32nd Electric Vehicle Symposium (EVS32)
Lyon, France, May 19 - 22, 2019

Socioeconomic Analysis of Electric Road Systems

Martin G. H. Gustavsson[1] and Askill Harkjerr Halse[2]

[1]*RISE Research Institutes of Sweden, Lindholmspiren 3A, SE-417 56 Göteborg, Sweden, martin.gustavsson@ri.se*

[2]*Institute of Transport Economics, Gaustadalléen 21, NO-0349 Oslo, Norway, askill.harkjerrhalse@toi.no*

Summary

Electric road systems (ERS) is a technology area that has the potential to significantly reduce fossil fuel dependency, reduce greenhouse gas emissions, reduce air pollution, and increase energy efficiency in the transport sector. The implementation of ERS at national and international levels will however be associated with large investments and it is therefore important to study the economic impact and benefits for the society. The present work describes methodology for conducting socioeconomic analysis on electrification of an existing road infrastructure.

Keywords: dynamic charging, electric drive, EV, finance, market development

1 Introduction

An electric road system (ERS) enables transfer of electric power from a road to a moving vehicle for both propulsion and charging of battery. ERS is a technology area with immense potential to reduce fossil fuel dependency, reduce greenhouse gas emissions, reduce air pollution as well as reduce noise in urban environments, while increasing energy efficiency in the transport sector. The power transfer can be achieved through different technologies from road to vehicle, such as rail, overhead line, and wireless solutions. There are several ongoing studies and development projects in Germany. Sweden and around the world with the aim to explore different technologies, business cases and user perspectives [1], [2], [3], [4], [5], [6], [7].

Demonstration projects currently under way will test ERS on public roads and in real-life environments, addressing various legal, political, economic, and efficiency aspects of ERS. Public road demonstration would provide decision makers and investors with a foundation for further investments that would bring ERS in commercial operation.

An operational full-scale Electric Road System (ERS) will be a system-of-systems consisting of power transfer systems, electrified vehicles, logistics systems, energy systems, as well as systems for safety, control and management as illustrated in Fig. 1. The implementation of ERS at national and international levels will thus be associated with large investments and it is therefore important to study the economic impact and benefits for the society.

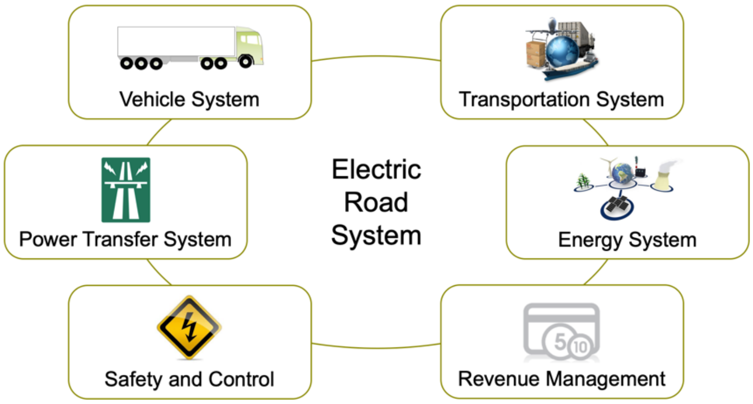

Figure 1: ERS is a system of systems.

The business ecosystem for the transport sector when an ERS has been adopted will involve several actors and roles [6]. There will be familiar actors, e.g. goods owners (industries), haulage contractors and road operators; and there will also be new actors, especially from the energy sector that will handle power distribution; as well as new roles for existing actors such as road operators and government on local, regional and national levels. This overall view of the future business ecosystem for electric road systems is illustrated in Fig. 2.

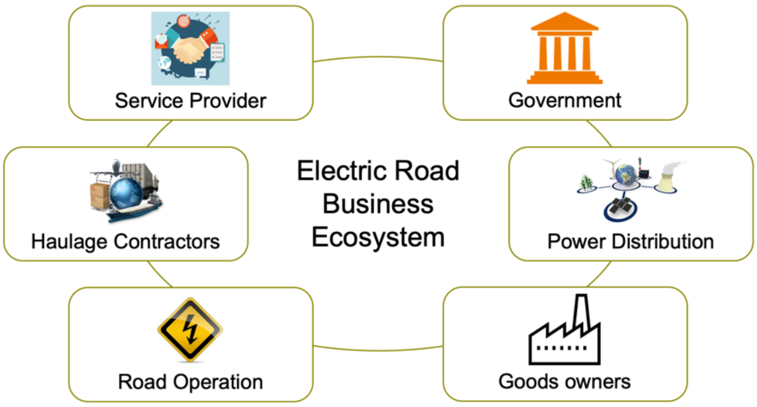

Figure 2: Business ecosystem for electric road systems with several actors and roles.

Electrification of roads can take place either as a separate deployment to existing road infrastructure, or in connection with a major infrastructure development. Socioeconomic analyses – often including a cost-benefit analysis (CBA) – are widely used in transport planning, especially when investigating large investment projects [8]. The presented work is based on the situation where the investment is made as an electrification of an existing road and not infrastructure development in general.

2 Methodology

The question of socioeconomic surplus is largely the same as the question for a private investor would be: How large are the gains in terms of cost savings compared with the cost of investing in new infrastructure and new vehicles? However, a cost-benefit analysis will follow a slightly different structure and include some more elements. The main differences are:

- **Break-even vs. net benefits:** When considering profitability for the society, the question is often whether the investment *is* profitable or not (break-even), and not *how* profitable or unprofitable (net benefit). Sensitivity analyses are based on changing one prerequisite (e.g. number of vehicles) and showing how much another prerequisite (e.g. the proportion of driving on the ERS) must change in order for the electric road to be profitable. In cost-benefit analysis, it is more common to change one assumption at a time and show how much profitability changes.

- **Net present value:** In cost-benefit analyses, a present value of net benefits is calculated from a discounting and summation of all future benefits and future costs. In the study of business models, one has instead used the annuity method, which gives the cost per year throughout the lifetime. Both methods are based on discounting, and it is easy to calculate the net present value from annuity costs.
- **Taxes and fees:** In a cost-benefit analysis, taxes and fees do not constitute a net cost to society, only a transfer from private individuals or firms to the government. However, it is customary to include taxes and fees in the calculations in order to show how the benefit of the measure is distributed between the public and other groups (e.g. road users).
- **External impact:** A cost-benefit analysis should include the cost of greenhouse gas emissions, local pollution, noise and accidents. It is uncertain whether an ERS investment will affect the two latter outcomes, but this must be investigated.
- **Demand effect:** In a cost-benefit analysis, it should be taken into account whether the saved transport costs make it more profitable to increase the transport volume. (It may also be considered profitable to distribute the transport on several and possibly smaller vehicles.) In practice, demand is often considered fixed, for simplicity.

There are not necessarily major differences between business and socioeconomic analyses, at least not in the case of a closed transportation systems, e.g. bus loops or mining transportation applications where the routes are predictable and relatively easy to service and maintain. However, open systems, e.g. along a highway, are more interesting as it is easier to achieve large traffic volumes and there is a clearer role for the public sector.

Compared to other types of infrastructure projects, analysing open ERS cases involve some specific challenges for traffic modelling:

- Railways are used by only one type of vehicle, and the capacity utilization is regulated by the government.
- Conventional roads are used by several types of vehicles (including private electric vehicles) and access to the road is open, but the infrastructure does not affect the choice of vehicle.
- For an open ERS case, the project will affect whether private business invest in electric trucks that can operate on the ERS, which again is crucial for the socioeconomic impact.

Moreover, private profitability and socioeconomic benefits will also depend on the existing ERS network. An electrified road link that is not profitable by itself could be profitable if it is close to an existing ERS network, because (i) trucks that use the existing network can now drive an even longer distance on electricity and (ii) using electric trucks now become profitable on distances that previously were served by conventional trucks.

3 Outlook

Benefits for the society due to a future adoption of ERS are discussed in a few recent reports. For example, the reports "Overview of ERS concepts and complementary technologies" from a Swedish-German research collaboration on ERS [1] and "Towards Road Freight Decarbonisation: Trends Measures and Policies" from the OECD International Transport Forum [9] cover cost-benefit comparisons of decarbonising alternatives for long- haul heavy trucks.

Cambridge Econometrics has in the report "Trucking into a Greener Future: The Economic Impact of Decarbonising Goods Vehicles in Europe" [10] concluded that the potential benefits if Europe embraces a transition towards heavy goods vehicles are substantial. The macro-economic analysis, based on several zero-emission vehicle technology scenarios including ERS, shows e.g. an increase in GDP of 0.07 % and an increase in employment of around 120 000 jobs by year 2030 in each of the scenarios compared to a business-as-usual case. However, the scenarios assume a high uptake of zero-emission vehicles without saying what it would take to reach such a scenario in terms of regulatory policies (e.g. subsidies). It is also not clear how the cost of the government investment is taken into account. While the report presents interesting findings, it does not constitute a conventional cost-benefit analysis.

The World Road Association (PIARC) has published the report "Electric road system: a solution for the future?" produced by TRL Limited [7], where TRL has used a CBA model previously developed in the UK to explore the economics of ERS. This CBA shows e.g. "that some types of ERS are financially viable if sufficient capital investment can be made, as long as the electricity mark-up and uptake is sufficient". ERS technologies that can be used by cars as well as heavy duty vehicles "are more likely to recoup the initial investment". It is also concluded that more work is needed in order to analyse the costs and benefits for ERS in various deployment cases, and in relation to complementary drive-systems as well as future social challenges.

4 Results

For an analysis of a public investment in an ERS system, the following data are needed for both a reference case and the ERS development case:

- Costs of road construction.
- Cost for deployment of ERS infrastructure.
- Cost of maintenance.
- Amount of traffic with heavy vehicles, electrical (development case) and conventional, distributed along the road network. This should preferably be based on a suitable demand model.
- Distance-dependent driving costs for heavy vehicles of both types.
- Non-distance-dependent capital costs (investment and maintenance) for vehicles of both types.
- Local emissions (and possibly noise) costs from heavy vehicles of both types, segmented by geographical area.
- Costs of greenhouse gas emissions from heavy vehicles.
- Other external costs, if applicable.

The analyses should be structured such that it is shown how the different costs are divided between different actors. This implies that taxes and fees are included as an expense for private actors and as an income for the public sector.

As to how many transports will be transferred to electric vehicles, the assumption should be that the companies choose electrification as long as the saved driving costs outweigh the additional costs of such vehicles (difference in purchase price and possibly maintenance costs). The decisive factor here is the proportion of transport distances that take place along the electric road. A simplified procedure would be to assume that this percentage is fixed. A more sophisticated approach will be to also take into account that the consolidation pattern changes so that a greater extent utilizes the ERS (such as for rail). This requires a logistics model.

If the ERS route is built on an existing route without great gains in terms of driving time savings, it is in our view not necessary to analyse wider economic impacts of the investment. If electrification occurs in combination with a project that also involves substantial transport time savings, one should also assess these effects. In all cases, one should follow developments in this field within transport economics.

In addition, the following general prerequisites are required:

- Analysis period and life of the investment. The analysis period should preferably be equal to the lifetime of the electric road, but one may possibly operate with a calculative residual value of the investment.
- Discount rate.

The recommendations above are quite general. They must be adapted to the specific case that is subject to a socioeconomic analysis. This particularly concerns the simplifications that can be made in the analysis as to which transports are affected and how the companies adapt. For cases where a single operator or a type of transport dominates heavily, a socioeconomic analysis will require less resources.

The Swedish Transport Administration has recently procured a tool to be used for socioeconomic calculations of ERS deployments. The presented for socioeconomic analysis presented in this work is intended to complement and inspire the use of the calculation tool.

Acknowledgments

This work was conducted as a part of the Swedish Research and Innovation Platform for Electric Roads funded by the Swedish Program for Strategic Vehicle Research and Innovation (FFI), the Swedish Transport Administration (Trafikverket), and the Norwegian Public Roads Administration (Statens vegvesen).

The authors would like to thank colleagues at RISE Research Institutes of Sweden and at the Institute of Transport Economics (TØI) for stimulating and helpful discussions.

References

[1] Martin Gustavsson, Florian Hacker, and Hinrich Helms, *Overview of ERS concepts and complementary technologies,* report from Swedish-German research collaboration on Electric Road Systems (CollERS), 2019.

[2] Håkan Sundelin, Martin G. H. Gustavsson, and Stefan Tongur, *The Maturity of Electric Road Systems,* proceedings of the 2016 International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles & International Transportation Electrification Conference – ESARS-ITEC 2016.

[3] Martin G. H. Gustavsson, Conny Börjesson, Robert Eriksson, and Mats Josefsson, *Automatic conductive charging of electric cars,* proceedings for the 30th International Electric Vehicle Symposium & Exhibition – EVS30, 2017.

[4] Stefan Tongur, *Preparing for takeoff – Analyzing the development of electric road systems from a business model perspective,* Doctoral Thesis, KTH Royal Institute of Technology, 2018.

[5] D. Jelica, M. Taljegård, L. Thorson, and F. Johnsson, *Hourly electricity demand from an electric road system – A Swedish case study,* Applied Energy 228, p. 141-148, 2018

[6] Conny Börjesson and Martin G. H. Gustavsson, *User Perspectives on Electric Roads,* proceedings for the 31st International Electric Vehicle Symposium & Exhibition – EVS31, 2018

[7] World Road Association (PIARC), *Electric road system: a solution for the future?,* 2018.

[8] Davide Sartori, Gelsomina Catalano, Mario Genco, Chiara Pancotti, Emanuela Sirtori, Silvia Vignetti, and Chiara Del Bo, *Guide to Cost-Benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020,* European Commission, Directorate-General for Regional and Urban policy, 2014.

[9] International Transport Forum, *Towards Road Freight Decarbonisation: Trends Measures and Policies*, ITF Policy Papers, OECD, 2018.

[10] Cambridge Econometrics, *Trucking into a Greener Future: The Economic Impact of Decarbonising Goods Vehicles in Europe,* European Climate Foundation, 2018.

Authors

Martin G. H. Gustavsson has a Ph.D. degree in Physics from Göteborg University since 2001. He has a profound experience of product management and business development from Ericsson. Currently engaged as Senior Researcher at RISE Research Institutes of Sweden and has for several years been involved in research and innovation on electromobility and electric roads systems.

Askill Harkjerr Halse has Ph.D. degree in Economics from the University of Oslo since 2017. He is a Senior Research Economist at the Institute of Transport Economics (Transportøkonomisk institutt, TØI) that is a national institution for transport research and development in Norway.