Impact of data generated by electric road systems

Term paper

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Contents

Abstract

This paper is written with the goal of examining the extent of the impact the data generated by electric road systems, *ERS* and other smart road systems, *SRS*. This paper will focus on how data from the SRS will have a significant impact on other technologies and businesses by answering the research question *To what extent will the data generated by SRS change other technological spheres than the road systems used today?*. This is done primarily by analysing the type of data produced by the ERS and other potential SRS and reasoning around what potential impact this could have on other technological spheres. Lastly, further research is suggested.

1. Introduction

This paper is based on a literature review researching the field of ERS, recognising it as part of the SRS, highlighting comparison of this technology with other underlying technologies such as EV and will also include a brief discussion on future opportunities for research in this topic. The initial goal of this paper is to first investigate the disruption in industries SRS can create, focusing on business disruption in the case of new technology, also known as *technological shifts* [Kuhn, 2012, Dosi, 1982, Blomgren, 2018]. Later, the focus will shift to understanding how the data generated by the SRS will affect the transport and logistics industry, with a focus on how data driven development can change the playing field completely. This was selected due to the observed trends and challenges of contemporary technology businesses, presented in several lectures in the course for which this paper is written.

As seen from the early findings from the literature review it seems a crucial part of cementing the technological shift is the usage of data generated by the SRS. This data shows potential in affecting other spheres that are not directly intertwined with SRS, leading to the adaptation of these spheres in order to achieve better optimization and data analysis procedures. This can be summarised by the draft question *To what extent will the data generated by SRS change technological spheres, other than the road systems used today?*.

2. Method

2.1 Definitions

Several definitions and distinctions are used in this paper and in order to provide more clarity, it is important to better explain the usage of these terms and how they are different from each other.

2.1.1 ERS

ERS is throughout this paper used as a collective term to describe the technologies under the umbrella term electric road systems. ERS is used as a descriptive word for any road system providing electric charge to a vehicle, independent of whether it is used for personal use, industrial transportation or any other form, as long as it is used on a road system.

2.1.2 SRS

SRS is used in this paper to describe the concept of digitalised road systems, coined smart road systems. The term is used to reflect on other smart appliances that are used throughout society today. However, SRS should not be confused with specifically solar highways and similar concept, as the use in this paper is meant to describe the connectivity of the road and the ability to have sensors in the road that can provide information that will be discussed later in this paper.

2.1.3 EV

EV serves to describe electric vehicles, but not necessary vehicles that get their source of electricity from ERS. It is important to distinguish between the ERS, the EV that will traffic ERS and general EV, seeing as this paper is meant to explore the use of data generated from ERS and other SRS, but not data generated from EV. However, it should be noted that while these two categories of data are different, they are not necessarily completely separate. In fact, these two categories will most likely have a major overlap, but the focus of this paper will be on the data generated by SRS and SRS alone.

2.2 Assumptions

In this paper, several assuptions are made, most significantly of the future of ERS and SRS in genera and are further explained below.

2.2.1 Extent of ERS

In order to provide any analysis, this paper assumes that the extent to which ERS will be used in society will be significant. While this could be avoided, the paper would most likely provide very little insight should this assumption be retracted.

2.2.2 Extent of SRS

Since this paper focuses on the potential usage of data generated by SRS, it is of importance to assume that all major road systems will become SRS in a foreseeable future. This assumption is the most critical of the assumptions made in this paper, but seem likely considering the general trend of digitalisation in society as a whole. The importance of the assuption can be explained by the fact that a limited flow of data, such that would be generated should SRS be a minor factor in a future society, will severely limit the usability of the data. This is mostly due to major data analysis needing large data sets to work on in order to provide significant insight into the problem examined.

2.3 Work method

This paper is based on a literature study researching the impact ERS could have on as a competitive technology, and what means ERS would have for guaranteeing its own survival as a dominant technology. At a later stage in writing this paper, the focus shifted towards understanding what impact the introduction of ERS would have on other technologies, and how the ERS as a subset would compare to the SRS as a whole. Part of the reason for the literature study was done in order to better understand and analyse the academic frontier of ERS as a complement and substitute for traditional road systems, and served to give insight on how the SRS might take form in a near future. During the literature study, the potential data generated from ERS was discussed, and an analysis on what effect similar heavily data generating systems, especially SRS, have on technology shifts and trajectories.

During the literature review consisted of an initial review of 23 articles, papers, books and chapters, resulting from searches in several databases hosting academic papers, as well as material previously known to the authors. In the resulting paper some literature from the literature review was excluded and material from new sources were included. The inclusion was done primarily as soon as another paper was found that would prove insightful to this paper, and was not done following any specific process at all. However, some of the added papers were discovered from references to other papers and articles presenting during course seminars.

The goal of the literature study was to recognise and build a theoretical framework that could be used to further analyse the research question. Since limited research has been done in the area of ERS from a social study perspective, much of the framework is devised from frameworks which are either valid in a broader sense or in scenarios with similarities with the ERS.

After the literature study was finished, the goal of the final paper was stated to be analysing the result of the study in order to establish a thesis question that could be answered by the material provided in the study. This was mostly done by analysis and discussion of literature available to the authors, but also by listening to experts talking about their experience with new technologies, and the impact of those technologies outside the original technological sphere.

3. Main sources

During the literature review, the following articles were analysed, and served as an original idea of how much effect the emerging technology in the form of ERS and potentially SRS could have, and what would be important factors for the technology to become dominant.

3.1 The business model dilemma of technology shifts

Cloud computing, big data, and smart assets are among the most recent technological advancements and issues that are of concern in the recent past. ERS are also a part of this wave. Several authors have through their research established how this advancement emerged and how they have been received in the modern society[Vendrell-Herrero et al., 2014]. Technological advancements are always related to the business world, and they improve it in one way or another. The articles explains how businesses and technological advancements are intertwined.

Tongur and Engwall discusses how technology shifts have affected businesses and business models. Tongur and Engwall writes explicitly about how the service and innovation dilemma has caught up with manufacturing companies. The focus is on the emergence of ERS as a business module. The ERS module has made businesses more comfortable in areas such as road travel and human congestion, especially in urban areas. However, the advancements have also brought along several challenges. Tongur and Engwall relate business modules to the difficulties that technological shifts have caused. In conclusion, Tongur and Engwall explains how technology is merging with businesses.

3.2 Clouds, big data, and smart assets: Ten tech-enabled business trends to watch

Bughin et al. explains how traditional business models can fit into the advancing technological world in the context of big data, and cloud computing space. The article describes how technology has affected business operations and marketing. With the process of globalisation, most transactions are likely to take place through the internet. It also explores how manufacturers have been able to optimise their model by using local resources. The article evaluates conclusively how organisations have been activated by networking and how their data and operations have changed. In conclusion, Bughin et al. inversely describes how business models can advance technology or how technology can be a slave to business.

3.3 Early findings from literature review

During the literature study, it was seen that the technological shifts occurring in society need to be well anchored in order to be successful. In order to fully shift the existing technology, the imposing concept cannot be made as an independent set of rules, but need to be incorporated into existing technologies, allowing for interconnected technologies to form around it as well as institutionalising the technology. [Perez, 2004, Dosi, 1982, Kuhn, 2012, Elrod and Tippett, 2002]

Further, the distinctive features of Schumpeter's business cycle theory are illustrated [Arena and Dangel-Hagnauer, 2002]. This theory describes how the business cycle and innovations are slaves to each other where business cannot thrive in exclusion of changes and technological advancements.

In the case of ERS, it seems plausible that the first stage of the technological shift is complete or heavily developed - there are already a significant amount of ERS being built or planned. However, in order to successfully change the commonsense principles, it seems necessary to adapt the technology using one of the most potent and advanced technologies in society - big data and cloud computing - advancing technology rather than being a slave to it. Lastly, a finding from the literature review is that the data generated from any business can often be used in conjunction with an existing business model and significant computing power to significantly change the business and much of its surroundings [Bughin et al., 2010].

4. Discussion

ERS are on the march and show little sign of stopping. This will most likely change the way both industrial and personal transportation is viewed and used, impacting not only the vehicle-, transportation- and energy industry, but affecting virtually any industry in connection to the previously mentioned ones. The reason for this is that the data generated by the cars will, much like the revolution of IoT in other appliances [Gubbi et al., 2013], create a field with vastly different rules than previous. Besides from completely changing the existing business models governing vehicle usage [Pernestål-Brenden and Kristoffersson, 2017, Kley et al., 2011, Bohnsack et al., 2014], it seems likely that SRS will provide a large amount of data, allowing for technologies to grow onto it [Gao et al., 2013]. This type of data is something that should be differentiated from the data generated by the EVs and other smart vehicles, seeing as an SRS could be able to provide data about more than the current state of a vehicle.

4.1 IoT vs. SRS

Some might argue that the implementation of interconnected SRS as well as connecting SRS with the internet will be no different than the regular IoT, but it stands to reason that smart road systems will be an area defined by a different playing field than IoT, especially in terms of expectations. Another differentiating factor is the fact that much of the data would not be generated directly by the SRS, but rather from measuring usage and relaying information of the users.

If examining the case of IoT, much of the focus has gotten to be about managing the data generated by IoT appliances and using this resource to create efficiency for everyone, rather than simply using the technology to create appliances that in themselves are smart [Gubbi et al., 2013]. In short, the product must be smart in every aspect, from interconnectivity to delivering data to production. However, for obvious reasons there will be fewer SRS than smart-phones or other connected products, thus creating fewer sources of data. This should not be confused with the size of the data generated, seeing as the SRS will most likely provide information about not only the SRS itself but the vehicles traversing it. This information will in turn contain everything from weight, speed and type of vehicle (and thereby also the loading factor and transport efficiency), as well as destination and intermediate stops. The SRS will likely also be able to gather information regarding current road condition.

The other aspect of the SRS differentiating them from regular IoT would be the heavy focus on B2B or government to business, where much of the data will be generated by transportation and logistics in some form [Columbus, 2017, Hunke et al., 2017], be it public or industrial, and used in a somewhat segmented field from regular IoT appliances. IoT devices today are usually focused on B2C, and are primarily used in connected homes an personal devices, taking up approximately 60%

of all IoT devices today [Statista, 2018]. However, it should be noted that the line often is blurred when observing IoT devices which can have a multitude of appliances within one device.

4.1.1 Road conditions

One type of data that could be utilised would be data about current road conditions in a broader perspective than temperature at the bottom of the vehicle; data could be gathered about construction work, icy areas or other hazardous environments in connection to the road. This is something that should be handy when used in conjunction with the smart or autonomous vehicles, providing data that can ensure a safer driving experience. This is especially important in today's Sweden that is very actively working towards a zero-vision regarding traffic fatalities.

Seeing as fatal traffic accidents is one of the most negative aspect of modern traffic, it surely would be beneficial to minimise the accidents on modern roads. It stands to reason that the data generated by the connected SRS in conjunction with smart vehicles would most likely provide a safer driving experience, seeings as approximately 90% of single accidents with a fatal outcome could be avoided by more advanced security features in the car involved in the accident [Hillerdal, 2011]. It would also seem reasonable that the AIs of modern smart vehicles would be apt to handle this type of information and be able to make a better risk analysis than the drivers typically involved in these type of accidents would seeing as AI is generally more system oriented than humans, who have a lack of general understanding that is one of the largest problems when dealing with risk management [Rasmussen, 1997, Wu et al., 2014].

Another critical aspect of accidents in the road systems is the active hindering of accidents, something that could be done by the SRS. In the case of a well integrated platform between smart road systems and smart vehicles, provided sufficient governmental legislation, the AI could efficiently assume control of the vehicle whenever entering zones defined by ERS, for example allowing a safe highway lane merger in the case of an accident in one of the lanes, or even a complete stop in the case of a multi-lane accident. This would most likely not stop any fatal accidents, seeing as a rather small number of fatal accidents are caused by a multi-vehicle pile-up. However, such a system would help avoid many non-fatal injuries as well as lessen the property damage often associated with traffic accidents.

Seeing as the zero-vision is just a vision, there will be a need for analysing the accidents that do occur. When analysing an accident and its cause, it is of importance not only to establish the direct cause of the accident, but also to determine the indirect causes and how these types of accidents can be avoided. In the case of direct cause determination, the parameters stored by the car prior to the accident can be highly useful in many cases, but it seems reasonable that the car would have little information of the surrounding environment that could be an indirect cause to the accident, which the data provided by a smart road system would be crucial to establishing. The data could also be used to investigate how the specific type of accident could avoided by changing the overall behaviour or structure of the road and the road-users.

In conclusion, the implementation of road conditions data usage in smart vehicle control AI optimisation and in accident management would not only be beneficial to the overall safety of the road-usage, but also a clear indication that the data generated by SRS would significantly change the technological sphere of road safety as well as the sphere of smart vehicles and their AI optimisation.

4.1.2 Vehicle production

Another interesting possibility of SRS would be using the data produced in order to more efficiently handle production. As seen in other articles [Munthe et al., 2014] and presented during the seminars [Jannis, 2018], data is of high importance for modern factories in order to better order their production. Similar conclusion can be drawn viewing transportation and logistics as production resources [Hansen, 2004].

Examples of this type of data would be similar to that of which is needed for fleet management, like load carried by the vehicles and the routes used. In this case with a shifted focus towards meta-analysis, where an overall increase of load transported on the road would not only be interesting for the road maintenance companies, but could imply that there is an emerging need for new vehicle production. Similarly, an increase in hours trafficked by transportation vehicles could provide a similar insight into an increase in vehicle demand.

Another possibility where data generated from the SRS could affect production is where behaviour of the transportation vehicles is significantly changing and a new type of vehicle construction would be better suited to the current need in the transportation and logistics sector, data that would too in a sense be the product of meta-data generated by the SRS rather than data directly generated by the SRS, but nonetheless stemming from the SRS.

In conclusion, the data generated by the SRS could be used to change the production of new vehicles, however, it should be seen as a minor impact on the technological sphere that is vehicle production, design and research.

4.1.3 Traffic flow, route optimisation and fleet management

Another type of data that could be generated by SRS specifically is data closely connected to traffic flow and therefore also route optimisation and fleet management. This data could probably be of high use even if kept as simple as information on what types of vehicles are trafficking the road, their position and their speed.

Seeing as the data collected by the roads today, regarding traffic flow, by the cameras some roads are equipped with is not something that is publicly accessible, much more in-depth data that could be generated by smart road systems. This would prove highly beneficial for companies working with traffic flow, route optimisation and fleet management. This would primarily be due to the companies being able to access the data themselves directly rather than relying on third party actors who collect GPS data about the vehicles connected to the third party actor's systems.

If the roads themselves captured the data and made it accessible for the companies, it would most likely result in a changed behaviour in terms of route optimisation, allowing the companies to better determine in real time which routes should be used and which should be avoided. It could be argued that this would have little impact on the routes already chosen by the transportation company, but it turns out that any sort of route optimisation is not only highly complex and computationally expensive but vary much due to every actor within the system changing their behaviour based on the other actors, causing every change in behaviour by an actor to have a complex effect on the system. Due to this, route optimisation is often done by approximation and can require large amounts of data in order to perform on an acceptable level.

A similar argument can be used in regards to traffic flow, but in this case rather as a centralised system providing information about the current conditions on the roads, a service that is already being provided by the Swedish Transport Administration. However, as is the case with manually reported data, the information can be lagging, incorrect or both, making the task of giving a definite report of the current state of the traffic situation and flow close to impossible. As in the example with route optimisation, this type of data could easily be made available by a centralised system collecting data from the SRS and relaying it to the Swedish Transport Administration that could in turn publish selected parts of the data as well as provide their own level of analysis of the data, allowing them to give a both accurate and updated report on the current situation on the roads connected to the system.

Another upside of vehicle data gathering by SRS would be using the data for fleet management. This could be done in a similar manner as the processes already mentioned, but with the minor change that the current load of the vehicle would be used, something that could easily be logged by the ERS as the ERS would know the current power consumption of the vehicle. This would in turn be monitored and used, in conjunction with the transportation company's information of package volume, to calculate if the vehicle could be used to transport other parcels along the route already determined by the system. It could be argued that it seems that this type of calculations would require a high level of system integration as well as highly efficient algorithms, something that is not available today. However, similar arguments could be made for many critical systems of today being taken by granted by most users, and should not be excluded simply because the technology is not ready yet.

In conclusion, the loading processes of today along with both the optimisation of routes and fleet management is both costly and complex and could be made more efficiently [Jelica, 2017]. One of the factors that could significantly change the cost and efficiency of these type of issues would most likely be data and the data processing closely affiliated with it. Using the data generated by the SRS, these processes could most likely be optimised further. Seeing as these sort of changes would be economically motivated, it too seems reasonable that the data generated by the SRS would significantly change the technological sphere of traffic flow and overall logistic processes.

4.1.4 Overall data implication

Overall, there has been an increase in data analysis tied to new emerging technologies and this is something that shows little signs of slowing down [Bughin et al., 2010]. If utilising the data generated by the SRS, it would seem plausible that this would fundamentally change the transportation and logistics sector, along with production and road safety and flow management. This can be seen already in Scania amongst other companies, where much of their data gathered is from smart vehicles and IoT devices is used in order to optimise production and development. It could be argued that this data will not be provided by SRS, but rather by the EV. However, this seems implausible not only due to the fact that inter-connectivity between EV and other smart vehicles being low when observing from a brand perspective, but also due to the fact that the SRS have potential of providing other data, such as conditions in areas where there are no cars at a specific moment, total load on the road, the risk of congestion and many other factors. Seeing as all this information could most likely be put to efficient use by several other sectors, there is much pointing towards SRS having an effect outside its own technological sphere, suggesting that it is impacting other technological spheres.

5. Conclusion

SRS is in a current position where it seems plausible that they will generate large amounts of data, even enough to qualify as big data. However, the data generated is generally different from ordinary big data generated by IoT devices and will most likely have different implication on the society as a whole. It stands to reason that SRS will highly effect some technological spheres by enabling us to gather data related to destination, intermediate stops as well as weight, speed and type of vehicle (loading factor and transport efficiency). The use of SRS in B2B business or business to government transactions highlights its importance compared to IoT. As much of data in government sector is based on transportation and logistics so SRS will get high importance in this sector. Data about construction work, icy areas and hazardous environment will be gathered in connection to the road which provides edge to this technology over IoT. Furthermore, implementing SRS will help in risk management by minimising traffic accidents with help of AIs that are smarter than human oriented systems and will be able to handle risk analysis efficiently.

Thus from overall study, it is concluded that data analysis has become an important part of any business with emerging technologies and SRS would change the data analysis techniques in transportation and logistics sector along with production, safety and flow management. It could increase efficiency in loading system by generating data related to route optimisation and fleet management by knowing the current power consumption of vehicles and hence it contributes in changing the technological sphere of logistics processes.

6. Further research

Seeing as this paper has focused mainly on the theoretical impact SRS would have on other technological spheres, it would seem beneficial to suggest that further research be done in that area, preferably by empirical studies of how the data generated affects the spheres mentioned in section **??**. Another topic where research could be of further use is the differentiation of data generated by SRS and that of the general IoT, either showing that they are, as suggested by this paper, different or that data from SRS is a subset of data from IoT. Another field that could provide some insights is the use of a governing body that controls the data generated by SRS. Lastly, the authors would if possible encourage the investigation of weather the introduction of SRS is impactful enough to constitute a paradigm shift as defined by Kuhn.

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