Envisaging the unintended socio-technical consequences of a transition from fossil fuel-based to electric mobility

Authors

Aleksandra Lis*, Adam Mickiewicz University in Poznań, Poland
Aleksandra Wagner, Jagiellonian University, Kraków, Poland
Franco Ruzzenenti, Groningen University, the Netherlands
Hans Jakob Walnum, Western Norway Research Institute, Norway

*alis@amu.edu.pl

1. Introduction

Electric cars are currently being promoted as a solution to private mobility's long-standing dependency on oil; however, few pay attention to the unintended consequences of electromobility on society and on climate change. For example, the predicted significant reduction in transport costs may create a rebound effect which could not only lead to an increase in energy use but also to structural changes in driving behaviours, with effects on society, the built environment and, ultimately, the climate (Galvin, 2016; Font Vivanco et al., 2014). What will our society look like when private mobility is not curbed by high fuel costs, nor by organic boundaries, such as the circadian time? If electric vehicles (EVs) do not lead to changes in mobility patterns, these will increase the impact of private transportation on society and the environment (direct and indirect pollutants from use, production and waste disposal) and could possibly lead to an increase in carbon emissions depending on the electric mix (Faria et al., 2013; Bulach et al., 2018). Conversely, if they do change mobility structurally, these changes, instead of meliorating individuals' life conditions as wanted, might lead to new, unexpected sources of stress for the environment and human beings.

2. Aims and questions

Our paper poses the following questions: What unintended socio-technical consequences might result from a transition from fossil fuel-based to electric mobility, and how to investigate them?

The research design has two objectives: (1) to work out methodological and conceptual perspectives for studying unintended consequences of the transition to electromobility, and (2) to present empirical illustrations of a transition to electromobility in two selected countries: Norway, where electric cars are spreading faster than in any other country in the world (20.9% of new vehicle sales in 2017), and Poland, where the internal combustion engine is still dominant on the roads but where the government is committed to promoting a fast transition to EVs. We propose a set of questions to guide future research on unintended consequences of the transition to electromobility.

3. Conceptualization

3.1. Electromobility as a socio-technical system

Electromobility as a socio-technical system stands for a set of interconnected networks consisting of relations between human and non-human elements. Following Geels (2004, p. 897), we "*make an analytic distinction between: systems (resources, material aspects), actors involved in maintaining and changing the system, and the rules and institutions which guide actor's perceptions and activities*". Our approach is consistent with the multi-level perspective (MLP), which explains how technological transitions come about and helps to better understand the interactions between actors, innovations and environments through the categories of landscapes, regimes and niches (Geels, 2014).

We propose to theorize electromobility as a socio-technical system which is emerging from the newly established relations between four other sectors: the energy, transport, information technology (IT) and financial systems (see Figure 1). This is done by analyzing the production/circulation of four different products: energy, mobility, information and money (financial transactions). In this context, we look at electromobility as a new kind of socio-technical system which produces and circulates a new product: a new type of mobility. The interconnected networks can be created on the level of regimes and niches. We look at whether electric vehicles are bringing change to the transport sector, and how the relations between the four sectors (Figure 1) are changing. Envisioning is going to be analysed on all levels, from the niche actors' future visions driving the novelty, to the more structuralized plans, strategies and prognoses developed by the regime actors, to collective imaginaries and utopian visions being part of a socio-cultural dimension of landscapes.

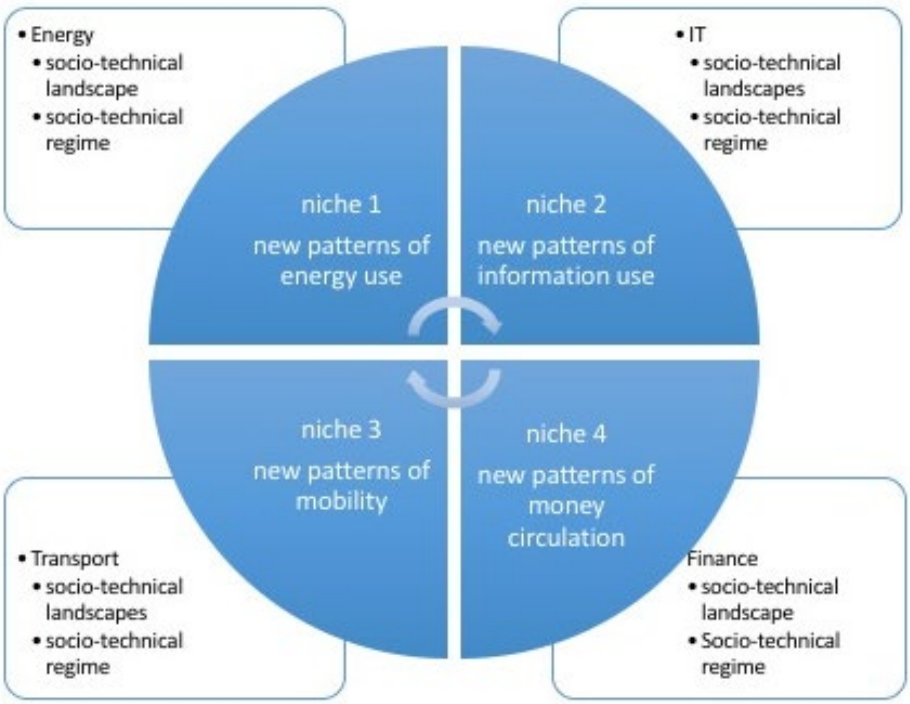

Figure 1 – Electromobility as niches in four sector systems.

3.2. Unintended consequences and visions of electromobility

Within this framework, we propose a new methodological approach to study the unintended consequences of the transition to electromobility. We conceptualize the unintended consequences as changes that have not been foreseen, expected, planned or anticipated in visions of electromobility proposed by actors[3] (both in the regimes and niches). Methodologically, we propose to search for unintended consequences resulting from the newly established relations between the four sectors and within the transport system. Our approach underlines both the importance of collective imaginaries for structuring social life, such as social expectations, anticipations and narratives about the future, as well as materialities of resources, institutions and practices. More broadly, methodologically, the project aims at proposing an interdisciplinary approach that allows bringing together social sciences: economics, sociology and science, technology and society (STS) studies as well as engineering and network theory, in order to integrate research on social and technical aspects of the transition to electromobility.

4. Research questions and hypotheses

The research questions we pose are both empirical (1, 2, 3) and conceptual/methodological (4):

1. How do future visions of regime and niche actors conceptualize electromobility? How do different social actors and different configurations of them in particular socio-technical systems imagine and conceptualize the consequences of a transition to electromobility?

3 The unintended consequences could be anticipated or unanticipated (Zwart, 2015). In this paper, we focus on unanticipated consequences of both organized and unorganized actions.

2. What institutional responses and social practices co-produce electromobility as a socio-technical system and as a particular type of socio-technical practice?
3. How do future visions of regime and niche actors conceptualize the new relations between the networks and the unintended consequences of a transition to electromobility?
4. Where and when in the socio-technical systems can the unintended consequences appear and how can we conceptualize and methodologically study them?

We propose two hypotheses to answer question (4):

1. The unintended consequences can materialize as a result of the newly established relations between the networks.
2. The unintended consequences can appear inside a network as a result of changes in relations between niches, regimes and landscapes – for example, niche activities interfere with a regime and result in its reconfiguration (see Figure 2).

5. Methodology

5.1. A qualitative framework

Methodologically, we propose to focus on new types of relations that are created in networks established between and within the four sectors, which are driven by visions of electromobility shared by various actors. We will study these new types of relations both as they are conceptualized in the visions (as intended, imagined, strived for), and as they are performed in practice (by actors, institutions, socio-technical devices). This distinction between the imagined (expressed in visions) and the practiced (by actors) will allow us to re-conceptualize the distinction between the intended and unintended, the anticipated and unanticipated consequences (proposed by Robert Merton, 1936) for the sake of studying complex socio-technical realities.

It will also allow us to propose a new methodological approach that combines discourse analysis (of visions), ethnography (study of practices) and system/network analysis (to understand the complexity of the existing and emerging systems/networks and new relations among them). Contributions from engineering studies and network theory are meant to shed new light on the quantitative side (mass, energy, money and people flows) of the system's analysis, which is often overlooked in social sciences. Critical discourse analysis theorizes imaginaries as representations of how things might or could or should be. A future vision serves as an "*imaginary which can be institutionalised and routinised as a network of practices*" (Fairclough, 2010, p. 266).

Thus, future visions have a preformative potential. We further argue that they can have a system-stabilizing function, which can be realized in various ways – from being a screen for current fears and hopes (Luhmann, 1976), to legitimization of decisions taken in the situation of uncertainty, to exporting unsolved problems or uncertainty itself beyond the assumed time horizon.

5.2. Quantitative framework

We envisage the possibility of implementing the network analysis with quantitative measures of interactions between actors within a given network and across networks. This is typically a multiplex framework (Gemmetto et al., 2016) in which every network represents a layer of a multidimensional topological object, the *multiplex (a multiple-network)*, whose interactions can be studied with the aid of null models derived from the statistical mechanics of graphs. In order to perform this analysis, we need data on national/urban level concerning financial, transport and communication interactions coupled with a simulation of the load distribution in the grid.

6. Analysis design

Research procedures are distributed between *prediction* and *action*, *cognition* and *creation*. Prediction and cognition are linked to identifying the problems, needs and desires, while action and creation are related to defining the solutions and their implementation. Envisioning is going to be analysed on all levels proposed by MLP, from the niche actors' future visions driving the novelty, to the more structuralized plans, strategies and prognoses developed by the regime actors, to collective imaginaries and utopian visions being part of a socio-cultural dimension of landscapes. Reconstructing how the future of electromobility is imagined by different actors and how it is reflected in the observed practices can help to understand the process of transforming visions into rules shaping practices.

Taking into account the MLP, we are going to focus on how systems respond to the new technological possibilities and new ideas. Each of the distinguished systems (energy, IT, finance and transport) can be described through the categories of socio-technical landscapes, regimes and niches. Actors create networks of mutual relations. The networks are changing dynamically and new relations appear both as a consequence and a cause of change made in all landscapes, regimes and niches. When analysing the future visions, we propose to focus on how communities of niche, regime and landscape actors deal with the unknown. We suggest to follow the relations between prediction (reflected in cost estimation, trend analysis, risk assessment and technological prognosis) and creation (expressed in scenarios, strategies, policies etc.) on the one hand, and relations between action (collective and individual behaviours, decisions taken, investments made by actors) and cognition (imaginaries, desires, social representations) on the other hand (see Figure 2).

Figure 2 – Dimensions of analysis: prediction (reflected in cost estimation, trend analysis, risk assessment and technological prognosis); creation (expressed in scenarios, strategies, policies etc); action (collective and individual behaviours, decisions taken, investments made by actors); cognition (imaginaries, desires, social representations).

This type of research design opens up new possibilities for identifying sites where new, unanticipated effects may appear. They can be recognized as the result of newly emerging relations of which the extremely important aspect is imagination, forecasting or planning. The investigators will bring together material aspects of the system, connections between actors and institutions, social practices and future visions (expectations, predictions, desires, imaginaries etc.). At the same time, researchers will have freedom of choice on the level of analysis, data, methods and tools. What is important is that this kind of study is designed to provoke a reasoned debate or exercise a system in dealing with the uncertainty rather than predicting or normalizing the system.

7. Poland and Norway: Different visions – different transitions

The application of the proposed research design can be illustrated by a comparative analysis of the development of electromobility in Poland and Norway. Both countries share some aspects of the landscape, such as international markets, global narratives of climate change or capitalism, but, at the same time, the socio-cultural contexts through which the landscapes are interpreted differ in the two countries. However, the socio-technical regimes and innovation niches differ and they configure different relations between the human and non-human elements. There are also some differences in the strategies of resistance and resilience of socio-technical regimes in both countries. Table 1 provides a brief introduction to further in-depth analysis. We point out the main analytical categories and some examples of possible unintended consequences.

7.1. A top-down transition to electromobility in Poland

Electric cars came onto Poland's political agenda after the change of government in 2015 and were framed by the ruling conservative party as a response to three challenges: climate change, economic development based on innovation and energy security based on domestic fossil fuels (Plan for Electromobility Development, 2017). The Polish electric car, and a broader concept of electromobility, was thus introduced by the regime actors with the objective of greening the Polish economy and making it more innovative. At the same time, electric vehicles, by increasing demand for electricity, would also increase coal consumption in the power sector, which currently accounts for up to 80% in Poland's electricity mix. In this sense, the EV is meant to become embedded in the existing regime of electricity production rather than to transform it. However, despite the idea of embedding electromobility into the regime system, Poland cannot rely on any well-developed industry, technical knowledge, regulatory or market infrastructures for the production or use of electric vehicles. It is thus rather at the level of visions, imaginaries and policy documents where electromobility is being developed, rather than in its technical or economic dimensions. The *Polish Programme for Electromobility* (2016) has been integrated into several policy areas.

On the government website[4], one can also find a reference to EU guidelines and regulations – the Plan for Electromobility Development (2017) is a response to EU activities aimed at popularizing electromobility and alternative fuels. In this sense, the Polish regime actors draw on some concepts that are circulating in the European landscape of broader climate and energy politics. The Minister of Energy is in charge of the Fund for Low Emission Transport. The fund will support the construction of infrastructure for alternative fuels and creation of a market for vehicles charged with these fuels. The annual funding amount will be around 155 million Polish Zloty, which equals about 35 million Euros. Moreover, the Plan for Electromobility Development (2017) is supposed to stimulate demand for e-vehicles. The regime actors are thus trying to create conditions for niches to develop electromobility in Poland.

4 http://www.ofvas.no/bilsalget-i-2017/category751.html [Accessed 5 March 2018].

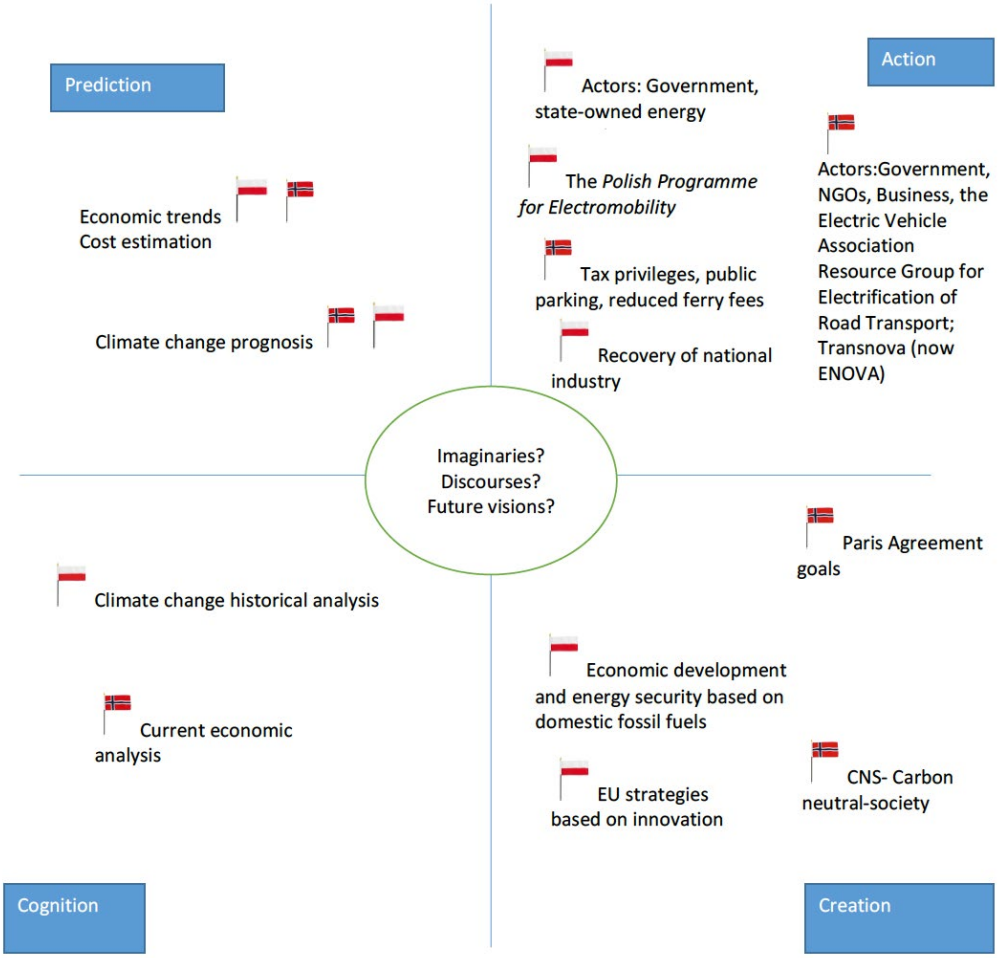

Figure 3 – Example of an analytical map.

7.2. The Norwegian case

The success of the Norwegian policy is partly explained by the fact that Norway (along with Denmark) has the highest purchase taxes on new cars in the world (see Table 1). Heavy financial incentives take the purchase cost of a battery electric vehicle (BEV) to the same level as a comparable internal combustion engine vehicle (Bjerkan et al., 2016). The reason for subsidizing e-vehicles is mainly to meet greenhouse gas (GHG) emissions reduction targets, even though business development was also important in an early phase. Policy for the promotion of e-vehicles in Norway can largely be defined as a top-down approach from the state; however, NGOs and business development have also influenced policy in Norway.

The unintended social consequences of electromobility have not been researched to a large extent in Norway. The cost of the policy, i.e. the high cost associated with tax levies and subsidies to reduce GHG emissions for society has spurred some debate, and the environmental impacts seen in global and life cycle perspectives have raised some interest (Holtsmark, 2012). However, the predominant view and policy in Norway has largely neglected this critique. Official policy documents state that the clean electricity mix in Norway as well as the ETS trading scheme will ensure that EV policy in Norway will be effective and lead to major reductions in GHG emissions. Issues such as how aggregated car ownership has been influenced by tax deductions and how low operating costs have influenced society have been overlooked. It is well possible that this might lead to increased household car ownership and use (Fridstrøm and Østli, 2016a; 2016b).

8. Unintended consequences

Table 1 – Possible unintended consequences of electromobility in Norway and Poland.

	Poland	Norway
1. Un-intended conse-quences between networks	(1) Electric vehicles, by increasing demand for electricity, would also increase coal consumption in the power sector, which currently accounts for up to 80% in Poland's electricity mix. In this sense, the greenness and cleanness of the car is put into question and the object itself is set in an ambiguous network of relations. (2) The construction of charging stations is a result of negotiations of various actors who envisage charging stations within a broader idea of electromobility in specific ways (e.g. charging stations in sites dedicated to leisure, such as moles, cinemas etc., or to work). A possible unintended consequence of this may be power grid overload in specific sites.	(1) The new national transport plan (2018-29) has set aside 536 billion NOK from 2018 to 2029 for road building and improvements, showing that road transport will be an important part of Norway's transport future, since it is probable that road improvements will increase transport volumes (Strand et al., 2009).
Common scenario *between* networks	(1) Interactions between financial and IT networks used for BEVs could reduce car ownership, with unpredictable consequences for the overall vehicle fleet. (2) IT networks used for BEVs could open the gate to new forms of hacking activity.	
2. Un-intended conse-quences within networks	(1) Expensive electric vehicles compared to cheap electricity can foster the use and increase average mileage (direct rebound effect). (2) Cheap, comfortable and environmentally friendly BEVs can increase individual mobility and, in consequence, add to the problem of huge traffic congestion in urban spaces (indirect rebound effect).	(1) There is a tendency that owners of BEVs on average have more cars than people who do not own electric cars; there is also a tendency that total GHG emissions from passenger cars are not curbed fast enough to meet GHG emissions reduction targets.
Common scenario *within* networks	BEVs could increase access to and acceptance of private mobility, curbing collective and alternative mobility (green paradox).	

9. Further recommendations

To sum up, it seems that both Polish and Norwegian policies have not taken account of unintended consequences of electromobility for society. In Poland, electromobility is still an issue for the future, the goals are declared and few examples of e-cars on Polish roads legitimize the technological promises to solve the problem of air pollution and climate change. In Norway, current trends indicate that mobility patterns in terms of driving distances have not been influenced by Norwegian EV policy: Cars drive about the same distances (Statistics Norway, 2017), and car ownership has increased. The Norwegian case points to the need to move beyond technology and support a shift from passenger cars to public transport, cycling and walking as well as to curb passenger car mobility in order to achieve major reductions in GHG emissions.

Based on the insights from this preliminary examination of the Polish and Norwegian cases, we share the concern recently expressed by other scholars in the field of social sciences (Bergman et al., 2017): This involves the risk of electromobility as a perpetuation of the status quo of a transport system based on private

mobility in the long run, and legitimating inaction towards the impending air quality crises in major European cities in the short run.

Finally, the model proposed here for analysing the unintended consequences of electromobility could be readily extended to self-driving cars, which in a foreseeable future will be coupled with BEVs to shape mobility in unpredictable manners.

10. References

Bergman, N., Schwanen, T. and Sovacool, B., 2017. Imagined people, behaviour and future mobility: Insights from visions of electric vehicles and car clubs in the United Kingdom. *Transport Policy*, 59, pp. 165-173. Available at: https://doi.org/10.1016/j.tranpol.2017.07.016 [Accessed 14 March 2018].

Bjerkan, K.Y., Nørbech, T.E. and Nordtømme, M.E., 2016. Incentives for promoting battery electric vehicle (BEV) adoption in Norway. *Transportation Research Part D: Transport and Environment* 43, pp. 169-180. Available at: https://doi.org/10.1016/j.trd.2015.12.002 [Accessed 14 March 2018].

Bulach, W., Schüler, D., Sellin, G., Elwert, T., Schmid, D., Goldmann, D., Buchert, M. and Kammer, U., 2018. Electric vehicle recycling 2020: Key component power electronics. *Waste Management & Research*. DOI: 10.1177/0734242X18759191.

Fairclough, N., 2010. *Critical Discourse Analysis. The Critical Study of Language*. Harlow: Longman.

Faria, R., Marques, P., Moura, P., Freire, F., Delgado, J. and de Almeida, A.T., 2013. Impact of the electricity mix and use profile in the life-cycle assessment of electric vehicles. *Renewable and Sustainable Energy Reviews*, 24, pp. 271-287. Available at: https://doi.org/10.1016/j.rser.2013.03.063 [Accessed 14 March 2018].

Font Vivanco, D., Freire-González, J., Kemp, R. and van der Voet, E., 2014. The remarkable environmental rebound effect of electric cars: a microeconomic approach. *Environmental Science & Technology*, 48(20), pp. 12063-12072.

Fridstrøm, L. and Østli, V., 2016a. *Vehicle fleet forecasts based on stock-flow modeling*. TØI Report (1518/2016). Oslo: Transportøkonomisk institutt, Stiftelsen Norsk senter for samferdselsforskning.

Fridstrøm, L. and Østli, V., 2016b. *Kjøretøyparkens Utvikling og klimagassutslipp. Framskrivninger med modelle BIG*. TØI Report (1518/2016). Oslo: Transportøkonomisk institutt, Stiftelsen Norsk senter for samferdselsforskning.

Galvin, R., 2016. Rebound effects from speed and acceleration in electric and internal combustion engine cars: An empirical and conceptual investigation. *Applied Energy*, 172, pp. 207-216.

Geels, W.F., 2014. Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. *Theory, Culture & Society*, 31(5), pp. 21-40.

Geels, F.W., 2004. From sectoral systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory. *Research Policy*, 33(6/7), pp. 897-920.

Gemmetto, V., Squartini, T., Picciolo, F., Ruzzenenti, F. and Garlaschelli, D., 2016. Multiplexity and multireciprocity in directed multiplexes. *Phys. Rev. E* 94, 042316, pp. 1-23. Available at: https://arxiv.org/pdf/1411.1282.pdf [Accessed 8 March 2018].

Holtsmark, B., 2012. *Elbilpolitikken-virker den etter hensikten*? Samfunnsøkonomen, 5, pp. 4-11.

Luhmann, N., 1976. The future cannot begin: temporal structures in modern society. *Social Research*, 43(1), pp. 130-152.

Merton, R.K., 1936. The unanticipated consequences of purposive social action. *American Sociological Review*, 1(6), pp. 894-904.

Plan for Electromobility Development, 2017. Available at: http://www.me.gov.pl/files/upload/27052/Plan%20Rozwoju%20Elektromobilno%C5%9Bc%20RM.pdf [Accessed 5 March 2018].

Strand, A., Næss, P., Tennøy, A. and Steinsland, C., 2009. *Gir bedre veger mindre Klimagassutslipp?* TØI Report 1027/2009. Oslo: Transportøkonomisk institutt, Stiftelsen Norsk senter for samferdselsforskning.

Statistics Norway, 2017. Available at: no/statistikkbanken/selectvarval/saveselections.asp [Accessed 16 May 2017].

Zwart, F., 2015. Unintended but not unanticipated consequences. Theory *and Society*, 44(3), pp. 283-297.