Translating Train Management to Norway

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Master thesis at the Center for Technology, Innovation and Culture

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University of Oslo
Norway, May 2017

I, Lasse Gullvåg Sætre, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

This thesis explores the transition of Norwegian rail signaling from mechanically to digitally based systems, delving into the translations of the European standard ERTMS to Norwegian railways. Through digital, technical and bureaucratic informants, this study investigates the preparations and makings of what promises to be one of the biggest revolutions in the technology to date. The ERTMS is a railway signaling technology, an EU political technology, and a case of digitalized European information infrastructures, known by many names, such as smart cities or intelligent services. Studied through the Norwegian railway system's digital integration towards Europe during the last 20 years, this thesis inquires into the material semiotic production of rail governance in the Norwegian context, as well as what it means to be an EEA member. From expert informers from the Norwegian infrastructure manager *Jernbaneverket* and its partial successor *Bane NOR*, through documents and field studies/interventions, the ways in which key players of the Norwegian and European railway sectors change are explored, mapping out the issue of signaling, and how players prepare for a transition that was always part of larger ideas of mobility, machines and governance, extending far out from rail space.

Acknowledgements

First of all I want to thank Frans Joakim Titulaer for his academic wisdom and support throughout the project. The thesis would not have been the same, without our many talks on science in society. Thanks also to my co-students, and to researcher Helge Ryggvik at the TIK Center for Technology, Innovation and Culture, for which this thesis would not have been written. I am grateful to *Jernbaneverket* and *Bane Nor* for allowing me to sit in on his interviews, and later do my own interviews with their employees. Thanks to my primary supervisor, Tone Druglitrø, who held me on course and put up with bad drafts.

Listening to and interviewing experts about the things they love is truly satisfying, because it reveals the exciting labor that goes into making things work. It is also infuriating, because they sometimes expose their ability to critically reflect. People who truly understand railways do not always understand why they are being done in the ways they are being done. Thanks to them for sharing both that and the pride they take in their work.

The forum for scientific theory at UIO has been very helpful in expanding my knowledge of a wide variety and range of scientific fields. Through alliances and treacheries, science progresses, also here.

Finally, I want to thank my family, especially Synnøve and Leon, as they teach me about life and love.

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Abbreviations

ATC	**A**utomatic **T**rain **C**ontrol
ATO	**A**utomatic **T**rain Operation
ATP	**A**utomatic **T**rain Protection
EEA	**E**uropean **E**conomic **A**rea
ERA	**E**uropean **R**ailway **A**gency
ERTMS	**E**uropean **R**ailway **T**raffic **M**anagement **S**ystem
EU	**E**uropean **U**nion
IM	**I**nfrastructure **M**anager
NJF	**N**orsk **J**ernbane**f**orbund
NoBo	**No**tified **Bo**dy

Chapter 1

Introduction

This is a thesis on the digitalization of railways. It is also about the translations and connectivities that happen within what I have come to shorthand as rail space, but also within technological and bureaucratic spaces. More specifically, it is a read on the governance of the Norwegian railway signaling situation, and its relations to the EU in general, and European Rail Traffic Management System (ERTMS) in particular. Mobilizing the history of the Norwegian railway, through the history of signaling emerges models of governance between the state, the superstate and technologies are explored together with the making of ERTMS.

Signaling technologies are fundamental to train systems, perhaps even more so than traffic lights are to road based systems. How railways' efficiency of low friction from steel wheels on steel tracks brings with it very long braking distances, is just one of many reasons why train systems need functioning signaling technologies that can help the train driver in transcending eyesight. To be able to run multiple trains securely on a rail network, the signaling system must stop, permit and enforce certain movements. Norway's current signaling system is based on a technology that matured in the 1950s, with much of it being built in the 1960s. As infrastructures, trains must be reliable to compete with other modes of transportation. However, an aging signaling system makes this a nontrivial task. Errors in signaling systems tend to stop train operations, because of their safety critical tasks. Norway got a stark reminder of its importance on a winter day in 2000, when a crisis occurred.

ERTMS is a technological project aimed at achieving the infrastructure goals and policies set forth by the European Union towards member and other states. It has been developed as a European technology, in cooperation with the often state run railway companies and private supplier companies to deliver a standardized framework and operating system for a new European Rail Space. Running trains throughout its territory takes commitment from this supranational entity, but doing it the direction set out by the EU demands standardization. The European standardization of its signaling systems is considered in this paper to be a way to do a railway market. A value of interoperability, a simple idea of trains should be able to cross through national borders, comes to co-produce the frontier on Norwegian EU-integration, towards a distinct pathways of smart infrastructures and intelligent transport services. Interoperability also means a lot more than trains crossing borders. It carries within it political technologies of co-producing complex mobilities among national and regional industries, the state and the superstate, and its bureaucracies and populations.

As such this thesis views ERTMS as basis for science studies into the dynamics of the application of science in a particular technology. The concern is not on one of something which should be done or not be done, but rather on power (Callon 1984). What is going on today, how is it being done, how is “progress” being made? Exploring public works and their creation of infrastructures “coming online”, this is a study on how contemporary European information infrastructures are performed, articulated and materialized in rail space. As far as technological projects go, ERTMS is a large one: In standardizing how communications between train and traffic manager should be done in the union’s railway systems, it is certifying commercial products and making economical sense of the technology. Being a technology tightly connected to the state, railway components were not priced, and to economize this socio-technical space is a massive undertaking. This project is what one can call a mega project, an orchestration of nation states in a whole regions of the world to replace long stretches of railway infrastructures, tearing up and fortifying metal skeletons of nation states.

For Norway, the implementation of the ERTMS represents the single most costly change in society associated with digitalization. The estimated cost has risen from 10-14 billion kroners in 2008 (Jernbaneverket 2008) to 33 billion in 2017 (about 3,5 billion Euro), and construction has not yet started. The state's maintenance of such a large, heavy and geographically extended technology, has always been seen as costly, but also socially useful enough to keep around since its emergence in middle of the 19th century. Creating mobile populations can be achieved in many ways, and different types of mobilities perform both different geographies and different populations. While other transport technologies have become obsolete, irrelevant or changed, railways are still prioritized and have a more or less familiar feel in most societies. However, while a large generational shift in infrastructure technologies is happening, it is doing so in the middle of a national railway reform that is separate, but not unrelated. The railway reform is also aimed at updating the institutional arrangements to better fit a singular European rail space. This thesis explores the contradictions between the doing two different spaces of mobility: A space of Norway as part of the EEA/EU, and the other one as new Norwegian governance infrastructures.

As materialities are patched and exchanged, railways are supposed flow from periphery to centrality, and back to periphery again with certainty. Regularity, reliability and security from the best science and technologies can do. Railway signaling concern the regulation of these flows, and are controlling technologies in for trains in this networked space between technoscience, humans and natures. How are the technological mediations and enablements of such chronological, standardizing, abstracting and authoritarian techniques changing today? Looking to the history of rail computerization, History brings up the many accounts of the computerization of European railways through both long and short perspectives. Models and prototypes of Automatic Train Operations (ATO) systems have been shown to World's fairs since the 1960s (Latour & Porter 1996). Proper digitalization can also be said to not really kick off until the 1980s, with the advent and implementation of Automatic Train Control systems (ATC) and electronic Automatic Train Protection (ATP). An even shorter perspective sees these as pretty basic systems; ATC and ATP had far fewer levels of abstractions, types of representations, instruments of sensing and degrees of freedom, compared with the digitalized railway systems being translated/tamed today.

The long view sees railways as having strong connections with the concept of modernity and the state. The early railways are in many senses ancestors of todays computer, in and of themselves. A modern day computer can exchange the algorithms it runs, while rail algorithms are built into the mechanics of rail space. The early signaling systems of railway workers using flags resemble logic operations of todays computers. As an earlier analog to the electronics and computer revolution, railways also sped up the pace of society in its time. Not only that, for according to Bowker (1995), railways are key in commodification of the world, through the its liquifying and standardizing effects. Together, the organization, the commodifaction and the technology of railways play central roles in abstracting time and annihilating space.

> "Railways were uniquely important in the nineteenth century because of the interconnection of two innovations. Railway technology created physically a new landscape marked by the free flow of massive physical objects on a straight line. The smells and touch of the local environment did not exist in the abstract landscape the traveler sensed (they were replaced by a motley collection of machine odors and noises); only quantities (time, distance, mass) did. Equally important, the railroads represented their own organization within this abstract space and time. They imposed a standard, administrative time on the countries they operated in. They developed organizational flow charts and command systems that traced out the contours of this abstract space." (1995, p.61)

The development of railways can be summarized as an acceleration of global flows, a synchronization of actor-networks or a proliferation of financial objects. People, chickens, metals, information, what have you, have become train-borne and had their networks' distance friction lowered.

1.1 Translating for market mobilities

When equipped with signaling systems, either by way of humans with flags or relays and lights, railways become large scale logic machines. In such, it was maybe no coincidence that when the world saw the first group of computer hackers coming out of the MIT of the 1950s, they formed from precisely the signaling division of the student model railway association (Levy 2001). Signaling systems, with command-and control, is a materialization of the basics of cybernetics, as classical examples of a control systems operating in space. Like algorithms, railway signaling systems take some information about where trains are located, and give driving permission according to pre-defined logic communicated by way of the signaling aspect. In a functioning signaling system, a restrictive signal aspect makes the train stop, and a clear signal lets it run.

It is not rocket science, but as documented by Latour & Porter (1996), many a space technology company have underestimated the challenges that lay in traversing distances through a variety of urban and rural spaces, and failed in performing railroad missions. In some senses, control technologies of satellites have simple tasks in comparison, as they only deal with closed systems in relatively empty space. Not so for railways. Investigating the design of their control technologies, seeing them deal with the troubles of repeating journeys day in and day out, through different geographies while having regards for stressed, angry and disabled passengers, and caring for animals walking into the tracks, together with all of the other problems one cannot fully predict that comes from operating inside of society, the study finds also control technologies traveling. Key technologies translate into the railway sector, and ERTMS being more than a ready-made technology to be deployed, is brought into a whole complex of negotiating governance technologies. Thus, my motivation for this study is to expand upon the STS idea of technological translations.

Seeing that markets have been done through or as a result of mobility, there is a transition towards the market resulting in mobility. However, the case of ERTMS shows how there is no smooth transition, that fully equipped market actors do not somehow magically appear to do the work when the state stops doing it. Neither are the logics of the "railway market" directly intuitive, as interoperability and the translations of economizing tools show that the railway market do not reflect markets that we know from our private economies and ideologies. Flexibility and modularity assumed in market creation does not necessarily fit smoothly into the railway as a concrete technology. The buyers of services are mainly states, as operating trains by ticket and freight income alone seems to be impossible. To avoid having the railways end up in negative spirals between shrinking funds and diminishing user bases, states have intervened with funding, and tickets are subsidized by orders of magnitude (Cantos, José Manuel Pastor, et al. 2010). Yet, there are quite a few people making their lively hoods off of trains, being the field of operations for many corporations, although a limited set of industrial giants dominate the international level. Railway economies do not function as mass production economies either, as there are only so many trains out there. While Norway is a small country with only some 600 trains, it illustrates a limited demand, without the sales numbers of for instance the car industry. Exploring interoperability as a form of economization, abstractions of market place creation is confronted with the particularities of a large technological system, that while being large in geography, is small in market size.

On a larger historical and geographical scale, railways have played important roles in European-style society building. In Europe and elsewhere the daily flows of information, trade and commuters are still sustained in part by railways. Mobility in this form has historically allowed for large scale industrial and societal development to escape the geographical boundaries of needing proximity to waterways (Rodrigue et al. 2013). As creative destruction in society is embodied by the materials of the world, it can seem to also lay inside the infrastructures for moving flows of animals, people and matters in what has been deemed useful directions (see figure 1.1 as an example). Crucial to social power are the extra- and in-humanities of objects and animals (Wood & Graham 2006). At the same time, trains have had a connection to the destruction of many parts to societies. As though everything solid is taken by the root and liquefied in the great machines of techno-finance, railway tracks are being blasted through the terrain, allowing for equally brutal amounts of speed and tonne-kilometers. Differences in temporalities are explored across differences in the scales of markets, political systems and geographies.

1.2 Co-constructing governance

The procedures of developmental control of ERTMS, where it is developed as a standard, where things like tracks, telecommunication systems, languages and ideological scaffoldings come together in documents people and ideas is constituting the EU level. Understanding not so much why the Norwegian ERTMS implementation is going where it is going, but rather how it is going there, requires some knowledge of how the technology develops and translates on the supranational scale, and by extension how implementation of it becomes a goal for nation states. Documented in different articles, directives and documents, the study learns from its informants how the European Railway Agency and the signaling standards are created and articulating a contemporary "Idea of Europe"(Parsons 2003).

Railways nevertheless pattern the spatiality of everyday lives: Where we are and who we are interacting with are conditioned by these things thundering through space either we are on them or not. By giving users the ability to extend their capabilities in certain directions, towards patterns of today's financial and ecological models, transportation systems lend structure to the basis on which modern life rests (Rodrigue et al. 2013). This implicates railways in forming the relationships between power and populace of society, and is an independent party also in configuring the nature/society contradiction. Although the railways in truth have played more central roles in societies of the past than they do today, there is no shortage of visions of future societies where railway technologies make up the transportation backbone of low emission economies.

It is this kind of reasoning that has steered the thesis away from asking questions of why railways not go faster, further, better, and rather towards considering how it is changing today. Norway serves here as a case of modern, well-funded national railway systems becoming part of continental-scale infrastructuring (Hughes 1987). The thesis deals with some of the main European institutions invested in the railway field, and is an examination of how they have been central in defining the ERTMS technological project through documents, standardizations and ontological orchestration. Standards work creates detailed building blocks of what is imported and implemented into the Norwegian territories, as specifications for market place creation, and the production of scales and horizons of a Single European Market, made in relationships between inscription devices and new technological objects.

If the ERTMS is a good technology in a well-functioning society, the trick will now be to turn it from documents, texts, politics, ideologies and goals into physical materialities and spaces in which there is useful movements within. To study how the Norwegian actors are progressing towards ERTMS implementation, some knowledge is needed about the political technologies at different scales, the tools for taming ERTMS and what kind of actors enters with it and is being taken in by Norway. The models for implementing ERTMS in member states and others, provided by the European Union, are sought out. The EU railway packages, the European Railway Agency, and other actors are described as to how they perform ERTMS into being. The experiences of informants from and around *Jernbaneverket* are queried, as the main weight of this thesis not on ERTMS and its relations to the EU, but rather how ERTMS is translated to the Norwegian conditions. This does not mean that Norway has been passive in ERTMS creation, but that this thesis is a moment just before the national rollout project is about to begin. Through interview data, site and document analysis, the negotiations, configurations and implementation work through existing frameworks of knowledge and policy making in between the two governance models are explored and analyzed.

The thesis explores Norwegian EU integration and the emergence of the inner market of the EU, through digitalization of one of its core mobility technologies: The railway. ERTMS is considered here as a case of how EU policy implementation and goal achievement has shifted towards regulating and standardizing technological artifacts and infrastructures. Although ERTMS has a European heritage, it is a global phenomenon. China is the premier adopter of this technology measured by track length, making ERTMS part of a global competition between several products and standards promoting their own ways of managing large sociotechnical systems of production, transport and logistics. As such, the ERTMS standard is not only a case of modern digital control systems, but also the state of the art in supranational bureaucracies' ability to enact social power and perform in space.

This is important as Norway is not formally a part of the EU, and rejected membership in 1994, but remain subject to EU law through its membership in the European Economic Area (EEA). The country implements the union's directives as law. When the Norwegian Parliament had the state of Norwegian democracy investigated in NOU 2003:19, its EU integration was heavily criticized:

> Norway has the right to veto EU directives, but the political cost of this is considered very high. In this way the Parliament's opportunities for independent legislation is curtailed in still more fields. (Translation from the original Østerud et al. (2003))

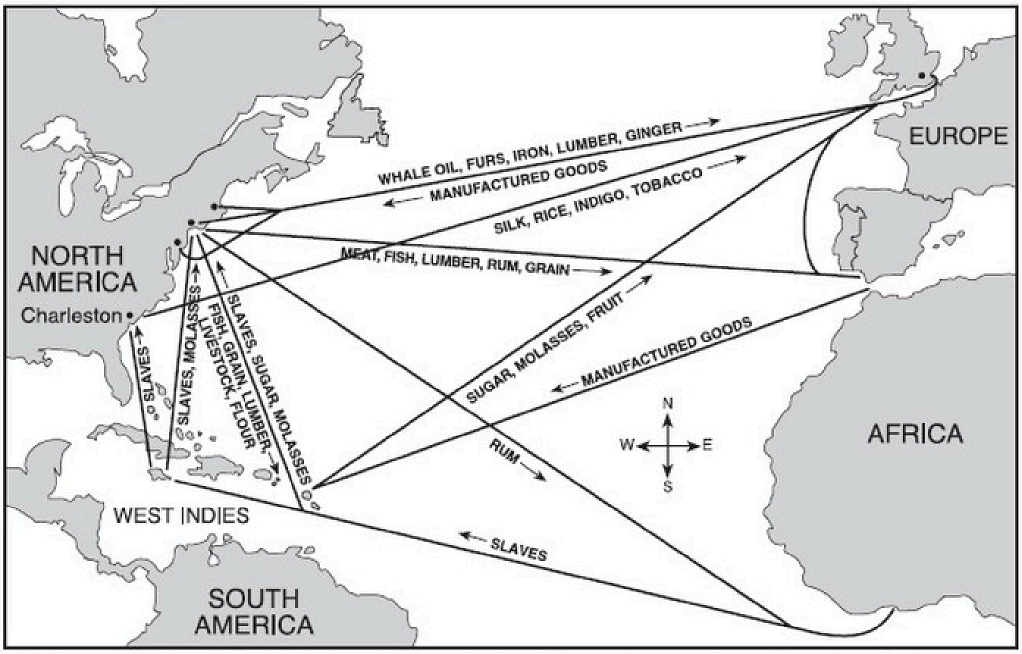
15 years later, integration is progressing. ERTMS materializes as such contradictions within dichotomies of market/state, national/superanational and democracy/technocracy, that makes a it a ripe object for pragmatic STS investigation into the politics of science and technology. As objects and publics are co-constructed in the STS view, the procedural and unprocedural performances of ERTMS into being are considered against public debate.

1.3 Research problem

- How is the ERTMS being translated to Norway?
  - How is Norwegian EEA membership being done through the railway?
  - How is infrastructural digitalization rescaling mobility management and control?

1.4 Summary of chapters

This is a brief outline of what went into each chapter. **Chapter 2** discusses the methodology, analytical framework and data collection. **Chapter 3** discusses how the ERTMS came to be a Norwegian railroad mission, and its embedding in the pilot line. **Chapter 4** considers a new valuation practice, ERTMS's conception as a European technology and Denmark. **Chapter 5** discusses connections between digitalized infrastructures and organizations, markets as infrastructure builders, and some different perspectives on the EU.



Source: Steven Goldberg and Judith Clark DuPré, *Brief Review in Global History and Geography*, Prentice Hall (adapted)

Figure 1.1: Actors moving in useful directions of imperialism in the Triangle Trade.

Chapter 2

Methods and analytical dimensions

I got in to railway signaling through the technological history project "*Jernbaneverket* - History of the Norwegian government's agency for railway services" during the spring of 2016. Through the summer and fall I gathered data, did fact checking and transcribed interviews for the historian and author, Helge Ryggvik. The project was financed by *Jernbaneverket* and TIK Centre for Technology, Innovation and Culture. Ryggvik's research resulted in the book *"Sporskiftet - Jernbaneverket 1996-2016"* (Ryggvik 2016), which documented the importance of the Norwegian railway infrastructure manager in its 20 years of service.

The book shows how *Jernbaneverket* transformed together with the railway infrastructure management, long before the controversial Norwegian railway reform of 2016-2017. In between the state monopolists collapsing into multiple institutions in 1996 and the aftermath of the Åsta collision with 19 fatalities in 2000, both security culture and arrangements of responsibilities had been turned inside out. Between the organization having to lay off almost 20 per cent of its work force in 2004 due to lack of financing, and 5 years later when the organization was asked to use more money fast, its societal mission had changed dramatically.

Through this research, it became increasingly clear to me that more than any railway reform, subtle and profound changes in the way we negotiate mobility. Within the dual tendencies of digitalization and integration emerges a new kinds of mobility governances. While the framework of the book project gave Ryggvik (2016) room to touch on it briefly, I saw the research done as a springboard for inquiring further into the effects of these two separate and interconnected processes.

Voicing the connections of a railway signaling technology can be thought of as the act of boundary work, the use of language to formulate realities between different strands of science and technology in articulating and defining a European information infrastructure. This thesis has aspired to do translation work between those with an interest in railway technologies, geographies and Computer Science. Is it science fact or science fiction? The Norwegian ERTMS project can be shut down tomorrow, and the paper would at best have described something which could have been, except for a little pilot line in the outskirts of Oslo. But, as shown, that is unlikely to happen as the project has gained such momentum that resistance seems, if not futile, at least hard. I have tried to follow the actors in creating this momentum, to write about them, tap into their knowledge and describe the atmosphere created around me. By intensely focusing on a seemingly obscure technological artifact, the interconnections that constitutes digitalization of society's infrastructures are sought out.

Coming from an IT background and working with an Internet Service Provider, the book project served as a great opportunity to explore a related infrastructure in a networked, but still completely foreign technological environment. Although I am myself an everyday user of transportation infrastructures, I have been participating in a long tradition of not questioning where our most basic abilities are coming from. Keeping in mind that rail and related tracked transportation technologies only make up a part of broader human mobility competencies, they are integral in conditioning contemporary life. The next time you get bad coffee from a dispenser on a train, think of the rich logistical history that lies behind not only how you got this cup delivered, but also your taste for coffee.

In attempting to correct my own blindness to infrastructures, Bowker &

Star (2000)'s "infrastructural inversion" has been helping. A research strategy to articulate what is implicit, a process to make visible what is often taken for granted, infrastructural inversion is a way to bring infrastructural, classification and standardization systems and their interconnections into the light. While classification systems are not the sole focus of this paper, it has benefited from their methodological insights in dealing with often dull technical documentation. ERTMS is in many ways a standard, and classifications does indeed comprise a fundamental part the ERTMS. In trying to understand the challenges posed by ERTMS deployment, their insights on infrastructures in general, information infrastructures, and standards was appreciated.

In what follows, I elaborate on the overall reasoning behind research strategy, methodological decisions and ethical concerns. The chapter also contains descriptions of the data gathered and reflects on their ability to answer the thesis' research question. First I will outline the reasoning behind foregoing a full literature review, and how that follows a greater attitude in technology studies for ambiguity towards the separation of methods from theories. Secondly, the way in which this project got started and materialized is reflected upon, before accounting for the data collection and mixed methods approach used in trying to understand the current digitalization patterns of society. Third and finally, the analytical lines along which this thesis' empirics will be discussed are described.

2.1 Why STS

Science and technology studies (STS) have used scientific inquiry to criticize the same subject matter. To honor their findings, one should try to avoid some of the pitfalls they point to. For instance, in studying the production of natural science through a laboratory setting, Latour & Woolgar (1986) observe how scientists draw on methods of purification, in which softer realities mixing the social and the natural, become hard and devoid of sociality in the final papers. As behaviors of concealing the heterogeneities of knowledge production is just as usual in the social sciences.

STS is no exception neither. However, STS has been an important contributer too to (Asdal et al. 2007, pp.17–19) in which sociality can seen to be (re)configured through research and the production of papers and articles. With such reflexivity in mind this thesis is not 'impartial', but rather intervenes into what is being described. This thesis has been produced to try to avoid what is being criticized here. To do so means to include some of that which is usually deemed "backstage" work, to bring out what often becomes hidden from the reader. This implies also showing how the paper focuses on technology while still being firmly situated in the social sciences.

Moreover, this means being methodologically and theoretically minimalistic. Studying the city, Amin & Thrift (2017, p.23) find that those concerned with the agency of sociotechnical systems have aimed towards honoring "heterogeneities that defy leveling generalizations and systematic abstractions". STS comes from veins of science and social studies with older conventions for opting out of traditional social scientific explanations of phenomena to better grasp their unfoldings. Garfinkel, contributing to the sociology of scientific knowledge, championed a scientific practice of "ethnomethodological indifference" (Garfinkel & Wieder 1992), in which the researcher deliberately brackets theory to observe social order being made in real time. Instead of finding irrational actors not adhering to an optimal set of actions specified in some theory, the aim is rather to unveil the inherent rationality in practical actions and reasoning. That is why this thesis follows a critique both of the *homo economicus* as well as the *homo sociologicus*, where actions are explained respectively through subjective self-interest or social roles and norms (Reckwitz 2002). It is the actors doing their own network tracings, that the researcher should study. This critique of scientific reasoning has been influential in studies on science and technology up to this day, and clears the table for this thesis to construct its own analytical framework based on ANT, to make a custom-fitted understanding the digitalization of railways.

Instead of treating scientific theory as internal to the empirical work of science and ocular only, this study reflects on it as social practices - as social ontology. While the studying the concept of social practices is meant to be encompassing of a broad range of human inputs and outputs, it is itself a thought model, a theory, heuristic and abstraction. Theories as such are technologies. "Positivist" social sciences sees technologies as something neutral that the social and political extends itself onto, a view Latour (1999, p.176) compares with the slogan of the National Rifle Association: "Guns don't kill people; *people* kill people." The institutional context which has exerted its influence on this text holds that not only does society influence science and technology, but that science and technology is key in performing society. In the hope of doing good STS research this thesis should therefore also go beyond a social constructivist critique of the phenomena in question. It should be a more generous understanding of knowledge production, and towards the 'positive power' (Foucault & Neumann 2002)* of the theoretical, political (etc.) technologies involved. In so, the question of who kills who is not the issue, but the role of research becomes rather to help in understanding the gun-person shooting.

In this model of telling science stories between humanities and social sciences, scientific and technological constructs, theories included, are seen to have autonomous power in the world. To illustrate, let us visit Winner (1980) exploring a case of the low overpass bridges of Long Island, built by famous New York city planner Robert Moses. As to how technologies can be used in political ways, bridges are not usually considered, but their limited height in this case prevented bus users from accessing certain areas. In this manner Winner shows how technologies can be used to settle issues in communities. He sees also another type of politics for technologies, in what he calls inherently political technologies, exemplified by an extreme: The atom bomb. Because of its lethal properties, the fact that it exists at all warrants top-down control to prevent its misuse. "The internal social system of the bomb must be authoritarian; there is no other way," (Winner 1980, p.131).

But the politics of scientific endeavors and technological artifacts are far more encompassing, and is discovered in more mundane and seemingly innocent places. Even scientific practices embody the political: As showed by Schaffer & Shapin (1985) in their study on the creation of an experimental air pump in the pursuit of vacuum, the construction of consensus on scientific facts was connected to creating legitimate political institutions. Haraway & Teubner (1991) point to the technological constitution of the contemporary human and the fluidity between bodies and things. Alder (2010) reinterprets the French revolution as a vast engineering project: Through standardization and metrification was made a break with the political economy of the Ancien Régime (see also the study of the standardized recipe for making guillotines by Foucault (2012)), and new production methods of interchangeable parts were created and resisted as challenges to the established hierarchies of artisanal manufacture. And finally, studying the extensive sociological changes needed to achieve Pasteur's scientific breakthroughs in disease prevention, Latour (1993, p.229) came to coin the phrase "science is politics by other means."

A key concern for much of the STS literature then is how humans relate to their built and natural environments, and how objects and animals affect what has previously been thought to be human-to-human relations. Since the work of pioneers in the 1980s (Callon 1984), studies have found that the government of natures and technologies is at the heart of politics between humans (Ingold 2011). Far from being outside of politics, scientific and technological interventions in natures, things and populations can be seen as the very stuff of sociality and power (Foucault 1990). While power does work in face-to-face situations, lasting social relations need mediation through science and technologies. Latour (2005) argues that we should replace the study of social institutions with that of associations or object institutions. This is the intellectual baggage the study brings with it and conceptualizes the railways with. Railways are as such taken to be a heterogeneity of actors from different organizations, assemblages and scientific fields, where natures, humans and machines fold in on themselves in their own reproduction, reinventing themselves, the railways and society simultaneously.

2.2 Translation and symmetry

There is a tendency in the STS field to emphasize the work done by signs, texts, symbols in creating social reality. The post-structuralist turn has been criticized for loosing materiality behind layers of representation, leaving it behind somewhere inside of discourse oriented analytical approaches. However, in later attempts of reestablishing some sort of primacy in materiality, it is also this writers view that one should not discard the should not suspend the conceptual insights from the relational and linguistic views of the post-structuralists.

The concept of material semiotics has thus become a term in wide use both in and beyond the field of STS, referring to how things are at once material and semiotic. It acknowledges the vitality of material entities in conceiving the social, but also calls attention towards the relationality of the entities studied. As an example, a train does not acquire its attributes by virtue of its materiality alone. It is only in relation to other materialities that the materiality of the train becomes meaningful, a relation which is semiotic in nature. The signal is just as much making the railway as the actual steel tracks or train cars are. This view points to the signifying qualities in all things, and the fact that this thesis focuses on ERTMS, precisely a signaling system, was just as much a happy accident and good advice, as a chance to study contemporary takes on how to make material relations explicit and deterministic.

STS not located only in the social sciences, but also lies between the humanistic and natural science, using social theory in a descriptory manner, fueled by a symmetry of value. Abandoning normative claims, this thesis aims to give a deep descriptions of social fields. This is a model, something in itself ontologizing, critiquable as much as Kant. I see through the lense of the methodological and theoretical framework of Actor Network Theory (ANT), and to its social power located between extremes of agency centered and structuralist approaches (Wood & Graham 2006). Materiality is not unitary, singular or stable in this view. Rather it is fluid, as fragmented, temporary arrangements beholden to their environments and in constant need of translations and reiterations. The sociology of translation is a term used by Latour & Porter (1996) to characterize the study of technological artifacts in opposition to the diffusion theory take on technological development (Rogers 1962). While diffusion theory sees innovations as united ideas stemming from distinct inventors, to then become transferred onto others, this thesis employs the maelstrom model of innovation, that is translation.

Latour & Kaplan (2009) take translations not to be merely a change of wording from one vocabulary to another, but “to mean displacement, drift, invention, mediation, the creation of a link that did not exist before and that to some degree modifies the original two.” In other words, no translations can happen without new innovations. Every time a new group gets interested in the technology, it will change (Latour & Porter 1996). The development and spread of technologies can thus be read as one long sentence, that keeps getting added to (Latour & Porter 1996). Technological objects never cease to become real, as they are created by both layerings and shavings. Which sentence or layer is then the right one for the researcher to follow? All and none of them, answers Latour. As more and more of the singular elements of a technology are described, the more they become coherent and isotopic. In the end, the sentence *cum* technology has become so long that it is muted, it is no longer a technological object, but has become an invisible, as infrastructure.

Studies employing ANT follow actors. To say that ANT is a methodology is not untrue, but does not tell the whole story either. Similar to a theory, ANT is both ontological and epistemological in nature. Ontologically it holds that things are always assembled, or as Mol (2001) would have it, performed, into being through materially diverse practices. This directs the thesis towards the productive aspects of practices around ERTMS. The principle of generalized symmetry (Callon 1984) does not distinguish between different types of actors, exempting no thing, human or extra-human, from the ontology of a network comprised of actors. The suspension of classic dichotomies of subject/object, human/non-human and so on, to better view the relational effects behind phenomena has been guiding this thesis.

By this, ANT also deemphasizes the social in social constructivism (Berger & Luckmann 1966). Reframing construcitivism as a material, common-sensical assembly process, allows us to contemplate on how things can unravel or even be in a different states (Latour 2005). In this kind of constructionist view, even scientific facts are viewed as emerged from the connections between heterogeneous elements which can be traced through their material semiotic relations (Latour 1999), as for instance the outcome of networks of scientists, microbes, texts and instruments.

Unlike conventional theories however, ANT is seldom sought out to explain why things are as they are. According to Latour (1996), it abandons ambitions of providing explanation along "mere description", together with the privilege of the researcher as an outside observer. The observer is seen to be on par with the other actors, as "[w]orld builder among world builders" (Latour 1996, p.377). The ERTMS project is thus not described through terms presupposing states of society, like neoliberalism or patriarchy, but as an immanent force, without the need for outside explanations. It is the actors themselves who are seen as the sociologists (Latour & Porter 1996). Callon (1984) provides some operationalizations for how to do so. In studying researchers, villagers, larva and scallops, Callon identifies four moments of translation, which are mobilized in this thesis: Problematization, interessement, enrolment and mobilization. This is why the tool set is rather adapted to articulating the unfolding of events and beings, placing "how"-questions front and center.

In terms of epistemology then, ANT offers only a negative epistemological view, with no language to account for languages, no metalanguage. In stead it promotes what Latour (1996) calls a deontology of networking, through the concept of translation: Either an account leads to all other accounts, and is good, or it stands in the way of incorporating other accounts, and is bad. "Either it is reductionist - and that's bad news -, or irreductionist - and that's the highest ethical standard for ANT". This also sets the scope for the thesis. It will follow the actors, the interviews, documents and places, sticking to the limits they set themselves.

In being one of the younger branches of STS, a field which itself still is in its formative years, ANT is not a calcified canon on which one can draw upon, but rather an academic complex in a state of becoming. Summing it up in a few sentences will then necessarily leave some views out. This summary also reflects the fact that only parts of the ANT toolkit has been mobilized here, while being augmented by other approaches. However, there is a precedence for using ANT in flexible ways, as Law (2009) describes ANT as “a diaspora that overlaps with other intellectual traditions”. This brings the argument to an intentional circle. A theory chapter is foregone because models on sociality is precisely what is being studied through Science and Technology Studies.

> Relativist sociology has no fixed reference frames, and consequently no metalanguage. It expects the actors to understand what they are and what it is. It does not know what society is composed of, and that is why it goes off to learn from others, from those who are constructing society. (Latour & Porter 1996, p.200)

2.3 Data collection and research strategy

The data collection process was comprised of several overlapping stages. It developed as an analytical process which makes an attempt at triangulating the subject matter(Hay 2016), and this way aims at describing a (sort of) totality. All stages have been documented and structured through field notes in a text editor, written in the Markdown language (Gruber 2004) and committed the UiO Github instance. Sensitive data have been kept strictly isolated. Following a recent trend for strengthening the reproducability of quantitative research, by writing this thesis in Markdown I argue that its human-readable source code is just as important for the long-term reproducability of qualitative research (Gandrud 2013). DOCX and similar ways of saving texts are fragile in the long run, as most who have tried to open a complex Word document from 20 ago can testify to. Separating input from output gives the added advantage of sane formatting across devices, screens and papers.

Referring to the railway system in Norway as the Norwegian railway system is fast becoming inaccurate. Sassen (2007) observes that while globalization is a process that transcends the national, it does so through the national, inside its territories and institutions. The railway is ambiguous in this regard: So much boundary work goes into keeping passengers in place, animals away from the tracks, and cars out of the way of crossing trains. Fences are put up, signs tell unauthorized personnel to stay clear, and tracks are laid out of the way, all to keep rail space separate from society and strict control of the flows within it. On the other hand, the railways are omnipresent, in that they co-produce new landscapes. As part of urban metabolisms (Amin & Thrift 2017), as carriers of materialities and as transportation technologies, they are key contributors in shaping geographies far beyond their own reach. With globalization, distant actors are increasingly becoming entangled in the national railway network, and the national is becoming hollow. This disembedding of social relations (Giddens 2013) poses challenges for the situated researcher wanting to study them.

Following the ERTMS and its network tracings (Latour 1996, p.378) through documents, led me eventually to the realization that I had to move myself in order to better understand. I had encountered what Burawoy et al. (2000) calls the ethnographer's problem of a break in the one-to-one relationship between the social and the local. ERTMS is not only a transcontinental infrastructure project, but also a political project of such magnitude that I felt I had to experience for myself the assemblies which ratified and sanctioned it. How do we reintegrate these ideas about globalization to the topical interests and case-orientedness of STS? It is important to problematize globalization and other ideas of epochal shifts, as they lack in attending to the question of "how". Ruppert et al. (2013) describe the challenge digital devices poses to social science. Quickly comparing the hyperbole around globalization with that of the digital (shift), theres a lack of understanding in the significance of the challenges posed to our conceptual apparatus. I want to see these processes co-produced in efforts across time and space at digitalization. Through going to the places of the ERTMS production, and recklessly harvesting historic materials, we see that these processes are kept within the bounds of bureaucracies as they articulate imagined futures of their digitalized selves. This has created three different data collection strategies, that are partly reflected in the partitioning of the thesis' empirico-analytical chapters 3, 4 and 5

2.3.1 Interviews

The 18 interviews informing this study on railway signaling can be divided into two groups. The majority of these were done in the setting of the book project concerning Norwegian railways in general, and not necessarily signaling. We met the informants in various locations around Oslo, many of which were the different office locations of Jernbaneverket . Ryggvik (2016) interviewed, while I did *in situ* transcriptions for all except a few, to avoid having to transcribe everything by tedious way of audio recordings. The selection process was done by Ryggvik, partly in collaboration with *Jernbaneverket*. This eased access, as most who were asked happily participated in telling this history.

Interview participants covered a broad segment of the people at the top of the Norwegian railway system. They included current and former leaders, project managers, security specialists, chief engineers, signaling people, strategists, geologists, and other types of employees required to make railways work. Included were also some transport politicians, the current and a former transport and communications minister, as well as the leader of Norwegian National Safety Authority.

Surrounded by technical and managerial expertise from the interviewees, and academic expertise from the interviewer, I interjected only a few times in this part of the research process. As the participants were asked about how their involvement with and first-hand experience in caring for the technology, the interview sessions often took a form more akin to oral history (Hay 2016) than research interviews. Ryggvik used orientation questions to find out about the participant's background, common questions centered on events and themes he wanted covered, and specific questions to uncover their individual experiences with certain phenomena. Accordingly the answers where often not related to signaling and ERTMS directly, although retrospection reveals more connections than I initially thought. For instance, at the time, I did not see how the sudden death of the *Merkur* project was related to the ERTMS project, but, as described below, the end of the first was indeed influential in paving the way for the latter.

I added two interviews, augmenting the 16 attained from the book project. Here I asked about the ERTMS specifically, and the participants were both leaders of the ERTMS project. This was done in winter 2017, when *Jernbaneverket* had shut down, and its partial successor, *Bane NOR*, was the new employer of my interview subjects. It is worth considering here then, that the interviews were done in a time of institutional change and relative insecurity. That gives reason to believe that many of the participants were under external pressure to and had internal self-interest in putting the railway organizations, as well as the outlook for the ERTMS project, in a good light, and give conservative estimates. Although the ability to critically reflect upon one's own work were apparent among the often highly educated participants, it is worth emphasizing that these views presented are both situated and particular.

Having said that ERTMS is an enormous undertaking on a global and continental scale, and that my knowledge about railway signaling was limited coming in to this project, I had a severe disadvantage compared to my informants with respect to understanding, in spite of my preparatory work. To overcome this, I typically asked open ended questions without knowing what the question meant until it was answered, like Rose's Gloss (Garfinkel & Sacks 1970): "ERTMS will sure change a lot of things, won't it?" Using the technological artifact as method, I risk overemphasizing it. Still, the information disadvantage sometimes resulted in the interviews resembling private lessons in signaling technology, and the possibilities connected to their digitalization, something which has bled over onto the thesis. This hopefully gives a magnifying glass to effect to this thesis.

Otherwise, these last two interviews were done in a semi-structured in manner, emulating that of Ryggvik's interviews. The common questions employed were structured around three themes: Where ERTMS came from, *Jernbaneverkets* involvement in the standard development, and the experiences from ERTMS pilot project. The reasoning behind following Ryggvik's lead was to keep consistency across the two different interview stages. Eventually, an archive deposit the recordings and/or transcripts should be considered, ensuring preservation and possible circulation of what in total makes up quite a significant collection of histories on the years leading up to Jernbaneverkets shut down at the end of 2016. This will require gathering permissions from the participants, as they were not informed about this possibility at the time of interviewing.

Since this thesis uses Norway as a case for digitalization of infrastructures and diffusion of European infrastructure technologies in general, English was selected as thesis language. This initially posed a challenge in reproducing interview excerpts, as all of the interview material is in Norwegian. Translated excerpts have nonetheless been include some places, because they directly convey complex information, in a way unreproducible by me. Translation has been done by me to the best of my ability and, in accordance with Temple & Young (2004), in the last stages of writing. STS literature (as well as this thesis) is concerned with the process of translation, which is explained later in this chapter. Consequently, interview excerpts are handled as paraphrases, and formatted like this:

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 This sentence mimics a translated interview excerpt.
- The author
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2.3.2 Document analysis

> "The text is the secret weapon of science. It is sent out from the laboratory and, if it does not strike terror into the hearts of those who read it, at least they are often obliged to take it seriously. By virtue of its transportability, its durability and its structure, it is often able to operate as a relatively autonomous agent thousands of miles from those who sent it out." (Law 1986, p.67)

Documents informing this study include everything from websites, standards specifications, verification application code, technical documents, powerpoints, to laws and articles about the ERTMS. The leads to finding the defining documents were often given to me by employees of the *Jernbaneverket*, but Google and DuckDuckGo (an Internet search engine said to avoid the filter bubble of personalized search results) also deserves a lot of credit in the document collection process. The only real common denominator for all documents is their relation to the technological artifact ERTMS. The collection process has taken up a lot of time, and was done throughout the project: First to get oriented, then to prepare for interviews, and later to document and complement interviews and fieldwork.

Of these, only some documents get the special treatment of being analyzed. Of these, the central ones are an article about the state of railway systems in Europe from the mid-nineties, meant to illustrate what was before and how what came after was not random, given or always there, but rather networked into existence. Document number two describes the ERTMS as a railway signaling standard, as it ontologizes rail space. The last document of centrality is the basis for the Norwegian concept choice investigation on ERTMS, containing a judgment device (Cussins 1998) of interest. More are included, but will be announced along the way.

Law (1986) argues that the words of documents index forces of different types to restructure environments of science and technology. They give the reader a route march, a bridge that must be crossed. Analyzing the documentation of the early Norwegian environmental issues, connected to aluminium production in the 1950s, Asdal (2015) identifies how style, rhetorical strategies and casting employed in written material indicate something about how and in which contexts the document has functioned. Styling a document can be done in many ways. Is it handwritten or printed? Is it formal or personal? What are the technological styles are the leaderships cascading through , and how can artifacts be understood to emerge with material semiotics? Asdal (2015) continues this line of argument, when she claims it is not sufficient to only call for greater attention to "materiality" or "materialities", while continuing to let all too human-centric concepts and categories shape our social studies. To understand social relations in their material heterogeneities, we must trace how built and natural environments are delivered to us as debatable objects and issues. In order to study the emergence of both objects and issues, we can observe the modifying work done through documents.

Das & Poole (2004), studying the state through the concept of marginality, finds that official documents "bear the double sign of the state's distance and its penetration into the life of the everyday" (Das & Poole 2004, p.13). This holds for the documents like the ones describing ERTMS from the various political and corporate scales, geographies, transportation technologies and the passenger are being redefined through the work of documents on the ERTMS and the problems it is supposed to solve. I spend time studying the ERTMS as it emerges as a knowledge object of the state and the transnational apparatus of the EU. Furthermore, I look at how ERTMS lives a life through documents, and its relations to the Norwegian and EU state bureaucracies. These relations I want to show, are also to be found in the digital devices that in the steps towards implementing ERTMS as more than a political project, incorporate the political technologies of signaling standards in "the good economy" of the European inner market. I therefore follow Asdal, but also extend upon her work. I want to point to what Matthew Hull Hull (2012, p.256) describes as the "anthropological distance" afforded towards practices of researching the work of documents in bureaucracy in the digital age, shining a light on previously unnoticed aspects of social practices of i. e. analog signaling. Adopting his point, I want to show that digital devices have to be understood through the practices they replace and the cultures (socio-technical landscapes) they are fitted into. And, as Hull (Hull 2012, p.18) states: "Rather than trying to define an institution and a terrain of operations, I describe the heterogeneous relations that come into being being through the use and circulation of the artifacts that mediate almost all bureaucratic activities."

My reading of the histories of the lives of these documents therefore could be said to have double purpose. I want to help adapt STS analytical apparatus to the work of analyzing government and political technologies; how ERTMS is 'delivered as a debatable object and issue' and how the study of documents can work to show how nothing could escape, or exist outside of, the networks that define them (Latour 1999). Moreover through, I also expand upon the analytical work that is afforded by the increasing distance with the non-digital and the becoming of the ERTMS as a technoscientific project; describing the effective employment of 'society into science and technology' through the co-ordination of new industries and markets. Telling the story of how ERTMS has come to be defined I therefore also contribute to the STS approach to the digital, or what Ruppert et al. (2013, p.25) describes as "the capacity of social scientists and cultural theorists to understand the significance of the digital challenge". Addressing the cultural specificity of digital code means to 'go beyond the restricted (and often restricting) understanding of code as the language of machines, and understand codes not only in terms of software but also in terms of cultural, moral, ethical and legal codes of conduct' (Mackenzie and Vurdubakis 2011: 4, cited in ibid, pp. 26).

2.3.3 Fluid investigations

The railway and its signaling systems are like other national institutions Increasingly interconnected with flows that transgress their previous boundaries. These challenges of late capitalism, globalization, postmodernity and technological divide that are posed to social sciences do not only call for more sensitive and reflexive methods, but also for the researcher of technologies to follow the transgressions inherent to the challenge (Law 2004).

Sociologist and philosopher Law & Mol (2001) bring the spatial metaphor into their research of technological change, as a rich tool for thinking the global. In contrasting network metaphors to that of spatiality, the authors criticize the focus on what they see as too narrow networks of movement to capture technoscience as what in their words is more fluid. Highlighting the often failing and broken networks science and technology travels in, and their presence in absence, the authors mobilize the fluidity of the Zimbabwe water pump (De Laet & Mol 2000) in their understanding of space. Contrasting "fluid space" to that of of "fire space", the authors make a hard distinction between euclidean spatiality and the systems metaphor.

The thesis mobilizes the spatial and network metaphors, both thought of as more or less temporary spaces where transfers and transformations can happen. As the work went on, I found the distinction of Law & Mol (2001) to be too inflexible. While the network metaphor is used both for the railway track network, and connections which information can travel through, rail space has been coined to capture the object of concern of the informants of this study. Rail space is a construct and heuristic used to point towards the directions of the trains, the spatialities of where they are run, made, cared for and controlled. It is confined to the railway lines, the stations or the railway offices, but, as I have tried to communicate, in reality also extends way beyond its explicit limits and borders.

ERTMS has an assembling effect in that it draws together different actors, from multiple locations and to step over the boundaries, and follow the ERTMS to its multiple construction sites, I have carried out two site observations. As Marcus (1995) points out, assemblages are inherently multi-sited objects of study that cannot be accounted for by remaining focused on a single site. The research strategy of this project as such evolved, from the securing of interviews with 'relevant' informants, towards following the making of these transnational networks and actors. By relocating to some of the central nodes in the (geographically extensive and hierarchically layered) spaces of the ERTMS network, I engage with what Star (1999, p.1) calls the "invisible work of an ecological analysis", to relocate and synthesize the political apparatus' debate, as I follow the methodological challenges involved in scaling up. To understand what it is that is being translated into Norwegian rail space and to cope with the internationalization of this national institution, I followed this European information infrastructure to its (imagined) center - Brussels. By engulfing myself in projects of similar interests to mine I became engaged in, and was invited to attend a conference called "European Commons Assembly". Translating ERTMS through pinpointing epistemological status of indicators given by interviews, misses the political reality that shapes this infrastructure as both transparent and opaque. How does a new civic society emerge within these relations that in the Norwegian case has seemed subject to formal political processes and institutionalized forms of controversy settlement?

STS has been done through fieldwork and historical analysis. Following Ryggvik's lead and doing interviews alone is somewhat inconsistent with this approach. Consequently, the research strategy of this project moved on from interviews towards using myself as an instrument for research, relocating to some of the central nodes in the geographically extensive and hierarchically layered spaces of the ERTMS network. Here I have sought out the invisible backstage of technology, the society shaping powers of the mundane and bureaucratic work practices that go into the railways (Bowker & Star 2000). To understand what it is that is being translated into Norwegian rail space and to cope with the internationalization of this national institution, I followed this European information infrastructure to its arguable core. My data is largely based off the accounts of one segment of the larger network of these digitalizing and globalizing networks, and this is a possible weakness carrying through to the analysis. At the same time, bringing light to the assemblies, bureaucratic spaces and documents that co-produce ERTMS, in order to pinpoint emerging control and management technologies, is also the strength and contribution this thesis brings.

Chapter 3

Entering the Norwegian Railway System

In this chapter a controversy is followed, that shaped Ryggvik's research, as well as the railway reform of 2016-2017. This reform shut down *Jernbaneverket*, and marks a point where my own research started. The controversy played out within close proximity with the emergence of a new bureaucratic paradigm, and only escalated into the public sphere through the performance of safety regulation and infrastructure. In covering the realignments of different railway actors, I argue that the STS approach to politics shows how a democratic shaping of ERTMS as technical object took form through attachments to safety and standardization. It also raises the issue of how digital technologies perform as enigmas in the social scientific readings of the facilitation of risky objects. Marres (2007) shows that the challenge STS poses to the study of democratic facilitation of technoscience is that issues are seldom directly debated in public, because they are not necessarily solvable. The assumption of republican takes on democracy, as well as discursive analysis within social sciences, is as I would argue, that social issues are solvable; a view that is challenged through this material semiotic reading of politics and infrastructure. The case takes us to how the Norwegian National Safety Authority's embedded itself into the Norwegian rail space, and later became attached with the values of technical and signaling interoperability, and how the ERTMS became the only possible solution to solve a nation's need for signaling.

The train services have in many ways been integral to how Norwegian geography is thought and performed. Norwegian is used as main language for operating trains and as work language in development projects. Generally competent users of English, some recent Norwegian construction projects have used it as main language. Changing signaling systems can in part be thought of as switching languages, or at least using another dialect. The exchange of technologies is about the changing communications paradigm within the model of a knowledgeable, central source and a lesser train driver. At the same time, it is entangled in all things command and control, as something reflecting onto both tracks and inside the offices of the central bureaucracy. Because with ERTMS comes also the question of which language to use in daily operations. Should Norwegian railways go the way of aviation, standardizing on English terms? ERTMS brings up another unanswered question as well: How should one deal with driver's permits? Should the Norwegian permit still have a national component while complying with ERTMS standards, or should it solely be based off the EU system, making all other EU permits compatible to the Norwegian railway? As such, it embodies many potentially heated controversies, still remaining cold or at least within the walls of railway organizations.

ERTMS is intertwined in massive systems of capitals, values and meaning. As natures move through the science-capital nexus, some things are kept strictly natural, while others become technical assemblages and considered part of society (Asdal et al. 2016). Some parts of the Earth is being used in high technologies, while most of what is dug up in Norwegian railway constructions become filament or waste. Valuation practices make some things and publics become valuable, others not. Agglomerations of meanings and truths, with their keepers of knowledge are made relevant in the rail space by ERTMS. Others become obsolete or irrelevant. This helps explain why parts of *Jernbaneverket* resisted ERTMS, as it carried a potential for change that would reach deep into the organization. Changing signaling systems reflect changing epistemic regimes, as they are bound in both the technologies they operate and are operated by, but also the work and knowledge practices that surround them (Cetina 2009). There is obviously skin in the game, but little public debate, so far. Technical standardization is enveloped behind the curtains of a semidigital bureaucracy, where the ability to partake in the openness of the standards are protected by relatively large barriers to entry. Directive 2004/447/EC requires member states and others to establish National Safety Authorities separate from the railway companies. Responsible for all things safety in the rail space makes them powerful players in the national scenes of Europe. All actors who work on the railways must obtain licences and safety clearances from this institution. New assemblies are being drawn up around this object institution.

I am going to show how the chaotic situation after the dismantling of Norges Statsbaner (NSB) in 1996 played a role in how ERTMS came to be a Norwegian priority as well. No smooth pathway was laid for ERTMS to walk into, but had to be created. With this creation came also the deviation from an older pathway, an arrangement and epistemic tradition that was shut down. I show that although the Norwegian standard met requirements to backwards and forwards compatibility, the issue became centered on whether they were tested or explicitly designed to work towards EU models of governance.

This story starts with the event of NSB temporarily being given back some of the total system control it had during the monopoly period of 1883-1996. The event illustrates the problems of dividing a unitary technology such as railways into its subcomponents, as these man-made divisions explode into each other in the course of everyday operations. With oversight and the ability to adjust each of the subcomponents of the system, NSB achieved the drawing up of new routes with departures in regular intervals, like 5, 10 and 30 minutes (Ryggvik 2016). This normalization of the timetables ordered and aligned the materialities of rail space in a manner that simulated clock time. The achievement made it perfectly obvious that large scale changes demanded coordinated efforts from a central locust of authority. But this singular power was only delegated and temporary.

Key in making sense of this story is also *Jernbaneverket*, who from 1996 and throughout 2016 carried the responsibility of providing working infrastructures for Norwegian train services to run on. In the words one informant: Railway is geography. The railway tracks in the Norwegian system stretches to a little more than 4000 kilometers, with about 600 trains running on them (Ryggvik 2016). A network of tracks, but also of tunnels, bridges, freight stations, level crossings and heterogeneities of equipment and terrain that is making up rail space in Norway. To where ERTMS goes, there is materiality, heavy stuff, ancient and new in an ambiguous mix. After the Railway Reform of 2016, it would become the leadership of *Jernbaneverket*, and not the bearer of the old monopoly name NSB, who finally reigned supreme as the new leader of the railway, establishing *Jernbanedirektoratet* to rule all railway institutions.

How did EU railway regulation get taken to the national level and incorporated into the Norwegian terrain? What was the institutional context ERTMS traveled into? This chapter brings up the implementation of a specialized cellular technology for railways, and how the ERTMS got transformed from papers and into a Norwegian ERTMS pilot line. The chapter aims to show translation in action, and integration between languages and ontologies. It also brings up how ERTMS had to fight off *Merkur*, a nationally developed signaling alternative. One of the most important actors in these developments, was the *Statens Jernbanetilsyn*, referred to from now on as the Norwegian National Safety Authority. It established its authority, but not before *Jernbaneverket* had fought it for a while. In the end, a pilot line was opened, showing to everyone that ERTMS could be more than just plans.

3.1 A first moment

While on the European level ERTMS was introduced as a needed technology to take railway to a next level of high speed and interoperability, this was not so much the case for Norway. For one thing, interoperability in Norway is not such a crucial point in and of itself, as no cargo or passengers are going through Norway, just because of it's location. The only point where Norway does not neighbor to either the Arctic Ocean or

Sweden is in the very north of this long country, with most of its economic activity is elsewhere.

The second reason why ERTMS was not very much discussed in Norway prior to 2004, might be that the country never went after high speed rail, at least not as a paradigmatic shift with new technology (Ryggvik 2016). The total length of high speed track in Norway is scaled to the country's size, or is perhaps even shorter. *Gardermobanen*, the line going from the capitol to the airport, is the country's sole bearer of the high speed emblem. It measures 60 kilometers of train service that can provide speeds of above 200 km/h, a trip lasting about 20 minutes. Hills, mountains and proximity between stations has participated in making the building of high speed rail as a paradigmatic new technology be seen to be more expensive than its worth.

While the EU developed ERTMS in the 1990s, the period was defined by an reconfiguration of railway institutional lines in Norway. These realignments were part of a wide and long standing contention within the European state apparatuses. While the 1800s had seen the expansion of the railway, with railway being an arena for the development of high technologies, the 1900s saw states internalizing railway services. The rising technological complexity of the expanding networks and technologies showed corporations inability to align heterogeneous railway infrastructure across regions. To correct what has later been called splintering infrastructures (Graham & Marvin 2001), states came into play, making the organization of railway a public good. In the post-war era it became increasingly difficult to justify the expenditures on the railway within the economic paradigm of innovation. Before 1996, the internals of the Norwegian state monopolist had been fragmented into several separate economic entities that could be monitored through accountancy practices. Internal invoicing and procurements followed a larger trend of re-regulating the social democratic economy to accommodate what Ryggvik (2016, pp.20–21)points to as the "road traffic model" (*Vägtrafikmodellen*), originating from Sweden. Apart from the general neoliberal trend of the late 20th century, the "road traffic model" arguably emphasized the lucrative aspects of private ownership as a model for industrial growth.

By the 1990s, the accumulation of debt had become major problems among many European railway state companies. Ryggvik (2016) points to the path dependency of the EU in its infancy to mobilize the transport sector in the process of creating free flow in an inner market. In this first moment of the story, the union had been created, but Norway voted to stay out of it. NSB was still a monopolist, but the boundaries of the railway infrastructure were in flux. Ryggvik (2016) show that it was essential for commodities and services to make use of the transport network, without the economic costs of temporal or monetary barriers. He goes on to point out that there was the general part of the legal framework of the EEA treaty that had largest influence on *Jernbaneverket*. The EEA specified that the competition within public procurements would extend into the boundary practices of classification and, consequently, discrimination of corporations by states. However, while Ryggvik's interest remain with *Jernbaneverket*, my starting point with a background from the left pointed me in the direction of an article, bringing a much wider framing. In article from 2012, retired parlamentarien and activist Folkvord, raises questions about Norway's relationship with the EEA and its democratic foundation (Folkvord 2012). Ryggvik (2016) also asks the question about what made powerful networks within the labor party influence the unions to accept an institutional split between infrastructure and traffic (what I will refer to as train operations), and simultaneously disassociate the new traffic company from the state. Folkvord, concerned with the democratic process, brings up the labor party's framing and temporal manipulation of the EEA debate and consequent enrollment, claiming they made it impossible for the Norwegian electorate to let itself be heard about the EEA, as he problematizes the backstage/frontstage processes in the epistemology around surveying the EU issue. Indeed, this critique can be seen as similar to that of the Norwegian democracy investigation described in the introduction, as it brings up undemocratic aspects of formal procedures.

This highlights a recurring concern in the thesis with the temporalities of the democratic debate and the bureaucratic processes. The reform of 1996 is the starting point of the story about *Jernbaneverket*. I characterize the period between the beginning of the decade and this reform to be the first moments of a new governance model that would shape the institutional landscape in the years to come. Ryggvik's concern is the railway's social institutional shaping of the state apparatus, and thereby shows that it was central in discoursing the New Public Management governance model, and not the other way around. However, by progressively giving an object institutional account, I want to contrastingly show a network of actors that framed controversies, shaping the railway reform of 1996, and the larger networks that made up the spaces that the railway reform came to co-produce; Norway as an EEA member and the railway as part of new Norwegian governance models.

In the process that formulated the background of the reform, Ryggvik points out that there were no concerns with the technological or safety challenges associated with institutional split between infrastructure and train operations. The central concern was governance and not competition. The competitive element was framed as a concern among the users and publics that openly criticised the norwegian railway, as it represented a prototype of the an inefficient, governmental commercial activity (Ryggvik 2016, pp.25–26). The engineering-manager and their language emerges as a key role in this story and it was the rationality behind their dealing with strong discontent within the publics, that can be said to have pushed the issue up and forwards as a political object in Ryggvik's account. The Ministry of Transport and Communications is said to have known that the changes that was being fronted would cause conflict, not least among the unions. However, the political process in which the central institutions was shut down and re-opened framed the question of the internal geographies of the Norwegian railway as an issue that did not concern regional developmental policy institutions. Union members feared that they as employees in a private commercial venture would lose important rights associated with their position as 'civil servants'. As providers of public goods within the state, these too were partaking in the enactment of a national space in which the organization of the railway would orient itself towards the product.

In the situation of the given moment, Ryggvik writes that there was a need for managers that had deep knowledge of the railway and at the same time was experienced with operation in the hybrid space between the state and private market actors. The double role of the engineering-manager, as technical experts as well as principal negotiators, became one in which the split between the rails and train operations defined the way the the tightly controlled political processes was enacted. In these processes the premises for the regulation of the transport sector as a whole, was negotiated. The ministry dealt chiefly directly with the railway management. However, the management was going to be divided in the coming reform. The period in question was marked by a chaotic conflict in roles among the Norwegian railway institutions. The break up of the state monopolist in 1996, in accordance with EU Directives 91/440/EEC, 95/18/EC and 95/19/EC, had drained employees from the old monopolist into a new institution that now would be responsible for train operations only. NSB was holding onto ownership and operations of trains, but left all elements the , but this was the institution that kept the NSB name, while *Jernbaneverket* was the new name put onto the majority of divisions from the old monopolist. These divisions, Ryggvik explains, expanded the influence and autonomy of the rail division who also inhabited some of the most skilled engineers in the railway, and the groups of engineer-managers that would come to form the core of *Jernbaneverket*. Along with other divisions, such as the electro and planning division, it formed part of the central administration who came to establish a new network of regional actors, previously organized in a decentralized fashion within regional divisions. In the emerging landscape independent corporate actors could run (and sell) complex operations, such as the services provided by rail renovation trains (factories on rails), all organized under the central supervision of the "rail division".

Within this landscape the social ontology of the actors became important in Ryggvik's account of the emerging issue of the new institutional boundaries. The machine division, who's train (machine) technical competence would form the basis of the new NSB, had always inhabited a support function, in which those in the central administration supported practical operations, and adjacent (specialized) technical expertise in regional offices. These ontologies in many ways inhabited vastly different spaces. The networks of leaders, that had developed across and in between the governance structures of the Norwegian and Swedish social democratic state apparatuses, was now drawing the boundaries between train and rails in ways that distinctly reflected these ontologies and forms of expertise. They were doing decentralized government within the space of concern in the making of the reform, a space that I in the next section show that ERTMS intervenes into.

Here emerges a certain timing within of the reform as performed through the spaces of the railway complex. In their efforts to settle the paradoxes that were inherent in the EU philosophy behind the split came the basis for contentions around the way the institutional split should be performed in this early period of the story. In having wanted to make up for the railway's lacking economy in the 'new NSB', the leadership had disassociated the machine division from the traffic manager and traffic information functions within the railway organizations. Ryggvik (pp.40-41) points out that such a division was done in accordance with the intention of the reform and the EEA law, as the regulation of traffic should be open to other actors than NSB. Yet, he also points out that these strategically important decisions were made by the engineer-managers at a moment in which the issue could not be opened up for democratic debate around the management and funding of these functions. The chronology of these processes were crucial. As I will show below, it was also a product of the governance system that formed the basis of the issue; namely the signaling infrastructure.

3.2 Second moment

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Subject 2:
The underlying reasons for the problems were the safety
culture. People had been allowed to do their things,
follow their own goals. So, I described what I had
seen, and what we were planning to do. Then we
got the temporary safety clearance for three years,
because they trusted in the measures we proposed:
Developing culture, developing leadership, developing
the organization. We lacked languages for these things.
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The second moment in this account of the Norwegian railway signaling history starts in 2008, when *Jernbaneverket* again was in a crisis. Ryggvik (2016, p.213) writes that the conflict between *Jernbaneverket* and Norwegian National Safety Authority reached its pinnacle this year. Jernbaneverkets general safety clearance got revoked. This was a drastic measure, because if they were not qualified to work on the Norwegian railway infrastructure, the infrastructure could not handle train operations anymore. It threatened to stop train services altogether. Phone calls from the ministry of transport and communications and a temporary safety clearance kept the trains running.

The Norwegian National Safety Authority, established in the reform of 1996, embodied an externalization of the responsibility for safe operations of railways. Following the reform, new divisions of labor and new cooperations had to be negotiated. Questions posed by the institutional split had deeply affected the field: Who should have the definitional power to formulate the demands of what makes a good and secure railway service? In the end, who should make the final decisions in railway issues that overstep institutional boundaries? And who should play the part of signaling system?

The conflict had started with the *Åsta* train collision of 2000, where 19 people were killed. Instead of blaming any single individual, the investigations commission pointed to systemic failures in safety management across *Jernbaneverket*. Ryggvik (2016) finds the investigation committee's conclusion differing dramatically from those of the two previous large accidents in Norwegian railway history. There the driver, and not the system, had been blamed. This established a problem for the Norwegian National Safety Authority to solve, a field of operations where it could go to work. It brought with it new ways of thinking safety, with its first leaders being experienced from the petrocultures of the Norwegian oil industry. From here came new ways of ensuring probabilistic safety, combining digital technologies with risk calculations. This deviated from the established safety philosophy from determinism and highly trained staff of the railway culture, and Ryggvik (2016) shows how the new routines of documentation and clearances were seen as time-consuming and bureaucratic.

Jernbaneverket went through its safety regime after the *Åsta* accident. In many ways it had been a systemic failure, as the line did not have Automatic Train Protection installed, and the communication between the stations and the train broke down (Ryggvik 2016, p.110). As the Norwegian National Safety Authority worked on establishing itself as the authority on safety in the railway field, it was inserted into the implementation of a new rulebook for traffic. This turned out to be a challenge, because the safety aspect of railways had been internal to building and operating organization, and both *Jernbaneverket* and *NSB* needed to guide the work]. In 2009 a new rulebook was finished.

While Norwegian National Safety Authority started with focusing strictly on safety and security, those terms would soon become displaced, and intertwined with standard adherence and the interoperability of railways. The EU had through Directive 2004/49/EC made Norwegian National Safety Authority responsible for overseeing compliance with EU regulation, not only on safety, but also on the much broader field of interoperability. The Norwegian adaption of EUs Technical Specifications of Interoperability (TSI), the Rule about realization of Technical Specifications of Interoperability for the sub systems of maintenance, command and control, and signals, infrastructure, energy, operations and rolling stock had come into effect in 2003. In 2004, the Norwegian National Safety Authority, who had been locked into an alliance with EU by this regulation (Callon 1984), demanded of *Jernbaneverket* that all larger railway infrastructure investments should comply with the TSI. It formally made the TSI a leading regulation for how Norwegian railways should be built. The TSI standardized the height of station's platforms, their lighting, the radius of lines curvature, the way trains and tracks should be built, and even the lighting of stations, making up a substantial basis of a new technical rulebook.

As *Jernbaneverket* and Norwegian National Safety Authority struggled with cooperation, the 2008 change of management in *Jernbaneverket* presented an opportunity to start afresh. The new director came from outside the railway sector, and was not entrenched in the strides that by 2008 had been going on for nearly a decade. But the revocation of the general safety clearance that the new director had inherited presented a challenge. Her organization was met with strict demands and little room for maneuver in how cooperation between the two institutions should proceed from there. This resulted in a new direction for *Jernbaneverket*. From now on, little space was given to struggle, and becoming trustworthy in the eyes of Norwegian National Safety Authority was the new goal, again demanding a change of culture in the organization.

The first ten years of this institutional arrangement from the reform of 1996 had been marked by a lack of funding, and dealing with accumulated years of neglected maintenance on tracks and signaling because of it. With deregulation, aging technology and a lack of political will to change the situation, the outside observer could get the impression of the railway being an outdated technology. This had changed dramatically by the second moment, with an explosive growth in both funding and technological ambitions, where ERTMS played a central role. To understand how the ERTMS became the central topic of upgraded railway, we must understand what came before it.

3.3 GSM-R and communications

Underneath digital signaling lies communications. Although the ERTMS is a standard for railway signaling, it is highly interconnected throughout the different technologies that make up the rail space. ERTMS is as such made up of two building blocks: The European Train Control System (ETCS) and the radio system: GSM-R.

Railway signaling and centralized traffic control (CTC) can be seen as an operational state of the railways, a high level service possible only when supported by a stack underlying hardwares and processes. Through signaling we have algorithms, running machine logics that make collisions theoretically impossible. An ontology of rail space from a modern signal oriented point of view goes like this: First it needs to have functioning railway tracks, then the functioning transmission of power and data respectively throughout the track network. After that it needs the software of CTC to function. Only when these technical and organizational components are working together, the signaling component of railway systems becomes capable and operative.

All of this rests on a communications backbone of GSM-R technology. The cellular technology was developed by the EU in the nineties, with the first specification ready in 2000. GSM-R is a version of the legacy commercial cellular technology GPRS (also known as 2.5G), fitted to serve the special needs of railways. Operating at around 900 MHz in the frequency spectrum, the backbone of fiber cables and base stations (radio block centers) was built in Norway in the mid 2000s. The system is supposed to be the foundational communication network allowing for data transmission connected to ERTMS operations. Experiences from European early adopters have however been that the bandwidth is too narrow to perform well in busy stations, where too many trains take up the limited number of channels in GSM-R. Here, different communications systems are in use (Bredsdorff 2016). Development of the next generation of a renewed or alternative communications technology in the EU is currently ongoing, taking railway communications into the world of 4G or 5G. This work goes on under the ERTMS umbrella, but it is still unclear to which extent the new system will need upgrading old GSM-R equipment and base stations, or if it can run on top of the regular commercial cellular networks.

Ryggvik (2016) finds that GSM-R was not built in Norway with the thought of later building ERTMS, but rather as a consequence of the devastating effects that could come with a break down in communications, as showed by the *Åsta* accident. On the day of the accident, the adjacent stations had seen the collision coming, but could not reach the train driver. Although ERTMS might have been in the back of the heads of some ofthe GSM-R's proponents, and made the later ERTMS interessement (Callon 1984) easier, as GSM-R played the role as communications system for an ERTMS strategy nicely. Although, the communications system had gathered *Jernbaneverkets* interest by its own merits, it did so on the back on the problematization from the Norwegian National Safety Authority, and as returned to in chapter 4, co-developed with ERTMS on the European scale.

When subject 15 came back to work for *Jernbaneverket* after some years with another company, he was mocked as being the Norwegian railway's most expensive man. Central to the development of GSM-R in Norway, subject 15 had left partly because of resistance and lack of support towards GSM-R technology in the organization. Like the ERTMS, GSM-R was felt by many as something being pushed on them from the outside, and had used up funds in a time of resource starvation. Almost half of the yearly budgets over several years had been funneled towards GSM-R. This serves to illustrate a general ambiguity towards EU standards in *Jernbaneverket* before the second moment. Nonetheless, the GSM-R project had been a great success. A new wireless communication system was up and running for the whole of the Norwegian railway network by 2007, making Norway one of the first countries to do a full transition to GSM-R.

New EU directives were being added to Norwegian laws as they came from the European Commission, and gave a line of power from Brussels into the very heart of the Norwegian railway system. On top of this came the national interoperability regulation, implementing EU Directive 2008/57/EC on the interoperability of the European rail system (Samferdselsdepartementet 2015). Similar directives exist in many areas, such as telecommunications equipment, radio communications equipment, medical equipment, machines, toys, lifts, cable cars, et cetera¸and make technologies conform to EU regulation. The Norwegian National Safety Authority had been given the task of enforcing both the TSI and regulation on interoperability on behalf of the Ministry of Transport and Communication, and by extension became the spokesperson for Europeanization of the Norwegian rail network.

A letter from Norwegian National Safety Authority to *Jernbaneverket* dated 4.3.2004 informed that the Ministry of Transport and Communications had asked it to make *Jernbaneverket* prepare an ERTMS implementation plan. This made the signaling division of *Jernbaneverket* create a preliminary report on ERTMS, followed by a strategy for signaling. One informant described it as a total assessment, the first of its kind in decades. The signaling division summed up the current state of the Norwegian systems: Varied, but generally old, with much of it reaching the end of its life cycle in around ten years from then. Concluding with the fact that the many of the current systems were from 1963, a transformation and a renewal should be started within the next ten years, with an implementation time of 15 years. In the meantime, competency needed to operate and renew the legacy systems would grow old together with the people who knew about signaling and electromechanics in this fashion, and it seemed counter-intuitive to train new generations in the knowledge of the past. Problems with end-of-life in critical components between the legacy signaling systems and ATC amplified the problem. This, as well as incompatibility with the new European laws of interoperability, stood as strong arguments for a strategy of total renewal.

A Norwegian adoption of the ERTMS was not given, and ERTMS was neither the only new signaling system around. The strategy came to recommend ERTMS to comply with interoperability laws and the TSI, while other factions championed different technologies. It did not look like a problem at the time, that the *Merkur* project was also leaping towards realization. After all, it continued the line of previous standards, channeling the power of the NSB standard name. The conflicting roles of the now 10 year old institutions was still going on. The slowness of Norwegian National Safety Authority ability to assert its own and the TSI's authority was again highlighted when the ERTMS recommendation in the signaling strategy was turned down by the management of *Jernbaneverket* in 2006. They did not see the need for a complete renewal. To understand why, we will look closer at the *Merkur* project.

3.4 *Merkur* and the production of obsolescence

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 Subject 1:
The Norwegian National Safety Authority forced our
hand, and made us build NSI63 when we did not get
Merkur certified.  They forced us to build 50 year
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old installations, because they held that to not
choose ERTMS would practically be to sabotage European
interoperability. This was at a time when the whole of
Europe was waiting for the next [ERTMS] version coming
in December 2015. [...] The thought being that if we
built anything newer, it would be in conflict with
the intention about interoperability. Then we had
to choose something that obviously had a short life-
span. And to me, that is a misuse of authority. They
should totally give no shit about that, they should
care about safety.
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Merkur was an upgraded version of an older Norwegian signaling standard, called NSB94. Using a set of cheap equipments, it provided a programmable logic layer on top of the traditional relays in the track. I met with the aborted signaling system through plans of finally taking down and dismantling the half made remnants of it.

Infrastructures in general benefit from upgrades that are both backward compatible and forward compatible at the same time (Howe et al. 2016). This is true also for the railway, and is connected to the availability of service parts to the infrastructure and the End of Life of its subsystems, which are often systems products with limited interchangability. This was an advantageous aspect with the digital signaling systems in use in the Norwegian network, other than NSB94 and Merkur. The Simis-C system by Siemens, and Ebilock from Bombardier had been adjusted to fit ERTMS solutions on the European continent, and became a key element in political and economic integration.

Jernbaneverket had developed the solution in the first half of the first decade of the millennium. They applied for a general safety clearance of *Merkur* , through an installation of the system at the freight terminal *Ganddal*, in the west of Norway. The application was turned down on the 24th of November 2008, where the Norwegian National Safety Authority informed that not only was *Merkur* not a legal system for new installations in its current configuration, but even with changes the chances of making this system legal at all were questionable.

How could a Jernbaneverket let a technological project on this scale fail so horribly? ABB was the company leading development, but tight cooperation had occurred between them and *Jernbaneverket*. A report was ordered from an external consultancy bureau PriceWaterHouseCoopers (2009), which summarized the failure in three subchapters: First, a breach of regulations on public procurements, distorting competition by too close cooperation between *Jernbaneverket* and a lack of documentation on why ABB won the contracts. Secondly, shortcomings in the procurement process, with lacking or hastily done documentation and standards adherence. Finally, the reason for the dismissal was a shortcomings in project performance, also here explained by lacking documentation on standards adherence.

The Norwegian National Safety Authority had no technical objections towards the technology whatsoever, but could not accept the way it had been designed, documented and implemented. However, the main objection was a lack of documentation that *Merkur* did not hinder (economically or through competence) the achievement of interoperability in Europe. The documentation behind the design became the object of politics. A missing safety clearance devalued several years and more than 500 million kroners (about 50 million Euros) of development, making the future of the *Merkur* signaling system all but defunct.

The only real competitor to ERTMS was out of the picture, and an enemy was thwarted (Callon 1984). But by 2010, *Jernbaneverket* did not see the ERTMS as a technology ready to be implemented, all the while the old systems were deteriorating fast, and delays were racking up because of them. The situation had many people frustrated.

Even though the management of *Jernbaneverket* had turned ERTMS down in 2006, the signaling division saw the transition as inevitable, and had continued working on plans. By 2007, the first ERTMS implementation plan was made, outlining the general strategy for deployment, mentioning the **Østfoldbanens østre linje** as location for a pilot line. Before going there, a consideration of what it is that is being replaced is due.

3.5 Traditions

The relay has similarly to that trains and railways themselves, an older technological history. Connected to the invention of the telegraph (Coe 2003), the mechanical relay consists of a coil, armature, spring, yoke and a moving contact. The moving contact is strapped in such a way that when energized, it either makes or breaks a connection with a fixed contact. It is a type of electric switch and relaying is kindred to conveying or handing something down; it acts on a signal and passes it on. They are assembled so that they shift states from open to closed (or vice versa) when given power.

Claude E. Shannon is one of the early figures of Computer Science and is described as the father of information theory (Gappmair 1999). Before joining the war effort to decipher German cryptography, he delivered his master's thesis to Massachusetts Institute of Technology in 1938. In what would come to revolutionize the study of switches and relays, the thesis drew on mathematical work done almost a century earlier. In 1847 George Boole had laid the groundwork for a what we know today as boolean algebra, but it was understood then to be more of theoretical value than anything applied (Barnett 2013). Shannon's thesis made equations that represented layouts of circuitry and illustrated the paper by the relays and switches of an electronic combination lock, a vote counting circuit, and an electronic adding machine. To make the examples work, these equations could be manipulated with a calculus analogous to the "calculus of propositions used in the symbolic study of logic" (Shannon 1938, p.2), found in Boole's work. Recognizing the inherent logic of the complex circuitry of the time, Shannon's contribution to making logic out of 1s and 0s turned out to be of great importance.

Computers do not have to be black boxes or microscopic circuitry. The principle is well illustrated in the history of railway signaling, where before relays were used, people, flags and eye sight were distributed along the railway track to give the train drivers information about the track ahead, and in totality making up logic systems. Discovered in the first half of the

19th century, prime uses of the relay technology have included everything from telegraphy, switchboards, industrial automation to railways. The core functionality saw digitalization in the 1980s, but Norway is still littered with sections of tracks using mechanical relay technologies with moving parts.

As relays are connected to the tracks, the switch mechanism triggers when the train axles short the current in the tracks. This way the relay switches state when a train is over it, forming the basic building block in the larger signaling system. In railway systems these relays have been set up in configurations allowing for interlocking. Think of a track with two other tracks leading onto it from the South. When a northward train is about to enter this track, from either of the two incoming tracks, our track must be marked as occupied. If a train axle on either of the two incoming breaks the current and switches the relay state in the inbound track, it is relayed to our track, switching the relay to the occupied state. In computing, this function is known as an OR gate (Mano 2006). When several relays are connected like this, they make up logic gates, allowing for AND, OR, XOR and similar operations, the basic Boolean algebra of most logic systems.

Boolean math makes systems logic able to safely operate trains from a distance, and had been going on since the 1800s, although it was not thought of it in this way at the time. The mechanical logics of a signaling system is impressive and complex by the black boxes we know from today. Electronics have made such machines look like something one finds in museums, but even the ERTMS glossary by the European Railway Agency (ERA 2009) sees interlocking as familiar with what these machines can do mechanically: "[a]n arrangement of switches and signals interconnected in a way that each movement follows the other in a proper and safe sequence".

Interlocking is a way to make two or more objects in rail space mutually dependent: When A and/or B and/or is are this, C is that. Applied to the rail space, this means that no conflicting movements are allowed in one section of track. As a train on route enters, the relays in upcoming tracks turn on or off in predefined logics, locking into restrictive signaling aspects to all of the track's entry ways except the one in use, which gets a permissive signaling aspect. At a minimum this operates on the level of signaling, but most of todays railway lines have interlocking connected to Automatic Train Control (ATC), machine barriers against trains driving on collision courses, that can physically stop transgressing trains.

The Norwegian railway still uses mechanical relays in much of daily operations. The NSI63 is the most ubiquitous of these, making up about 80 per cent of the total network (Kjenne 2016). The "NSI" name (*Norsk Signal Industri* - Norwegian Signaling Industry) reveals a time when there was production of signaling equipment in Norway. While several different signaling systems have been implemented in different parts of the Norwegian rail network, it was the this assemblage that had acted as the default fallback as others were replaced. *Jernbaneverket* have struggled with committing to any one newer type than this over time, either due to bad implementations or internal power struggles with a changing of priorities and systems. As other types of signals had required some sort of expertise, special parts or software from a vendor, *Jernbaneverket* has had all the parts and knowledge it needed to build NSI63 themselves. Thus it have become the *de facto* standard, and although an old solution, based on mechanical relays with cabled components along the tracks, it has served relatively well.

> Subject 11:
> The first relay based interlockings were named NSI, and was built from the early 1950s. There are still interlockings of this type from 1954 in operation. A successor of this type of interlocking was named NSI63 which became remote controlled. The next interlocking type was named NSB77 which was installed at Oslo S and Skøyen. After this we went back to installing NSI63 interlockings, before a new design called NSB78 was introduced on the Bergen line. Then we fell back to use the NSI63 design until a new design named NSB84 was introduced between Oslo and Ski. After this, once again NSI63 interlockings were built. As one can see from this, it's not easy to progress further from something

`which is well proven, the NSI63.`

ERTMS standardizes systems based on electronic relays or Programmable Logic Controllers (PLCs), the common names of digitalized equipment that perform the same functions as mechanical relays. They replace the hardwiring of mechanical relays with semiconductors and silicone. These embedded computing devices achieve logics like the ones of mechanical interlocking relay systems, but does so through software. In abstracting this function, it is laying the groundwork for fewer moving parts in the tracks with dynamic control systems that are computers. As older types of such systems are also present in the network of tracks, the Norwegian state of signaling before ERTMS roll out can be described as diverse.

What motivates the Norwegian implementation of ERTMS? In being an arranging component in the railway technological system, signaling influences much more than just trains. The ERTMS project is seen as a vehicle for a change in the Norwegian railway. The reason for the upgrade was communicated by *Jernbaneverket* as “the need for renewal of signaling systems more than the need for interoperability. When renewing old or building new signaling systems the European standard system ERTMS was chosen based on TSI requirements and cost/benefit analysis” (Jernbaneverket 2013). This is the short and boring version of a story of ERTMS growing from ambivalence, treachery, alliances and deals.

Since it involves a reconfiguration of how railways will be worked on, managed and used, it is understood by the Norwegian railway management as an opportunity to transform the both the railway organizations and cultures. The exchange of physical objects in space will give the ability to change performances from workers, both human and inhuman. ERTMS replaces something old, and the parts which are not replaced will none the less be reassembled into new arrangements. Through the standardization and abstraction of signaling systems, and moving train control away from physical signs, mechanical switches and eye sight, the goal is a 90 % reduction of technology in the tracks, with the possibility of driverless trains on the horizon. An operational shift to a simpler, more static paradigm, where mechanical devices and humans are abstracted into semiconductors, silicone and software. This also means an adjustment in required types of competencies and expertise. But how did it come to be?

> Subject 11:
> The ERTMS National Implementation project is a huge project that will force changes to almost all that we are doing related to signalling, or else we will never finish. It forces us to think about for example how to build, how to test and how to migrate (for example switch forth and back between new and old technology). The positive about it is that it forces us to change the way people think and how they work, and not only the signalling people but actually the whole organization.

As I move between the interview participants, spread across the higher buildings of Oslo, it hits me that I am studying an elite in a system that stretches out from them. Oslo Central Station has about ten times the traffic that the next biggest stations have (Jernbaneverket 2015a) They are nodes in the network, with the capitol of Norway as a center point. The Norwegian tracks are in topological terms a star network. Oslo has appendages: *Nordlandsbanen* stretching to the north, *Dovrebanen*, *Gjøviksbanen* and *Rørosbanen* to the North. *Bergensbanen* to the West and *Sørlandsbanen* to the South. To the east is *Kongsvingerbanen* and *Østfoldbanen*, with the ERTMS pilot line on the eastern part of it. By 2017, this is the only part of the Norwegian rail network that has gotten the ERTMS upgrade, but the plan is to upgrade the whole network.

Looking out from the windows of the tall building where we meet the heads of *Jernbaneverket*, I'm forced to consider how the city is embedded in the terrain. From here, one sees over the mountaintops surrounding the capitol. It gives a strong sense of directionality, as tracks reach towards the different cities of Norway. The ERTMS project has a different kind of directionality. The aim is to make a large amount of state funding transform through 13 years into a successful technological project, translating the European standard into a Norwegian but compatible variant, all while avoiding becoming a mega project failure. For success, the Norwegian railway lines should be upgraded in such a way that it is both certified by the EU and satisfactory to the Norwegian public. Both are moving targets. The project should build new signaling systems in the lines mentioned above, and show its worth through running reliably for passengers, freight customers and commuters on all lines over time.

Knowing from before that new things are not always better than old things, new things can often be preferred to old. ERTMS has this going for it, the new car smell, the excitement before the unwrapping (McGowan 2013). The possibilities are enthralling, its size and scope are awesome. The cost of 30 billion kroners (about 3,2 billion Euros) over 13 years is approximately 2,5 billion kroners each year. In 2005 this would have made up half of the yearly budget for Jernbaneverket. Today it makes up about a tenth of it. But the cost of implementation keeps rising, as the estimated costs in 2005 were only a third of the current estimations . The story the ERTMS implementation must be considered up to this fact, that it is part of development where railway budgets have increased immensely. To justify such an increase, reliability, regularity and the service level of the railway should follow. Digital control of railways promises to usher in a new era of speed and capacity. The digitalized human or digital *sans* human is supposed to drive trains better and faster. The stakes are high in a project like ERTMS, technological projects at societal infrastructure level can make or break careers. Documents around it, of which there are too many to count, are committed to its success. So are the people I interviewed.

Both trains and transportation technologies in general are directly influential in how we provide our means of sustenance, how we live our lives, do our travels and are co-producing what we consider meaningful and valuable. An example that comes to mind is how our sense of geography, our spatial sight, is shaped by bridges, roads, buildings, walls and also rails (Rodrigue et al. 2013). Like all the railway commercials about going home - back to a magical place - they are involved in both the creation of and benefitting from this spatial construct. Railways allow for a way of social mobility where one can work in the city and go home, back to where one came from, usually around Christmas. In constructing human understanding of geographies, in thinging worlds into being (Haraway 2016), the railway companies partake in modernity's false victory over nature, the stark separation of man and milieu, recreating the distinction, all the while transgressing it. Railway lines cross through the boundaries put up by people in their geographies, while also being instrumental into the government and upholding of territories. The overstepping is a fundamental aspect of governance, at the same time to be distant and within, open and closed (Foucault 1990).

3.6 ERTMS travels to *Østfoldbanens østre linje*

Between the alternatives considered to act as the Norwegian pilot line for ERTMS, *Østfoldbanens østre linje* had several advantages. For one, it was close to the capital, where most of the suppliers where located and where the train operator had most of their drivers. This in itself made it a good choice, as logistics would not be a problem, training could be done in Oslo and experiences gathered there. Secondly, it had some of the oldest signaling systems in the Norwegian network, with no Automatic Train Protection system installed. Before the pilot line, its signaling system was based on telegraph technology, sending morse code to the stations ahead. Whereas the Western line of *Østfoldbanen* is Norway's main connection to Sweden and Europe, the Eastern line had little traffic, a low safety level, and is generally a simple 78 kilometer stretch through flat terrain.

The choice of location had been made already back in 2006 by the signaling, who's interest for ERTMS had been caught years before the rest of the organization (Jernbaneverket 2009a). Subject 11 describes the importance of the pilot line:

> Subject 11:
> The ERTMS Level 2 pilot line which started operating August 2015 was fundamental for the progress towards the ERTMS National Implementation project. The signaling system requirement specification was first

created back in 2005. At that time we believed the progress to ERTMS would go much faster. The specification was further refined before the request for tenders for the pilot line went out in the market. After the pilot line was ordered, another two years have been used for further refinement, before the ERTMS National Implementation project sent out its Request for Quotation. It has been a long process from the initial requirement until where we are today with our signaling system requirements, but this has helped us to increase the quality of the requirements before getting a system that shall be rolled out throughout the complete Norwegian railway network.

Request for tenders went out, bids came in and the UNISIG company Bombardier won the contract. Construction started in 2012, fiber cables were laid, a GSM-R radio block controller was built, and trains got on-board systems installed. The first Norwegian train to get upgraded to become compatible with the new European signaling system was the NSB Type 69. The model had been running on Norwegian railways since the early 1970s, and was now carrying the latest and greatest of European train control. This was done for testing, and when the line opened, it would mostly be operated by the newer FLIRT models.

The pilot line was going to fulfill a range of missions. The obvious goal was to get experience from creating requests for tenders and building ERTMS, but also to develop traffic rules for the new system (Jernbaneverket 2009a). Furthermore, the Central Train Control in Oslo had to be adjusted, and in addition to trains, maintenance machines also needed upgrading. Systems for management, operation and maintenance were to be put in place and a whole spectrum of employees had to be trained.

Subject 9:
We have learned to get things that are close to the track out and tested early on. And it does not have to be in relation to ERTMS.

Internal testing started in late 2013, and the line opened for commercial traffic in the fall of 2015. Although the second day of operation started with troubles, using busses as backup, this was due to a train error. Otherwise the new line was mainly considered successful, although there were problems.

The first and biggest problem was discovered during the testing phase, and ironed out before the official opening. One of the innovations brought by ERTMS level 2 concerns the way trains are detected. To make the block system work, it has to know the location and presence of trains. Done conventionally by the train axles shorting the current in the tracks, the new system used axle counters. These are devices mounted onto the tracks that recognize the electromagnetic signature of train wheels passing. Meant to give more accurate information about speed, direction and length of a train, the Bombardier produced axle counters now showed all of the pilot line's blocks as being occupied by trains.

It was wintertime, cold and wet, and a layer of frost attached itself to the tracks. The friction between the wheels and the frost messed with the electromagnetic signature. While the error source was discovered relatively fast, this was a case where not having the total system control became an issue. A fix to the problem needed only minor adjustments in the software to compensate for the friction and make the axle counters detect correctly. As Bombardier delivers software updates to not only Norway, but to all countries where their axle counters are in use, they held the update, gathering more fixes for other faults. This, in combination with the certification needed by being classified as the most strict Safety Integrity Level (SIL 4), was the reason that it took more than half a year before the update went out and the fix got implemented.

Another but similar problem was found in summertime. Again there were disturbances in the electromagnetic field, but this time the source was harder to locate. Eventually the source of the disturbance was found to be a train generator that had been turned on for climate control inside the train.

Subject 9:
We feared that we would have problems with new technologies, typically computer stuff. But as things turned out, there were relatively few problems concerning that. The problems were in the combinations. Train types, cold, aggregates, things that you can't... Electromagnetic noise is hard to relate to, because it comes from sources that you cannot... It is real hard to think of all possible combinations that cause electromagnetic disturbance.

But testing cannot fully reproduce the conditions of everyday operation. One issue came up later in the autumn of the opening, with double train sets resisting separation. In times of rush hour traffic, an extra train would be connected to the first for a part of the line, going from the capitol to *Rakkestad* station. Here they were supposed to separate, and the second train should return to the capitol, leaving the leading train to proceed. The error stemmed from the second train, which had been put into sleeping mode to get pulled by the leader, and had not registered its position. As the two train cars disconnected, this resulted in the rear train going into trip mode, irrevocably activating the brakes. To get the train going again, manual disconnection of the drivers dashboard was needed.

In waiting for an update to the on-board systems, this error was easily worked around by temporarily avoiding driving with double train sets. Yet, it had demonstrated some of the challenges of the new system, now that *Jernbaneverket* again was forced to wait for the supplier to update their systems. In an organization that has played the part of creator of its own technology, this was something new.

Subject 9: So, you are training an organization in taking these kinds of new technologies in use. And you should not underestimate that. An organization like Jernbaneverket comes from a world where one did very much oneself. In that we externalize much of the technology, and one becomes more of a controller of the work that is supposed to happen, in so it is also about training an organization in the future ways of work.

TÜV SÜD had won the contract of being EU interoperability conformity authority for the project, but, as had happened before, *Jernbaneverket* had a bad experience with the institution, called a Notified Body (NoBo). One informant describes it as total breakdown in communications, and TÜV SÜD as being a very difficult NoBo. It is not known to this thesis author what exactly happened, but the ERTMS pilot line got built in the end without a NoBo certification. How did it happen? An educated guess from an informant says the prestige project was getting delayed and got pushed through from above. Being a simple pilot line with no international connections, one can assume that formal verification from a difficult NoBo could be skipped. Still, similar certification issues would resonance in Denmark, which I shall return to, and might not be as easily fixable when national implementation begins.

In summation, this chapter saw the interessement and enrollment strategies coming out of Statens Jernbanetilsyn, ending up with a Norwegian ERTMS materialization. By the second moment of this chapter, the central management of *Jernbaneverket* was fully on board with the ERTMS project, enabling the roll out of the *Østfoldbanens østre linje* ERTMS pilot line. What had happened between the ERTMS dismissal in 2006 and then? And what was it that had entered the Norwegian rail network? In answering this, the next chapter analyses a government investigation, the concept of interoperability and the case of Denmark.

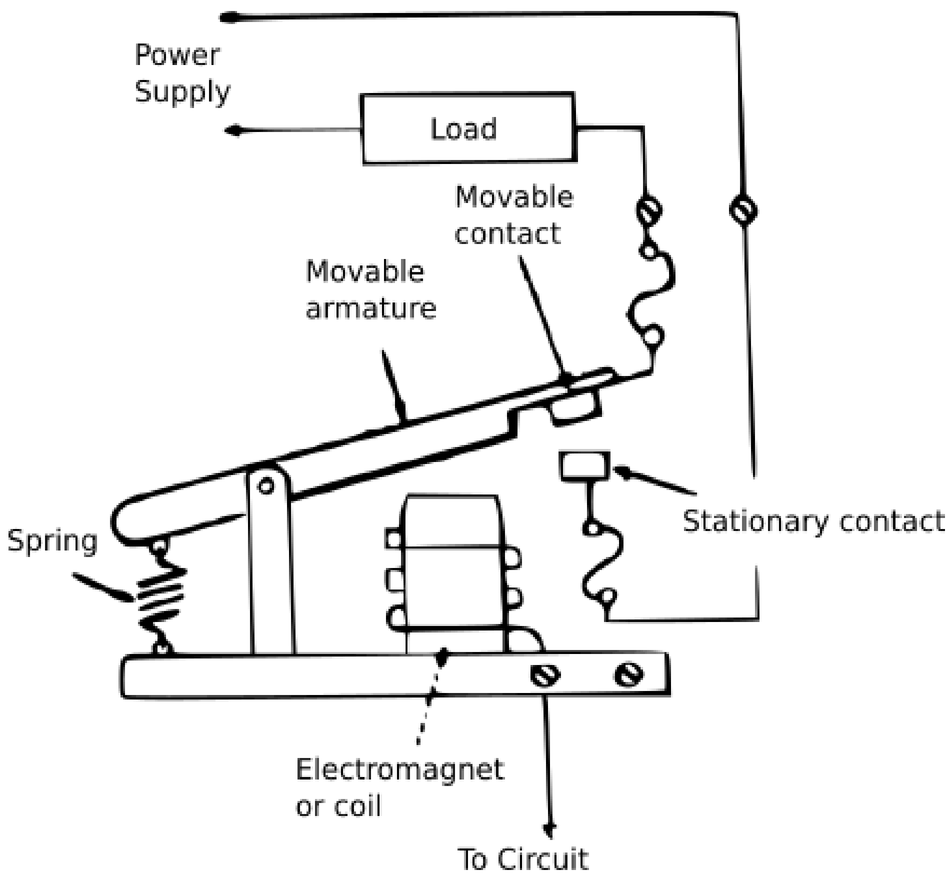

Figure 3.1: Basic components of a mechanical relay

Chapter 4

Eurorail

The following chapter saw the pilot line got built. This chapter follows the actors around ERTMS, looking at what a European technology is supposed to accomplish through a study of the values it is attached to, and how those got integrated as Norwegian values. To pinpoint what it is translated, representations of the technological artifact and the problems it is supposed to solve are explored. In doing this, first the general EU motivations for transport governance are visited, then the collision and reattachment with the Norwegian governance model is explored. Interoperability is considered, before the focus is moved to new alliances over borders, and resistance in Denmark.

Although other modes of transportation, especially cars, aviation and shipping, have taken a lions share of total freight of passengers and goods since railways heyday in the middle of the 20th century, the EU is commits to and emphasizes the role of railways in its future transport system. Planning and regulation is hoped to achieve increased mobility, while at the same time cutting emissions and decreasing congestion. In a EU White Paper on Transport (European Comission 2011), railways play a pivotal role in defining the objectives, which includes:

- an overall 60 percent cut in transport emissions by 2050
- a 50 percent shift to medium distance intercity passenger and freight journeys from road to rail and waterborne transport

- no more conventionally fueled cars in cities

The EU has been influencing the macro scale direction of transport and energy networks since the early 1990s (Marshall 2014). Central to this has been the Trans-European Networks (TENs), programs for aiding and furthering establishments of networked transport, communications and energy infrastructure corridors throughout the continent. The large scale and complex political technology is still working with on a job that is seen as unfinished. Political scientist Dyrhauge (2013) shows that development of the corridors have been drawn out due to lack of national funding and differing interests between national and regional scale. Responding to this, EU focus has shifted from planning and building of large infrastructure projects to harmonization of regulatory fields and technical standards. This is connected to ERTMS, since achieving the goal of a pan-European railroad network is now seen to require large scale realignment of policies, technical implementations, funding and efforts from a multiplicity of actors that make up the European transport field. This is embedded in the ERTMS technology. But bringing order to the complexity of European rail space is not unproblematic. First, a return to the Norwegian translation, at a point where the EU and Norway were locked into alliance.

4.1 Modes of Authority

Before the pilot line was the governmental concept choice investigation process. With a resolution to the long standing conflict between *Jernbaneverket* and the Norwegian National Safety Authority in 2009, plans for implementing ERTMS could proceed. 1,2 billion kroners (about 120 000 Euros) in funds for developing a pilot line were given in the national transportation plan for 2010 - 2019 (Samferdselsdepartementet 2009). Ryggvik (2016) finds that the internal signaling conflicts of *Jernbaneverket* had not reached the political sphere, and little to no skepticism concerning ERTMS or EU plans of interoperability in neither the Norwegian parliament, nor the government. On the contrary, it was seen as a future-oriented solution to Norway's aging network of signaling.

Jernbaneverket's signaling division, who had been interested in ERTMS already in 2004, could by 2009 also count on backing from the central leadership. Now was the time to get it passed through a political process. All public works projects with a price tag above 500 million kroners (about 50 million Euros) required a quality assurance process from the Norwegian Parliament. This process, called concept choice investigation (*konseptvalgsutredning* in Norwegian), is centered around developing a set of concepts, ranging from the cheapest to the most expensive alternative, and having external consultancy firms check and recommend the best concept, to then get it approved by the parliament.

As is typical for these processes, it was *Jernbaneverket* themselves who wrote out the document to initialize the process. Actively mobilizing the 2004 signaling strategy, the report concludes on a need for renewal. Jernbaneverket considered the following ten options, including a null-alternative of doing nothing (Jernbaneverket 2009b):

0. Do nothing
1. Reduce the railway network
2. Reduce demands on signaling and accepting a higher rate of errors
3. Renew signaling systems without changing functionality or performance
4. Build a new system without ERTMS
5. ERTMS level 1
6. ERTMS level 2
7. ERTMS level 3
8. ERTMS limited supervision
9. ERTMS regional

10 alternatives had to be reduced to a more manageable size. To filter out the unsatisfactory or unrealistic alternatives, a judgment device (Karpik & others 2010) of three absolute requirements were created, seen as an essential subset of a longer list of requirements. The requirements were:

- The contribution of the signaling system to the infrastructure should at least be maintained

- It should comply with the safety regulation
- It should comply with interoperability regulation

Option 1 and 2 did not satisfy the first demand, while option 3 and 4 did not comply with interoperability regulation. Option 7 was deemed unrealistic, since development on ERTMS level 3 would not have been finalized before the next 20 years or so. The two options of limited ERTMS implementations, options 8 and 9, also fell due to failing to satisfy the second and the first demand, respectively. But, in the end, ERTMS had passed in a trial of strength (Akrich et al. 2002). The report had filtered out every option but 0, 5 and 6, as unsatisfactory or unrealistic. The only choices deemed realistic and worth evaluating were ERTMS or doing nothing. Alternative 5 and 6 represented two different levels of ERTMS, where level 1 is a somewhat simpler system, and level 2 is a little more complex, both explained in further detail below. After the filtering, a cost-benefit analysis found option 6 to be the most economical, while also satisfying all non-absolute demands. Although, ERTMS 2 was considered still in development, the report presupposed that the standard would be much further along by the time a Norwegian pilot line was in place.

ERTMS or nothing does not really fit into a concept choice investigation, meant to evaluate several alternatives. The final chapter of this document has been edited after its publishing, in 2010. Reflecting the later events, it describes how the rest of the concept choice investigation process had been canceled, in cooperation with the Ministry of Transport and Communications. No external quality assurance was considered necessary, as the choice of ERTMS level 2 was in line with the ministry's and the Norwegian National Safety Authority's understanding of the political latitude set by the EU.

Initiating a full scale national roll out with such a price tag needed political backing and a clear top down initiative. A thesis informant describes one of his greatest railway accomplishments to be making the Ministry of Transport and Communications pen a letter to *Jernbaneverket*. Reiterating that the only possible options within the EU framework were either closing down lines as their signaling systems became obsolete, or start implementing ERTMS, the ministry was convinced. The government had decided that the Norwegian signaling upgrade was to be done in line with the European standard (Samferdselsdepartementet 2012). As an echo of the argument from the report in the canceled concept choice investigation process and the thesis informant, the ministry letter concluded that there was no alternative.

In 2013 the ministry notified the European Surveillance Authority that Norway was committed to ERTMS. The leader of the ERTMS project at the time described it as one of the most important milestones in the project up to then, and ERTMS was now to be seen as a national obligation (Jernbaneverket 2013).

- MOVEMENT AUTHORITY
  - Permission for a train to run to a specific location within the constraints of the infrastructure (ERA 2009)

The informants of this study are pragmatists, being bureaucrats, definers and leaders of railways, expert actors of a spaces where so many are being shuffled through each day. Through them I was introduced to the events leading up to the implementation of ERTMS in Norway, between 2000 and until 2013. In the previous pages, the translation processes were followed, where ERTMS entered into Norwegian laws, ideals and plans. The actors are members of an ongoing process of digitalization, which has been shown to not really be new, as we saw the powerful model of boolean algebra being present long before digitalization became a word that tasted good in the mouths of politicians. What is new is an alignment towards electronics, levels of abstractions and EU modes of governance. What abstraction levels come to mean for the Norwegian railway is explored further in chapter 5, but here they are visited in exploring how the EU will to power are authored by the mechanisms that mediate it (Ruppert et al. 2013).

4.2 Transforming semaphores

Large scale infrastructures have some disadvantages compared to smaller sized technologies. Their size usually makes implementation and phase-out gradual processes, requiring them to work in towards both past and future technologies (Howe et al. 2016). This also makes these technological systems apt to the influence of long term valuation practices in for instance political processes. It is therefore also important to understand how the those concerned with the laying of tracks have become interested in ERTMS as a technology that supposedly sports a 90 % reduction of track-side equipment. We will turn our attention back to the previous chapter and the boundary work that happens between the train machine and the rail infrastructure.

ERTMS in many ways intervenes into the same space that the former NSB management cut off from its (exclusively train operating) hair, as it moves all signaling away from track-side equipment to inside the train driver's cab. Let us now however consider how ERTMS in this process also becomes seen to afford cheaper railway tracks. Behind the process outlined above, in which the technology became specified, it also in many ways passed a trail of strength within the Norwegian state apparatus. It already became clear that no one version was in and of itself better, except for when seen in relation to the external processes and standards that the Norwegian railway was to adhere with. Looking into the specifics of how the signaling systems that makes up the technology perform within the cost-benefit analysis by virtue of a technology (ERTMS level 2) that was still in development, we however become aware of the ways that translation happens.

It is this way that we could understand how the material basis of the system could be said to become so drastically reduced, and how the process nevertheless supported rising costs. ERTMS was said to result in a infrastructure that are simpler to maintain, while allowing for high speed situations where reading stationary signs or lights are passing by too quickly to see. In this sense the interoperability standard underpins a shift in temporality both within the train and outside. A train driver might be interested in how it treats trains as being in different modes by virtue of abstractions in the 'operating states' that standardizes the splits of operational responsibility between the system and the driver. This measures degrees of automation and even autonomous driving.

A traffic controller could find it interesting that ERTMS can allow for 'moving blocks'. Moving blocks can allow for more traffic on the same railway lines, as opposed to the traditional fixed block system which controls the separation of trains by dividing the line into sections where no more than one train can run at the same time (UNIFE 2016). Yet, as we saw above, as well as in chapter one, the temporal shift also has consequences for the political objects that are passed through the regulatory bodies. Much of the signaling systems have avoided political consideration. Rather, I will show that they become abstracted onto the level of semaphores. Objects of information and communication technologies that overflow from the basic infrastructures that the new systems is said to manage.

I have argued that the management of the gradual processes of infrastructure replacement that characterizes the Trans-European Network to a large degree happens on the EU level. We have also seen that co-ordination happens through the regulation of interoperability, which has a history that I followed into the creation of the ERTMS. In 1989 the European minister of transport put together an expert group given the task of creating a common European rail traffic management system (Stoop et al. 2009). By 1991 the European Special Interests Group (EUROSIG), representing the industry, together with the International Union of Railways (UIC) and the European Rail Research Institute (ERRI), representing the various railroad infrastructure managers, had decided on basic specifications of an industrial development that could lead to a European signaling- and control system (De Tilière & Laperrouza 2009).

These institutional arrangements resulted in several planning documents. The EU council directive 93/38 was passed in 1993 and titled "Coordinating the procurement procedures of entities operating in the water, energy, transport and telecommunications sectors". The document takes a central role the in structuring and coordinating the standardization between member states and companies, by regulating the building of railways in the Technical Specification for Interoperability, and outlining how it should be developed and implemented. The 1996 EU council directives 96/48/EC about interoperability between high speed trains and 1001/16/EC further committed states to standardize around the ERTMS initiative.

Definitions of ERTMS are changed through time and space, where the above mentioned documents are mobilized and the ERTMS enacted. As translations without innovations are mere repetitions, moving and translating ERTMS from Brussels and similar techno-locational nuclei onto other terrains and languages, all the while keeping operational compatibility for trains running between systems, exist as very real challenges for implementors of the technology. Lots of work goes into perfecting systems of routines, nomenclatures and glossaries, logics and algorithms around this project. This problem was mentioned briefly in relation to the case of NoBos in Norway. Here we however stop to consider how this processes of valuation often have tended to divide rail space into four levels, as seen from a train with ERTMS compliant equipment installed, so to give a functioning description of the technology-in-the-making. This can be seen as a part of ERTMS's ontological choreography (Cussins 1998). It concerns the technological levels of track-side equipment, from the train's perspective. It starts with currents tracks, and works itself up to technologies that are still in development.

Thales (2016) writes that the **ETCS level 0** consists of trains with ERTMS installed, without any ERTMS technology in the tracks . The trains on level 0 is controlled by train driver, in accordance with traditional, national signaling systems, often based on lights and signs. One of the official explanations of ERTMS is how it is a system composed of two core components: GSM-R is the wireless telecommunications standard that trains use for communicating with the Centralized Traffic Control (CTC), while the European Train Control System (ETCS) concerns the track-side technologies. ERTMS is the totality of these two complexes, with a control system on top, known as the Train Management System. Here the numerous heterogeneous information sources come together and gives the CTC control abilities.

ETCS level 1 has tracks with ETCS, enabling communication between trains and Eurobalises in the tracks as the trains run over them. Conceived in France in the late 1980s, the Eurobalises has since been standardized by the UNISIG, enabling production by members of the UNIFE. The balises are connected with signaling equipment on the side of the tracks, enabling the Interlocking system of safety. Information is sent from the Central Traffic Controll to the trains through track side equipment and balises. The system activates the brakes on train running in a locationally embedded block where movement auhority is not given. This system allows for deployment of ETCS level 1 on top of existing national signaling systems, enabling them to run in parallel.

ETCS level 2 has the Eurobalises acting as passive positional beacons in the tracks. Other track side equipment is not necessary anymore, as the trains now use GSM-R to communicate with the Radio Block Centre and towards the Central Traffic Controll. The communication includes the position of the train, with updated movement authority from the CTC, as well as track description for up to the next five locational blocks. Information is here mainly given through the cockpit heads up display, although track side equipment is still used to activate brakes for trains running on blocks without permission.

ETCS level 3 removes all track side equipment, except for the Eurobalises. The trains use GSM-R to continuously send positional information to the Central Traffic Controll. Doing train integrity checks internally in the trains allows for moving blocks. Having blocks that are moving together with the trains, allows for more dynamic speed and movement permissions, as well as continually updated braking for and minimum distances between the trains. This will enable higher train density and speed on the tracks.

4.3 Signaling as governance technology

The four levels that have been used to describe ERTMS clearly shows us that there are no definitions that perfectly explain the technology, but rather a complex of technologies that fit under the label. Moreover, this raises the question of how these definitions are explained differently depending on who does the explaining and who is being explained to.

The semaphore, the semiotic technology of the conventional signaling systems, has now traveled to inside the driver's cab as part of visualizations from the Driver Machine Interface, that can be monitored on the screen by the train driver. The lines of communication between the Central Train Control and the train driver are moved. Where it once was between inside the cab and the outside sign, it is now a process internal to the drivers cab. As such, ERTMS is a technology meant to standardize train control, signaling and protection, with parts of it also referred to as European Train Control System (ETCS). Moverover, it has developed from what was first done by sight and flags in the 19th century, then later by bells, telegraphs, signs and mechanical implementations with motors and lights, and to ERTMS' digital representations.

Digital semaphores are relatively recent innovations. Railway signaling semaphores on the other hand, have been in use since the middle of the 19th century and is a common component of a mechanical signaling system (Hill 1995). Mounted on poles, communication of the track ahead is established between the system and the train driver through the control and observation of semaphores. They consist of a backlight and pivoting arm with different colored lenses attached near the pivotal point. An extended, horizontal arm indicates to a train driver the most restrictive signaling aspect, while angled and retracted arms indicate less restrictive aspects. As the arm pivots, the colored lenses are shifted in front of the backlight, indicating the status of the track ahead to the train driver.

Like in railways, computing must in some cases be deterministic, when files are required to be accessed in a specific sequence, or some subsets of the computer should not used at the same time. Semaphores prevent what in Computer Science is called race conditions and deadlocks, by enabling parallell operations to be handled in deterministic and sequential manners. The word “semaphore” comes from Greek and roughly translates to “sign holder”. While mechanical signaling systems have evolved during the twentieth century, they are operating by a similar logic. Critical to modern day computers are the algorithms of resource management. Similar to railway signaling systems, keep track of processes to prevent simultaneous usage of an exclusive resource (Berger et al. 2009).

Below is an example of a digitalized semaphore, the source code of an algorithm (taken from Shukla (2007)). `s` is the semaphore variable, `W(s)` is waiting for the semaphore to become available, while `P(s)` signals the semaphore. If `s` is 0 or less, the resource is busy. If it is greater than 0, the resource is available.

```
W(s)
 while  (s<=0)    {
   //do  nothing
}
s=s-1;
P(s)
s=s+1;
```

ERTMS will not rid the railway of semaphores, since the their functions as resource managers are still very much in there. However, the physical pole, the arm and the lights are going away, favoring the abstract computer logic of its digitalized familiar. This is an essential component in programming multi threaded applications, where resources are used in parallel to gain efficiency in multi-core CPUs. As power consumption has become an issue, Moore’s law has been followed through adding cores instead of clocking up core frequencies (Koch 2005), a trend which has made this type of computing omnipresent.

Standardizing the use of these technologies must as such be seen as a work of abstraction, in which several layers of systems becomes integrated in the ERTMS, and reestablishes determinism and sequentiality. The basis of these systems have been the settling of disputes described as deadlocks, and the exclusive functions that becomes the result of the management system reproduces a form of discipline within the trains as well as the operators. The digital semaphore therefore overflow into other languages within the rail space.

4.4 Interoperability

Puffert (1994) argues that the differentiation between technological practices in Europe's railway networks has developed as a consequence of national railway companies prioritizing integration of local subnetworks over European level integration. Standardizing the European railway network is thus closely tied to systemic innovations in national and continental policy (De Tilière & Laperrouza 2009). The idea of creating a single European inner market is one such systemic innovation, although it is not new. Already in the 1957 Treaty of Rome the main direction for the EUs (then European Economic Community) society building was set, focusing on creating a common market for the free flow of goods, capitals, persons and services. The first two paragraphs of Article 26 of the European Treaties was, and still are, central, and states the following:

> 1. The Union shall adopt measures with the aim of establishing or ensuring the functioning of the internal market, in accordance with the relevant provisions of the Treaties.
> 2. The internal market shall comprise an area without internal frontiers in which the free movement of goods, persons, services and capital is ensured in accordance with the provisions of the Treaties. (Council of European Union 2016)

Through a united European producer and consumer base, the inner market is thought to deliver a bigger and stronger economy, able to compete on the world market (European Commission 2017). Achieving an effective transport system on a continental scale is a basic and underlying condition for a creating single European marketplace in the same space. Marketplaces rely on ways of getting commodities to and from the market place. Overcoming distance friction is key in creating Europe as a single marketplace, as ineffective means of transportation will undermine possibilities of the market's singularity. For instance, the idea of a free market is threatened when Spanish producers cannot to compete with Finnish producers in Finland, if the cost of transportation already puts them at a great disadvantage. Building and maintaining an effective transport system can thus be seen to directly affect the economic performance and competitiveness of Europe.

In the chapter 3 two moments in the Norwegian railway system was established. Here I want to show another, but connected moment on the European level. While the EU has pursued its single market strategy since its inception, reality is always at some distance from the ideal. Of course, markets are still split between nations, cities and even neighborhoods. However, progress towards the strategy's fulfillment took a huge step during the 1990s, when the European social democratic parties, in varying degrees, changed their relations to the working class. By continuing market liberal reforms brought forth by a wave of conservative and liberal governments in the 1980s, the social democrats distanced themselves from the idea of social control of the means of production through the state, in Britain and academia known as a "Third Way" politics. Here state and market was no longer to be seen to be in tension, but rather as a partnership between the two that should be fostered (Kolarz 2016, p.119). Public services, having previously been owned and delivered by the state as representative for the working class, was now to be primarily produced in the market, directed and aided by the state. This marked a departure for the social democratic parties from working for the gradual socialization of society, towards privatization of the means of production. No longer was capitalism treated as something to be transformed, but rather as the systemic base level to which government activity should be subservient.

> ". . social democrats [cannot] any longer see either capitalism or markets as a source of most of the problems that beset modern societies." Giddens (2000) pp. 28

With this shift in the social democratic view of the market, parliaments in most European nations generally had a massive majority for letting it produce public services, defining for the "Third Way" moment. The process, along with the decentralization of state power, has been referred to as the "devolution of the state" (Jones et al. 2014), and has had great effects on the railway field of Europe for the last 20 years or so. As we saw with the case of Norway in chapther 3, the devolution of the states' power in the railway field started with splitting up what had usually been a single state owned railway company into two, where one company handled infrastructure, and another doing train operations. This was done in part as a follow up to the European Commision's first railway directive, implemented into EU law in 1991 by 91/440/EEC. Here it is laid out how competition on rails will up the quality of services, and demanded that member states split up their railway monopolies, separating infrastructure from train operations. Sweden had already done this in 1988, while Norway was also relatively early, with a formal separation into *NSB* and *Jernbaneverket* in 1996 (Cantos, José Manuel Pastor, et al. 2010). Since then, the deliverance of railway services in Europe have become more fragmented through both horizontal and vertical separations, and efforts to let private capital flow into the railway field has been done in varying degrees. Contrary to this however, France has only done minor adjustments to its railway monopolist, whereas Germany's DB stands relatively unchanged through the period (Dyrhauge 2013).

Besides being a technical matter, interoperability also serves as a framework for understanding EU railway policies and a reason for developing ERTMS. The ERTMS glossary defines it like this:

> "Interoperability means the ability to allow the safe and uninterrupted movement of trains that accomplish the specified levels of performance." (ERA 2016b)

Interoperability is the North Star of the European rail policy, and is aimed at the technological, regulatory and operational barriers to the free flow of trains across Europe. Although railway standards have been worked on since the late 19th century, the situation in European railway which was responded to by the EU in the early 1990s, was one of varying signaling and control systems both between and within national borders. Nation states prioritizing the development of their national networks, strengthening their national economies and needs, resulted in a diverse supranational railway network. It is still not uncommon for trains crossing national or even subnational borders to have multiple signaling systems installed, while some borders require either changing locomotives or whole sets entirely. Interoperability has become a key principle in terms of combating this situation.

Looking behind the word is like opening a Pandora's box. While interoperability might not seem too big of a challenge, the complex particularities of unifying a railway network spanning hundreds of thousands of kilometers, and built across a century of technological developments, is governed through a multitude controls and checks of languages, with changing them constituting a massive undertaking. *A posteriori*, the article "From missing networks to interoperable networks" by economic geographer (Nijkamp 1995) can be seen as an contemporary view on the situation, coming from a time and place where the EU had a world to win.

As the TEN programs had started nearly five years before, this article is doing the work of fleshing out what a trans-continental system of transport should mean in practice. From a perspective of the mid 90s, Nijkamp sees that national authorities are recognizing the growth in social costs of transportation, with congestion and emissions as main culprits, but he sees no will to reduce or halt the increased demand for mobility. Failing that, two policy options remain:

1. More efficient utilization of current transport infrastructures.
2. Expansion of the capacity of transport infrastructures.

Option 1 is not able to cope with the increased demand for mobility alone, so the author concludes that states are right in intensifying investments in infrastructure. The 1980s saw investments in road infrastructures leaving public transport investments behind, partly because of a demand driven logic of state funding. But as opposed to the demand driven investments of previous decades, to cope with “social costs” and “externalities” of increased mobility, European transport policies of the 90s took a turn towards emphasizing the supply of public transport systems. The question then became how the EU should structure this new European transport system?

As competitiveness, private-public initiatives, and openness became the new buzzwords of governance literature in the 1990s (see for example Jessop (1997), Lengrand & Chatrie (1999) and Roberts (1998)) , so followed the railway literature. Creating a European transport space was seen to require the realignment of railway companies from working with national interests towards a continental orientation, and shift from being state owned monopolies towards business-as-usual commercial entities. Although national interests may favor infrastructure managers in the short run, the long-run consequences of such an approach are described to be detrimental to infrastructure owners, users and the general European economic performance alike (Nijkamp 1995).

Achieving the full potential of a continental railway network is helped through viewing the sector through the lense of five critical success criteria (figure)4.2), used identify and attain synergy effects across national borders in the sector. Hardware refers to the tangible assets, like technical equipment, stations, terminals and the likes. Software refers to the systems controlling hardware, but also the user-oriented services, like booking, route guidance, and the likes. Orgware comprises all regulatory, administrative, legal, management and coordination activities and structures regarding both demand and supply side. Finware represents not only socio-economic cost-benefit analysis of railway undertakings, but also ticketing, franchising, the other tools of securing capital flows into the rail space. Ecoware refers to ecological and environmental concerns. Only through a harmonizing all areas, can economies of scale be achieved.

Through the pentagon model several problems are identified. The solution to these problems comes in the form of whole-scale regulation for an environment where a multiplicity of actors make up, contribute to and use the transport network in cost-efficient and business-oriented manners

(Nijkamp 1995). But this ideal is only achieved with a high level of interoperability, and without it any talk of free market or competition in the rail space becomes hollow. Interoperability here comes to mean more than just the ability of trains to run across borders. The term expands to incorporate smooth flows between different modes of transport, the inter-modality of the systems, as well as their inter-connectedness, the ability incorporate third parties into service production and manufacturing.

Although the categorizations used by Nijkamp (1995) have not been brought on in the further development of EU rail policy, the author deserves credit nonetheless for being extremely clear-sighted in analyzing the future direction of European mobility politics. The author's supposition about politics of interoperability as penetrating throughout the mobility spectrum, connecting it to intermodality and interconnectedness, has since the time of writing become leading ideology of union's agenda. Since the goal of interoperability is not yet achieved, we have no way of telling if it will indeed make transportation cost-efficient, but it has certainly become business oriented in many areas.

4.5 Coordinated efforts at ERTMS

While there are many more organizations and actors involved in the European railway field that the ones mentioned here, almost all information behind this study points back at the EU railway packages, UNISIG, the ERTMS User Group together with the European Railway Agency (ERA) and the Technical Specification of Interoperability (TSI). These are thus used to characterize the process that coordinated the moment of "Third Way" politics. In the last section of this chapter we saw that the repetitive processes that moved the ERTMS definitions out from the center of Brussels also mediated innovative processes at different levels and locations. By doing this I argue that the context is enacted by the material-semiotic practices that have allowed interoperability to emerge as a standard and as an technology. This is also an argument that is central to what Asdal (2012) describes of the contextual analysis of texts. Asdal (p.1) states that "the focus on that which is constantly being enacted seems to have privileged the contemporary as the object of study". This section therefore looks further into the documents and technologies that have come to formulate the context and enroll national actors in which the above mentioned "transformation of semaphores" is enacted.

4.5.1 Trans-European Transport Network

The Trans-European Network (TEN) for railways has already been introduced above. However, the TEN program is wider and goes back all the way to the 1957 treaty of Rome, being a key political tool for creating the infrastructure of an inner market (Council of European Union 2016). It consists of three network classes: Energy, telecommunications and transport.

The formation of the Trans-European Transport Network (TEN-T) in 1996, acts as a sort of opening in my account of the moment that transcended the more limited boundaries of the European rail project before the 1990s. TEN-T seeks to "close the gaps between Member States' transport networks, remove bottlenecks that still hamper the functioning of the inner market" and to "connect the continent between East and West, North and South" (EC n.d.). By coordinating the building and upgrading of roads, rails, air and water transport networks, the aim of TEN-T is to strengthen inter-modality.

It is through the TEN-T that most of the EU transport infrastructure funding comes from, and is a key political technology for pushing ERTMS implementation. TEN-T is concerned with the building of grids or networks of transport corridors running across the continent, and connects to Norway through Sweden and *Østfoldbanen*. Beyond this continental transportation system we however now see that the language that was introduced and transformed with the digital signaling systems also transfers into many other regulatory spaces.### Trans-European Transport Network

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4.5.2 Railway packages

Following the first railway package in 2001, three later groups of directives related to railways have been adopted by the EU. The first one established common rules for licensing rolling stock, a common safety framework and common rules for network access. Dyrhauge (2013, p.60) summarizes this package as the basic framework for on-track competition and a competitive railway market, central for the later railway packages.

The second railway package of 2004 broadened safety regulations, extending it to cover on-board staff, and further liberalized rail freight services, fully opening it to competition from 1 January 2007. To gradually harmonize technical regulations and establish common safety objectives, this railway package also established ERA (EC n.d.).

In 2007 the third railway package was passed, opening for competition on international passenger transport, and regulating passengers rights. The third package also introduced a common European train drivers license, allowing drivers to circulate on the entire EU network.

The fourth railway package was passed nearly ten years later, in 2016. It is described by the EU as the completion of the market opening that started with the first railway package (EC n.d.), but shown by Dyrhauge (2013) to be a response towards nation states not even implementing the first railway package. The aim of vertical separation between infrastructure manager and operator had been to open up the infrastructure for operation by new market entrants, but market shares show incumbent operators prevailing. The fourth railway package made a new push for opening passenger transport to competition by introducing rules for public service contracts for domestic passenger services, while creating stricter rules to separate legal, financial and operational aspects within integrated holding companies such as Deutsche Bahn (Dyrhauge 2013, p.94). It also strengthened ERA's licensing power through recasting the safety and interoperability directives.

The common values mobilized through the presentation of these packages are revitalization of the railway sector through competition, transparency, competitiveness and efficiency, and non-discrimination (EC n.d.).

4.5.3 UNISIG

EUROSIG was formed as a working group of the *Union des Industries Ferroviaires Européennes*, the European rail industry union, in 1994. Focusing on the signaling components of railway technologies, their members include some of the industrial giants of the Western world, including the German Siemens, the Canadian Bombardier, the Swedish-Swiss ABB, the French Alstom and Thales, and the Italian Ansaldo STS. In 1998 the name was changed to UNISIG, as the European Commission requested their participation in finalizing the ERTMS standard. The ERTMS specification hit a kind of 1.0-moment by the year 2000, after approximately ten years of development (De Tilière & Laperrouza 2009).

The ERTMS development had been industry led, mainly through UNISIG and in cooperation with the EU and the national railway institutions, meaning that it was developed by the suppliers of railway infrastructure equipment to EU specifications, and tested out in cooperation with infrastructure managers. By 2004 the UNISIG companies had invested around 600 million Euros to develop the technology, while the European Union had contributed around 250 million Euros (Vinois 2004). Since the overall goals were set by the EU, the technological implementations from industry had work within this framework.

UNISIG themselves claim that companies do not have to be involved with UNISIG to develop ERTMS products, as the ERTMS specifications are freely available from the ERA. However, the realness of this claim is contested by one informant, pointing to the fact that outside companies have had to buy their way into UNISIG to be able to deliver to the European market. While all the companies mentioned above are multinationals, only Ansaldo STS can be said to represent the interests of Asian railway industry, as Hitachi Rail bought a controlling stake in the company in 2016 (ANSA 2016).

4.5.4 European Railway Agency

The European Railway Agency (ERA) was established in 2004 by the second railway package. With headquarters in Brussels, its official goals is to "make the railway system work better for society, and to contribute to the effective functioning of a Single European Railway Area, without frontiers" (ERA 2016a). Its management board consists of representatives from all member states' NSA, but as Norway is only an EEA member it does not have voting rights.

Levi-Faur (2011) writes how EU policy has gone from supporting the establishment of European networks, special interest groups and economic interest groups, towards creating a single European regulatory space. While networks are seen to be relatively stable sets of relationships of a non-hierarchical and interdependent nature, agencies are distinguished by being an administrative organizations with a distinct, formal identity, an internal hierarchy, functional capacities and at least one principal. While the first European agency was formed in in 1975, the second was established during the 1990s, by 1999 there were 8, and by 2010 there were 28. Levi-Faur concludes that agencies and "agencified" networks are becoming the dominant form of governance in the EU.

With the fourth railway package, ERA is to become the one stop shop for railway regulation, a single certification authority to issue vehicle authorization. Instead of having to obtain licenses from National safety Authorities (NSA) in each country of operation, railway undertakings and vehicle manufacturers can turn to ERA (EC n.d.) for continent wide authority.

4.5.5 National safety Authorities

To prevent the railway sector from using the safety as a barrier to market access or an excuse to resist change, the establishment of a separate safety institution for each member state were introduced as obligatory with directive 2004/49/EC (EUR-Lex 2011), but the general direction was clear from the early 90s. A basic premise for creating a marketplace out the railway was to separate out safety and security. National Safety Authorities (NSA) do not have any immediate responsibility for safety, but rather provide national regulatory framework, which they supervise the operators' performance against (Jovicic 2010). Together with National Investigation Bodies, another EU abstract term for quite differently arranged political solutions to the problem, they play the parts of platform builders for market entities around, encroaching on and of incumbent regimes of railway.

The Norwegian NSA, SJT, was established as an independent entity already in 1996, but gained both relevancy and responsibilities as European regulation extended, moving focus from safety to ensuring conformity with EU regulation (Ryggvik 2016). Although TSIs are implemented as Norwegian law without translation, it is the responsibility of the NSA to translate them for comprehension purposes, and to monitor the material effects of the laws by way of rail space players conformity.

4.5.6 TSI and NoBo

The Technical Specification for Interoperability (TSI) is the documents working on behalf of EC to try to reduce technical barriers to entry, enabling rolling stock to run across networks. TSI's protocols how railroad lines and technologies are built. By that they are covering much more ground than just signaling.

TSIs are the operative EU documents for implementing policy on railroad technologies and to push ERTMS to the national level. They are to be translated for national languages and conditions by the countries' NSA, making them into national regulations. There have been many expansions and revisions to the TSIs over the years. While it is the English version of the TSI that are legally binding, translations are made for better comprehension. Infrastructure managers being aware of the TSI, they also try to implement TSI into their own national rules. Deciding what goes into the TSIs are done by different international and EU expert committees from the rail industry beyond direct political control of EU (Dyrhauge 2013), where also representatives from *Jernbaneverket* and the Norwegian National Safety Authorities participates.

Notified Bodies (NoBo) have been taking over the work of NSAs in verifying European standards conformity. Described by EU as a building block of the inner market (EC 2017), the CE marking (*Conformité Européenne*) commonly found on everything from household appliances to medical devices is a tell-tale of the verification work done by a NoBo. The NoBos concerned with railways are organized in the NB-Rail Association, coordinating the different bodies in matters such as uniformity of assessments, guidelines and recommendations for carrying out standard conformity verifications (NB-Rail Association n.d.).

A key function of NSA, besides translating TSIs, is appointing NoBos for the rail space. These are entities, usually corporations, given permission by the ERA to certify the TSI compliance of new railway infrastructure investments. When new infrastructures are built, builders must publish a request for tenders for a NoBo, and then document and cooperate with them to prove that that the newly built infrastructure is indeed conforming to European standards. At the time of writing, there were 66 NoBos in Europe connected to the 2008/57/EC rail interoperability directive (EC 2017).

According to Ryggvik (2016, p.291), *Jernbaneverket*'s experiences with the NoBo institution since it came in effect in Norway in 2009, have been mostly bad. Not only has it been seen as a costly and bureaucratizing affair, it also threatened to take away employees in a time of lacking qualified workers. The way the NoBo arrangement is set up, it creates a lucrative market for private corporations to enter rail space.

4.5.7 ERTMS User Group

The ERTMS User group is a European Economic Interest Group was created in 1995, originally consisting of DB (of Germany), FS (of Italy) and SNCF (of France), and later joined by other European railway companies (Palumbo 2013). The official goal of the user group is to ensure interoperability, and specifically to help the national companies apply the technology in a harmonized way to enable the free flow of trains and a competitive railway. The user group, with headquarters in Brussels, have regular meetings to facilitate communication and exchanging of experiences between the national railway companies.

This institution is meant to let each of the national railway companies bring their particular concerns and interests into debate, and formulate common grievances to be sent in to UNISIG or ERA. Norway has actively participated in user group, and informants of this study describes it as a positive environment for sharing knowledge across borders.

In this context the term "user" does not refer to passengers, but rather to national railway companies. The developers of ERTMS as both standard and technology is the industry, UNISIG, and the EU, through ERA. The railway companies are not even implementors, but rather users. Browsing through EU powerpoints and illustration charts, I find it is not uncommon for their models of rail space conflating national infrastructure managers with passengers, under the term “users” or “consumers”. The term has in a sense become transformed through a process of overflow, in which the objects and objectives that have shaped the technologies and standards have also been co-produced together with widened networks.

4.6 Something rotten in Denmark?

These actors can be seen at work in the case of Denmark. The previous head of the Danish ERTMS project was hired as a consultant by the head of the Norwegian project, after the two leaders had met in an ERTMS user group meeting. Denmark is described as a virtual test bed for ERTMS deployment by informants of this study, having a somewhat similar organizational structure and infrastructural state. Following up the split decree from the EU, Denmark had separated infrastructure and train operations in 1997, and opened for competition on train operations in 2001 (Cantos, José Manuel Pastor, et al. 2010). Deciding in 2009 to upgrade their entire national network to ERTMS, Denmark was the first of the European countries to do so (Ryggvik 2016). With the plans of complete transition to ERTMS level 2 baseline 3 by 2021, Denmark could claim another first, to make use of the latest version of ERTMS.

Subject #14 sees ERTMS deployment as participating in a bicycle race - sometimes others take lead, other times we are ahead. However, Norway has recently been gaining on Denmark, due to Danish problems and delays (McGhie 2017). The problems have resulted in the Danish auditor general characterizing the ERTMS deployment as a runaway project, and three directors of Banedanmark, the Danish infrastructure manager, left their positions. The project is currently 4,4 billion danish kroners (about 600 million Euros) over budget and delayed by three years.

The first reason for the delays were problems with getting the software systems certified (Abild & Bredsdorff 2015), but more issues came up as the case unraveled. In a statement from Banedanmark, the delays were partly blamed on the extensive documentation needed to get safety certification from the NoBo in accordance with the Common Safety Method (CSM-RA) of the EU (Banedanmark 2016). This risk assessment and safety evaluation procedure, passed in 2009 and amended in 2013, had never been tested out on such a large project.

The budget overruns were explained by Banedanmark as having to do with Denmark taking the role of the early adopter (Banedanmark 2016). No previous deployments had given similar experiences from which one could calculate costs, and suppliers had relied on estimates of economies of scale, learning curves, their own performances and cooperations with the danish infrastructure manager, that had shown to be too optimistic.

Overall, Banedanmark concluded that they had severely underestimated the complexity of the project's totality. As an illustration, they wrote that their internal certifications processes between their different departments and suppliers had been just as delayed as the delay that came from the EU safety regulation. This was said maybe as a way to share the blame with EU. From this broader perspective however, the complexity involved is a product of the larger networks and the friction between the transcontinental space and the installed base of the national system.

Technical issues were connected to delays in making ERTMS work on the Danes' complex rail network. While ERTMS has been adjusted to fit conventional rails, its inception came from the need for a system that could handle high speeds. Contrary to what might be intuitive high speed lines are generally simpler than conventional lines, in that they go from point A to point B, with large distances between the stations, combined with few level crossings and track switches. In the Danish case, the ERTMS based switch motors, together with other infrastructural components, resisted safe functioning and certification. One thing was the difficulties in interesting the Danish train operator DSB with installing ERTMS in trains. However, negotiations between 'national' actors and the consortium of the ERTMS 'users' also coupled with delays of other kinds participating in the breaking of the original timeline. The issues that formed around the delays within the coordination of software development stands as a premonitory symptom to the future consequences of abstracting the strict disciplinary mechanisms of the railway into the fluid spaces of software. The economies of scale that was hoped for in the case of the Danish implementation program rested on a premise that the developers would adhere to the same rules as the earlier railway economy. Yet, the race conditions of the bureaucracy is different than those of the highly structured rail space.

- FULL SUPERVISION MODE
  ERTMS/ETCS on-board equipment mode giving full protection against overspeed and overrun.

- SLAVE MODE
  The ERTMS / ETCS equipment runs in one of the slave modes when it is not the controlling (leading) unit of the train composition. There are the followings slave modes:
  non leading mode
  sleeping mode

- TRIP MODE
  An ERTMS / ETCS mode that calls for an irrevocable application of the brakes.

- POST TRIP MODE
  An ERTMS / ETCS train borne mode that is entered after a train trip when the train has been brought to a stand and the driver has acknowledged the situation.

Figure 4.1: Excerpts from the ERA (2016b) glossary on ERTMS

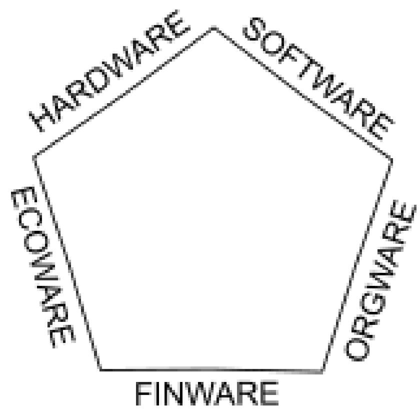

Figure 4.2: The pentagon of critical success factors for interoperability. Source: Nijkamp (1995)

Chapter 5

The Planners' Perspective

In the last chapters it has been argued that the co-production of ERTMS is intrinsically intertwined with conceptions of what a good economy is. This conception have been shown to be embedded into the ERTMS, something which in implementation is showing signs of co-creating frictions between incumbent national governance models and the EU. Between the ontologies of planners on different levels, ERTMS re-assembles national networks through the EU political technologies, where it is interesting management in new ways of doing railway organizations. This chapter outlines an epistemic shift, its uses and a plan for national roll out. Getting different perspectives through visitations to connected locales, a short discussion on Europe closes the chapter.

5.1 Knowing rail space as data

ERTMS can also be seen as a building block in a larger project towards knowing the rail space as data. Today's Norwegian railway network is only partly digitally modeled, with originals still being paper maps or scanned versions of these. An effect of a total renewal of the signaling network, is a similar renewal of the railway maps, models and representations. Rail based services of transportation have, as previously mentioned, co-evolved with the technologies of reporting on, measuring and organizing space

(Bowker 1995). What is new about the current round of digitizing space, is reflected as an ongoing switch in the knowledge and management systems of the railway. The conventional model of organizing railway knowledge is one where the physical installations come first, with digital equipment on top. The new model, however, is based on the concept of meta data, making rail space into a structured world of data first.

Tagging all equipments, tracks, trains, freight goods, passengers and geographies with meta data provides a back end for a system that can deliver the right information about the right system to the right people at the right time. It makes sense, considering the system today is a result of paper documents crammed into the computer, a world of scanned paper drawings of computers monitoring the actions of complex mechanical machinery. The idea is to flip it on its head, so that any person instead of having to search through pages and pages of documentation, will have the relevant information presented to him or her automatically. Defining a digital ontology of rail space, where before one had to search scanned PDFs from various locations for the relevant paragraph, a hub of semantically linked and updated data would be able to provide necessary information based on context. From the data pile to the data system, as it were.

According to subject 9, the digital railway is built with transmission as basis. Transmission is here understood as fiber cables. In a few years, the Norwegian railway will own about 5000 kilometers of fiber cables, in a network more extensive than its track network. Above that is the sphere signaling, ERTMS, and similarly wireless communications, GSM-R. Having 530 base stations, the Norwegian railway is one of five telecommunication operators of Norway.

On top of this comes a layer of condition monitoring. Embedded computing devices with sensors are already being put in place to create the railway's Internet of Things. This will be reporting on the deviancy of track switchers, motors, and other objects in rail space. Collecting data on and through all of the previous layers is the Train Management System, with its hub in the Central Traffic Control. From there comes the app layer. Managers, planners, maintenance workers, traffic controllers, passengers and freight consumers will have their information needs covered from this layer. This is what an entirely digitally modeled system can do. When a track switch motor has broken down, the app on the maintenance worker's device is supposed to know his location, identify the system in question, query its status and errors, and bring up the right documentation needed to fix the track switch motors, and then provide a way for documenting it afterwards.

As the Norwegian railway is moving from being a state monopolist, towards a more heterogeneous field of commercial actors, the epistemic upgrade is needed. Processes of documentation have traditionally been lacking, and what was *Jernbaneverket* and now has become multiple institutions, work both towards keeping the railway up to speed with the latest technology, and at the same time conserving the knowledge materialized in the NSI63 standard. Through disembedding information from paper, it can be shared across space, time and organizational walls. Through structuring the information as semantic data, it can be freed from the knowledge barriers previously needed to find whatever is relevant there and then. Whatever emerges between the development of the digital and models of governance is co-produced in the railway.

```
 Subject 9:
This is very exciting stuff. Just that thing [ERTMS]
is Norway's biggest program of renewal, you know,
for 25 billion kroners. But this thing here, when I
am out talking about the digital railway, it's the
operational part of it. The biggest program of renewal
in Norway, the biggest ITS [Intelligent Transport
Services] program, the biggest IT-whatever you like.
That gives me energy in the morning.
```

5.2 Markets as infrastructure builders

Contracts for the Norwegian ERTMS deployment are expected to be awarded by the end of 2017. The different contracts are made to be big, giving one large contract to each subsystem. Again, the united technology of railway systems is split up in a new configurations. The train management system is split from the signaling system, which is split from the on-board systems, again split from the preparatory works and decommissioning. On top of this comes services, such as consultants, assessors, NoBos, et cetera (Therp 2016).

As Ryggvik (2016) shows, both development and maintenance were gradually outsourced from Jernbaneverket for the duration of its lifetime, making the institution into more of a buyer of services than a doer of railways. This is even more true for the ERTMS project. As the procurement processes are also standardized through the EU, so too are the way in which the equipment that gets laid down. To make these large state funds work, they must transform into different contractors from a supplier market to implement and maintain the changes. Thus contracts will play central roles for defining the national needs of the railway, as a singular moment of definitional power from the infrastructure manager.

As the ERTMS has been implemented in Europe and elsewhere, experiences from the various infrastructure managers have been that although the technical standard seems to work mostly fine, the different manufacturers systems are very hard to get to work together. One informant describes the situations where two digital signaling systems from different suppliers must be connected with mechanical relays to get them to talk to each other.

As time has passed, it has become more obvious that although interoperability is the name of the game in some senses, the modularity of ERTMS components is limited because what one can euphemistically call market failures. Market players want to avoid competition, says one informant, and describes the lock in processes inherent in the commercial ERTMS solutions. The large shift in equipment in the laid railway tracks represented by the ERTMS also presents a unique opportunity for infrastructure managers to affect the railway equipment producers. Through a cooperation between 10 mostly northern European infrastructure managers, initialized by Deutsche Bahn, the EULYNX project aims to augment the standardization work done in ERTMS by adding additional standards for how infrastructure managers procure the new systems. How should the infrastructure managers formulate their demands of interoperability, documentation and maintenance in their requests for tenders? The Norwegian deployment of ERTMS will be one of first procurements based on this system, meant to standardize the elements and interfaces, and make upgrades and maintenance cheaper.

Again, there are adjustments of temporalities within the railway technologies, co-producing synchronizations in the railway organizations(Bowker 1995). Negotiating the future of the railways is done between the technologies involved, the commodification practices put to use and the organizational change that is envisioned.

The old building housing *Jernbaneverket*'s central offices was located centrally in Oslo, with nothing more than fifteen floors. While this was one of the taller buildings of the city before the seventies, since then it has become overshadowed by new attempts for steel and concrete to reach the sky. Although the steel has become increasingly visible, the new tall buildings hide their concrete in favor of reflective glass paneling. Excellent views from the inside, hard to see through from the outside. At the top of one of Oslo's two skyscrapers, *Jernbaneverket* has relocated their central offices. Having looked down on the city from the hills surrounding it many times, the view from their new offices was an entirely different experience. Not only could one see the hills, but one could see past them. I thought of this vertical social movement of power, and felt like I could watch my everyday self, as I I sat in the meeting room interviewing *Jernbaneverkets* managers.

Moving from flags, signs and lights, and towards data streams, one way to see the switch to ERTMS is as a continued increase in bandwidth between the train and the Central Traffic Control. At the same time, the defining feature can also be said to be the decrease of equipment in the tracks. The plan says only 10 percent of the equipment needed for conventional signaling systems is required for ERTMS level 2. A central component of ERTMS level 2 installations are the Eurobalises found in the tracks. These small, yellow boxes found between the tracks, do communicate with the trains wirelessly, but are in level 2 connected to radio block centers through cables.

Eurobalises in the current generation communicate movement authority to the train, and if permissive, will let the train keep up or increase its speed for another block (ERA 2016b). Although the train estimates its own position through odometry from its sensory apparatus, deviations from reality must be corrected by the precise location communicated to it by the Eurobalise. With the EU and European Space Agency's Galileo navigation system, going partially online in 2016, the yellow boxes will be freed.

Getting positional data from satellites via Europe's own Global Positioning System to trains will be another step in a direction towards smarter trains and simpler tracks (Rispoli 2013). Ridding the ERTMS system of Eurobalises is currently in the sphere of development and plans, with expected finalization in 2021. Although tested with the American GPS and Russian GLONASS systems in Italy, it is a potential future, along with moving from GSM-R and 2.5G communications to IP based broadband for trains, and driverless automatic train operations. Nevertheless, power does another vertical jump.

Through machine intermediaries, documents and plans, the particularities of the Norwegian railway system are transformed in representations through series of equivalencies (Callon 1984), making the heavy tracks and the signaling systems into mobiles to be exchanged. Thousands of kilometers of the railway network is spoken for in a few requests for tenders, which will be posted in 2017.

5.3 Rolling out

Differing from the Danish deployment plan, Norway has decided to take a more lax approach. While the Danes spoke about a “big bang” deployment, Norway will deploy line by line in an increasing tempo up to 2030. The first line up is *Nordlandsbanen*, with a rationale of it currently having the oldest signaling technology and largest need for immediate upgrades. Norway has currently implemented ERTMS for only a few percentages of its total rail network, on a simple and relatively disconnected stretch of rail track, close to the capitol. The challenges in coming years will be to extend it the rest of the country. The first working document for roll out was the signaling plan and national implementation plan from 2013. This plan outlines the general purpose, time-period, order and methods for the roll out (Jernbaneverket 2013). Before emphasizing that it is indeed the need for renewal more than a need for interoperability, it goes on to mobilize TSIs and EU directives requiring new signaling systems to be built as ERTMS compatible.

Being from 2013, the plan states that the project should cost between about 15 - 20 billion kroner (1,7 billion and 2,2 billion Euros) in total, of these, with a sum of 7 billion kroner (about 750 million Euros) that have already been allocated in the national transportation plan for 2014 - 2023 by parliament. Roll out is expected to to start in 2015. *Jernbaneverket*, being concerned with infrastructure, considers here also the issue of financing the on-board systems upgrades for trains and rolling stock. This was seen as a burden for the train operators, but by 2013 the decision for how it would be managed had not been made.

A revised signaling plan of 2015 updates the prospects from 2013 (Jernbaneverket 2015b). This revision is sent through the parliaments quality assurance process, to be checked by external consultants, similar to that of the concept choice investigation from chapter 3.2. The plan’s stated goals are to be leading for all procurements of new signaling systems, to comply with nationalized EU regulation for railway infrastructure, and to make a coherent plan for the renewal of both ERTMS and the in-between signaling system (class B). The reason for the revision is stated to be the experiences gathered since 2013, resulting in an updated progression plan where to earliest deployments have been pushed back a couple of years. Financing has disappeared from this plan, and the issue of how to finance rolling stock upgrades with it. The plan also emphasizes that the timeline presented here is not set in stone, but that a balance should be struck between the need for a predictable horizon for planning and the need for dynamic changes in changing environments and conditions.

By march 2016 the plan had passed a final trial of strength in the quality assurance process, and was approved, with advice on how to coordinate upgrades of infrastructure and train materials, methods for selecting which type of signaling systems for projects that are being built now, the arrangement of procurements, and the interface between contracts (Samferdselsdepartementet 2016). Its project organization, approval process and plans on handling deviations were also added to. With a revised national budget from parliament, a plan of subsidizing rolling stock got financed, and later approved by ESA, together with new commitments to financing the growing costs, now estimated in the 23 - 26 billion kroner range (about 2,5 billion Euros) (Carazo 2016).

> Subject 11: Deploying ERTMS in Norway is not really a technically very complicated task. But if If you look at Norway as a country, the logistics of building new signalling systems for 4200 km of track is a big challenge. Look at Bergensbanen for example where you have 500 kilometers of "nothing", or Nordlandsbanen with 700 kilometers of the same. Where are people going to sleep, live, eat, etcetera ? Where do you put your workshop, and where are the parts warehouses? Furthermore, how do you bring equipment to the different locations, is it by helicopter, by train, or..?

The transformation of immobiles into mobiles, multiples into singulars, is being enacted by their representatives (Callon 1984). There are a lot of parts that go into upgrading 4200 kilometers of track, and the signaling plan expected 75 percent of *Jernbaneverket*'s employees to need some sort of ERTMS training during the period (Jernbaneverket 2015b). Although presented as not very complicated here, throughout the country, old materialities are to be exchanged for new ones. Although about 550 trains of 83 different types are to be upgraded, it is the infrastructure that will be changed the most. Just the preparatory civil works are to include about 500 kilometers of cable paths to be dug and constructed, along with about 4000 manholes and 2700 excavated crossings. 7100 axle counters are to be installed, likewise for 11200 ballises, and 4750 marker boards will be put up (Rønold 2016). These are just some of the things to be installed, not to mention all the things that is supposed to be dismantled.

5.4 Failed translations / closing controversies

In the beginning there was heat, and although some striking train drivers came to visit and strong remarks were made, it became more considered and calmer throughout the days of the congress. I had been following the railway where it led me, while taking things into account. In a room of the labor union's big conference center, Oslo kongressenter Folkets Hus, the space is an active contributor as much as any, as it co-shapes the participants in new ways. Its historicity is a great boon to a researcher of technologies, to walk around smelling the halls and eating in the dining rooms that has contained and entangled so many organizations of change. The insides are all renovated. The venue is either brightly lit up or very dark, and has a hardness to it. Being large and modern, its visible staff included receptionists, servers and cooks. A proper conference center with wardrobe service and everything. The A/V-unit of the production crew broadcasts it. The railway union (NJF) is having its national congress, and participants have been given gift bags with Kindle e-readers.

Here participants are truly new, technological beings through and through, with our machine literacies and illiteracies. While the Minister of Transportation tells about how he grew up on a gas station, we cyborgs listen

(Haraway & Teubner 1991). Recent videos from the union's Youtube-channel are beamed onto screens and into computers. As though crunched through an Adobe algorithm, the digital centralization in software used is reflected in centralization of speech and knowledge in the actions performed. I'm in the back, the observer, with a video stream giving me a close up of the speaker. Participants are taking them in politely, from huge faces on walls. While its sent through open source HTML technologies, the back ends are tightly controlled companies as profitable technologies. She is in there, somewhere, the Apple girl who threw a hammer to Hegemony, but here we find her in the ordered and serial kind of way.

Following the speakers online, I see the *Jernbaneverket* organization of course keeping up with the times, as they are co-producing new realities from the state sphere. Its public-facing wiki is running the same software that runs Wikipedia, Mediawiki. This is the technical rulebook on how to build and maintain railway infrastructure. It is in wikiform, although in the most strict command-and-control sense of the word, open to the day in the front, but closed in the back. There seems to be only a select few who can edit it. Today's Norwegian Railway networks are centralized affairs, differing from the networks found in distributed computer systems, like bittorrent, bitcoin and blockchains. Technical discourse on railway signaling is entirely within the paradigms of central control, from the urban spaces of command and control centers and out towards the hinterlands. Simultaneously, there is a decentralizing movement. NJF, *Jernbaneverket*, the Labor party and the other actors co-creating rail space, are making it conform to EU standards and regulations and trying to get commercial players make nice.

As the schedule plays itself out on top of it, the stage hosts only some people at the time. Most times the people are centrally picked, although sometimes the room is opened to debate. Open, but only some frequent these spots, and most people stay passive. Although staged actors do include other workers from time to time, they become part of the cast others are watching. Everyone are invited formally, but throughout the days of the congress it becomes a kind of show, with union leaders, politicians and company management as central actors, sharing the field of view and bandwidth of streams. The show lasts a couple of days, and I get to follow it from there and online. This is an intersection where nodes are magnetized, told to represent or witness the representation of the constituents, meeting a room that is utterly constructed for most to be quiet, sit down and take in the central source.

In the meantime and over the stage, the “folksonomy” of the Web 2.0 dream (O’reilly 2005) is performed by labor, state and businesses. Commercials for the Railway bank are blasted onto participants, both present and remote. The Union band is streamed outwards the masses, although the amount of live viewers are in dual numbers. Not being able to revolt with technology, here I meet the fake revolutionized worker: Future shocked and lost in to the tools of advertisements said would help. Powerpoints, speeches and Youtube-videos follow in quick succession.

But thought leaders of the union have a counter-model, to dual the government’s railway reform of 2016-2017. The reform from the right wing government is not well liked in this room. Workers are struggling to keep hard won benefits, full time employments and pensions. The reform versus the union’s “NSB 2.0”. The union leader (to be) goes on stage and explains how they have analyzed the numbers, worked hard and thought the model through. NSB 2.0 can be great, comply with EU-regulations, and still secure jobs and worker’s rights. And keep the name. But during the next days, representatives from the labor party enter the stage: We cannot go backwards. When we get in position, we will make life better for everyone who loves railways, because so do we. We cannot go back to NSB. Norway is small, but sharp. We are a family, we are going into the future. We are a family. Labor party representatives and union leaders hug.

Statements from the union are voted over. The political statement (Norsk Jernbaneforbund 2016) is agreed upon and reads like this:

> The nation state of Norway has renounced its ability to organize its railway sector. The EEA agreement allows for weakening the working conditions and collective wage

> agreements through its ban on "discriminatory agreements and restrictions/controls". NJF strongly opposes railway package 4, and demands that the government reserves itself from it. At the same time, NJF wants the Norwegian Confederation of Trade Unions to assess if the EEA deal should be abandoned, in favor of a free trade agreement between Norway and EU.

This was the last national congress where NJF had *Jernbaneverket* on the employer's side of the table. Unsuccessful in opposing most of the deregulating and privatizing reforms leading up to this point, their model of NSB 2.0 did not win through either. The union is dissenting, and does a hostile intervention into the careful translation work involved in ERTMS. Although they do not address the technology directly, it can be felt as an underlying issue of which controversies from other social ontologies concern themselves. Can workers successfully torpedo the ERTMS project, are they needed to join into some obligatory passage point (Callon 1984)? It is possible, but a more cynical view sees that through series of equivalencies the workers will probably become cooperative, their spokespersons will probably not represent the dissent, and their immobility once again become mobile. If resistance is kept up, voter education and employee training has already started (in)forming them into choosing the right intermediaries for the job.

5.5 From the top

On the map I see the layout of the European Parliament building complex, distanced to the east of Brussels' city center. Big even there, in person it is awesome, like a super structure or something akin to a real-life pyramid. While the main seat of the parliament is in Strasbourg, France, the Brussels complex was built to be closer to the other EU institutions, in the unofficial capitol of Europe.

Entering the building is not entirely different from going through the motions of airport security. You find the right counter, show your passport or

ID papers, state your business and get a visitors ticket. From there I must wait in line to go through a metal detector, take off shoes, belt, wallet, put them in a box. Visitors, parlamentariens and employees alike are all shoveled through the security theater, some being patted down, before ending up in the halls of the parliament. In here smartly dressed people are moving about with intent and purpose. Younger aids and lobbyists encircle the older parlamentariens. In the middle of a hall intersection is a TV news studio, with desks, green screens and cameras all set up.

Voices give off several monotonous echoes in the headphones of an assembly room hemisphere. Most speakers are encouraged to use their own languages and then become translated. Surrounding the seats are dark windows partly concealing the translators making passionate French into Danish devoid of emotions, and vice versa. The multilingual discussions put Firenze and Gothenburg next to each other, Krakow is entered, but only briefly, before moving on to the Iberian Peninsula. Jumping scales is done effortlessly here, connecting EU laws with plights of national populations. Here, distance is already obliterated, language barriers are already overcome. Other things become difficult: Like the physical access, WiFi access has this similar Kafkaesque presence. The concept of Europe is omnipresent here, for inside this inner chamber of the union sits not only a locust of power, but the concrete practices of a configuration of spatial and territorial models of organization.

The fall of the Berlin wall and Soviet Union in the early 1990s were followed by a period where the EU strengthened itself immensely. The successful ratification of the Maastricht Treaty in the beginning of the decade, paving the way for the Euro-currency and common fiscal policy, was followed by the Amsterdam Treaty some years later, where national governments devolved powers of immigration, security and foreign policy, as well as other areas, to the EU (Wallace et al. 2015). This is the period when many of the EU regulations on railways saw the light of day, and in the latter part of the decade saw the very earliest translations of ERTMS from plans into test lines, where ERTMS was fueled by EU enthusiasm of the 2000s. After ten years of development and sunken costs, this time was spoken of as an exploitation and dissemination phase. Deployment of

ERTMS level 1 lines happened in the core countries of the union, while level 2 was being tested out. The successful eastward expansion of the Nice Treaty, after first having been rejected in the Irish referendum, gave the EU project an aura of strength and attractiveness.

If the EU project ever had grace, it can be said to fall from it during the 2010s, in part as result of a perceived failure to handle the economic crisis. The occupy movements in the beginning of the decade sat the tone for the following years. The Greece affair and Brexit were accompanied by ambivalence of the core countries towards committing to ERTMS. Convincing sovereign nation states to give up their sovereignty in favor of supranational European policies was never a straight-forward deal. The EU project has constantly had to fend off controversies around democracy (Hooghe (1995), Follesdal & Hix (2006) and Jensen (2009)), bureaucracy (Moravcsik (2002) Wille (2013)) and efficiency (Vollaard (2011) and Börzel et al. (2010)). Lacking nation states' legitimizing benefit of an established identity, and unwilling or only hesitatingly attempting to create one (see figure 5.1), the EU is constantly fighting battles for legitimacy. If a nation state fails in achieving its strategic objectives, what will happen is a change of government, or at worst a civil war. The EU, on the other hand, still needs to perform if it is to continue. Large national infrastructure managers in core countries can be seen to resist changes from the EU (Dyrhauge 2013). The morning of 24 June 2016 was a starch reminder of this, as 51,9 % of Britains had had enough.

The decision by the British to leave the EU, followed by the American election of Trump as president shortly thereafter, poses hard questions not only of the EU project, but also for more general political ideas like liberalism, cosmopolitanism and trans-national political institutions (Morgan 2016). This is only exacerbated by European political parties of a nationalist tendencies, like the *Partij voor de Vrijheid* in the Netherlands, *Lega Nord* in Italy, and *Front National* in France, showing strength in polls. The ideology of nationalism that seemed to be defeated by a united Europe is now returning as farse (Aisch et al. 2016).

European unification has remained an elite project to the

> present day because the political elites did not dare to involve the general public in an informed debate about alternative future scenarios. National populations will be able to recognize and decide what is in their own respective interest in the long run only when discussion of the momentous alternatives is no longer confined to academic journals – e.g. the alternatives of dismantling the euro or of returning to a currency system with restricted margins of fluctuation, or of opting for closer cooperation after all.
>
> Habermas (2017)

Through the study of the translation processes, it becomes clear that not everyone has a voice, or rather some are being spoken for, in the what Habermas calls the European unification project. This is one strength of the object institutional approach, that it strips away some of the mythology that surrounds social institutions. On one hand, both chapter 3 and 4 saw national actors aligning with the goals of the EU, allying with it and articulating themselves through it. Counter to what the NJF statement says, this view proposes that Norway is not renouncing its right to form the railway sector, but rather co-evolves with it, and finds it a distinct flavor of railwaying in friction between incumbent and EU governance models.

This study also gives Habermas (2017) right in claiming that the EU integration project stays an elite project through the workings of national elites. There issue is not open to discussion, or at least it stays within the confines of a controversy that seldom touches upon the deeper issue. What we saw in the case of Denmark is a good illustration, with the issue of how to do EU integration being discussed in the frames of budget overruns and delays, pigeon-holing the blame on the Danish infrastructure manager instead of raising the issue of democracy extending above and below the nation state, into the things of everyday life.

On the other hand, the Habermas goes on after the quotation above, to claim that the only way forward is stronger unification, as he calls for Germany to get over its indecision and form a European party system. Here is either faulty logic at play or a breakdown of communications, something which partly can explain the sentiment of Le Pen. The object institutional approach again shows that the EU is not something magical and unique, which cannot be otherwise, except in barbarism. Generalized symmetry (Callon 1984) lets us view transnational cooperation between railway companies to not be bound to only do so through the EU, while ERTMS and its companions become in this view just another signaling technology of many. As countries can make bilateral trade agreements outside of the EU order, railway cooperation can be, and is, happening in other places. Multilateral projects like the Thalys cooperation between Paris, Köln, Amsterdam and Brussels (Thalys 2017) is just one of many examples that pose alternative visions of mobility governance and transport cohesion, and if extended can also work towards a claim of there being already existing alternative orders to the EU.

> "A new Europe will emerge […]. For all patriots, for anyone who loves liberty, today is a day of joy. It is not that Europe is dead but that the European Union is teetering, and the nations are being reborn."
>
> Marine Le Pen cited in Zerofsky (2016)

If the EU order ends up being threatened remains to be seen, but there are signs pointing in both directions. If we look to rail space, there is first off, the core countries of the union only partially following up on ERTMS conversion, making more peripheral countries into early adopters. National implementation plans of ERTMS keep being pushed back (UK 2016), making the overall European Deployment plan from 2009 so out of sync with reality that it become revised in 2017 (Gazette 2017). Deadlines set in the 2009 plan predicted more than half of the European transport corridors having ERTMS by 2015, with the rest being built by 2020. The new plan postpones these dates to 2023 and 2030, respectively.

Secondly, supranational but sub-EU networks of coordination between national actors can undermine the strategy of standardization and push their own agendas in the face of EU and UNISIG. On the other hand, ensuring interoperability between not only systems, but also individual components (i.e. modularity) like the EULYNX project, bears a potential to make the high price of switching over to ERTMS systems more palatable for states. After an initial price barrier, the resulting ERTMS implementation could then be much cheaper to upgrade and maintain because of standardized parts. This in turn can end up strengthening the viability of the ERTMS project, and the tools which the EU project rests upon.

Either way, by leaving a focus of social institutions behind, and applying our political understanding to things, it becomes obvious that both EU and digitalization are little except for the assemblages that mediate them. Temporarily, ERTMS seems to work a lot better than the identity technology of Captain Euro. However, like Captain Euro vs. Dr. D Vider, Habermas is engaging in a discourse of no alternative to unification. In doing so, he can be accused of removing communicative rationality from things. Bringing things into the public debate could be just what is needed to "expand the spaces for possible democratic will-formation" (Habermas 2017) and better transnational cooperation.

Figure 5.1: The officially sanctioned Captain Euro vs the Evil Dr. D Vider, along with the the other action friends of the European Union.

Chapter 6

Conclusion

6.1 Thesis summary

The study of translations is the study of power (Callon 1984). In a non-linear fashion, this thesis has ended up outlining the relationship between two spaces, Norway as an EEA member and the railway as part of new Norwegian governance models, co-produced by an actor-network around ERTMS. As levels of governance in society are changing, the translation of ERTMS to Norwegian conditions also becomes a case of rescaling of politics (Sassen 2007), but also of how EU politics is performing and progressing towards set goals. Following the ERTMS translation into these, the Norwegian implementation is found to be rolled out in neither streamlined, nor smooth. The ERTMS pilot line of *Østfoldbanens Østre linje* embeds the EU ontological orchestrations into Norwegian rail space, through the concerted efforts of several interested actors, and in negotiations with and adjustments to both Norwegian laws, bureaucratic processes and *Jernbaneverket*, as they were enrolled. As such, neither digitalization, nor EU integration can be explained as one way affairs. On the contrary, the perspective has let the thesis locate agency between fragile messes of relations and reiterations, where the ERTMS deployment in its splendid imperfectness becomes an awakening of something dynamic and elusive. Within temporary orderings of materialities, control systems are found to be evolving to adjust to new environments, organizational and societal missions.

Deviating from the account of Ryggvik (2016), the multi-sited ANT framework revealed not only the devices of interessement, but also the coordinating practices around them. Ryggvik starts off by describing how the Norwegian railway's management-engineer role was shaped through networks that was established between Sweden and Norway, in Scandinavian space. These networks made sure that no larger changes went through without both governments having oversight. However, in his historical work this network features as historical background in an opening chapter. This thesis however sees the leadership network being partly extended and replaced through the inversion of ICT infrastructures following the political crisis around the *Åsta* accident. Interessement happens between new actor-networks on a different scale that is enacted through GSM-R and later ERTMS. Decentralization of authority is done differently, and new valuation practices followed suite. The case of the accident also illustrates how the use of systems perspectives on crisis is a powerful definitional tool. In selecting a systems cartography (Law 2000) of the accident, not only was the driver implicated, but also all of the relations that brought him there. The training, the rulebook, the communications, the traffic control and the leadership were all brought into the controversy, key in creating

Working with the historic and spatial contexts around ERTMS, it became not only mobilized as background, but also as description of how translations were enabled. I have seen contexts as something that must be explored, something I join Asdal (2012) in arguing has been under-appreciated in the translation literature. By using methodological triangulation to describe some moments and places, that might seem arbitrarily selected, became a way for me to historicize and ground the technology, in spite of the often future-oriented networkings of ANT. Through this, control systems were observed doing vertical leaps through moving into the driver's cab, centralizing away previously decentralized functions in the names of efficiency, competitiveness, et cetera. The digitalization of European railways is found to have a longer history and deeper connection, one that not should be forgotten in this race towards modernization. An example of railway and digital powers being misused is the history of the IBM Hollerith counting machine. During the last twenty years it has been documented how Nazi Germany was co-created by International Business Machines (IBM) to organize the infrastructure of the Third Reich (Black 2001). The same kind of analogue counting machine that was blown up by saboteurs in occupied Oslo (Bing 2009), were used by Nazis not only to keep information on its populace, but also to keep an overview of capacity in the death camps. Industrial genocide relied on a transportation system to run with deadly efficiency, and to keep trains on time and track of passengers, goods and victims, the IBM Hollerith was used. If there ever was a military-industrial complex, it has surely been running by both computing and railways for a long time. In making the space abstraction capabilities of railways more powerful, actors also share a greater responsibility for its use.

In ERTMS' dealing with unwanted variation, this thesis does a discovery similar to that which has been done earlier in other fields (e.g. in Information Systems Jacucci et al. (2003)). Standardizations can induce side-effects, and result in more unwanted variation. Both the Norwegian and Danish cases show signs of a blossoming bureaucracy that is identified to threaten the translation processes. This is in parallell with the phenomenon of standardizing one area, leaving another to explode in heterogeneities. Although a counter to the systems inflexibility of the current supplier industry is located in the EULYNX project, time will tell if ERTMS' standardizing goals are undermined by its own doings.

Exactly what emerges from the Norwegian ERTMS project cannot be answered on the basis of this work. Rather, I have sought to give an STS account of its doing, and to map the social issues inherent in the processes of EU integration and digitalization, by using this technological artifact as object of research. The complex work involved in transforming EU goals into an authority in rail space has been seen to be both technical, legal, moral, cultural and more. Learning about governance through the artifact strips away some of the positive and negative mythologies of both the EU and digitalization. In one way, studying them from the perspective of ERTMS reveals how the artifact is aimed at solving problems that to some extent preexisted it. While the concept of interoperability is formulated in achieving what earlier governance structures had dealt with earlier, more or less successfully, the digitalization of railways has also been found to be older than one might think, and inherent to the technology itself. The perceived need for making economical sense of the railway is found to predate the formation of the EU, although the EU is co-constructing digitalization of bureaucracy, opening up new possibilities for heterogeneous actors to enter into what has previously been more monolithic governance structures.

In becoming the estranged ethnographer (Agar 1980), it is increasingly difficult not to notice the prevalence of CE markings onto our most intimate cyborgic extensions. Turn over any device, and underneath is exposed the standardizing work of a EU NoBo. There is no clear line where European railway regulation ends, and European electrical regulations begins. It is all interwoven, as EU laws and standardizations penetrate throughout the socio-technical spectrum. On those terms, ERTMS is just another delivery vehicle for governance structures aimed at coping with the challenges ahead from a Brussels planners' perspective, delivering the numbers, and ensuring the continued cohesion of the union. If this is good or bad is not the point, but the strategy of governance through standardizing technology is hidden in plain sight. As so, this thesis has been increasingly motivated by, and felt to be uncovering, the need of bringing things into public debate.

6.2 Future research

Railways are common objects of research for Science and Technology Studies, with prominent writers in the field continuing to put out books about them. Because the Norwegian deployment has not yet started, it promises to be a fruitful case of science applied to society for years to come. Norway being a kind of special member of the European Union, only makes it more interesting. Being a single researcher trying to untie the triple knots of railway technologies, EU integration and digitalization made me wish I was part of team of researchers from mixed academic backgrounds. This thesis contains as such many clues for where to start future works, most which cannot be included here, although some keywords are EULYNX, Hitachi Rail, semantics and digital representations.

Mixing computers and railways are generally interesting concepts. This study has not at all considered the producers of the systems, nor passengers, nor drivers, for that matter. How are they being co-constructed within the new technologies, and how are their geographies changed? In relation to this, digitalized infrastructures promises a lot, but is by many considered a bad idea, as an untamed technology. For instance, trains are expected to last decades, while softwares have a much shorter lifespan. The thought of infrastructures having broad attack surfaces and outdated software, worries me immensely. While safety played a role in the Norwegian ERTMS translation, the recent Wannacry virus and similar attacks threaten to undermine any gains. How safety management of infrastructures are changing to cope with this, would be an interesting study.

Finally, I would like to bring up centrality as an issue. Concerned with signaling, management and democracy, this study has in essence been about centralized control systems, with knowledgeable centers and lesser peripheries. How are different control systems changing today? Are there alternatives to the upscaling and centralization of power, outside of computers, and how are they being translated into infrastructures?

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