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Publication date
2024

Document Version
Final published version

Citation (APA)
Tavasszy, L., Saeednia, M., Otten, J., Liao, X., Duijn, K., & Wang, M. (2024). *Prospects for Electric Road Systems (Ers) on the Dutch Freight Corridors*. Paper presented at Vervoerslogistieke Werkdagen 2024, Tegelen, Netherlands. https://vervoerslogistiekewerkdagen.com/wp-content/uploads/2024/03/PROSPECTS-FOR-ELECTRIC-ROAD-SYSTEMS-ERS-ON-THE-DUTCH-FREIGHT-CORRIDORS.pdf

PROSPECTS FOR ELECTRIC ROAD SYSTEMS (ERS) ON THE DUTCH FREIGHT CORRIDORS

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Abstract

Electric Road Systems offer dynamic charging infrastructure for electric trucks, by means of overhead lines or rails that conduct electricity, or through induction loops in the pavement. Charging trucks while they are moving has important advantages over stationary charging, as batteries can be smaller and drivers and cargo do not have to wait while recharging. There are significant knowledge gaps about optimal network sizes, impacts on different stakeholders and cost/benefits of these technologies. This paper summarizes 4 MSc thesis projects on these topics by students of TU Delft. Their findings support the growing insight that ERS could make the electric truck landscape more efficient than if based on stationary chargers alone.

1. INTRODUCTION

The lack of charging capacity is a key bottleneck for the roll-out of the battery-electric truck landscape. Technologies for dynamic charging are not included in the current plans, but are a promising opportunity to complement stationary charging facilities and accelerate electrification of road freight. There are different technologies for dynamic charging systems (also called Electric Road Systems, or ERS), including conductive systems (with overhead lines or rail-based conduction) and inductive systems.

The potential advantages of dynamic charging systems are threefold. Firstly, they allow drivers and trucks to work during the charging process. Secondly, they allow reduced battery costs, due to reduced sizes and longer lifetimes. Thirdly, they ease the load on the electricity grid because of their lower power requirements and spatially distributed deployment. A key challenge for dynamic charging is that it requires new investments from road infrastructure providers and managers, who are not equipped to include this technology in their extension and maintenance plans. Research and experiments are needed to understand the extent of these effects and the different ways in which implementation could take shape.

This report summarizes 4 studies into knowledge gaps around ERS. All studies emphasize the system dimension of ERS, looking at different impacts for different stakeholders.

The first study, carried out by Janske Otten during an internship at the Port Authority of Rotterdam, creates a framework for cost-benefit analysis of energy options. It sets the scene with a focus on the position of the batter-electric option as opposed to hydrogen and biofuels. ERS is included as one of the additional technologies for charging. A salient finding is that none of the technologies considered will be sufficient to achieve the high targets set for decarbonisation in the EU. Relatively speaking, however, between all the options, batter-electric trucks emerge as the ones with the highest societal net present value. Compared to stationary charging, the higher investments in ERS could be balanced by savings in battery costs and driver wating times, but this was not investigated here, and instead addressed by the next study.

The research on ERS by Ximeng Liao was developed with hosting and co-supervision of DAF BV. The study investigates what is an optimal extension of infrastructure networks with ERS, focusing on the trade-off between capital expenditures for infrastructure and savings in costs of ownership of vehicles. As stated above, savings are expected due to reduced battery sizes and increased lifetimes. The study area includes the combined networks of the Benelux countries and Germany. It finds that the savings are of the same order of magnitude as the investments needed. Calculating this in more detail, taking into account expected freight flows in 2030, his conclusion is that very large scale ERS networks of up to 20.000km are financially feasible. The problem then reduces to one of shift in investments from carriers to public stakeholders, responsible for highway infrastructure. Clearly, such coordination and centralization of investments could be instrumental to accelerate the energy transition.

The third study was carrier out by Kevin Duijn, during an internship at Siemens. The company has been investing in ERS for many years, supporting live pilots and producing valuable knowledge and experiences. In order to feed the debate on how to connect major hubs on EU level corridors, a detailed system design was made of the connection between the port of Rotterdam and Antwerp. We are not aware of publications detailing such a design for another corridor. The design alternatives included 3 trajectories between the two ports and the lay-out of the ERS facilities, subject to predictions about truck flows in two directions. The evaluation is framed as a cost-benefit analysis. The main result is that the East route (A16) has the highest benefit/cost ratio. Results are sensitive to various assumptions, which is also explored in more detail.

The aim of study 4 by Mo Wang was to explore impacts for all stakeholders of ERS of two different technologies: inductive and conductive charging. While conductive charging has been tried and tested, and widely applied for trains and buses, inductive charging is new. Induction loops need to be integrated in the road infrastructure. Their use requires mainstreaming in infrastructure design, building and maintenance programs. Trucks need to be adapted, including its charging and battery equipment. Also, as charging power is reduced compared to overhead lines, logistics processes will need to be different. The effects on stakeholders seems profound and need to be mapped clearly, as a precondition for successful rollout.

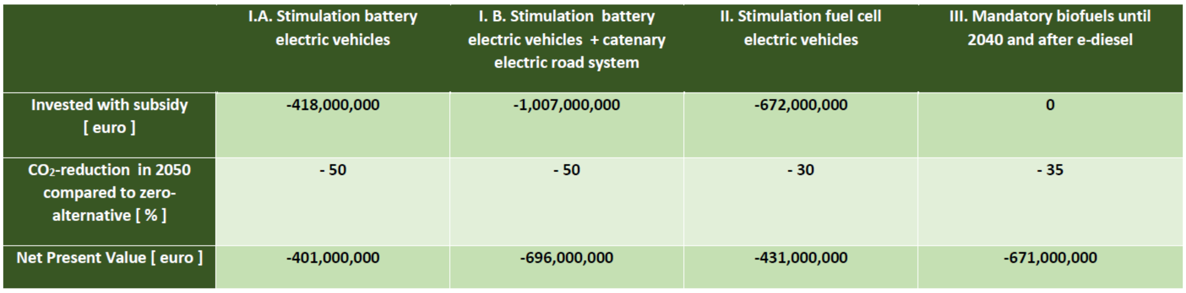
The remainder of the paper follows the 4 thesis studies along with the summary of the Antwerp study. We conclude with a discussion across the studies, highlight the main findings and provide recommendations of practice and research.

2. COST-BENEFIT ANALYSIS OF ENERGY OPTIONS FOR ROAD FREIGHT TRANSPORT

The main aim of this study (Otten, 2023) was to investigate the socio-economic feasibility of strategies for decarbonization of heavy-duty road transport in the hinterland of maritime ports. More specifically, the objective was to find a more clear direction considering the alternative energy carrier. The socio-economic feasibility of the strategies can be compared by making a social-cost benefits analysis (SCBA). The scope of the SCBA is the Rotterdam – Duisburg corridor, since most freight by road is transported to Germany. The time horizon of the analysis was set from 2023 to 2050.

The strategies proposed in this thesis were developed based on the availability of promising energy carriers and technologies to decarbonize heavy-duty freight. A technology or energy carrier is only included in the strategy if it is available. Furthermore, the subsidy for the zero-emission technology is only provided if the TCO for zero-emission technology lies below the TCO of a fossil fuel based technology. Otherwise, a subsidy would not be necessary. The results in table 1 show per strategy the invested subsidy, the CO2-reduction compared to the zero-alternative and the Net Present Value (the balance of the costs and the benefits from 2023 to 2025).

Table 1 Headline results of the CBA



	I.A. Stimulation battery electric vehicles	I. B. Stimulation battery electric vehicles + catenary electric road system	II. Stimulation fuel cell electric vehicles	III. Mandatory biofuels until 2040 and after e-diesel
Invested with subsidy [euro]	-418,000,000	-1,007,000,000	-672,000,000	0
CO_2-reduction in 2050 compared to zero-alternative [%]	- 50	- 50	- 30	- 35
Net Present Value [euro]	-401,000,000	-696,000,000	-431,000,000	-671,000,000

Considering the socio-economic feasibility, the negative net present values show that all proposed strategies are not welfare enhancing, and thus unfeasible from a socio-economic perspective. This means that for all strategies the benefits do not outweigh the costs, even with the environmental benefits included. The negative net present values are mainly caused by the severe losses of tax on fossil fuels. The strategies show a CO2-reduction between 30 – 50 % compared to the continuation with conventional fuels. However, the climate target of 100 % CO2-reduction is not achieved in one of the strategies. Relatively speaking, the strategy in which BEVs are stimulated by subsidy are the most feasible from a socio-welfare perspective.

The environmental benefits are the highest due to the early availability of renewable electricity and the subsidy is the lowest due to the lowest purchase price compared to other zero-emission vehicles. It can also be concluded that strategy II stimulates the purchase of fuel cell electric vehicles too early in 2025. We assume that green hydrogen will only be available after 2030. Therefore, between 2025 and 2030 there will be a peak in carbon emissions caused by the usage of grey hydrogen in the fuel cell electric vehicles. This results in an overall cost for the carbon-emissions from 2023 to 2050. It also means the Net Present Value of strategy II becomes even more negative, when the environmental prices for emitted CO2-emissions rise. The uncertainty analysis showed that the strategy in which BEVs are stimulated by subsidy would be welfare enhancing if the CO2-valuation would be increased up to 500 euro per kg. The strategy in which the catenary electric road is subsidized is perceived as the second welfare enhancing option if the CO2-valuation is increased. We note that the calculations did not include ERS typical benefits of smaller battery packs, longer battery lifetimes or time gains of drivers. Including these may change this result.

The study knows several limitations, and several recommendations arise from these. The study considers only the Rotterdam – Duisburg corridor. It would be recommendable to consider the entire European network, since road transport is mainly organized continental (Pastowski, 2017). Another limitation is that most of the costs and benefits are considered from the refuelling and usage part phase (the tank-to-wheel scope). However, it could be that the production, distribution and conditioning of the energy carrier also have high expenditures (Prussi et al., 2022). Therefore, it is recommendable to also investigate these costs and benefits. Lastly, by the use of the SCBA, the technical feasibility is disregarded. This could cause potential barriers in the future, for example, grid capacity for recharging BEVs, lack of equipment to distribute hydrogen or production of e-fuels in sufficient quantities (Tol et al., 2023). It would be interesting to do further research on the technical feasibility of the alternative solutions. Also, some cost and benefit categories that may be relevant have not yet been included, like infrastructure costs for hydrogen or benefits of ERS for the logistics sector. Future studies could choose a different scoping to allow these categories to be included.

3. OPTIMIZATION OF ERS NETWORKS

As introduced above, ERS requires significant investment in infrastructure but also allows large savings to be made in battery costs of trucks. The more infrastructure is equipped with ERS, the more trucks can rely on dynamic charging, and the less they need to store electricity on board. This means that carriers would not need to invest in very large batteries to travel long distances. Another effect or ERS is that, as it allows direct use of electric motors, the lifetime of batteries will be longer. This implies additional savings for carriers. The central challenge in this study is how the balance of these costs will be in an ERS network: to what extent would the savings help to recuperate infrastructure costs? As there are many potential network links to equip with ERS, choosing which links to electrify is not a straightforward task: the design of an ERS network is a combinatorial problem which requires solving an optimization model.

The study (Liao, 2023) addressed this multifaceted challenge by introducing a multi-objective optimization model. The model minimizes the costs associated with ERS infrastructure investment and the total transport costs. These total transport costs depend on a range of factors, including the procurement of batteries, energy consumption, and toll charges. The model factors in battery purchase costs that depend on projected lifespans. These projected lifespans, in turn, are influenced by the chosen route’s electrification rate (ERS implementation).

The decision variables in the optimization model include the links in the network to equip with ERS and the battery sizes to adopt for trucks. The objective function includes the costs for infrastructure and the cost of trucks. The optimization model weighs and adds these functions, to reflect that a societal optimum where these costs are equally important (i.e. where Euros are Euros) might not always be the politically preferred outcome. The model identifies the best investments for any combination of weights, the so-called Pareto optimal set of networks. The various underlying cost factors and constraints were specified with several other equations that can be found in the thesis document. The solution algorithm involves the use of advanced meta-heuristics, here building on a Genetic algorithm complemented by an Elitism strategy.

The model was applied for the case of the road networks of Germany, the Netherlands, Belgium, and Luxembourg. Data on freight flows and the network were obtained from the ETIS dataset. The spatial resolution was at the NUTS-2 level (Dutch provinces, German Länder) and predicted flows were used for the year 2030. To determine the population of electric trucks, we chose a 50% share of all movements, equally distributed across the study area. Several assumptions concerning truck operations were made concerning e.g. average payloads, number of days driven per year, truck energy consumption and battery characteristics, which are documented in detail in the thesis report.

We adopted an installation cost of 1 million EUR per kilometer (bi-directional) for our investigation, under the assumption that a larger network will allow to reach values lower than a simple average cost. The annual operation and maintenance (O&M) cost is projected to lie at 2% of the initial investment cost. Additionally, the technical operational lifespan of ERS infrastructure is observed in the literature to span 20-35 years, with our research assuming a 25-year operational lifetime. To amortize all investment costs over this duration, a discount rate of 2% is applied. Battery cost are anticipated to reach 150 EUR per kilowatt-hour (kWh) in 2030 while electricity cost was assumed to be at a level of 0.22 EUR per kWh. Charging rates for ERS were assumed of 150 kW, with a transfer efficiency of 90%. Finally, a mild discount was assumed for ERS highways on the truck tolls that exist in these countries. A discounted toll rate of 0.1 EUR per kilometer is allocated for ERS, while the standard toll rate of 0.15 EUR per kilometer prevails for conventional highways.

The calculations reveal a that investing in ERS consistently proves advantageous. The total reductions in transport costs surpass the ERS infrastructure investments and run into billions of Euros. This effect persists up to very large network sizes. Including subsidies, tolls and energy costs, the optimal network size is at almost 20.000 km. It could be argued that tolls and subsidies would be controversial as a factor to determine optimal network sizes, if benefits for the sector are as high as found here. Energy costs have a negligible influence. When we disregard these factors and focus on the trade-off with battery costs, the optimal ERS network reduces to around 15.000 km. Only well after this point, the total costs start to rise. Figure 3 shows this trade-off between the two cost types, as well as the total system costs. Note that the cost function is very flat. This implies that much larger networks could be built at comparatively small extra costs.

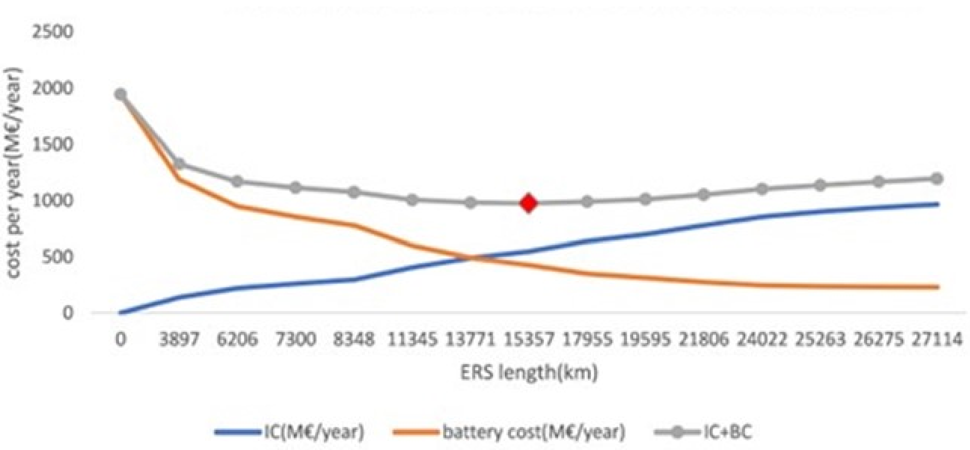


Figure 1 Trade-off between infrastructure costs and battery costs per year

One can see a sharp drop in battery costs, already when the first ERS links are built. The largest effects are obtained with the first 5000 km of network. The network belonging to the equilibrium point noted in the above figure, is pictured below. It covers almost the entire highway networks of the 4 countries, with ERS absent in Luxemburg and the Eastern periphery of the study area, as well as in the Northern part of the Netherlands.

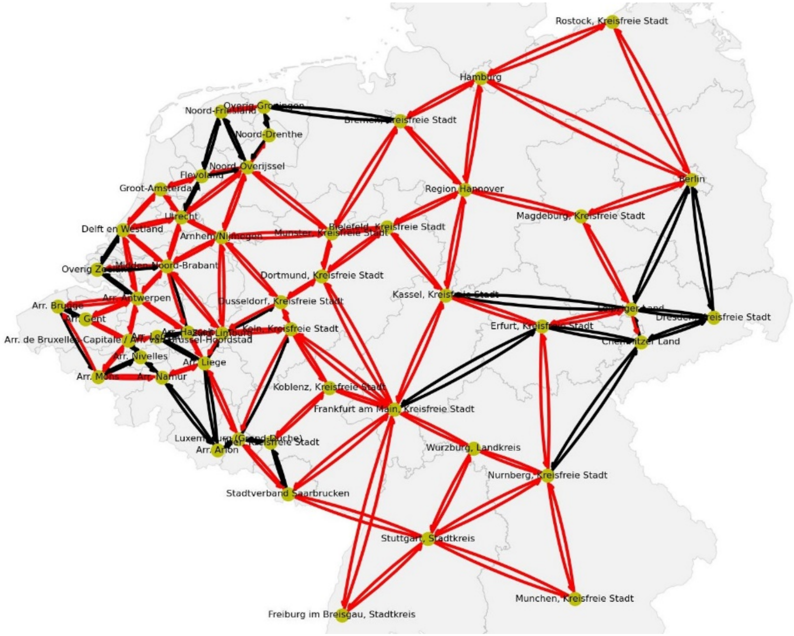


Figure 2 Optimal ERS network links (in red)

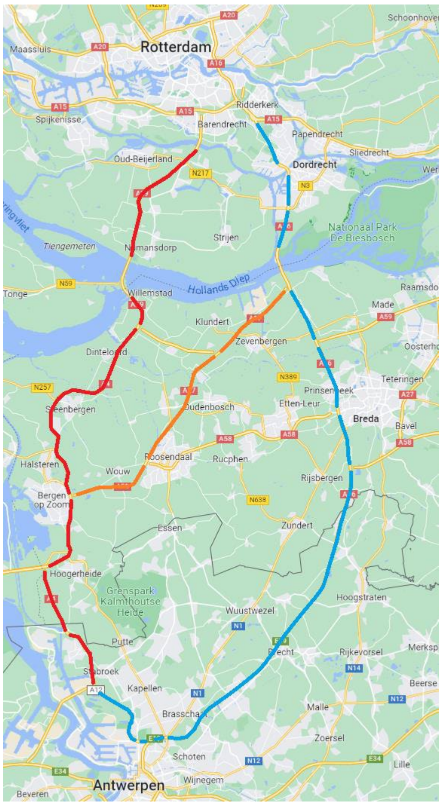
A sensitivity analysis produced the following interesting lessons. Firstly, a change in battery price of 40% will result in a network length increase of 20%, while the sensitivity for price decreases is about twice as high. Secondly, the population of electrified trucks is important – if this would be 30% instead of the now assumed 50%, the optimal network size would be 1/3 (about 5000 km) lower.

Thirdly, ERS investment costs are important – a doubling of the investment costs would reduce the optimal network size to about 3000 km, while battery sizes would need to be 3 times as high.

In conclusion, the network design model offers new insights for the sizing and location of the network. The optimal network size found was nearly 20,000 km of ERS lines, almost the entire network considered. The benefits of reduced battery size appear to be dominant in the savings booked with ERS, and of such magnitude that they more than balance out the investment needs for ERS, up to this optimal network size. Societal savings will still exist for even larger network sizes, albeit at lower levels than the required investments.

4. A CBA for ERS BETWEEN THE PORTS OF ROTTERDAM AND ANTWERP

In order to understand detailed parameters that determine the costs and benefits of ERS, a concrete case study was undertaken for the relationship between Rotterdam and Antwerp. The research was done by Kevin Duijn during an internship at Siemens. The method used was Social Cost Benefit Analysis (SCBA). The time horizon was 30 years, starting in 2025 (2025-2054).

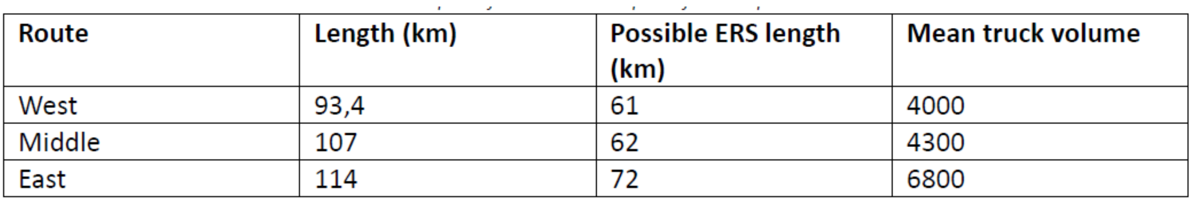


The map shows the three routing options that were considered. Table 3 shows the main characteristics of these options.

Note that truck volumes were assumed to be independent of charging scenarios. Along these 3 routes a detailed inventory was made of all the possibilities for ERS along these routes. The allowed ERS length varies due to the existence of physical barriers like bridges, underpasses, traffic management equipment or reserved space along the highways.

The current heavy duty trucks are most still containing an industrial combustion engine (ICE) and are driving on diesel, only 0,16% of the total number of heavy duty trucks in the Netherlands are electric trucks. The expectation, according Fabius et al (2020), is that the battery truck will dominate the heavy duty truck (HDT) market from 2030 and onwards. In figure 7 the growth of electric heavy duty trucks can be seen, where the total number of all trucks is 110.000. It is expected that battery trucks in 2050 will be 43% of the truck fleet. This prediction is used as the zero alternative in this research, combined with stationary charging following the development of electrification. An accelerated situation is defined as zero+ scenario, where stationary charging is all built early-on and creates a faster uptake, at the cost of a lower utilization rate compared to the zero scenario.

Table 2 Route characteristics



Route	Length (km)	Possible ERS length (km)	Mean truck volume
West	93,4	61	4000
Middle	107	62	4300
East	114	72	6800

Results

The societal analysis yielded the following results (Table 4). The benefit/cost ratio is high for all 3 options. Note that a 50% adoption rate of ERS was assumed. With lower adoption rates, this ratio would fall.

Table 3 Performance of 3 alternative ERS routes

	West	**Middle**	**East**
NPV (mln. €)	151	217	445
Benefit/Cost Ratio	1.6	1.8	2.3
Vehicle savings (mln. €)	334	408	625
Infrastructure costs (mln. €)	194	191	180

Clearly the East route is best, due to lower infrastructure costs and a higher demand. Its current value is almost three times that of the West option and double that of the Center option. A strong benefit/cost ratio was found (2.3) and, even for the least attractive route, it is still above 1. The conclusion is that building ERS between the ports delivers substantial societal net benefits.

5. A COMPARISON OF CONDUCTIVE AND INDUCTIVE ERS TECHNOLOGIES

There are different types of ERS technologies in terms of charging options (conductive and inductive) and relative to road surface (overhead, in-road, side). The overhead conductive system is largely operations-ready and several practical trials have been carried out since 2010, mainly in Sweden and Germany. The technology for in-road inductive system has been slower to develop, with demonstration projects starting. Little is known about the real-life feasibility of either of these technologies, particularly as in-road inductive systems are partly still under development. The aim of this study (Wang, 2023) was to evaluate, from a systemic perspective, the different impacts that the two technologies will have on all stakeholder groups. The stakeholders to be considered include public authorities, in the role of regulation authority or infrastructure provider, the ERS operator, the technology provider, the ERS service users, the non-service users i.e. citizens, the energy provider, the vehicle manufacturer and the driver as individual. The methodology consisted of a qualitative system analysis, based on literature review, stakeholder interviews and conceptual modelling. Its approach is inspired by Technology Assessment and Multi-Actor Multi-Criteria Analysis. The corridor between Rotterdam and Antwerp was taken to represent the user situation. Stakeholders were interviewed to understand their main values and criteria for evaluation. Data on ERS was collected from many sources to carry out the evaluation and comparison. Results were mapped and shard with stakeholders for validation purposes.

The **main findings per stakeholder group** are summarized below. A table is included in the Appendix. For detailed explanations, we refer to the thesis report.

For the **regulation authority**, irrespective of the time period, overhead conductive technology will allow to roll out ERS projects faster and with less risk to meet pressing environmental goals. This gap between the two technologies will be reduced in the future as the technology matures, but it is still inevitable that induction technology will require more time for road construction. When both technologies are fully mature, in-road induction technology presents more opportunities because it can theoretically support a wider range of vehicle types. The impact on **citizens** is vastly different for the two systems. The overhead conductive system may negatively affect non-ERS users on the road, affecting visual, safety and traffic performance. The inductive system does not have these drawbacks but may face safety (electromagnetic) issues in the future as it is scaled up, creating possible concerns for the public. **Road authorities** are met by a broad range of challenges. During construction, in-road inductive technology has higher costs due to the need to rebuild the upper two layers of the road surface. Although investment cost will gradually decrease in the future as it is scaled up, the cost will still be higher than for overhead system due to the difference in raw materials as well as the amount of construction work. However, in terms of maintenance, the in-road induction infrastructure requires little additional maintenance effort and has a much lower cost overall. The higher risks associated with overhead conductive system will result in additional emergency situation and are more likely to cause disruption during operation. Finally road authorities raised concerns about the lacking standardisation of the technology. The **ERS operator** is a new role only when the technology is mature that can support large scale implementation. Interestingly, the payback period for the overhead conductive system is longer than that of inductive system. With growing use, the gap between payback periods will increase considering the more expensive operation and maintenance cost of the conductive system. For **technology providers**, the main issue identified is that induction technologies still need to mature for a large scale rollout. As long as there are uncertainties, business risks exist. **Service users** will be affected mainly in their logistics efficiency. Conductive systems are more sensitive to weather and thereby may easier disrupt services more often. Clearly, charging infrastructure needs to be available sufficiently close to endpoints for the operation to be feasible at all. Concerning costs of vehicles, it is expected that induction charged vehicles will have relatively high purchase costs, but lower maintenance costs. One interviewee saw the potential for in-road inductive system to support a wider range of vehicles as the biggest advantage for logistics companies. **Energy providers** are less concerned about impacts on revenues than about stability of systems. The expectation is that demand will be more volatile for induction systems as the range of vehicles operating on it will be broader. Both systems would require batteries in trucks to help bridge temporary outages. The difference between systems in the required necessary reserve battery capacity is unknown but could be significant. For **vehicle manufacturers**, conductive systems would be cheaper to build but would require more intensive maintenance. As the deployment times and TRLs differ, the business case is less certain for induction based trucks. For **drivers**, the main differences in impacts can be found in the area of safety and risk. While both systems are sensitive to extreme weather conditions, in particular snow and ice, they are impacted in different ways. Electromagnetism from embedded coils may be a consideration. Current electromagnetism meets the criteria, but there is no data available to demonstrate a continued level of safety in the future, especially as energy capacity increases. This should be studied further. Additional differences relate to a higher probability of disruptions and a higher aerodynamic noise level for conductive systems.

In summary, the study has mapped the wide range of impacts towards different stakeholders. These should be taken into account during the further development of these systems towards their deployment. The analysis was limited due to the lack of robust data on many aspects of the performance of systems. This is understandable; while TRL levels are high, there is little experience with practical deployment in a full-scale complete logistics and energy system. Future experiments should be designed to reduce these uncertainties.

6. CONCLUSIONS

The four works provide different angles to look at larger scale ERS systems. They have all explored new dimensions of the future electric truck landscape.

Janske Otten has positioned this in the broader context of the energy transition. Important findings are that there is no course in energy transition that is welfare enhancing, if we do not apply higher CO2 prices, and that decarbonization objectives cannot be met. ERS performs worse than stationary charging without the inclusion of benefits for the logistics sector. Including these benefits is therefore important. **Ximeng Liao** has quantified the potential savings from battery size reductions with ERS. He finds that savings in battery costs increase quickly with growing ERS network. The added potential savings would be large enough to fund the ERS infrastructure. As this infrastructure is a collective good, some form of centralized intervention would be needed. In addition, business models should be added to capture these benefits with positive outcomes for all actors. If government does not wish to fund infrastructure with the knowledge that societal benefits will be incurred by users, market-based solutions are a second best option. **Kevin Duijn** has shown that introduction strategies and a smart choice of network segments can make a difference for the favoured technology and societal outcome. There is a lack of insight in the dynamic interplay of charging infrastructure extension and fleet electrification. The chicken-and-egg situation can be resolved with major upfront investments to accelerate the transition. Finally, **Mo Wang** has systematically explored the impacts of inductive and conductive ERS technologies for all relevant stakeholders. The two are at different TRLS and appear to have very different impacts for specific performance indicators, including sensitivity to weather, maintenance costs and visual intrusion, all at the advantage of induction charging. From this perspective, it is striking to note the lack of interest of some road authorities.

The **recommendations** are as follows. **Firstly**, Societal Cost-Benefit Analysis is an important tool to allow a systematic and transparent account of effects. They have addressed important gaps in earlier SCBA's of electrified freight transport, including the value of subsidies for electric trucks and the benefits for the logistics sector of reduced battery costs. All studies emphasize that time plays an essential role in SCBA. There are many uncertainties about the speed at which policies can be introduced, infrastructure can be implemented and truck fleets can change. It would be important to give more attention to dynamics of the system. **Secondly**, all stakeholders should be brought on board with targeted information. The comparison between induction and catenary charging painted a rich picture of the very different impacts of seemingly similar technologies on stakeholders. In particular, the logistics industry stakeholders would need to be investigated further, with more emphasis on the smaller companies. In addition, the Dutch road authority should be sensitized to the opportunities of induction charging. Although not part of its current mandate, their involvement could be important to accelerate the electrification of truck transport. **Thirdly**, the studies confirm that ERS has strong potential effects for economy, sustainability and position of the logistics sector. This potential should be explored further so that responsible institutions can take relevant steps. This should include viable societal or market-based business models for all actors, so that the expected benefits at macro level can be captured with a positive result for all.

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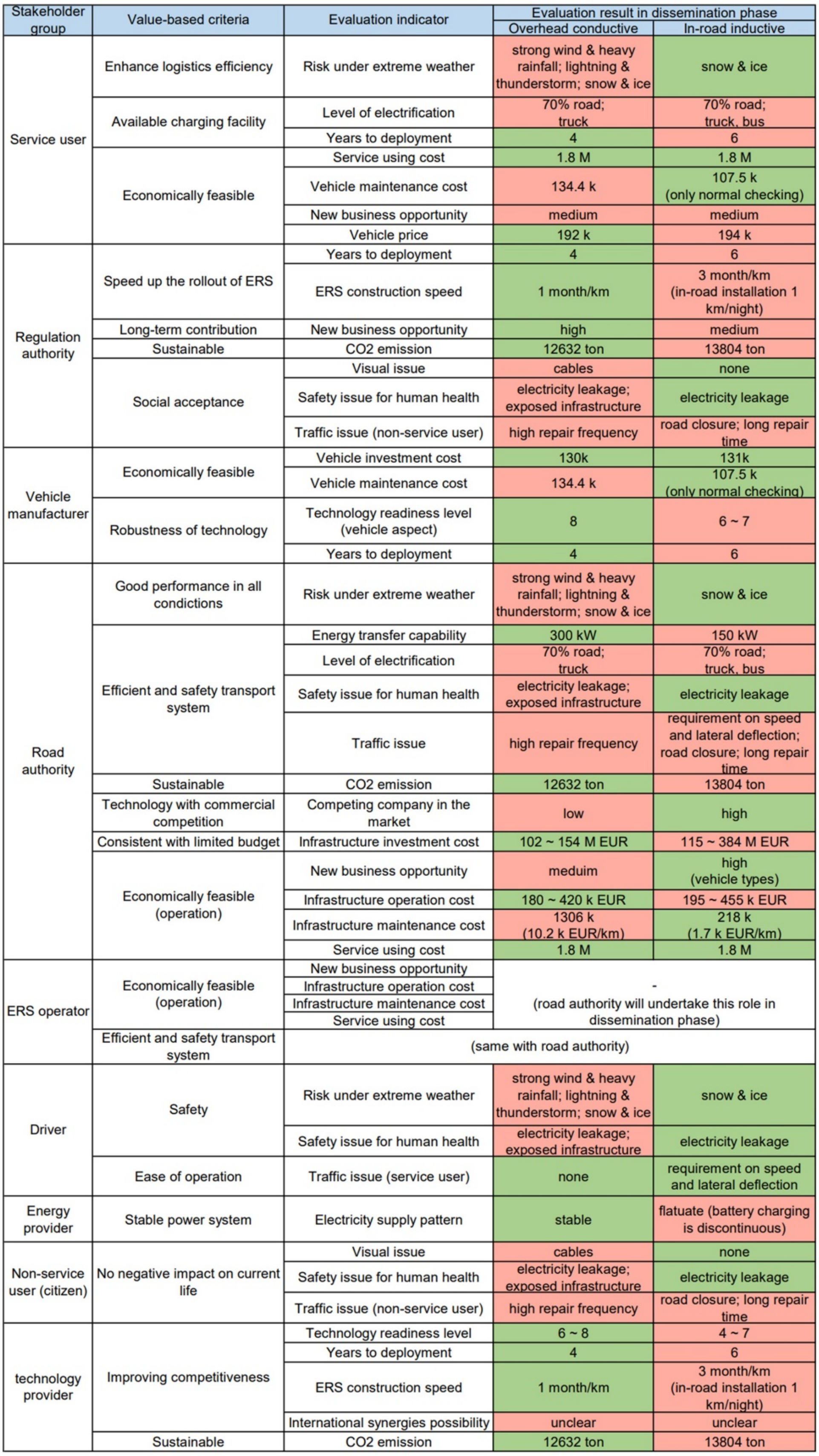
Acknowledgements

We acknowledge funding of the Ministry of Infrastructure and Water Management for organizing the joint presentation of the students' studies and for preparing this synthesis report. Also, we are grateful to Port Authority Rotterdam, Siemens Mobility and DAF, for kindly hosting the student projects and supervising the research from the company perspective. The views expressed in this report are those of the authors and not necessarily of the supporting organizations.

Appendix: Comparison of inductive and conductive technology for ERS



Stakeholder group	Value-based criteria	Evaluation indicator	Evaluation result in dissemination phase	
			Overhead conductive	In-road inductive
Service user	Enhance logistics efficiency	Risk under extreme weather	strong wind & heavy rainfall; lightning & thunderstorm; snow & ice	snow & ice
	Available charging facility	Level of electrification	70% road; truck	70% road; truck, bus
		Years to deployment	4	6
	Economically feasible	Service using cost	1.8 M	1.8 M
		Vehicle maintenance cost	134.4 k	107.5 k (only normal checking)
		New business opportunity	medium	medium
		Vehicle price	192 k	194 k
Regulation authority	Speed up the rollout of ERS	Years to deployment	4	6
		ERS construction speed	1 month/km	3 month/km (in-road installation 1 km/night)
	Long-term contribution	New business opportunity	high	medium
	Sustainable	CO2 emission	12632 ton	13804 ton
	Social acceptance	Visual issue	cables	none
		Safety issue for human health	electricity leakage; exposed infrastructure	electricity leakage
		Traffic issue (non-service user)	high repair frequency	road closure; long repair time
Vehicle manufacturer	Economically feasible	Vehicle investment cost	130k	131k
		Vehicle maintenance cost	134.4 k	107.5 k (only normal checking)
	Robustness of technology	Technology readiness level (vehicle aspect)	8	6 ~ 7
		Years to deployment	4	6
Road authority	Good performance in all condictions	Risk under extreme weather	strong wind & heavy rainfall; lightning & thunderstorm; snow & ice	snow & ice
	Efficient and safety transport system	Energy transfer capability	300 kW	150 kW
		Level of electrification	70% road; truck	70% road; truck, bus
		Safety issue for human health	electricity leakage; exposed infrastructure	electricity leakage
		Traffic issue	high repair frequency	requirement on speed and lateral deflection; road closure; long repair time
	Sustainable	CO2 emission	12632 ton	13804 ton
	Technology with commercial competition	Competing company in the market	low	high
	Consistent with limited budget	Infrastructure investment cost	102 ~ 154 M EUR	115 ~ 384 M EUR
	Economically feasible (operation)	New business opportunity	meduim	high (vehicle types)
		Infrastructure operation cost	180 ~ 420 k EUR	195 ~ 455 k EUR
		Infrastructure maintenance cost	1306 k (10.2 k EUR/km)	218 k (1.7 k EUR/km)
		Service using cost	1.8 M	1.8 M
ERS operator	Economically feasible (operation)	New business opportunity	- (road authority will undertake this role in dissemination phase)	
		Infrastructure operation cost		
		Infrastructure maintenance cost		
		Service using cost		
	Efficient and safety transport system	(same with road authority)		
Driver	Safety	Risk under extreme weather	strong wind & heavy rainfall; lightning & thunderstorm; snow & ice	snow & ice
		Safety issue for human health	electricity leakage; exposed infrastructure	electricity leakage
	Ease of operation	Traffic issue (service user)	none	requirement on speed and lateral deflection
Energy provider	Stable power system	Electricity supply pattern	stable	flatuate (battery charging is discontinuous)
Non-service user (citizen)	No negative impact on current life	Visual issue	cables	none
		Safety issue for human health	electricity leakage; exposed infrastructure	electricity leakage
		Traffic issue (non-service user)	high repair frequency	road closure; long repair time
technology provider	Improving competitiveness	Technology readiness level	6 ~ 8	4 ~ 7
		Years to deployment	4	6
		ERS construction speed	1 month/km	3 month/km (in-road installation 1 km/night)
		International synergies possibility	unclear	unclear
	Sustainable	CO2 emission	12632 ton	13804 ton