeholders
In addition to the direct stakeholders, there are also indirect stakeholders who in some way have an interest in the development of electric roads or who may be affected by it. These are, for example:

- Construction companies
- Academia and other research entities
- Ministries and authorities
- Regions and municipalities
- Suppliers of fossil fuels
- The general public

4 OVERALL COSTS FOR THE DEVELOPMENT AND OPERATION OF AN ELECTRIC ROAD SYSTEM

Since electric roads are a relatively new technology that has not yet been tested on a large scale over a long period of time, it is difficult to accurately calculate the costs of developing and operating such a system. The figures and data described in this chapter are based on previous studies and investigations, and in many cases estimates are based on early experiences and other similar solutions such as light rail, railway and trolley bus. Even though the actual costs of future development are likely to differ from these early-stage assessments, they still provide an indication of the magnitude that should be reasonable.

Table 2 below shows an overview of the costs associated with the electric road in order to provide an illustration of the size of the investments required.

Table 2. Overall investment costs and operating costs for the electric road

Investment costs		**Source**
Development of the electric road (Infrastructure for power transmission and electricity grid extension) in both directions	Conductive overhead: 9-14 MSEK/km Conductive from the road: 5-10 MSEK/km Inductive from the road: 10-35 MSEK/km	[24], [28], [29], information from manufacturers
Only electricity grid extension	4-8 MSEK/km	[24], [29], [28]
Additional cost of vehicle adaptation	0.5-0.8 MSEK/vehicle	[24]
Operating costs		
Electric power and electricity grid charges when using the electric road	0.7-1.6 SEK/driven km	[24], [29]
Maintenance of the electric road	Estimate of approx. 1.5% of CAPEX	Information from manufacturers and the Swedish Transport Administration, based on experience from railways

The investment needs for electric roads are uncertain, depending on technology choices, but also for individual technologies. The investment volume for inductive transmission from the road appears to be particularly uncertain, probably due to it being a newer and less proven technology. The lower limit in the range for inductive technology is probably an optimistic estimate. The infrastructure for power transmission also has an uncertain service life, making it difficult to make investment estimates. Electricity grid extension has a comparably more predictable service life. Despite the uncertainty, it is interesting to compare the investment needs of the electric road to other infrastructure. In light terrain, the investment cost for a motorway is estimated to be approximately 50 MSEK/km and double-track railway approximately 100 MSEK/km according to the experience of the Swedish Transport Administration. However, functionality is not completely comparable. Even maintenance costs are a rough estimate based on experience from railways and studies in Germany. The electric road could potentially complicate the maintenance of the road infrastructure, which could cause additional costs.

The investment for expanding the electricity grid depends, for example, on which section of a road that is electrified, how many transformer substations are required and what capacity the grid needs to cope with. The capacity alone can have an additionally large impact on the cost. In an electrification of the Stockholm-Jönköping-Gothenburg route, Viktoria Swedish ICT calculates the investment cost to approximately 20 MSEK/km to achieve maximum capacity [28]. In this case, due to the need for reinforcements in the regional grid, the investment needs will be significantly higher than those presented in Table 2, which illustrates the uncertainty. However, the calculated maximum capacity in this case was very high.

Additional vehicle costs consist of pick-ups and other additions needed to pick up electric power [24].

The cost of electric power and electricity grids varies but also depends on the vehicle's energy consumption per kilometre. The difference between this cost for electric operation and diesel determines the potential economic gain an electric road can provide for the carrier. For this reason, changes in taxes for these two fuels can have a decisive impact on the business for the carrier and thus the entire electric road system's value offering and feasibility. Several market participants have highlighted taxes as an important parameter for feasibility [30]. The effect of any tax changes is not examined any further in the context of this investigation, but it can be considered to have a significant impact on the economic potential of the electric road in the long term. Using diesel itself as a comparison is due to it currently being the lowest cost alternative. This may change in the future, partly due to taxes, and the comparison may then need to be made with another fuel instead.

The uncertainty in investment costs and operating costs affects the economic calculation, which makes it particularly difficult to calculate the level of annual traffic on the electric road at which it becomes profitable, i.e. break even. Due to this, implementing demonstrators and pilots is essential in order to accumulate additional cost data and experience.

How the costs in Table 2 relate to different implementation phases is difficult to determine since the sources differ in terms of how they present the timing of the costs. The cost estimates are probably best illustrative of an early commercial phase, as mentioned in one of the sources, which is not about the very first installation, nor about a mature phase. It is likely that vehicle costs and the cost of infrastructure for power transmission may decrease over time.

5 Payment models

For use of the electric road, four components overall can be identified as cost drivers and which need to be taken into account when designing an appropriate payment model:

- Electric road infrastructure
- Energy (electricity and electric grids)
- Vehicles and pick-ups
- Road infrastructure

As the road infrastructure is currently financed through government grants and is also expected to continue this way in the event of the development of electric roads, the item should be excluded from the payment model for the electric road system. However, it may be conceivable that road fees will be introduced in the coming years to a greater extent than today, which may affect the financing model. The other three components are therefore considered to be included in a future payment model for the electric road.

5.1 Payment models addressed in previous studies

Possible payment models for electric roads have been addressed in previous studies to a limited extent. However, RISE Viktoria has specifically investigated the issue in its *Feasibility study on payment systems for electric roads* [16], and it is therefore used as the primary source in this chapter without addressing different proposals and their feasibility. The feasibility study compares electric roads with telecommunications and railways. Per kilometre tax on roads is also addressed as possible user financing. The payment models described, based on telecommunications, railways and kilometre tax, are shown briefly below.

In a model similar to that of telecommunications, the infrastructure may be owned by one operator, managed by another and used to sell services by a third party. The user can utilise an operator's infrastructure at one point and then utilise infrastructure owned by someone else at another point in time, which may be the case in an electric road system with different sections of electric roads that are managed by different electric road operators. However, the user only has contact with the vendor of the final service [16]. The customer often pays a fixed price for a subscription, which includes a certain amount of usage of different services.

The electric road system has similarities to railways because it basically constitutes trading in electrical energy for transport assignments. On railways, the user pays charges to the Swedish Transport Administration, where one part is electricity consumption. In turn, the Swedish Transport Administration purchases electric power on the market through agents [16]. However, this solution is a special case for historical reasons and is not obviously applicable to electric roads.

In order to finance future maintenance and investment in road infrastructure, a per kilometre tax may be charged. There is currently no such tax in Sweden but in a potential model the user would be provided with a vehicle device that provides information on user ID and position. In this way, the vehicle owner can be taxed based on the distance driven by the vehicle [16].

RISE Viktoria [16] also describes possible payment models for electric roads with different application areas. One of these is goods transport by electric road. In this example, the manager of road infrastructure in the form of the Swedish Transport Administration or municipalities is assumed to provide the electric road and a local electricity grid for the road. In turn, the electric road is connected to several different electricity grids, and the manager of road infrastructure pays the total fee to the respective electricity grid companies. The forwarding agent pays the manager of road infrastructure for usage and maintenance of the electric roads. The forwarding agent purchases the electricity either from any electricity supplier or from the manager of road infrastructure, as on the railways. This model is not altogether different from the roles and structure described in Figure 5, except that it is assumed that the manager of road infrastructure and the electric road operator are the same party and that this party is the Swedish Transport Administration or municipalities.

5.2 Opportunities for payment models in an electric road system

As mentioned earlier, the payment model for an electric road system should handle payments for use of the electric road infrastructure, consumption of electrical energy and connection to the electricity grid, as well as vehicles and pick-ups.

Electric road infrastructure

Potentially, the user can pay for the use of the electric road infrastructure in several ways. For example, payment can be based on how much electricity has been consumed, how long the user has used the electric road or based on the distance driven. There is also the possibility of creating subscriptions with a fixed price. Advantages of basing the price on electricity consumption are that it creates incentives for energy efficiency, and that a fairer structure is created since heavy vehicles of different weights consume different amounts of electricity per kilometre.

In a phase where electric roads are developed on a large scale, situations may arise when the user utilises different electric roads owned by different operators. To avoid separate agreements with several different operators, it is therefore likely that some form of roaming agreement will be developed, similar to telecommunications.

In theory, the electric road infrastructure can be seen as part of the road infrastructure, which is thus financed within the same financing form. Options such as the previously mentioned kilometre tax are then possible. However, in this case, possible payment models are affected by the so-called Eurovignette Directive, which describes the ways in which heavy goods vehicles should be charged for the use of certain infrastructures [31]. Further examination of legal conditions as mentioned above is not included in this investigation, and there will therefore not be any further description of the possibilities and any limitations with the kilometre tax. The Swedish Transport Administration is examining this and other legal implications for electric roads separately.

Electricity grid infrastructure

The fees charged for transmission via, and connection to, the electricity grid, are regulated by the Energy Market Inspectorate, Ei. The electricity grid charges normally consist of a fixed subscription fee and a variable electricity transmission fee [32]. In an electric road system, the user can potentially move between areas with different electricity grid companies, which means that payment can then be made to the majority of operators. One possibility for facilitating the payment model is to include the electric road operator in the electricity grid agreement and for it to pay the electricity grid charges to the relevant electricity grid companies, and then add a corresponding surcharge to the pricing for the user, as suggested in the *Feasibility study on payment systems for electric roads* by RISE Viktoria [16] and during interviews [33].

Regardless of how the electricity grid is expanded, see section 6.1 for a description of the options, a physical interface between the distribution system operator and the electric road operator will arise where the components owned by the electric road operator meet the components belonging to the electricity grid. It is therefore logical that the electric road operator is included in the electricity grid agreement.

Electricity trading

Consumption of electricity is normally paid to an electricity supplier chosen independently by the person or company that has entered into an electricity grid agreement [34]. The price per kWh is determined on the market and the customer can choose a variable price or to fix it over a certain period of time [35]. It is likely that electricity trading in an electric road system will work in a similar way, meaning that the electric road operator purchases electric power from the market, in accordance with the reasoning that the electric road operator holds electricity grid agreements as in the previous paragraph. The theoretical case that the Swedish Transport Administration should be the electric road operator has similarities to the model for railways, where the Swedish Transport Administration purchases electric power that is sold on, corresponds to a certain extent with the proposal above that the electric road operator purchases electric power. However, the model for the railway is seen as a special case and will probably not be replicated for electric roads according to the initial discussions conducted with the Swedish Transport Administration during this investigation.

Giving individual carriers the opportunity to choose an electricity supplier is another option. Like today's fuel market, the carrier could independently choose fuel supplier, which means increased competition compared to the above-mentioned options. However, this scenario is more complex since transactions between carrier and electricity supplier need to be handled. To make this possible, some party needs to be responsible for measuring the electricity consumption in each vehicle as well as handling information on which electricity supplier is the supplier for each vehicle. It is doubtful whether a future electric road operator would be motivated to offer such a solution, but electricity trading could possibly be separated into a scenario where another party is responsible for measuring electricity.

Regardless of who purchases electric power from the market, a variable price throughout the hours of the day can be introduced for carriers. At which point, a cost incentive can be created to schedule certain transport assignments during evenings and nights when the electricity price is lower, which coincides with times when the road network less heavily subscribed. At the same time, this may also lead to other increased costs, e.g. for staff, which can counteract the cost advantage from the electricity price. However, this is not examined any further in this report.

Vehicles and pick-ups

Finally, the vehicle and the pick-up must also be paid for. Scania, Volvo and other vehicle manufacturers are handling these together and are driving the development using different types of pick-ups for their vehicles [36] [37]. For Elonroad's electric road solution with conductive transmission via a rail on the ground, the pick-up is developed separately as a third-party solution [38]. In the future it is possible that pick-ups will be purchased separately from the vehicle and retrofitted. In a more mature market, vehicles and pick-ups can potentially be seen as a service included in the business model for electric roads where new value offerings can be created, e.g. by offering transport solutions and not just fuel. However, this investigation assumes that the vehicle and pick-up will be procured, i.e. purchased or leased, by the carrier in a separate transaction.

Possible payment model

A possible business model based on the reasoning in the sections above can be described in overall terms by Figure 6.

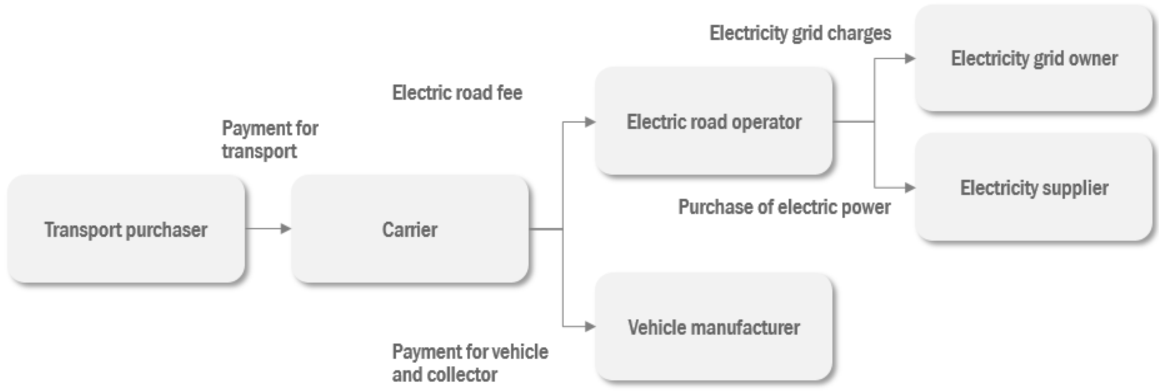

Figure 6. Possible payment model for an electric road system

In the event that the electric road operator purchases electric power, there is the opportunity for different value offerings for carriers, which need not be based on electricity consumption. On the one hand, in a model where charges for the electric road are not based on electricity consumption, there is no need for an electricity meter in the vehicle. On the other hand, individual electricity measurement creates incentives for energy-efficient driving. The possibility of allowing the carrier to choose an electricity supplier independently, which would strengthen competition in the market, and any restrictions as a result of the Electricity Act, should be investigated further.

5.3 Pricing

Whether or not the price paid by the carriers to the electric road operator for using the electric road should be regulated has been discussed in the investigation. Like the electricity grid, natural monopolies arise since there will only be one electric road available on a specific section, which suggest that regulation is needed. However, the carrier has the choice to not use the electric road, provided that the vehicle is hybridised. With market pricing, within the framework of the Electricity Act, it is therefore reasonable that the price for using the electric road, including electricity consumption, approaches but does not exceed the effective price per kilometre for the alternative fuel. In order to justify the additional vehicle cost, there is likely to be a need for a difference between the alternatives. If the price for using the electric road in the long-term exceeds the alternative, it is unlikely that carriers will invest in a vehicle adapted for the electric road. In connection with the development of the demonstration section on the E16, carriers were asked about their willingness to pay, and it emerged that they were only willing to use the electric road as long as it was cheaper than alternative fuels [39].

If the electric road fee to achieve the desired return on infrastructure investment needs to be so high that the carrier does not reduce its costs, a development of the electric road will probably not be economically viable if individual sections of road are viewed independently. The sections of road with the best economic conditions are the ones with a high percentage of heavy transport, which are also the sections or road where electrification can contribute most to reducing emissions. Another important prerequisite is open standards for electric road technology and adapted vehicles in order to facilitate effective competition and increase accessibility to the system for different suppliers. In a competition-driven market, there is a tendency over time that participants not achieving profitability in certain submarkets can still provide services through internal cross-subsidisation. During a transitional period, support from public parties may be required to achieve sufficient profitability for certain sections of road.

6 POSSIBLE BUSINESS PACKAGES FOR THE DEVELOPMENT OF ELECTRIC ROADS

Based on the overview of the system and its overall scope, the various physical components and services can be packaged in different ways in order to create different businesses. A number of criteria have been developed to guide the business packaging:

- The business must contain at least one physical asset
- There should be related services for this asset
- There should be a clear supplier and customer
- Possibility of supply commitment over time should be available and the supply should be measurable
- There should be the option for alternative forms of implementation, i.e. it should be possible for a private party to operate the business in full or in part

The purpose of these criteria is to as far as possible develop commercially viable businesses that have the potential to attract private parties to contribute to the development of electric roads.

During the investigation, four proposals for business packages have been drawn up that have progressively appeared to be reasonable and sustainable based on these criteria and the interviews, meetings and workshops that have been conducted. The packages consist of the different physical components and services described in the electric road system above and can be seen as building blocks in a larger system. These business packages should be seen as a first step towards future businesses and may well have a different appearance when it comes to the actual development, both in terms of content and implementation. The sections below describe each package separately, and then describe possible combinations of packages.

6.1 BUSINESS PACKAGE 1: ELECTRICITY GRID EXTENSION

The first business package consists of the connection point for the electric road, as well as the electricity grid along the road. See Figure 7.

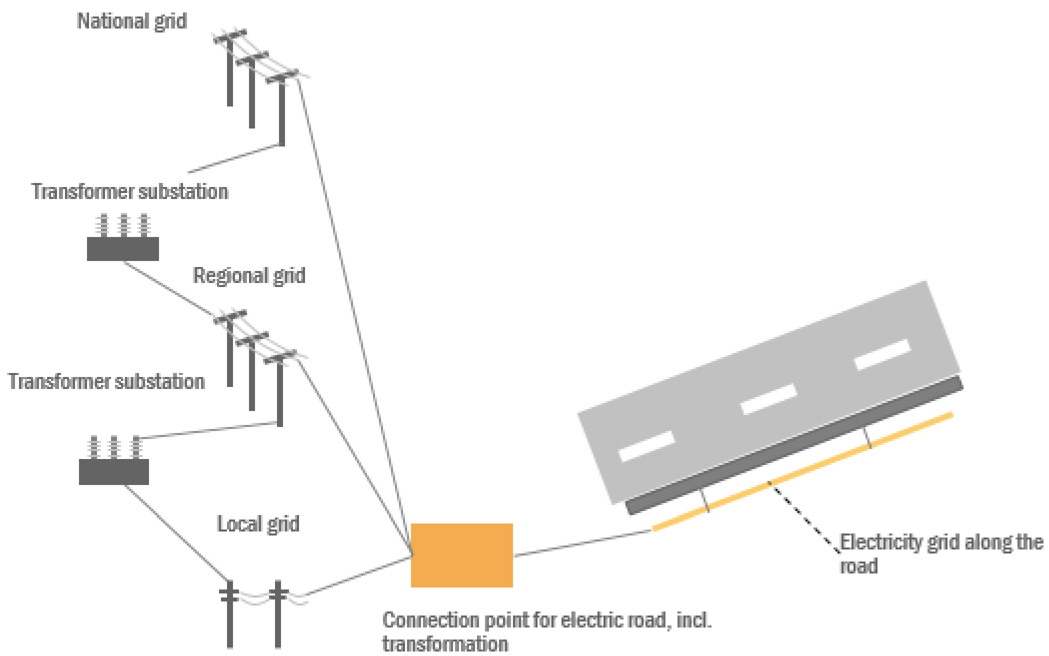

Figure 7: Components in Business package 1

Components	Possible supplier	Possible customer
• Connection point for electric road • Electricity grid along the road • Any reinforcement	• Electricity grid owner	• Electric road operator • Users of the electric road (carriers)

Whether the electricity grid along the road is expanded from the national grid, regional grid or local grid can be left open since all options are possible [40, 33].

In this package, the potential provider is an electricity grid owner and the customer can either be seen as the electric road operator paying the electricity grid charges or the user of the electric road, depending on how the payment model is designed. See the section above for a description of the possible payment model.

This business can be seen as a traditional extension of the electricity grid and there is currently a functioning regulated market for it. Compared with other packages, the business should represent a relatively low risk as it can be seen as a conventional business compared with other packages for a distribution system operator for as long as there is usage. The utilisation rate for the new installation is something that is emphasised as particularly important by electricity grid companies in order to reduce risk, where there is also a need for an investigation as to whether any guarantees for this could be given by the government [33, 40].

In addition, there is the potential for using the extension of the electricity grid for more than just the electric road. An electricity grid along the road can be used e.g. for static charging infrastructure or other installations such as new wind power [30]. The extension can be compared with the extension of open fibre, where several parties and suppliers can join afterwards. With this approach, electrifying the road can be a good investment for the electricity grid in general in order to strengthen and expand the capacity [40, 41]. Being able to use the electricity grid along the road for usage areas other than just an electric road indicates that there is a logical business interface between the electricity grid along the road and the infrastructure for power transmission.

How extension of the electricity grid can be implemented in practice is regulated by the Electricity Act (1997:857) and Regulation (2007:215) on exemptions from the requirement for network concession in accordance with the Electricity Act (1997:857), the so-called IKN Regulation, and three alternatives are shown to be:

1. The electric road is connected to the respective network concession for the area (local electricity grid) that the electric road passes through; the extension to the road is then included in the current concessions
2. The connection point for the electric road and electricity grid along the road is extended, from the regional electricity grid, through a new network concession for a line
3. The connection point for the electric road and electricity grid along the road is extended, e.g. from the regional grid, as an internal non-concessionary grid

Alternative 1 above would mean that the electric road needs to be connected to several different grid owners and that several different electricity grid charges should be paid, which risks being a complicated solution in practice, as mentioned in section 5.2. Figure 8 illustrates an example of how the road can be routed through different area concessions and that there may be a line concession along the road. Alternatives 2 and 3 above have both been highlighted as feasible for electric road development during the meetings and interviews held. However, if the electricity grid is extended as a non-concessionary grid, the possibility of using the grid for other commercial purposes will disappear. In this scenario, electricity grid extension is integrated into the electric road infrastructure.

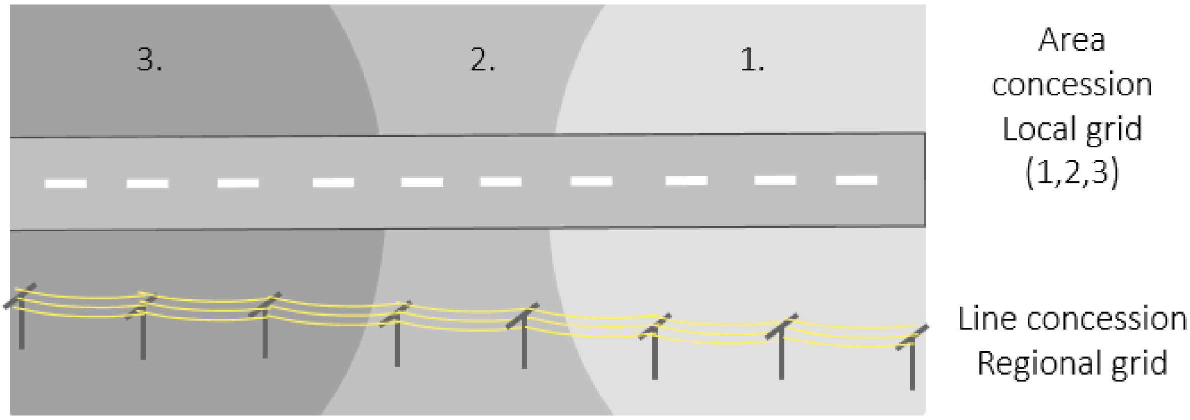

Figure 8: Illustration of area concessions and line concession

Exactly how the electricity grid extension can be organised is something that has been discussed a lot during the investigation and it has not been possible to reach a completely unambiguous conclusion. It is noted that the development of the electric road involves a new situation where the current regulation and its interpretation must be tested in a new situation, such as in a future pilot section, by the market and by the regulatory authority. One hypothesis is that the electricity grid will be subject to a concession under the Electricity Act, although it will not be expanded within the current concessions, but a new concession award will be made by Ei. However, how the electricity grid will be expanded and treated in practice in terms of the regulations, will only be determined when Ei conducts a review on request of an applicant.

One advantage of this business package regarding electricity grid extension is that it is a known structure and that there is a known regulatory authority through Ei. This is something that can make it easier for private investors and create some assurance that there is stability and long-term prospects.

Payment model

When using the electric road, a cost for using the electricity grid is incurred and electricity grid charges must therefore be paid. There are two possible options for who will pay these charges as described in more detail in Section 5.2:

1. The first option is that the provider of the infrastructure for power transmission, the electric road operator, is considered as a customer of the electricity grid owner and pays the electricity grid charges
2. The second option is that the user of the electric road, in this case the carrier, is considered as a customer of the electricity grid owner and pays the charges

Figure 9 describes the first option schematically.

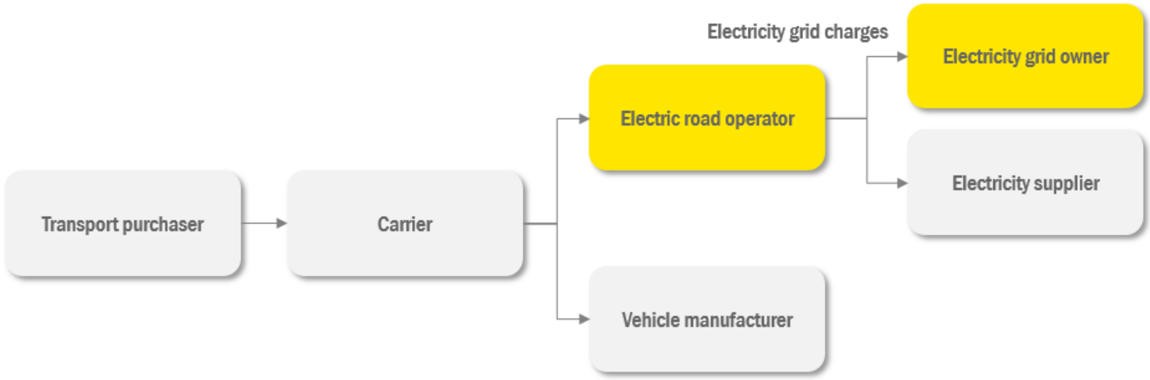

Figure 9: Possible payment model for business package 1

6.2 BUSINESS PACKAGE 2: ELECTRIC ROAD INFRASTRUCTURE

The second business package consists of the infrastructure for power transmission. See Figure 10.

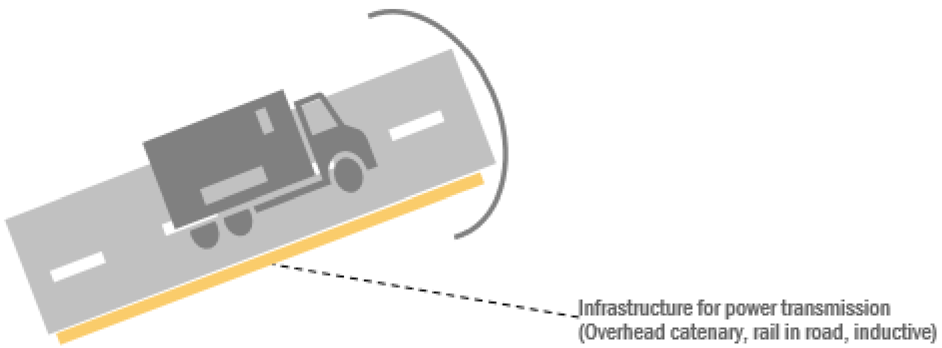

Figure 10: Components in Business package 2

Components	Possible supplier	Possible customer
• Infrastructure for power transmission (e.g. overhead power lines, rail in the road or inductive transmission from the road)	• Electric road operator	• Users of the electric road (carriers)

This package includes electric road technology such as conductive in overhead power lines, conductive in the road or inductive in the road. A potential supplier is an electric road operator that is responsible for the construction and operation of the system with the user of the electric road as a customer. There is currently no market participant that can naturally take on the role of being an electric road operator, but it could be a consortium or a new company with the sole purpose of operating the electric road. There are a number of suppliers of electric road technologies, but they primarily view their role solely as technology and service providers, and have not expressed an interest in operating the electric road in the long term [30].

Another proposal that has been raised is that an electricity grid owner could account for the entire electricity transmission from the existing grid to the vehicle [40, 30]. This would mean a merger of Business packages 1 and 2, which is generally considered attractive by investors since it increases investment volumes [42]. However, in this case, the electricity trading must take place separately from the electric road operator because a distribution system operator may not sell electricity, according to the Electricity Act. In addition, the electricity grid owner would have an interface to the manager of road infrastructure, which can be perceived as difficult to regulate, e.g. in terms of maintenance and responsibility.

Compared to Business package 1, the electric road business transaction, Business package 2, involves a higher commercial risk since the market is immature and it is not possible to determine how the use of the installation will continue to develop. It is also uncertain on which electric road technology or technologies a commercial development on a larger scale will be based, so it is important to build up more knowledge and experience through demonstration projects and pilots. In addition, uncertainties over construction costs and operating costs over time can be reduced in pilots. Costs are difficult to assess in the current situation, which poses a risk.

Payment model

The electric road operator that provides the infrastructure for power transmission may potentially be able to charge users, the carriers, in several ways, which is described in more detail in Section 5.2. Regardless of how the electric road fee system is structured, the carrier makes payment to the electric road operator for use of the electric road, see Figure 11. In the event of a broader development of different electric roads, carriers may eventually come to use electric roads owned by different operators along the sections of road on which they drive. One way to accomplish this is to create a roaming system, as in telecommunications, as described by RISE Viktoria in its feasibility study on payment systems for electric roads [16] as previously mentioned. The carrier then only needs to be the customer of one operator but can use infrastructure from other operators. In turn, the operators enter into agreements to process payments between each other.

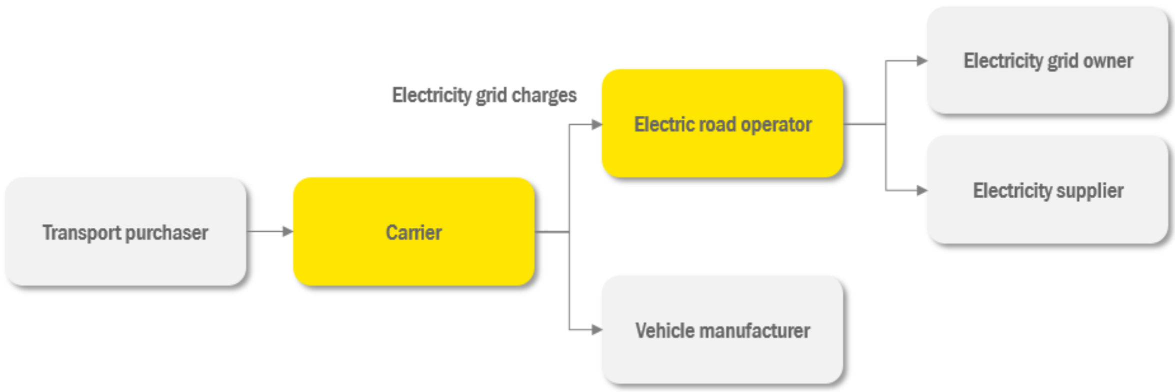

Figure 11: Possible payment model for Business package 2

6.3 Business package 3: Vehicles adapted for the electric road

The third business package consists of the vehicle, the pick-up and the utilisation measurement system. See Figure 12.

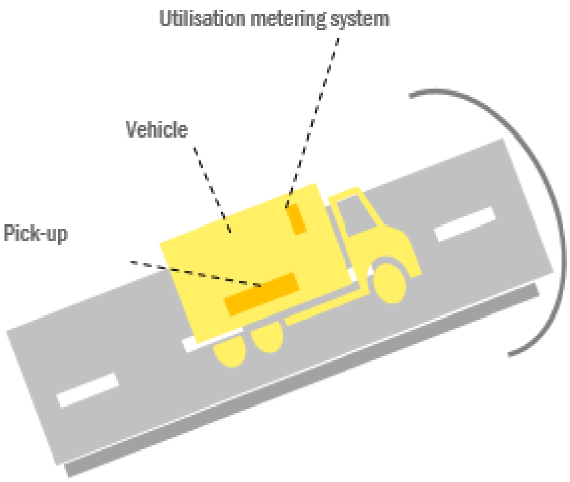

Figure 12: Components in Business package 3

Components	Possible supplier	Possible customer
• Vehicle • Pick-up • Utilisation measurement	• Vehicle manufacturer	• Carrier

In the vehicle package, the hypothesis is that both pick-up and utilisation measurement system will be integrated into the vehicle itself. The supplier is a vehicle manufacturer and the customers are the carriers.

The utilisation measurement system is assumed to at least involve identification and electricity measurement. Whether or not the electricity meter should be in the vehicle is something that has been discussed during the investigation and there are different possibilities. If electricity consumption is to be measured for each individual vehicle, the electricity meter can be either in the vehicle or in the electric road. Metering from the electric road is described in more detail in Section 6.4. If electricity consumption is not to be measured per vehicle, the measurement for the total consumption that takes place in the interface between electricity grid owner and electric road operator is described in Business package 1 above.

For vehicles to be able to drive on sections without electric road, they will probably be hybrid vehicles. The pick-up may not necessarily be included in the sale of the vehicle but could be procured separately or in another business package. The vehicles would then need to be built in such a way that another party could easily fit the pick-ups. Initially, before electric roads have been established, it is likely that vehicle manufacturers will develop pick-ups as a part of the vehicle in order to ensure that the technology works.

In the long term, it may be appropriate to purchase and install the pick-up separately or that it is included in some type of subscription, similar to Business package 2 above. For vehicle manufacturers, it may also be more attractive to sell vehicles where pick-ups and any utilisation measurement systems are retrofitted in order to further standardise manufacturing.

Something that is particularly important for carriers is partly that the vehicle transaction is profitable over the short depreciation period, about 2-3 years, and partly that there is a well functioning used vehicles market for these vehicles in order to minimise the risks at the time of procurement [41]. To achieve higher liquidity in the used vehicles market, it is important to have a technology standard so that a vehicle can be used on more than one particular section of electric road. A liquid used vehicles market also promotes a future solution where pick-ups and any utilisation metering and billing systems are fitted separately to allow a vehicle originally adapted for electric roads to be used on normal roads, but also to be able to purchase a used electric hybrid vehicle and then adapt it for electric roads. However, such possibilities are affected by the type of electric motor and battery capacity of the vehicle, which have not been examined any further in this investigation.

In the future, it will be possible for pick-ups to be purchased separately from the vehicle and then retrofitted. In a more mature market, vehicles and pick-ups can potentially be seen as a service included in the business model for electric roads where new value offerings can be created, e.g. by offering transport solutions and not just fuel. However, this investigation assumes that the vehicle and pick-up will be procured, i.e. purchased or leased, by the carrier in a separate transaction.

Payment model

The payment model for vehicles adapted for electric roads is probably relatively similar to that of vehicles today, at least initially. The carrier procures the vehicle from the vehicle manufacturer, either by purchasing or leasing, in a transaction separate from both fuel and infrastructure, see Figure 13. In the longer term, it is possible that the vehicle payment model will change, e.g. because it is no longer the carriers who procure the vehicles.

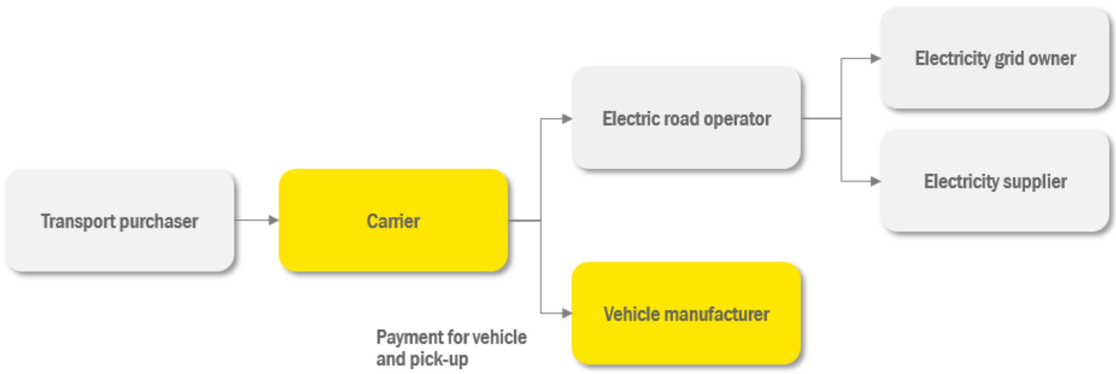

Figure 13: Possible payment model for Business package 3

6.4 Business package 4: metering and payment systems

The fourth business package consists of a system for metering usage, payment service, information processing, and access control. See Figure 14.

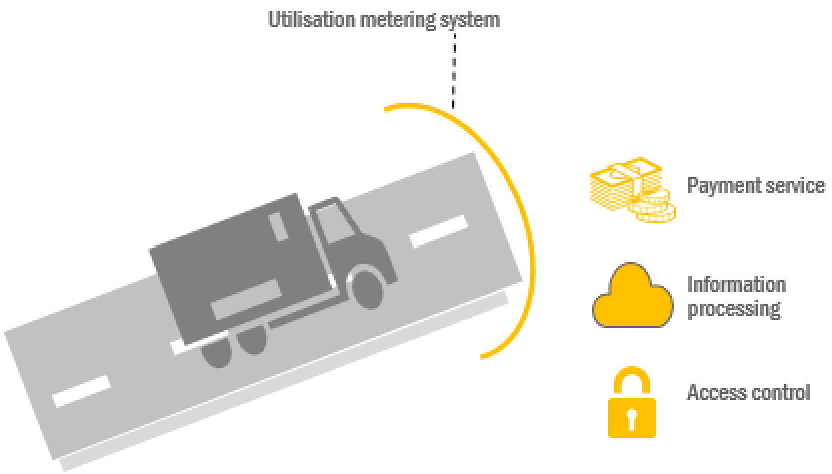

Figure 14: Components in Business package 4

Components	Possible supplier	Possible customer
• System for metering usage	• New participant: operator for metering • Electric road operator	• Electric road operator • Users of the electric road (carriers)

This package includes the system for identifying vehicles and to measure electricity consumption where appropriate, as well as avoid unauthorised use.

The system for metering can be organised and developed in different ways, in the figure above it is illustrated as an arc across the road, similar to congestion tax controls. Regardless of design, the system will need to communicate with a device in the vehicle that reveals ID, position and time. Electricity consumption can also be measured and communicated to the system.

One way of communicating with the vehicle is directly from the electric road. In this way, it is also possible to integrate utilisation measurement and access control by measuring and checking the supply of electricity to the vehicles. However, this requires the possibility to identify the vehicles as well as turn the current on and off at short intervals, in order to be able to check individual vehicles while driving. This is illustrated in Figure 15 below.

Figure 15: Illustration of identification and electricity transmission

In Figure 15, the truck communicates with the metering system that identifies the vehicle and allows the electricity transmission at the vehicle location. There is no vehicle behind and in front of the truck to communicate with the system, so there will be no current in these intervals of the electrified road.

Different interval lengths are possible, e.g. approx. 44 metres for conductive transmission via a rail in the road with Alstom's technology [28] and only approx. 10 metres for conductive transmission via a rail on the road with Elonroad's technology [43].

There is currently no market for metering, which makes it difficult to identify a potential supplier. However, similar services exist in many different areas, such as telecommunications and mobile data, where the device is identified and charged based on consumption. In addition, electric roads probably coexist with autonomous vehicles in the future, making communication between vehicles and infrastructure particularly important.

The supplier could be a completely new participant, an existing party from e.g. the telecommunications industry, but it is also likely that an electric road operator would also want to take responsibility for this package and that Business packages 2 and 4 could therefore constitute one and the same business. The potential customer can therefore either be the electric road operator or the user of the electric road, i.e. the carrier, depending on whether Business packages 2 and 4 are one and the same business.

Whether the use of the electric road should be subject to further control has been discussed in the investigation. Additional control functions such as road fees are likely to be ruled out since the road should be accessible to all vehicles and to avoid traffic queues. Metering systems similar to the congestion tax system may be an option in order to ensure that unauthorised use is minimised, but that may involve a relatively large amount of work to develop and administer.

Payment model
The payment model for the system for metering and payment differs from the others since there is not a direct consumption or service that is visible to the users, and the customer does not necessarily need to be the carrier either, even if that is where the payment originates. One solution could be that the electric road operator is the customer and that the payment service provider receives a smaller compensation for each transaction. In the case where Business packages 2 and 4 constitute one and the same business, the fee for metering can be included in the electric road charges, as described in Business package 2 above. This would mean a simpler solution for managing payments and is illustrated in Figure 16 below.

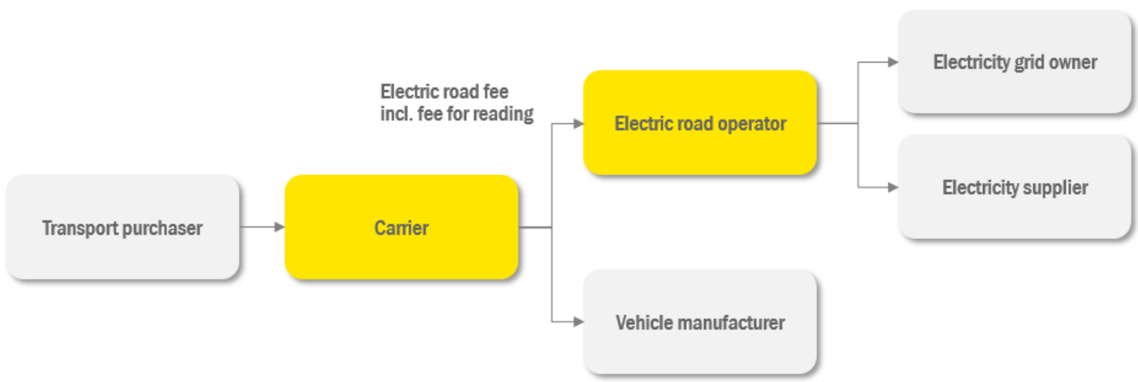

Figure 16: Possible payment model for Business package 4

6.5 COMBINATIONS OF DIFFERENT BUSINESS PACKAGES

As mentioned in the sections above, there are different possible configurations for the different packages. Different combinations or additional subdivisions are also conceivable. Since it is still at an early stage and the market is under development, there is potentially a large number of different possible combinations and subdivisions. This chapter describes the alternatives shown to be possible:

- Completely separate business packages as described above
- Combination of Business packages 2 and 4 by means of the electric road operator having overall responsibility for metering, payment and transmission of electricity to the vehicles
- Combination of Business packages 1 and 2 by means of an electricity grid owner having overall responsibility for the extension and provision of electricity grids and the transmission of electricity to the vehicles
- A combination of Business packages 1, 2 and 4 by means of an electricity grid owner having overall responsibility for the extension and provision of electricity grids, transmission of electricity to the vehicles, as well as metering and payment
- Subdivision of Business package 3 into vehicles and pick-ups respectively where pick-ups are fitted separately

In a large-scale development of electric roads it is possible that different combinations of business packages will occur on different sections of road. However, in open systems on public roads it is likely that a dominant structure for the interfaces with the carriers will arise.

7 RISKS AND AREAS OF RESPONSIBILITY CONCERNING ELECTRIC ROADS

Good overall risk management is important for managing a project's total risk exposure, reducing costs and increasing the fulfilment of the project objectives. The development of electric roads will probably be by means of private and public sector parties adopting different roles that could largely be organised outside of government administration. The risk management below therefore needs to be performed by both private and public sector parties. An overview of the risk analysis has been made in this study using three steps:

1. Identification of risks
2. Valuation of risks based on probability and consistency
3. Allocation of risks between different parties

The risk analysis has been conducted based on different risk categories that have been valued and allocated between public sector and private sector parties. The purpose of the analysis is to understand the categories in which the government or the Swedish Transport Administration may need to play a larger role and the parts of the market for which the private sector actors should be able to take responsibility. The analysis has been conducted by means of a risk workshop with the working group and invited representatives from, among others, the Swedish Transport Administration and KTH Royal Institute of Technology with knowledge and experience of electric roads.

The risk categories used are based on a project's life cycle. See Figure 17:

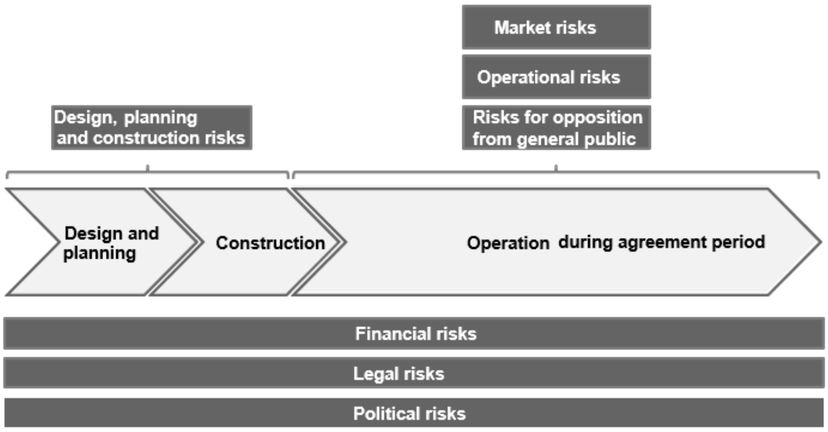

Figure 17: Overview of risks during a project's life cycle

A number of risks have been identified for each category based on the risk workshop held, experience from the demonstration section on the E16 [44], and EY's experience from similar transport-related projects. The identification of risks aims at describing the category and clarifying what type of risk it represents.

The categories and examples of risks per category are shown in Table 3:

Table 3. Examples of risks per risk category

Risk category	Risk example
Design, planning and construction risks	• Necessary market access not granted • Planning risks due to the Road Act, Planning and Building Act, the Environmental Code • Shortcomings in design and planning • Cost overruns during the construction phase
Operational risks	• Deficient quality and functionality • Maintenance measures leading to damage to electric roads or maintenance vehicles • Insufficient technical development and innovation over time • Unforeseen large and costly maintenance needs • Increased complexity for rescue operations in road traffic accidents • More road traffic accidents occurring due to the electric road • Failures due to extreme weather conditions
Market risks	• Demand is lower than expected • Insufficient load capacity in the installation to meet demand • Limited competitiveness in electricity trading • Complicated and expensive solution for payment is established • Standardisation decisions make electric road technology obsolete
Financial risks	• Low level of interest from private investors and financiers • Changes in electricity prices • Interest rate changes
Legal risks	• Changes in laws and regulations • Uncertainty in the Electricity Act (concession or not) • Necessary permits and approvals are not obtained • Electrical safety
Political risks	• Lack of interest in driving the electrification issue • Electricity tax for transport assignments is introduced to compensate for reduced income from other fuel taxes
Risks of opposition from the general public	• Inadequate communication with the general public • Negative local opinion and opposition among the general public

7.1 VALUATION OF RISK CATEGORIES AND IMPACT OF DIFFERENT ELECTRIC ROAD TECHNOLOGIES

A valuation of risk categories has been made in order to understand which ones are of greater importance for the electric road and which ones are of lesser importance. As described in the previous section, the risk categories appear in different phases of a project, from design and planning to operation. In turn, the project can be implemented in different phases of electric road establishment, from technical demonstrators to a fully developed solution in a mature market. This risk analysis is based on an early commercial phase, even though parts may be applicable in a large-scale development as well. The valuation of risk categories has been based on a general risk level graded between 0-3:

- Risk level 0 does not involve a significantly increased risk compared with a reference scenario in which no electric road development is taking place, i.e. a road without electrification
- Risk level 3 involves a very high risk of delays, cost overruns or obstacles to electric road

establishment at an early commercial phase

In order to investigate whether, and if so how, the different technologies affect the risk profile, an assessment has been made based on whether any technology appears to involve more or less risk compared to the general risk level for electric roads that has also been estimated. The aim is to provide a current situation profile of the technologies and how they may affect the risks, and not to assess their potential. This is illustrated by a plus sign or a minus sign in Table 4 below.

- A plus sign (+) means increased risk
- A minus sign (-) means reduced risk

The result of the overall risk assessment is shown below in Table 4 below:

Table 4. Overall risk assessment

Category		**General risk level for electric roads** (scale 0-3)	**Technologies** (if one differs from the general level)		
			Conductive, overhead	Conductive, from the road	Inductive, from the road
Design, planning and construction risks		2			+
Operational risks		3	-		
Market risks		2			
Financial risks	• **Electric road**	2	-		+
	• **Electricity grid**	1			
	• **Vehicle**	2			
Legal risks		2			
Political risks		1			
Risks of opposition from the general public		1		+	+

It can be generally noted that the categories considered most prone to risk are operational risks and those considered less prone to risk relate to financial risks for electricity grids, political risks and risks from public opposition. No major difference in risk exposure can be seen between the technologies. However, inductive appears somewhat more prone to risk and the overhead slightly less prone to risk than the general level. The different technologies have different TRL levels and it is important to point out that regardless of technology, an adequate TRL level needs to be achieved before large-scale development is possible.

Risk assessment per risk category is described in overall terms below with the possible impact of the different technologies:

Design, planning and construction risks

The different technologies involve different conditions in design, planning and construction. Overhead technology needs more space alongside the road, which can be problematic unless sufficient ground access can be ensured. Conductive technology in the road surface is seen as more prone to risk due to the potential for the carrying capacity of the road to be impaired by changing road construction. Inductive technology is considered most prone to risk in this context, since a major part of the road needs to be excavated, and it is uncertain how the technology and road foundations will be affected by seasonal variations, temperature differences, soil frost thawing, etc.

Operational risks

During the operating period, there are also differences between the different technologies that may affect the design. The poles for overhead technology can affect snow ploughing and other roadside operations. There may also be risks associated with wear and damage to the overhead contact line during higher traffic flows, but these are not considered to be extensive and are something where there is knowledge and experience from similar solutions, for example, railways. The rail inserted in the road pavement for such conductive technologies changes the maintenance needs of the road and can, for example, be affected by moisture, wetness and frost. There are also a lot of components in the electricity supply that need to be maintained since the electricity needs to be turned on and off continuously. This also applies to inductive technology in the roadway. Inductive technology may also mean it is difficult to replace parts because the roadway needs to be opened. However, one advantage is that there is no mechanical contact in the transmission, which reduces the risk of parts wearing out from direct contact.

A general risk for all of the technologies is ensuring that there is adequate electrical capacity at the time and place it is required.

Market risks

Demand can be assumed to largely depend on the price of electricity for electrical operation compared to the price of other fuels to the user, so the introduction of electric roads will probably be facilitated if the price is lower compared with other fuels. Depending on the importance of sustainability to a user, the benchmark value may be fossil fuels or biofuels such as biodiesel. Market development is also affected by standardisation where a standard should mean that carriers are more willing to invest in vehicles that can use the electric road. In particular, standardisation of the interface to the pick-up is important regardless of transmission technology.

At an overall level, the market risks are affected by the development of electric roads in neighbouring countries. If an electric road technology different from the one chosen by Sweden for large-scale development has greater impact internationally, there may be a risk that the electric road technology in Sweden needs to be replaced and possibly also the pick-ups in the vehicles if they are not standardised as above.

The market risk of electrification along the road can be reduced thanks to the development providing added value other than the electric road, e.g. reinforcement of local or regional electricity grids.

No major differences have been identified regarding the different technologies, other than that conductive technology from the road and inductive technology may potentially mean more customers, since vehicles other than heavy vehicles will be able to use the electric road.

Financial risks

The financial risks include willingness to invest, which is considered to vary between the different subcomponents in the electric road:

- Electric road - The service life of the infrastructure is long, which can provide prospects for long-term returns. However, there is a risk that the willingness to invest will be low as long as the TRL level is low, so the inductive technology may be slightly more prone to risk and the overhead slightly less. In the long term, there is also a general risk that the electric road will be made unviable by other fuels, new battery types with better performance or by competing electric road technologies.
- Electricity grid – Electrification of the road would add power lines that could be used to strengthen the electricity grid in general, which should create greater willingness to invest. The electricity grid infrastructure has a long service life and involves a relatively safe investment, provided that there is a usage or usage guarantees.
- Vehicles - Dynamic electricity supply is competing with other fuels, which is why price and availability are important. In addition, the vehicles have a short service life and need to be rapidly amortisable.

Legal risks

The legal risks are difficult to specify since all the technologies are untested. However, it may be noted in general that there is a risk that conductive technology from the road and induction technology will adversely affect electrical safety. There may also be a risk that the Planning and Building Act and Road Act affect the development plans. If there is an established formal highways plan for the section of road planned for electrification, the plan may be affected. If there is no highways plan, one may be need to be drawn up, which can be a time-consuming process.

Electric road development could also be affected by infrastructure planning for the area where, for example, future reconstruction of a section of road is affected by the existing construction of an electric road infrastructure, regardless of its technology. This is something that needs to be regulated in future agreements as well as investigated more closely in the event of an actual development of, and any changes to, the section of road in question being planned.

The legal responsibility for damage to infrastructure or vehicles is not clear, which in itself poses a risk.

Political risks

Political decisions will largely govern price levels, not least in terms of taxation and pricing of other fuels. How different fuels are taxed is an issue of political prioritisation. However, reducing carbon dioxide emissions is a high priority in government objectives, which suggests that electric roads will probably not be taxed too highly.

Risks of opposition from the general public

A category added during the investigation is the risk of opposition from the general public, which from experience has proved to be of great importance. For example, there is a risk that people living near the construction of a new electric road installation will be dissatisfied if they are not involved at an early stage.

Overhead technology is relatively easy to understand and the general public is more accustomed to it from railways and light rail systems, but it is more visible and can be perceived as more unsightly than the technologies incorporated into the roadway. It may also be perceived as less robust since the experience of the general public from the railways may be associated with faults in overhead contact lines resulting in stoppages. Inductive technology is more difficult to understand, but the installation is not visible and may attract greater interest due to it being a new technology. Conductive technology via a rail in the road pavement may be perceived as prone to risk since it is possible to come into direct contact with the rail. However, the risk can be limited since there are rails for trams in urban environments that the general public comes into direct contact with without them being perceived as hazardous.

7.2 ALLOCATION OF RISK CATEGORIES BETWEEN PUBLIC AND PRIVATE SECTOR PARTICIPANTS

Allocation of risks can have a major impact on the financial outcome over the life cycle by creating incentives for different parties to work properly in order to optimise and manage the total risk exposure. It is important that the allocation is made in an informed manner and that risks are allocated according to what is most appropriate for the specific project, rather than according to traditional patterns.

This investigation makes an overall allocation of risk categories in order to analyse which categories may potentially be owned by private market participants and by the government or the Swedish Transport Administration respectively, in the case where the government or the Swedish Transport Administration is the principal for the electric road. The allocation is illustrated in Figure 18 below, which also shows that a category does not necessarily need to be allocated by 100% to either the public or private participant but can be divided between them to a varying degree.

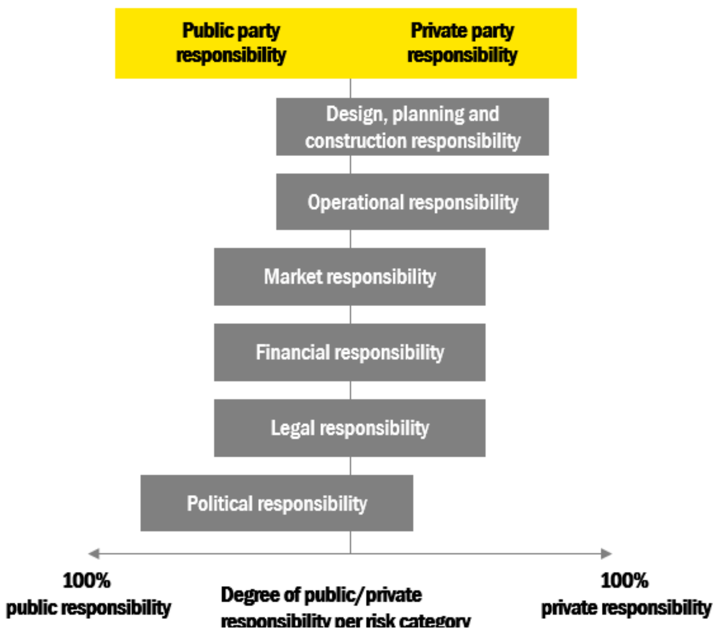

Figure 18: Allocation of risk categories

The allocation of risks shows that most categories will probably need to be shared between public and private participants, which may be natural for projects similar to electric roads that are not particularly proven and are likely require an amount of public support to be established. As the market matures and the risks related to the establishment of the electric road system decreases, the appearance of the above allocation may change and it should be possible to allocate more categories to private participants. The general risk level described above may also be affected and possibly reduced when more experience and knowledge exists.

It is important to note that the allocation has been drawn up based on estimated market interest and experience from the meetings, interviews and workshops conducted during the investigation. It has not been adjusted based on the so-called appetite for risk of specific market participants, i.e. interest in bearing risk based on possible remuneration, or the appetite for risk and capacities of the client. In order to develop a more comprehensive and concrete allocation, it is important that all risks in the project are carefully reviewed and balanced against the different types of market participant.

Below is a brief description of the allocation per risk category:

Design, planning and construction risks

Allocated mostly as the responsibility of private participants. Permits and conditions are a task for the Swedish Transport Administration; while design, planning and responsibility during the construction phase should be handled by the provider, i.e. a private party. Here there are different established types of procurement and contract forms that can be applied.

Operational risks

Responsibility during the operating period should be managed by a private party to a large extent. Depending on contract structure and who owns the electric road, a functional undertaking may be likely which involves greater responsibility (and risk) for the private party.

Market risks

Should be managed by private parties in the long term, but at an early stage when there is uncertainty about the establishment, public risk taking may be needed, e.g. through government subsidies or guarantees.

Financial risks

Affected to a large extent by other categories and is therefore allocated equally between the parties.

Legal risks

Permits and conditions, in addition to the Electricity Act, are a task for the Swedish Transport Administration as well as possible decisions on future reconstruction of the section of road in question. The private party should be responsible for ensuring that the technology meets the regulations for electrical safety and similar. Otherwise, risks within this category should be shared between the parties.

Political risks

Should be allocated to the public sector to a large extent at an early stage due to uncertainties surrounding the establishment. An example of political risk may be the risk that electric roads are no longer considered sustainable in the long term compared with other alternatives. In the longer term, these types of risks may probably be shared more equally between the parties due to the consequences of any changed political policy or decisions being handled by both parties.

8 FINANCING OF ELECTRIC ROADS

The development of electric roads requires extensive investments that are not necessarily part of the public sector's responsibility. The government, and in some cases municipalities, have traditionally held responsibility for road infrastructure for public roads (private roads excepted) while fuel is provided by private market participants. Since electric roads combine the road with electricity as an energy carrier, there is no party that obviously has the task of being responsible for the entirety, which makes it important to investigate different forms of financing, amongst other things.

Public sector participants can be expected to assume responsibility for certain parts of the electric road system, while private sector participants may come to be responsible for other parts. Financing is such a part where private participants may come to be involved, in particular after the government's announcement in connection with the formal adoption of the National Infrastructure Plan of 50% private co-financing for pilot facilities [45].

A shift in the allocation between the sectors may also take place over time, such as in the transition from an early introduction in a pilot phase to planning for a more large-scale development. In a more mature market, private sector participants will probably be responsible for essential parts of the electric road systems, as well as in areas that could be seen as the current area of responsibility of the Swedish Transport Administration. It is quite simply a new situation that is now appearing for road traffic, road infrastructure and its organisation and financing. It cannot be ruled out that regulation affecting the allocation of responsibility may therefore need to be adjusted over time.

Previous sections described different market participants and stakeholders for electric roads, as well as possible business packages and suppliers, revealing good opportunities for private participants to take on different roles in the development. Some parts should therefore possibly be provided and financed by private market participants, while other parts may be subject to government funding.

8.1 PREREQUISITES FOR PRIVATE FINANCING

There is a declared interest in investing in an electric road development based on the meetings and reference group meetings that have been held. Electric roads are capital-intensive and reportedly there is capital available on the market as well as interest in such investments. What are primarily considered most attractive are the long-term perspective, predictability, a known structure and clear regulation. It is therefore not necessary for the government to meet the entire investment.

Parties considered as suitable for investments in projects similar to electric roads are those seeking long-term safe cash flows, such as infrastructure funds or pension funds with some knowledge of technology and risks associated with this area. The investment horizon should not be too short; a horizon of at least 10-15 years has been suggested as appropriate [42].

Several parties have highlighted that well defined regulation and established guidelines are important to private investors [41]. It is considered beneficial if it is possible to apply existing regulations to as great an extent as possible in order to create recognition. From an investment perspective, stable conditions involve lower risk premiums and therefore less expensive capital, and in the same way, uncertainties involve higher risk premiums.

What is decisive for private investors is the potential for return, and an important driver for electric roads is traffic volume. It is possible for private investors to take on some risk on volume, but forecasts are required for them to be able to make reasonable estimates, which is requested by the market [46, 30]. It is seen as positive if long-term development plans are established in order to estimate volumes in the long term.

One risk mentioned is that of the electric road technology becoming obsolete, and that the electric road technology being developed will need to be replaced by another in the future. One challenge is also that the service life of the different components in the electric road varies greatly, fixed infrastructure can have a service life of around 40 years, while electronics and metering systems may only have approx. 5 years [42]. Pilot facilities are therefore very important for scaling up and testing the technology and understanding how the different components work together.

To work to identify a technology that is as compatible as possible, and to find a common standard, is positive for ensuring long-term sustainability. The Swedish Transport Administration has been identified as an important party in driving the standardisation issue [30]. However, the technology risks are not considered to be the most decisive factor overall for investors, but rather the nature of the financial calculations, i.e. revenue and cost flows.

Traffic volume is considered to be the most important parameter for creating an economically viable estimate and, at an early stage, there will probably need to be some type of subsidy, guarantee or similar from the Swedish Transport Administration or the government to increase interest [42, 46]. A model that is emphasised as being of particular interest consists of concessions that is a known structure and considered to be an attractive model [46].

8.2 Public support and instruments

In the case where the electric road is not economically viable, different types of subsidies may be required for private parties to be interested in financing and operating the electric road. One such means of support that has been highlighted during the investigation is volume guarantees, i.e. that the government accounts for revenues up to a certain volume of traffic [46].

In other countries, there are different types of instruments to promote the development of fossil-free transport. In Germany, for example, a subsidy of EUR 40 000 is granted for the purchase of trucks over 12 tonnes powered by electricity or fuel cells [47]. In Germany, trucks powered by electricity may also avoid paying road fees in order to provide increased incentives to carriers to change to electrical operation [48]. In Norway, electric cars are exempt from road fees, road taxes and registration fees [49], which is a step in the same direction, even though trucks are unlikely to be affected to a particularly great extent since full electrical operation for trucks is still unusual. In Sweden, the bonus malus system was introduced on 1 July 2018 to promote vehicles with lower carbon dioxide emissions [50]. The system only applies to new passenger cars, light buses and light trucks, but similar systems for heavy transport could also be introduced in the future.

To facilitate the introduction of electric roads and for carriers to change over to vehicles adapted for electric roads, there may be a need for different support measures and instruments, as illustrated by the example from Germany. However, different types of instruments and their potential effects have not been further investigated in this assignment and are factors that should be investigated in more detail in a subsequent stage.

8.3 Alternative financing solutions and forms of implementation in a government undertaking

Even for the sections of the electric road that qualify for government involvement, alternative financing solutions and forms of implementation may be appropriate. An alternative form of implementation involves a public party, such as a government agency, having the intention to initiate, design, build, manage and/or operate an installation, while having a preference for a private partner to be wholly or partly responsible for the implementation. The basic idea is to share responsibility, risks and funding in order to create incentives for the private party to increase efficiency and develop new solutions.

A private financing component is included in order to create additional efficiency incentives and it normally consists of a combination of equity capital and borrowed capital in order to identify an optimal level of average capital cost, based on the client's perspective. Private funding should primarily be seen as a way of sharing risk, and the often higher capital cost should be seen as a risk premium. If it is considered reasonable that a private investor, e.g. an infrastructure fund, has the capacity to deliver increased value compared to a situation where the funding is wholly public, alternative funding may be an interesting option. If this is not the case and only the capital injection itself is sought, it may instead prove to be cheaper using public financing.

With regard to revenue, there are mainly two different models: availability-based and demand-based models that are based on different risk and incentive allocations:

Availability-based model
An availability-based model is based on a private party providing an infrastructure solution and which is remunerated for this by the public party that constitutes the client. The remuneration is independent of the utilisation rate, which means that the private party does not bear a risk on volume, which often results in slightly lower risk premiums compared with demand-based models.

Demand-based model
A demand-based model is based on a private party providing an infrastructure solution and which is mainly remunerated by user charges. This means that the risk on volume is borne to a greater extent by the private party than in an availability-based model. In order for a private party to be willing to bear a risk on volume, a general requirement is the possibility for the installation in question to be used in an open market or that demand is expected to be relatively constant.

Concessions represent a common variant of the demand-based model where a private party is given the right to operate a facility and receive the income from this as remuneration, or part of the remuneration, in order to develop and maintain it. During the concession period, the private party may levy fees on the users that can be supplemented by compensatory support from the public party in the cases where the installation is not expected to generate sufficient cash flow to warrant the investment. For more information, see Appendix I.

9 Consideration whether public procurement or concession is appropriate for the development of electric roads

As described earlier, some parts of the development of electric roads may require government involvement while private market participants are likely to be responsible for other parts under market conditions without government procurement.

For the parts that the government may take responsibility for, either concession or public procurement can be considered. This chapter broadly outlines what considerations need to be taken to assess whether concession or public procurement may be applicable and at a very general level, what types of procedures could be used. Selection of procurement procedure then needs to be preceded by an in-depth feasibility study based on a proposed procurement object, which is not included in this investigation. Appendix I contains a description of the procurement of concessions according to LUK (Act on Procurement of Concessions) and public procurement according to LOU (Act on Public Procurement) and LUF (Act on Public Procurement in the Utilities Sectors), as well as a brief description of different procurement procedures.

9.1 CONSIDERATION OF WHICH BUSINESS PACKAGES MAY BE RELEVANT FOR CONCESSION OR PUBLIC PROCUREMENT

To determine whether concession or public procurement is applicable, it is important to clarify who it is that constitutes the principal, i.e. who is ordering the implementation. If this principal is a public party, it means that either construction/service concession or public procurement is likely to be used for the electric road development. There may be different potential principals based on the business packages described in Section 6, which affects the parts of the electric road development that may be considered for concession or public procurement. The packages are described below based on potential principal, whether concession, public procurement or something else may be appropriate, as well as possible government involvement.

Business package 1: Electricity grid extension, involves a regulated activity that is examined by Ei upon application from any of the electricity market's participants. The package can be handled separately and then included in current electricity grid concessions, be viewed as a new concession or alternatively classified as a non-concessionary grid, depending on Ei's examination.

The electricity grid extension could be handled in combination with Business package 2, Electric road infrastructure, with an electric grid company as principal. In such a combination, an electricity grid concession is relevant for the actual electricity grid extension, even though public procurement or a service concession is conceivable for the development of the electric road infrastructure.

The role of the Swedish Transport Administration for Business package 1 may be to clarify the prerequisites for electricity grid companies and provide access to the road area. It would also be possible for the Swedish Transport Administration to set requirements and set conditions for granting the land. Proposals have also been given during the investigation that the Swedish Transport Administration or the government could cover some type of volume guarantee [33], which could reduce the risk for electricity grid companies.

Business package 2, Electric road infrastructure, may have a public party as the principal where the Swedish Transport Administration is a natural option, even if this does not have to be the case. Construction of the installation could be performed by a party that is awarded a building concession or through public procurement. In the longer term, construction or service concessions appear to be the most appropriate to be able to replicate market conditions as far as possible.

In the short term in a pilot phase, there are advantages with both concession and procurement. By using a concession for a pilot development, the structure tested would be more similar to the future solution, even though the conditions are not identical. Advantages of using public procurement for a pilot phase are that the public party is then given greater control over the testing as well as opportunities for control during the contract period thanks to the absence of any operational risk being transferred.

Regardless of whether a concession or public procurement is applied in a pilot phase, it is important to take the uncertainties involved in a pilot phase into account, e.g. that the testing does not at all achieve the expected results or that a party is affected by financial problems. The contract therefore needs to be sufficiently flexible to handle such changes, e.g. through clauses for any termination of the contract for both parties and the opportunity for the public party to take over the undertaking.

Proposals for setting requirements that may be relevant to the procurement or award of a concession may be requirements for e.g. payment flows, competition neutrality and non-proprietary technology, technical compatibility and compliance with applicable regulations at national and EU level.

Business package 3: Vehicles, probably requires no public support as the assumption is that the market is driving the development and should therefore not be relevant for service concession or procurement. In the construction of the pilot section in Hessen, Germany, vehicle development also takes place via projects separate from the development of the electric road [22], which indicates that it should be a reasonable assumption.

Potentially, any public undertaking can facilitate the development, e.g. procurement of a certain number of vehicles to create a basis for the development. Something that has also been mentioned by different parties is that the government should work for a common standard, preferably at European level, in order to reduce the risks of the market participants developing solutions that later become obsolete [30]. This applies to both vehicle-based and infrastructure-based technology.

Business package 4: System for metering usage, does not have an obvious principal, and based on the fact that the current solution is relatively undeveloped, there should be good opportunities for the market without public subsidies to drive development and innovation in the area. A private market participant could potentially be purchased by the government through the Swedish Transport Administration but a more probable solution is that this is the subcontractor of the electric road operator. The electric road infrastructure in Business package 2 needs to work well together with the system for metering usage, so the interface between them should be expedited. In the short term, this function can be seen as unique with a high degree of innovation, while in the long term it can consist of a standardised solution with several electric road operators as customers.

Based on the hypothesis that Business package 4 is driven by a subcontractor to the electric road operator, it is doubtful whether public procurement is appropriate and whether the government or the Swedish Transport Administration should have any role at all in the business. The Swedish Transport Administration could possibly be able to contribute to the requirements setting for Business package 2 above regarding how the service should work on the condition that the Swedish Transport Administration is the principal for it. A concession is doubtful for Business package 4, since it requires that some operational risk is borne by the private party, for which there are limited opportunities.

Table 5 below summarises whether concession or public procurement is considered appropriate, who the possible principal is and what requirements a potential government undertaking and business package might set.

Table 5. Overview of whether concession or public procurement is appropriate per business package

Business package	Potential principal	Suitable for concession?	Suitable for public procurement?	Potential government undertaking
Business package 1, Electricity grid extension	Distribution system operator	Yes, electricity grid concession	No	No, type of development examined by Ei

Business package 2, Electric road infrastructure	The Swedish Transport Administration (even if this must not be the case)	In the short term in pilot phase: May be appropriate based on more testing of future conditions In the long term for large-scale development: Yes, construction or service concessions with transferred operational risk should be appropriate	In the short term in pilot phase: May be appropriate as a higher degree of public control may be required during testing	Swedish Transport Administration potential client in pilot phase and in large-scale development
Business package 3, Vehicles	Vehicle manufacturers	No, since the principal is a private party	No, since the principal is a private party	No, since the development is assumed to be market driven
Business package 4, System for metering usage	Electric road operator (even if this must not be the case)	No, since the principal is assumed to be a private party	No, since the principal is assumed to be a private party	Doubtful. Could be able to contribute to the requirements setting through the procurement of Business package 2 (provided that the Swedish Transport Administration is the principal)

9.2 Considerations in selecting procurement procedure

Depending on whether procurement is relevant, different procurement procedures may be appropriate for different parts. There are a number of different procedures set out in the procurement legislation and it is important to see the full range of options in order to choose the one that best suits a particular procurement object. Which procedure is most appropriate can be chosen based on:

1. Threshold values and type of object
2. Degree of uncertainty about what is required to be procured including:
    a. Balance between a general function and specified instruction in requirements settings
    b. Need for supplier cooperation during procurement
3. Degree of innovation

As the development of electric roads involves comprehensive investments, the threshold values mentioned in paragraph 1 above can be assumed as being met regardless of business package. This means that primarily the degree of uncertainty and the degree of innovation should govern the appropriate procurement procedure. How to assess these risks is described in more detail in Appendix II.

Electric roads, which are a new type of infrastructure that has not yet been developed on a large scale, can be seen as being characterised by a high level of uncertainty, as it is not possible to determine in advance how the future solution will be designed. It can also be noted that the degree of innovation is high since the solution is new to the market and has great potential for further development over time.

The business packages described in Section 9.1 constitute a hypothesis about different procurement packages that can be characterised by a higher or lower degree of uncertainty as well as a higher or lower degree of innovation. Based on the analysis, Business package 2, Electric road infrastructure, appears to be primarily relevant for public procurement, based on the fact that it is the only one assumed to have a public principal.

Different road technologies can also show different degrees of uncertainty and innovation. For example, overhead catenary technology seems slightly less uncertain since it has been tested to a greater extent than inductive technology. However, it is important to note that even though the electric road technologies achieve a higher degree of maturity during the tests and demonstrations that are carried out, and are thus considered to have a higher degree of security, there is also development potential for the system's peripheral services and application. For example, high potential for innovation can be related to the payment model and information processing.

A further dimension that is relevant to electric road development is the time perspective. Different procedures are likely to be appropriate depending on whether the development takes place as a pilot phase rather than a large-scale commercial development.

Figure 19 below illustrates the link between different procurement procedures and the degree of uncertainty over what is required in the procurement in a case where the Swedish Transport Administration is considered to be a suitable principal. Perspectives that have been relevant for electric roads, the time perspective and degree of technical maturity, are illustrated using a scale for electric roads at the bottom of the figure.

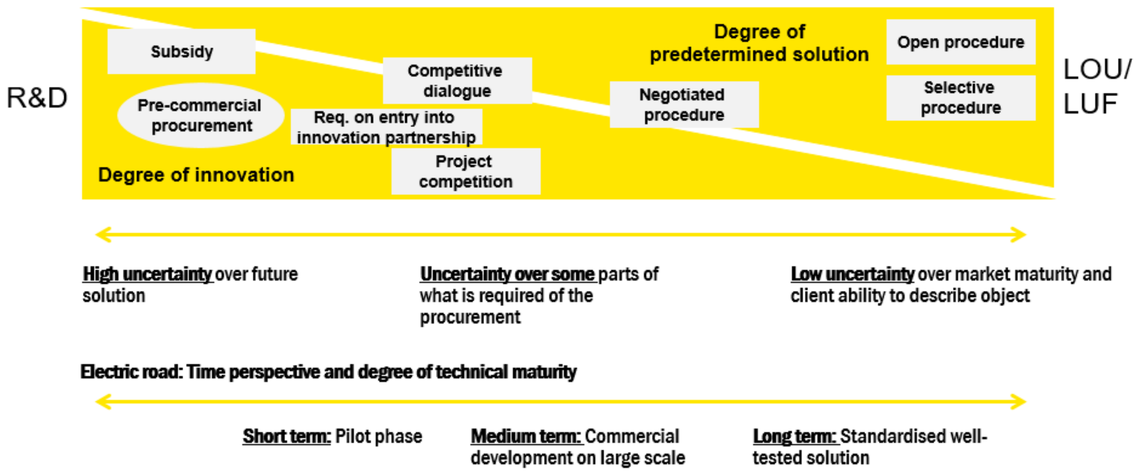

Figure 19. Time perspective and technical maturity for electric roads

In the figure, the yellow fields illustrate a sliding scale between the use of the exemption in the public procurement legislation allowing for research and development services to be procured without a formal procurement process, “the R&D exemption”, on the left and traditional procurement according to LOU and LUF on the right, where the solution is predetermined to a higher degree.

The procedures on the left are, in principle, suitable procurement objects with a high degree of uncertainty, and the packages on the right have a low degree of uncertainty. The procedures that are shown as relevant for electric roads based on degree of uncertainty and innovation, at a very overall level, are mainly competitive dialogue, negotiated procedure, and procedure for entering into innovation partnerships. This assessment needs to be balanced against the procurement strategy that the Swedish Transport Administration applies.

When it comes to the choice between competitive dialogue and negotiated procedure, it is important to think about what it is that defines the uncertainty and at which point during the procurement that information from the market should be acquired. Negotiations do not take place in a competitive dialogue but on the other hand, one or more dialogue phases are conducted under procurement secrecy following a pre-qualification. Indicative non-binding bidding procedures can be conducted within the framework of the procurement itself, with the purpose of working with the suppliers to draw up the right tender documentation with proper descriptions of functional requirements, risk allocation and payment model. Following which, final tender documentation is established where the parties to the dialogue can choose to submit tenders. Competitive dialogue is therefore particularly suitable when uncertainty exists regarding functional requirements when it comes to new technology, appropriate allocations of risk and responsibility, as well as financing. If the degree of innovation in technology, implementation and operation is considered to be sufficiently high, the procedure for entering into innovation partnerships may also be appropriate.

In the Swedish Public Procurement Act, LUF, the competitive dialogue is an exception procedure that may be used when there is technical, financial or legal complexity. These criteria may be considered as being met in this case.

In a negotiated procedure, any contact with the tenderers takes place after the tender has been received and the contact consists of negotiation where the price can be negotiated. The content is established in the tender documentation and may not be renegotiated. The procedure is suitable when it is relatively obvious how technical and other system solutions should be described in order for suppliers to be able to deliver complete and competitive solutions, but where there is a wish to be able to negotiate price and, for example, risk premiums included.

For a specific procurement, the selection of procurement procedure needs to be more carefully evaluated for the respective procurement package by means of an in-depth feasibility study.

9.3 INNOVATION PROCUREMENT

Innovation procurement is something that is often discussed and interpreted as a means of purchasing products and services that are not currently available on the market, but this form of procurement may have a significantly broader use than that.

In innovation procurement, a larger and broader perspective is taken regarding needs and challenges and how they can be met compared with traditional procurement. The difference in approach can be described simply by stating that traditional procurement is based on current needs that are met by procuring the most suitable goods or services already available on the market. Innovation procurement is meant for finding new ways of solving future needs and meets more overall objectives. Future-proofed solutions are demanded in innovation procurement and the solution ultimately procured may not necessarily be currently available on the market. The Swedish Transport Administration works with innovation procurement in order to promote and stimulate development in the supplier market and considers it as an incentive to obtain better function and increased productivity [51].

For more information on innovation procurement, where it is appropriate and different types of innovation procurement, see Appendix III.

Innovation procurement as described in Appendix III appears relevant for the development of electric roads because the market has great development potential and it is important that the solution procured supports further development, in particular during a pilot phase but also later. Innovation procurement is suitable for both procurement of electric road development with technologies in different stages of maturity, but also for the ability to develop and improve the system as a whole over time. This includes all peripheral services such as payment solution, access control, system robustness and maintenance needs, etc., as well as additional functions over time.

The methodology for innovation procurement is independent of procurement procedure and selection of procedure can take place during an in-depth feasibility study based on the parameters described earlier: degree of uncertainty and degree of innovation. This means that innovation procurement is suitable for procurement of electric roads regardless of procedure. Since procurement of concessions in accordance with the Act on Procurement of Concessions, LUK, may be designed relatively freely, innovation procurement should be appropriate even in these cases. Based on the assessment in Section 9.1, Business package 2, Electric road infrastructure, appears as primarily applicable to either procurement or concession, and thereby also for innovation procurement.

10 Conclusions

The climate impact of the transport sector is significant and a range of efforts is being made to reduce fossil-fuel use in favour of more sustainable alternatives. The development of electric roads is one of many solutions that are currently making great advances through technology development and testing, both in Sweden and internationally. Sweden is the first country in the world to have introduced an electric road on a public road.

This investigation aims to investigate business models for electric roads and how they can be developed organisationally and financially, and function as an open system in Sweden. During the investigation, many parties and stakeholders have been involved, interviewed and have made contact, indicating that interest is great, not just from the public sector. An important prerequisite for the investigation work has been to avoid locking in the allocation of responsibilities prematurely, e.g. by starting out from a traditional government undertaking for transport infrastructure, but instead to conduct an open-ended investigation into which parties can and should take what responsibility, and the way in which the electric road system can be owned, financed and operated over time.

Since electric roads are still a relatively new type of installation there is still no established market. It is therefore difficult to draw complete conclusions about the business conditions with any certainty. As a starting point, a survey has been conducted of the electric road system as a whole, after which a proposal for subdivision into four overall business packages has been drawn up. These hypothetical business packages appear to be an appropriate means through which to analyse the market. The design of the packages has been based on a number of criteria and they have gradually been proved to be plausible based on the interviews, meetings and workshops that have been conducted. The packages into which the electric road system is proposed to be subdivided are:

- Business package 1: Electricity grid extension
- Business package 2: Electric road infrastructure
- Business package 3: Vehicles adapted for the electric road
- Business package 4: Metering and payment systems

The different packages have different characteristics and contain combinations of technical components, services and systems. The contents and allocations of responsibility for each package are discussed based on potential owners and suppliers. It is also possible to combine the different packages, in particular a combination of Packages 2 and 4, since business Package 3 can be seen as a separate business and Package 1 is largely regulated by the Electricity Act, and is considered to be significantly more mature than the other packages. The difference between different technologies has not been found to affect the business package itself, but the different degree of maturity of the technologies affects the time perspective and when they are ready for pilot phase or large-scale rollout respectively.

The time perspective is a particularly important factor and, depending on which phase the system is developed in, i.e. in a semi-commercial pilot phase or large-scale development, it is likely that different levels of public commitment and governance will be required given the market's maturity and development. Different types of public support and guarantees will probably be required at an initial stage, both to attract private parties and investors for the development and operation of the electric road, but also to create incentives for growing the vehicle fleet for heavy transport vehicles powered by electricity. Experiences and lessons learned from Germany's recently introduced subsidies for purchasing trucks powered by electricity are valuable if a Swedish equivalent model is under consideration. However, any support and guarantees need to be carefully balanced to ensure sufficient incentives to increase the use of the road without creating other undesirable behaviour, such as full transition to goods traffic on the roads instead of on the railways.

Other types of public undertakings that may be appropriate, in particular in the early stages of a pilot development, are that the government, e.g. through the Swedish Transport Administration, takes on the role as principal for parts of the system. Of the different business packages, Package 2 appears to be the most relevant for such a public undertaking. In a pilot phase, either concession or public procurement may be suitable as the procurement method for this stage of the electric road, and then concession in the longer term, where a market participant can operate the electric road with full or partial risk on volume. However, this needs to be further investigated in order to determine the market's interest for such an undertaking. Procurement procedures that can handle a high degree of uncertainty and innovation, and which allow dialogue with suppliers, should be appropriate regardless of whether it is procurement or concession. The choice of procurement procedure needs to be evaluated in particular by means of an in-depth feasibility study in advance of a future pilot development.

Interest among private parties in electric roads has proved to be great, and although the market has not been fully tested in this investigation, it can be concluded that there are private parties interested in different parts of the electric road system, i.e. the various business packages above. The uncertainty that is primarily highlighted is the risk that the electric road technology that is being developed will later become obsolete and that standardisation, preferably on a European level, is therefore important.

Investments in transport infrastructure are generally considered to be potentially secure and stable, and are attractive to investors seeking long-term investments, such as pension funds or infrastructure funds. There is an interest among investors to invest in an electric road development and also to take on a certain amount of risk on volume on the condition that these risks can be calculated, i.e. that there is decision data for calculations and forecasts. Continued development of pilot facilities is therefore important in order to gain more experience and to increase the reliability of the data and assessments.

To create good business conditions for electric roads, it is important that there is a difference between the price for using the electric road and the price for using other fuels. In addition to any public subsidies, it is this difference that will back up all investments, the operation of the electric road, as well as incentives in the form of profit margins for carriers and the parties in the electric road's value chain. Something that may affect this difference is how the taxation of fuel will evolve in the future. Such an analysis has not been included in this investigation, but various parties have highlighted the issue during the course of the investigation.

In conclusion, it can be noted that there are good prospects for the development of electric roads in Sweden, although a lot of work will be required in the form of testing, pilot projects and inquiries before a large-scale commercial system can become a reality. A likely development is that smaller local systems will be developed first where there are particularly favourable conditions in the form of large vehicle flows in shuttle traffic, which can later be linked together. Standardisation is therefore important again in order to make such interconnection possible and facilitate the usage of the electric road within Sweden's borders and in the long term also across national borders.

In addition to government initiatives, it is also important to support market participants to continue to drive the development from their own perspectives, e.g. through the development of vehicles and electric road technologies. By means of a declared interest and ongoing inquiries and investments by the government there are good conditions for encouraging and promoting private development as well, which will be required to realise the development of electric roads.

11 RECOMMENDATIONS FOR FURTHER INVESTIGATIONS AND THE NEXT STEPS

During the investigation, a number of areas have been identified where further examination is needed to understand whether, and if so how, the development of electric roads may be affected. Those that are considered to be of greatest significance are described briefly below. Work is already underway in the Swedish Transport Administration for several of the points raised.

Conduct a supplementary and in-depth feasibility study in advance of a future pilot development

A number of analyses have been carried out during this investigation for the purpose of examining suitable business models and financing solutions for electric road development. However, analyses have largely been carried out at an overall level and would need to be made more in-depth by means of a supplementary feasibility study in order to answer questions about technology choices, costs, risks and their allocation, as well as funding and procurement.

A pilot structure similar to the business packages drawn up in this investigation is proposed and then, in particular, a subdivision of Package 1, the electricity grid infrastructure, with a distribution system operator as principal and a combination of Packages 2 and 4, electric road infrastructure and systems for metering usage, with the Swedish Transport Administration as principal. If this option is chosen, the Swedish Transport Administration is further suggested to procure Packages 2 and 4 as a joint procurement object, either as a concession or through public procurement, which needs to be investigated further by the in-depth feasibility study. The proposed structure needs to be thoroughly evaluated and detailed during the feasibility study since it is not necessarily suitable in practice, even though it has been found to be plausible in this investigation.

The possibilities for 50% private financing according to the decision in the National Infrastructure Plan need to be investigated in particular in order to examine whether there is sufficient interest in the market. Even though a general interest has been expressed during this investigation, it is not necessarily the case in practice. More data to base decisions on is needed in the form of calculations and forecasts in order to be able to investigate market sentiment more concretely.

Continue to carry out demonstration projects and pilot projects

Continued tests in the form of demonstration projects and pilots are required to develop and test detailed structures for a business model and financing in practice and how suppliers and users of the system experience it in order to be able to further specify the business structure. Parts proposed for testing in particular include payment model, systems for metering and utilisation measurement and access control that have been difficult to assess during this investigation.

The cost data available related to investment and operation of the electric road is uncertain and it is therefore important to gain experience from continued demonstration projects, pilots and international collaborations in order to collect as much cost data as possible based on actual outcomes as a basis for further analyses and market research.

Test a suitable form of connection to the electricity grid for the electric road

As described earlier in the report, the connection to the electricity grid can be organised in different ways, which creates different business conditions for the extension of the electricity grid. The way that is most appropriate needs to be investigated further, eventually by means of Ei considering the issue.

Continue to investigate future development of electricity taxes

The economic incentives for carriers to change from current alternatives to the electric road are created by the difference between the cost of diesel and electricity. This difference is affected by taxes for the respective energy source, where there is a potential risk that the reduced tax revenues from fossil fuels during electrification would be compensated by increased energy tax on electricity as a fuel. This could lead to the disappearance of the difference between these types of energy, which risks reducing the incentives for using the electric road if the cost of alternative fuels is lower. The effects of energy tax changes therefore need to be further investigated in order to reduce the uncertainty in the market. Proposals for how any possible reduced tax revenues from fossil fuels could be compensated should also be further investigated.

Continue to investigate legal aspects

This investigation has not included the examination of regulatory aspects for electric road systems, although several regulations and laws have been shown to be important for how electric road development can be organised and financed. The Swedish Transport Administration is therefore recommended to continue investigating these aspects in order to understand if and how an electric road development can be affected as well as if any changes to current regulations and laws may be required.

Pursue the issue of standardisation of electric road technologies

Standardisation of some parts of the electric road system is important in order to reduce uncertainty in the market as the technology later becomes obsolete. Whether international or national standards are needed and which parts should be standardised need further investigation and in cooperation with other countries.

Investigate possible incentives for establishing electric vehicles on a larger scale

Electric road technology and its introduction have been studied in this investigation, but in order for it to have a large impact on the market and thereby reduce emissions, the automotive market also needs to be developed and the vehicle fleet for heavy transport powered by electricity needs to grow. Further investigation is required to review how incentives at an early stage can be created to encourage the use of a greater number of heavy electric vehicles.

12 SOURCE LIST

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Appendix I: Procurement of concession according to LUK and public procurement according to LOU or LUF

Concessions, public procurement and different procurement procedures are briefly described below.

Procurement of concessions in accordance with LUK

In the case that a construction or service concession is relevant, procurement take place in accordance with the Act on Procurement of Concessions, LUK [52]. A construction or service concession means that the client entrusts the execution of an assignment to one or more suppliers where the remuneration either consists entirely of the right to offer the service in question against payment from the users, or partly the right and partial payment [53]. An important prerequisite is that operational risk is transferred to the concession holder, which means that the concession holder takes on full or significant risk to achieve sufficient results in the activities and thus is not guaranteed to receive coverage for its investments.

In the procurement of concessions there are no special procedures that need to be used, but the client is free to design the contract itself as long as the principles in Chapter 4, Section 1, and other provisions in accordance with LUK are observed [53].

If a service is not defined as a concession, it is usually purchased through public procurement in accordance with LOU or LUF [54].

Public procurement in accordance with LOU or LUF

Depending on the type of procurement object, public procurement takes place in accordance with the Act on Public Procurement, LOU, or the Act on Public Procurement in the Utilities Sectors, LUF. Both are conceivable for procurement of electric roads and an in-depth analysis is required to determine what should be applied to what. Since both include similar procedures, the descriptions below are based on the procedures per se and not the legal provisions to which they belong.

Description of procurement procedures

A brief description of possible procurement procedures is given in Table 6 below. These procedures exist in LOU and LUF. However, in LUF there is competitive dialogue and the establishment of innovation partnership exemption procedures.

Table 6: Description of procurement procedures

Open procedure	• All suppliers who are interested may submit a bid • Contract negotiations are not permitted • The contracting authority may freely choose to use an open procedure
Selective procedure	• All suppliers may apply to participate, but only applicants invited by the contracting authority after pre-qualification may submit a tender • Negotiations on tenders are not permitted • The contracting authority may freely choose to use a selective procedure

Competitive dialogue	• The contracting authority conducts a dialogue with the tender applicants who have been invited to participate following pre-qualification • When acceptable solutions that meet the authority's requirements have been developed, the final bid is requested • The procedure is aimed at complex technical, financial or legal circumstances
Negotiated procedure	• The contracting authority invites selected suppliers after pre-qualification and negotiates the terms of the contract with one or more of these • There are no formal rules in LOU/LUF specific for the negotiations, and nor is there a formal conclusion of the negotiations • Contract terms are negotiated based on a defined solution
Project competition	• The purpose of a project competition is that the contracting authority should purchase a drawing or a project description that a jury has nominated as the winning entry. • If the contracting authority also wants to award a service contract, i.e. not just purchase the drawing or project description, it can take place through negotiated procedure without prior notification. • If the competition has resulted in more than one winner, the authority shall negotiate with all winners.
Innovation partnership	• The purpose of an innovation partnership is to procure a product or service to meet needs that cannot be met by solutions available on the market. • The partnership shall be divided into stages that follow the steps in the research and innovation process. The stages may also include the purchase of the goods and services • At interim targets, the contracting authority may terminate the partnership or reduce the number of suppliers.

Appendix II: Assessment of degree of uncertainty and degree of innovation during procurement

Degree of uncertainty

Figure 20 below illustrates the connection between different procedures and the degree of uncertainty over what is required of the procurement. The procedures on the left are, in principle, suitable procurement objects with a high degree of uncertainty, and the packages on the right have a low degree of uncertainty.

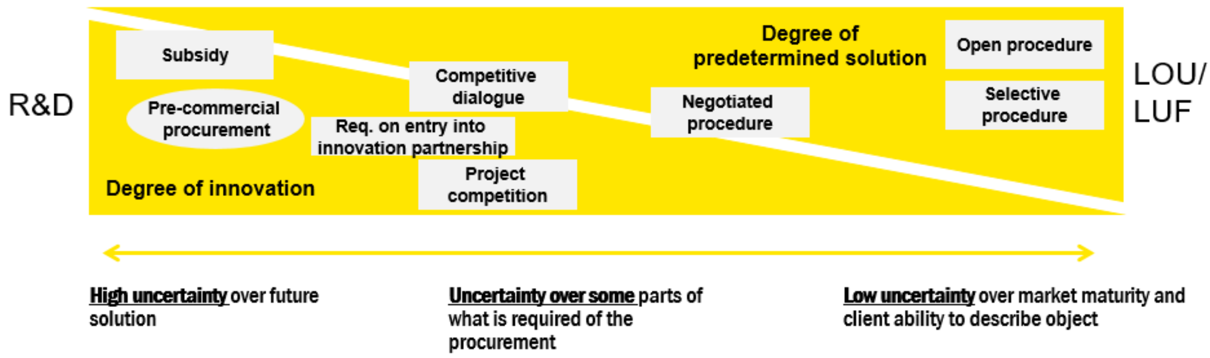

Figure 20. Selection of procurement procedure in relation to uncertainty over future solution

Degree of innovation

The degree of innovation can be assessed through two considerations:

- Whether or not the solution is currently available on the market
- Whether there is potential for further development of the service/product over time

Figure 21 shows the link to a potential low or high degree of innovation. A high degree of innovation means that the market is immature and that there are no existing solutions to purchase. In a similar way, a low degree of innovation means that the market is mature and there are solutions that can be procured.

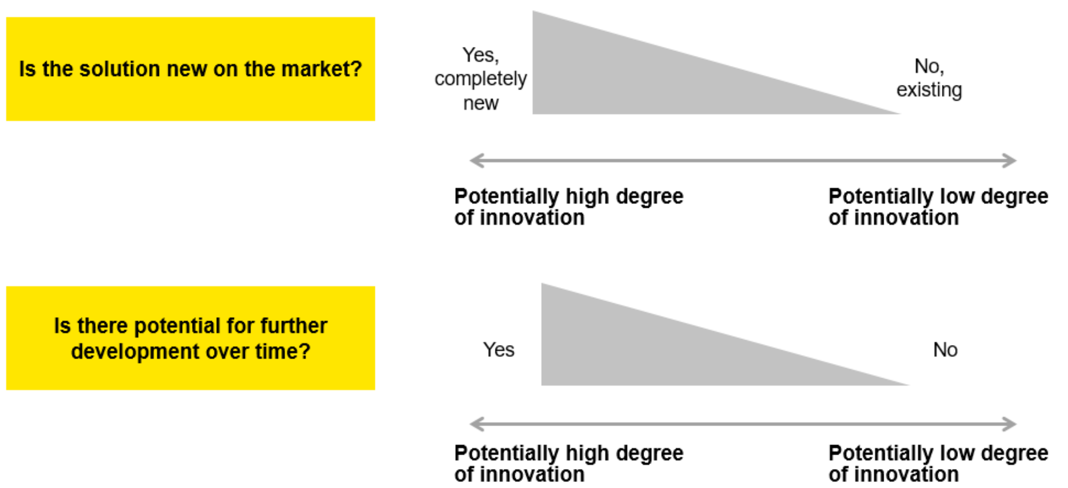

Figure 21. Degree of innovation

Appendix III: INNOVATION PROCUREMENT

Innovation procurement is appropriate if the market is changing or has development potential [55]. Some examples are:

1. Industries where development goes quickly, such as technology and IT
2. The economic impact over the life cycle is high, which can allow added value over time
3. The procurement object has great potential to be improved over time, such as with respect to technology, finance and end customers
4. In the event of major changes, such as within an organisation, the procurement must meet future needs

The Swedish Transport Administration starts out from the definition from the National Agency for Public Procurement and divides the concept of innovation procurement into three parts [56, 51]:

1. **Development-promoting procurement:** The contracting authority or entity is open to new solutions, but does not demand this
2. **Procurement of new solutions:** The contracting authority or entity acts as a reference customer or first customer of solutions
3. **Procurement of research and development services:** The contracting authority or entity requests development or even research to develop new solutions

Figure 22 below illustrates how early in a solution's development process the different types of innovation procurement become appropriate:

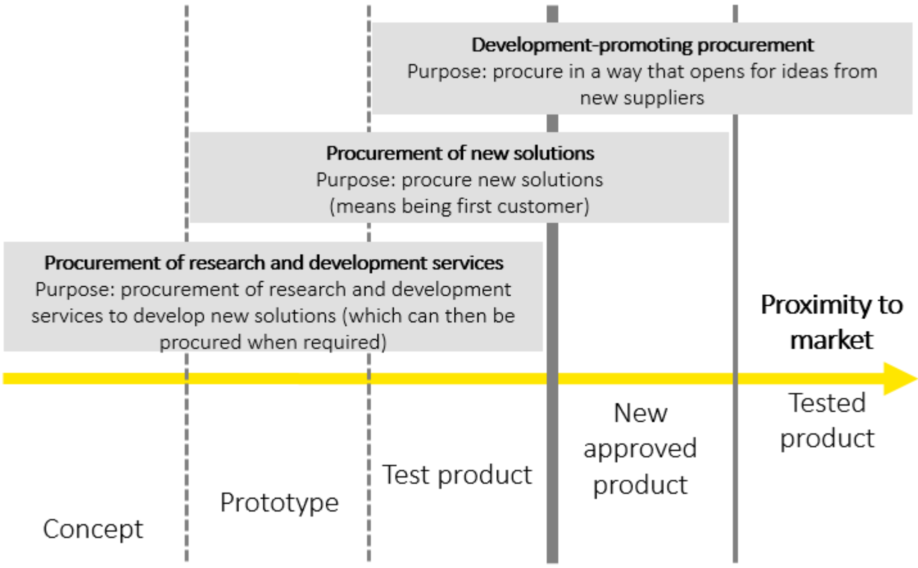

Figure 22. Three levels of innovation procurement, illustration based on the National Agency for Public Procurement's model [56]

Another method for looking at innovation procurement is to divide it into two types, which also provide guidance on the choice of procurement procedure. Figure 23 illustrates two types of innovation procurement [55]:

- **Innovation-friendly procurement:** A procurement where the solution further supports innovation development
- **Procurement of innovations**: A procurement of a solution that is not currently available

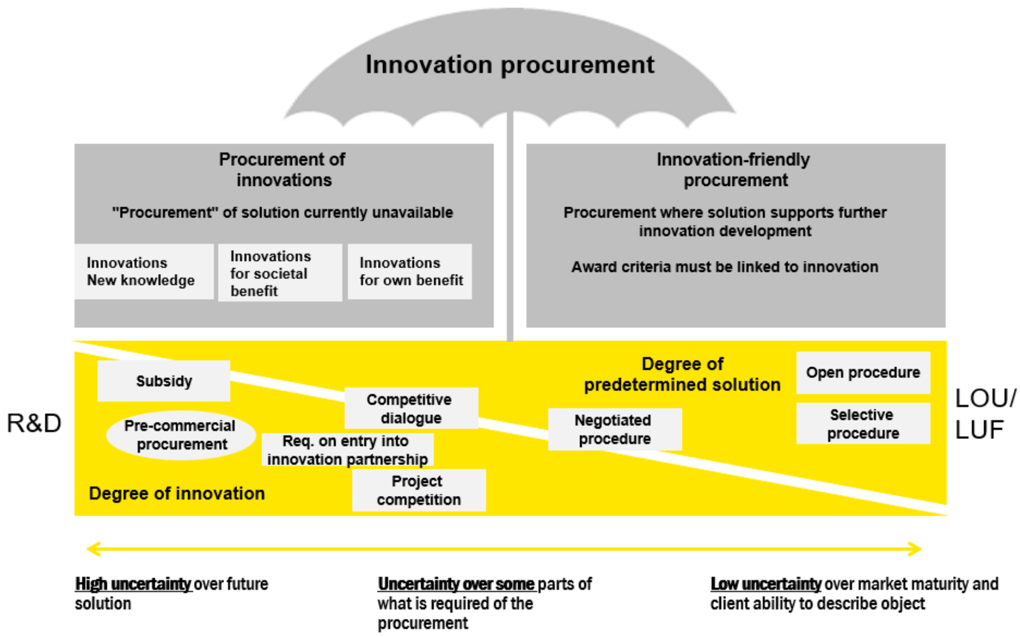

Figure 23. Innovation procurement

If a procurement object is characterised as an innovation, different methodologies can be used during the procurement depending on when the innovation is intended to appear:

- **Innovation direct** – There is a proposal for a solution or a solution can be developed during the procurement and there are suppliers in the market that can deliver. Requirements setting can take place through functional requirements and any "mandatory" requirements.
- **Incentives for innovation over time** – The solution procured is regulated through a payment mechanism that creates incentives for innovation over time. Supplier dialogue is particularly important in order to assess whether there are suppliers who have the potential to deliver based on the incentives over time.
- **Innovation partnership over time** – The partnership is a joint undertaking over time between client and supplier in order to develop the requested benefits as there is no available solution on the market. Here too, the supplier dialogue is important for assessing partly whether there are suppliers who have the potential to develop the required benefits and partly whether there is an interest in cooperation on innovation over time.

The process of innovation procurement has similarities to an in-depth feasibility study before the actual procurement process is started. Some of the analyses recommended during the feasibility study are [55]:

1. Vision and objectives setting
2. Needs Analysis
3. Market dialogue
4. Identification and prioritisation of innovations
5. Packaging of innovations
6. Financial analysis
7. Selection of procurement procedure