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Rhythms of Information Infrastructure Cultivation: The Case of e-Mobility in Berlin

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Declaration

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I warrant that this authorization does not, to the best of my belief, infringe the rights of any third party.

I declare that my thesis consists of 68,742 words.

This PhD is dedicated to Aba and Ami,
my loving parents
Javed and Farida Malik …

… and to my wonderful husband Parag Khanna
and our dear children Zara and Zubin.

Abstract

This thesis investigates the importance of temporal rhythms in the study of information infrastructures (IIs), responding to the call to address an II's "biography" by focusing on its evolution over time. It enriches understanding of how socially constructed rhythms, a temporal structure under-examined in the II literature, influence II cultivation. A strategic niche project to develop an e-mobility II in Berlin is used as the case study and reveals the influence of rhythm in disciplining (constraining) and modeling (motivating) II cultivation. It demonstrates how the intermediary may mediate these influences through the interventions of harmonising, riffing and composing. Based on these interventions, the study develops the concept of facilitated II cultivation, which adds to the emergent literature exploring the tension between planned and emergent infrastructure work. In doing so, the study presents a framework that helps combine short-term implementation concerns (strategic interventions by the intermediary) with long-term path dependency and evolutionary concerns (influences of past and future temporal rhythms) for IIs.

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1. Introduction

The topic of heterogeneous large-scale information systems known as Information Infrastructures (IIs) has received attention in the IS field in the last few years. Characterised by their complexity (Hanseth & Ciborra 2007; Kallinikos 2007), researchers have acknowledged that such IT systems have "been continuously growing as existing systems, new and old, have been increasingly integrated with each other" (Hanseth 2014). The Software Engineering Institute (SEI) at Carnegie-Mellon University states that the emergence of such ultra-large-scale (ULS) systems "require a broad new conception of both the nature of such systems and new ideas for how to develop them" (Northrop et al. 2006). Integrated large IS systems are also emerging in urban settings under the umbrella of "smart city" initiatives. Smart cities are defined by their use of ICT to improve efficiency, sustainability and quality of service in sectors such as transportation, governance, and healthcare.

IS scholars have found that complex integrated systems like IIs cannot be developed using traditional top-down design approaches (Henningsson & Hanseth 2011). Existing ICT systems, processes, and practices, collectively referred to as the installed base, heavily influence an II's development. Developing an II is better understood as the cultivation of this installed base (Aanestad & Jensen 2011; Ciborra & Hanseth 2000; Grisot et al. 2014), a process that involves integrating heterogeneous sociotechnical components into the existing foundation rather than building the II from scratch. The II constantly grows as components are added to this installed base, "fixed in modular increments, not all at once or globally" (Star & Ruhleder 1996).

While researchers have attempted a theory of design for cultivating the installed base (Hanseth & Lyytinen 2010), the complexity of IIs can side-track design plans as components interact unpredictably. The uncertainty and risk of such side effects are inherent to the integration of multiple dynamic components (Kallinikos 2005; Perrow 2008), which makes it difficult to understand and analyse how IIs emerge. Given the unpredictability of II growth, this thesis starts with the question: "How do IIs cultivate over time?"

The thesis relies on The Trichordal Temporal Approach to Digital Coordination (henceforth referred to as the Trichordal Temporal Approach) (Venters et al. 2014) as its theoretical foundation to investigate this broad research question. The theory conceives the coordination of digital grids as an emergent process that unfolds as human and material agencies interact. It is notable because it pays attention to the role of materiality and temporality in the coordination of IIs, which have hitherto received limited attention in studies. It views both human and material agencies as temporally embedded, influenced in the present by the past and the future.

While temporality in coordination has been receiving more critical attention in IS research (Orlikowski & Yates 2002; Ancona & Chong 2006; Staudenmayer et al. 2002; Ancona et al. 2001), the literature has still to address a nuanced and rich examination of temporality in II cultivation. This thesis extends the Trichordal Temporal Approach (Venters et al. 2014) to focus on the role of socially constructed rhythms (Jackson et al. 2011) in this area. It refines the research question to: how do temporal rhythms influence the mangle of human and material agencies during the process of II cultivation?

This thesis studies the prototyping of an electric mobility (e-mobility) II in Berlin as its case study. The project known as BeMobility was part of a smart city experiment aimed at developing an e-mobility infrastructure, which would allow consumers to seamlessly select, book and pay for multiple vehicles (bus, train, car, or bike) to complete a journey. Such a multi-modal transportation system that encompassed both public and private transport required the integration of ICT systems across several stakeholders. The goal of BeMobility was to create a prototype of an integrated mobility infrastructure that would discourage individual car ownership, providing an alternative, sustainable and convenient mobility option to city residents. Funded largely by the German federal government, the BeMobility project was part of the country's national strategy to pivot its transportation system to a more sustainable mobility system and to establish Germany's automotive industry as a leader in next-generation mobility approaches.

The study of BeMobility in Berlin serves as a means to understand II cultivation and to gain insights into the evolution of IIs. Even though the project was a "proof-of-concept," this thesis views the journey of the project as providing an ideal case study for examining the factors that influence II development.

1.1. Motivation and Scope

A deep interest in sustainable transportation motivated the researcher to pursue this topic along with a desire to mitigate the adverse effect of current transportation systems on climate change as vast areas of the world rapidly urbanise.

The 21st century has been referred to as the "urban millennium" by Kofi Annan, Secretary-General of the United Nations (UN): over 70% of the world's population will live in cities by 2050 (Handwerk, 2008). The number of migrants is staggering: the next 15 years will see 350 million Chinese migrate from the rural to the urban areas, while the next 30 years will see 400 million Indians do the same. The UN estimates over 9000 new cities will have to be built by 2050 to accommodate urban migrants, while almost every major city will have to expand its infrastructure and services (United Nations 2014). Urbanisation puts severe pressure on existing, often dilapidated, urban infrastructures and rapidly increases the carbon footprint of cities.

One of the biggest culprits of pollution and congestion in cities, both in the developed and the developing world, is the transportation sector. Transportation systems today are heavily reliant on individual car ownership and vehicles such as buses and taxis, almost wholly powered by fossil fuels. The effect of this on climate change has become a major challenge for cities (Moriarty & Honnery 2008; Banister et al. 2011; Geels et al. 2011). The smog and greenhouse gas emission also present serious public health concerns: World Health Organization (WHO) estimates that air pollution causes seven million premature deaths annually and urban transit is one of the significant drivers of air pollution[1].

Given how much pollution is driven by urbanisation, it is not surprising that many believe that "the battle for sustainability will be won or lost in cities" (Bai et al. 2010). The question of how to build a sustainable transportation or mobility system for cities is the starting point of this study.

The key to sustainable mobility is first to discourage private ownership as far as possible and to instead move to a system based on the sharing economy in the private sector (for example, car sharing and bike sharing) integrated with public transport (Canzler & Knie 1994; Canzler & Knie 2011). Second, different transportation modes should be mostly electric and powered by renewable energy sources like solar and wind, further reducing greenhouse gas emissions.

Information systems (IS) are viewed as a key enabler of electric mobility concepts such as car-sharing (Hildebrandt et al. 2015). A platform of integrated mobility would require the digitisation and integration of multiple parts of the existing infrastructure. For the end consumer, all modes of transportation (public and private) would be conveniently available through a single smartphone app. At the backend, however, the digital features of this e-mobility infrastructure would manifest themselves as complex information systems that span several industries, including public transport,

[1] "7 million premature deaths annually linked to air pollution", World Health Organization, March 24, 2014 (Source: http://bit.ly/1jpGo4S)

car parking lots, automobile manufacturers, and energy providers. The IS literature describes such large sociotechnical systems that are open, heterogeneous and continually evolving (Hanseth & Monteiro 1998; Hanseth 2006) as information infrastructures (IIs).

The new integrated approach to transportation represents radical innovation in the current system, and the II is a core enabler of how different modes of transport are integrated seamlessly and made available through one application to the consumer. In recent months, research scholars and the industry have increasingly referred to integrated multi-modal systems as Mobility-as-a-Service (MaaS) (Brendel & Mandrella 2016).

"Mobility as a service (MaaS) is arguably an idea that has already arrived, via services such as car-sharing and wider solutions involving multiple modes of transport booked through a single provider." (KPMG 2014)

When cities experiment with radical innovation such as MaaS, they conduct investigations in protected spaces known as strategic niches, which are the "creation, development and controlled break-down of test-beds (experiments, demonstration projects) for promising new technologies and concepts" (Weber & Truffer 1999). These test beds provide a learning environment for the stakeholders and users to understand the viability of innovations (Schot & Geels 2008).

This study explores the development of a sustainable e-mobility II by observing a strategic niche experiment that aims to prototype such an innovative system. It seeks to fill a gap in the IS and strategic niche management literature (SNM) that has under-examined the development of e-mobility IIs in cities.

While the SNM literature recognises the importance of ICT products in enabling transition pathways to sustainable mobility (Geels & Schot 2007), it has not focused in-depth on how an urban-scale ICT system or II is coordinated and integrated. For e-mobility systems, for example, studies have concentrated more on features such as geography (Xue et al. 2016), policy (Wee et al. 2012), competition (Bakker et al. 2012) and business models (Christensen et al. 2012) rather than on the design and implementation of ICT.

The IS literature has covered such large-scale systems albeit in other sectors such as healthcare (Aanestad et al. 2014) and cloud computing (Zheng et al. 2011). It is to this literature that the thesis looks to provide the analytical framework and research approach necessary to investigate mobility infrastructures in cities. In particular, the thesis uses the II and CSCW (Computer-Supported Cooperative Work) literature on the coordination of large-scale systems to understand the phenomena of urban infrastructure innovation. The literature frames II cultivation as an emergent process and reveals a gap in the understanding the temporal context of this process.

The impetus to study a MaaS-type e-mobility II is even more urgent now than at the start of this study six years ago. At the beginning of this research, integrated mobility did not exist on an urban scale. However, in the last two years, several MaaS-type prototypes have been launched including in Helsinki by the company MaaS Global[2] and in Singapore by the public transportation company SMRT[3]. This study can provide valuable insights for these projects on how such e-mobility IIs develop.

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[2] Nanette Byrnes, MIT Technology Review, "Helsinki Hopes This App Will Make People Ditch Their Cars," November 17, 2016 (Source: http://bit.ly/2f2VrjQ)

[3] The Straits Times, "SMRT teams up with NTU, JTC to collaborate on transport research," Feb 13, 2017 (Source: http://bit.ly/2lDUhTW)

1.2. Research Project

The researcher launched this PhD study in September 2011 motivated by the reasons outlined in the previous section. This section presents the main components of the research, including the theoretical framework and research questions, the case study and field work, and the contributions of the study.

1.2.1. Theoretical Framework and Research Questions

As stated, the goal of this study is to investigate II cultivation in the context of urban e-mobility. The theoretical framework devised to understand this phenomenon is based on The Trichordal Temporal Approach (Venters et al. 2014), which explains the coordination of large-scale information systems through the interaction of temporally embedded material and human agencies. The theory developed by Venters et al. (2014) lies in the broader domain of sociomaterial practice, which is appropriate for studying IIs since they are complex networks of both human and material actors (Orlikowski 2007) and represent an "inextricable interlinking of technology, work and organisation" (Walsham 2012). Using the sociomaterial lens, Venters et al. (2014) examine how material agency, in addition to human agency, plays a critical role in digital grid coordination. According to the theory, digital infrastructures evolve when there is "a mangling of human and material agency" (ibid). Material actors, such as software systems and hardware charging stations, are fundamental to e-mobility IIs and it is essential to understand their role in II cultivation. The sociomaterial approach uses a relational ontology that privileges neither technology nor humans in its analysis (Orlikowski 2009).

Venters et al. (2014) demonstrate how both human and material agencies are temporally embedded and that agencies in the present are influenced by "social and material inertias of the past" and by "future-oriented projections." Temporality has a strong impact on urban infrastructures since they have a long history spanning decades as the city builds up its municipal and private transportation systems. Also, radical innovations, such as new technologies like electric cars and sensor networks, will dramatically change future mobility systems in previously unimagined ways. The literature review identifies a gap in the examination of II cultivation against this background of experienced past and anticipated future, especially when considering temporality in the form of rhythms. This study extends Venters et al. (2014)'s approach with two analytical concepts: first, a categorisation of rhythms of collaboration (Jackson et al. 2011) and second, a matrix of rhythm interactions (Lefebvre 2004). It uses these extensions to create a richer theoretical framework for examining how rhythmic time influences II cultivation. The study broadly categorises past and future temporal rhythms as organisational, biological, infrastructural and phenomenal (Jackson et al. 2011). Phenomenal and infrastructural rhythms represent the material forces that affect the temporal structure and "account for the role of non-human forces and actors in the shaping of time" (Jackson et al. 2011). Each of these rhythms influences the way human and material agencies entangle during II cultivation.

This enriched theoretical framework is employed to investigate the research objectives of this study. The desire to examine time in richer detail is not without precedence in the IS literature. Researchers have begun to emphasise that "time also matters" (Reddy et al. 2006), and advocated a deeper understanding of the temporal aspects of work in large-scale collaborations (Karasti et al. 2010). The extended framework helps refine the study's research questions on the cultivation of urban e-mobility IIs as below.

- How do temporal rhythms impact the process of II cultivation?
- How do these rhythms interact with each other during II cultivation?
- Why does one rhythm dominate and direct the II's trajectory when there is discord between rhythms during II cultivation?

1.2.2. Case Study

To study e-mobility IIs, the researcher searched for a strategic niche involved in prototyping new urban mobility infrastructures. The researcher identified a strategic niche project called BeMobility (short for "Berlin *elektromobil*") in Germany that had embarked on a program to design and prototype an e-mobility infrastructure to integrate public and private transport services. The project, which would ultimately last for four years, was already underway when it became the case study for this thesis in November 2011.

The German government launched BeMobility in September 2009 as part of a larger strategy to become the market leader in e-mobility markets. The government-sponsored the project to specifically investigate and demonstrate how to build a next-generation transportation system for Berlin, which could become a model for the world and a showcase of German mobility providers. The project would provide Berlin residents with multiple transport options while limiting individual car ownership and environmental pollution. Specifically, the project aimed to integrate electric car-sharing and bike-sharing schemes into Berlin's public transport system of rail and buses.

The project started with the hypothesis that urban residents are agnostic about using different mobility vehicles, for example, a car or a train, so long as they can conveniently reach from origin to destination of their journey. All mobility options would be available to the customer via a smartphone application. Such a mobility system would require a chain of mobility options linked to each other seamlessly. A citizen could route a path to her office, for instance, that included using a car-sharing vehicle from her home to the train station and then boarding a train from the station to her office. This multi-modal mobility offering would be attractive if customers found it easy to use through a user-friendly app that provided data on the availability of mobility options and payment. It would also be sustainable if the vehicles were electric or hybrid, and powered by renewable energy instead of fuel or diesel.

Such an integrated e-mobility infrastructure would have a significant role for information technologies. Developing this e-mobility II would require the integration of the different information systems or installed base that existed across the various stakeholders (for example, parking, train, bus, and car-sharing operators). The II's complexity would be further intensified by the large multitude of stakeholders and the implementation of new technologies and would need extensive coordination.

Over thirty-two stakeholders participated in BeMobility over four years with Deutsche Bahn AG as the lead partner and InnoZ as the research institute tasked with project coordination. Deutsche Bahn AG is the largest provider of public transport in Germany, and its portfolio includes several means of passenger transport such as high-speed trains, city buses and car-sharing and bicycle-sharing.

Multiple organizations participated from the following sectors: energy and charging infrastructure providers (eg. Vattenfall and RWE); academia (eg. TU Berlin, LSE and MIT); car manufacturers or OEMs (Original Equipment Manufacturer) (eg. Daimler, Honda, and Toyota); public transport companies (eg. Deutsche Bahn AG, BVG); car part suppliers (eg. Bosch); electricity management (eg. Schneider Electric); public and private parking providers (eg. City of Berlin and Contipark); government agencies (eg. federal government and EMO); and startups (eg, Salon).

The II that emerged during BeMobility included not only existing systems but also new modules, databases, and APIs that were developed specifically to help with the integration of different stakeholder systems. Adding to the complexity of the II was the fact that software systems needed to extract data from many immature (at the time) hardware technologies such as electric cars, pedelecs, micro-grids, and charging infrastructure.

The project was carried out in two phases in Berlin: the first phase focused on integrating public and private transportation services, while the second phase focused on integrating the energy infrastructure with transportation systems to drive sustainable mobility. The BeMobility project represented a typical strategic niche set up by the government to experiment with new technologies. As discussed earlier in this chapter, strategic niches are "protected" from existing monopolistic forces that resist innovation (Hodson & Marvin 2009). They involve a diverse group of stakeholders from the industry, government and research universities, and derive lessons from deploying technologies in real-world settings.

Infrastructure related strategic niches sometimes include the creation of an integrated large-scale information system built upon the existing systems of multiple stakeholders. However, these niches (e.g. including those with electric vehicles in Germany from 1992-1996, Switzerland after 1995, and Norway after 1991) largely assumed ICT was a static entity (Hoogma et al. 2002). BeMobility placed priority on the integration of information systems as part of the e-mobility infrastructure development. The emphasis on information systems made the project particularly relevant to the research objectives of this study.

1.2.3. Contributions

This thesis set out to answer research questions on the nature of II cultivation and the influence of temporal rhythms on this process. At the conclusion of the research, the study makes a contribution to both the literature on IIs and to the policy efforts to build sustainable e-mobility systems in cities.

Theoretically, the study makes a contribution to the emerging literature on temporality and II cultivation (Venters & Whitley. 2012; Venters et al. 2014). By doing so, it supports the view that II cultivation stretches over the social, cultural and physical settings in which it emerges. The thesis uses the concept of the rhythmic temporality of past, present, and future (Jackson et al. 2011) to examine how the temporal orientations of human and material agencies influence II cultivation in the present. The findings demonstrate that past rhythms can influence the mangle of practice through diluting, stalling or blocking II cultivation. Meanwhile, future rhythms can influence it through motivating the combining, extending, and replacing of II modules so that it can grow. These findings add to the literature on how II cultivation in the short term (known as project time) relates to the longer biography of the II from its experienced past to its imagined future (known as infrastructure time). To build an explanatory framework, the researcher delved deeper into the question of II trajectories when multiple rhythms are influencing the present. The study found that when there is discord between rhythms, the intermediary will sometimes intervene and mediate their influence. The intermediary employs the intervention techniques of harmonising, riffing or composing, and the evidence supports the scholarly work on strategic intervention in II cultivation. The intermediary's ability to mediate rhythmic influences contributes to the debate in the II literature between controlled and emergent cultivation, making a case that it is possible to intervene and guide the evolution of the II incrementally.

The study also adds to the strategic niche management (SNM) literature (Geels 2012; Geels & Schot 2007; Kemp et al. 1998) that has largely treated information systems development as a black box, by providing a lens to understand the development of large-scale complex ICT systems in cities. It adds to the SNM literature on intermediaries, which traditionally limits their role by viewing them only as arbitrators between innovators and users (Canzler et al. 2017; Howells 2006; Stewart & Hyysalo 2008). This research highlights their role as active participants through their ability to harness temporal rhythms to influence II cultivation.

From a practical perspective, this study will be valuable to policymakers who are experimenting with mobility infrastructures in cities. The thesis makes several recommendations to help policymakers successfully prototype e-mobility IIs based on the analysis of how rhythms influence II cultivation. For instance, given the motivating influence of seeing the technical viability of the II in the future, it is advisable to develop an innovation lab where stakeholders can visit to see new and integrated technologies in action. Intermediaries should also research the profile of the future user so that stakeholders can appreciate the commercial business models that will justify investing in the efforts to develop the II. Understanding the impact of past rhythms is also important for policymakers who should anticipate the disciplinary inertia of the past, and make plans to counter it. For example, one way to reduce the drag on II integration by the installed base is to help companies build APIs (application programming interfaces) that allow legacy systems from multiple stakeholders to communicate with each other.

The intermediary emerges as a strong partner to policymakers in harnessing or countering temporal rhythms to cultivate the II. Traditionally considered as only a project manager and liaison with the government, the intermediary is capable of a larger role in multi-stakeholder strategic niches. Given its vantage point and ability to view the project holistically, unlike individual stakeholders whose work is limited to their working groups, the intermediary can adeptly recognise and harness temporal rhythms to drive II integration. By illustrating the inner workings of an II's cultivation, this study makes a case for policymakers to appreciate and work more closely with intermediaries in strategic niches for urban IIs.

1.3. Thesis Outline

This thesis has eight chapters. Chapter 1 discusses the inspiration that motivated the research interests and introduces the study's theoretical framework, research methodology, case study, and contributions. It explains the primary motivation of the researcher to study sustainable transportation systems for cities, primarily by reducing car ownership and integrating public transportation with car-sharing and bike-sharing systems. The goal of the study is stated as an investigation to understand the development of urban e-mobility IIs by examining them through the lens of II cultivation.

Chapter 2 reviews the literature and situates the study in its research domain, which is the study of II cultivation in strategic niches. This chapter evaluates three critical areas starting with large-scale complex information systems known as information infrastructures (IIs). The II literature shows that traditional design methodologies are inadequate for understanding II evolution and IIs instead "grow" through the coordination efforts that cultivate their installed base. The chapter delves deeper on the concept of II cultivation, turning to the CSCW literature on large-scale system collaboration. This review illustrates that II cultivation can be conceptualised as emergent and unfolding over time, but the study of II cultivation is still in its nascent stages, particularly concerning the examination of the role of the temporal context in II cultivation. Finally, since the e-mobility II studied in this thesis resides in cities, the chapter reviews the strategic niche management (SNM) literature, which examines urban infrastructure prototyping in protected spaces. The SNM literature reveals that information systems are widely taken as a black box in SNM research and not examined closely. The chapter concludes by describing the general problem area of the influence of temporality on II cultivation, which will be refined using a theoretical framework to generate specific research questions.

Chapter 3 outlines this study's theoretical framework, which is based on a sociomaterial ontology and the Trichordal Temporal Approach (Venters et al. 2014). This approach provides a framework for understanding II cultivation based on the interaction of temporally embedded human and material agencies. The theory is appropriate for the study of urban e-mobility IIs for three reasons: it addresses the coordination of large-scale digital infrastructures; it recognizes that material agency is as influential as human agency in the study of IIs; and it surfaces the role of temporality and the interplay of the past, present and future in influencing agencies in the present. This study enriches the Trichordal Temporal Approach (Venters et al. 2014) by introducing concepts related to temporal rhythms and their categorization (Jackson et al. 2011) and their interactions (Lefebvre 2004). This enriched theoretical framework guides the research questions and helps refine the problem area to the specific research problem of understanding how temporal rhythms influence II cultivation in a sociomaterial context.

Chapter 4 illustrates the research methodology employed in this study. The chapter explains the philosophical assumptions that have structured the research, starting with the choice of the social constructionist epistemology. Within this epistemology, the chapter describes the selection of interpretivism and the processual approach (Langley 1999) as the theoretical perspective and the case study method (Yin 1994) as the research methodology. It explains the choice of a single case study as the optimal methodology for investigating urban e-mobility IIs. The chapter then introduces the various data collection and analysis methods that are consistent with the theoretical perspective and methodology. It explains why the primary mode of data in this thesis is semi-structured interviews which are examined using a combination of thematic analysis and the narrative and temporal bracketing strategies of the processual approach. The chapter presents some limitations to the research methodology and recommendations on how to overcome issues through cross-checking and triangulation with other data sources. Finally, the chapter explains how to generalise case study research.

Chapter 5 focuses on the case study – the BeMobility project in Berlin - that is used to investigate the research questions. BeMobility started as a strategic niche with the goal of prototyping an e-mobility II. This thesis focuses on three features of the BeMobility II: a smartphone application that recommends the best multi-modal journey that includes various public and private transport options; an integrated payment card that allow users to pay for all public transport and car-sharing and bike-sharing services; and a micro smart grid which can intelligently manage the integration of energy and mobility networks for sustainable transportation. The chapter introduces the major participants in BeMobility and describes the different goals, stages and results of each of the two phases of the project.

Chapter 6 and Chapter 7 describe the data analysis of the evidence gathered from the case study. Part 1 of the analysis (Chapter 6) focuses on answering the first research question, which is related to understanding the influence of temporal rhythms on II cultivation. The analysis illustrates the sociomaterial entanglement in the present during data integration efforts, showing how temporal rhythms influence II cultivation through several ways: they discipline the e-mobility II through *diluting, stalling* and *blocking* II development, and they model the II through *combining, extending* and *replacing* parts of the installed base. Part 2 of the analysis (Chapter 7) addresses the remaining two research questions on what happens when temporal rhythms interact, and why one rhythm dominates another to direct II cultivation towards a particular trajectory. The analysis demonstrates that the intermediary intervenes in the influence of temporal rhythms through the three interventions of *harmonising*, *composing* and *riffing* and therefore, exercises some control over II cultivation. It also shows that the intermediary increases its own capabilities by changing its biographical rhythm to become more technically proficient.

Chapter 8 discusses the main themes brought forth by the analysis of the data and interprets the findings in the context of the current literature. The chapter uses the two-step process of analytic generalisation described by Yin (2003) to confirm the theoretical approach taken by the thesis and to identify findings that can be generalised beyond the case study. The findings and analysis validate the Trichordal Temporal Approach (Venters et al. 2014) and provide the basis for developing the concept of facilitated II cultivation that helps to demonstrate how the intermediary may intervene in the influence of temporal rhythms to guide II cultivation. The chapter also develops the concept of a rhythmic intermediary that contributes to the notion of intermediaries in the strategic niche management (SNM) literature.

Chapter 9 summarises the findings of the study and outlines the theoretical, methodological and practical contributions of this study. On a theoretical level, the thesis makes a contribution to the emerging II literature on temporality and infrastructure. It adds to the SNM literature by describing a new kind of intermediary that can harness temporal rhythms to facilitate II cultivation. The study also makes a methodological contribution through its extension of the processual approach by adding temporal rhythms to organise and analyse processes. On a practical level, the thesis helps policymakers better understand the potential of the intermediary in guiding II cultivation and recommends allocating resources towards developing innovation labs and user behaviour studies that model the II's future commercial and technical viability. The chapter concludes by outlining future areas of research.

2. Literature Review

2.1 Introduction

This chapter provides a critical review of the academic literature relevant to the research domain, which is concerned with the development of sustainable urban mobility systems. With this research objective in mind, the chapter has the following parts.

Section 2.2 reviews the literature on large-scale information systems known as Information Infrastructures (IIs). It draws upon the research related to their nature and the difficulties in designing them due to their complexity. The section describes the key role of the installed base and the ramifications of its path dependency. It frames the problem of II cultivation as one of emergent coordination, underscoring that the II is always in a state of "becoming".

Section 2.3 examines the CSCW literature on emergent coordination and the emphasis on context as a key influencer. It summarises the recent work by CSCW scholars on collaborative design and the concept of infrastructuring as an "unfolding, longitudinal process" (Pipek et al. 2017). The section delves deeper into the literature related to the temporal context of II cultivation, revealing a gap and providing a refinement of the research focus.

Section 2.4 reviews the strategic niche management (SNM) literature to study the impact of the urban context on emergent II coordination. Strategic niches are protected spaces set up by governments to tackle the challenges of motivating alignment amongst multiple stakeholders and bootstrapping the II. The SNM literature, however, views IS development as a black box. It delegates coordination to the role of an intermediary that is limited to being a broker and project manager, highlighting a gap in the literature's examination of the process of II cultivation.

Section 2.5 synthesises the literature and highlights opportunities for the thesis to contribute. It also outlines the research guidelines that emerged from the literature review: the researcher should use a theoretical framework that acknowledges material agency and employ a research methodology that studies infrastructure “in the making” as a process in the flow of time.

Section 2.6 summarises the chapter.

2.2 Conceptualising Information Infrastructures (IIs)

Despite recognition of information systems (IS) as a critical enabler of new kinds of urban mobility, the mobility literature has been mostly limited to their net benefits (Alessandrini et al. 2015; Wagner et al. 2014) and design and implementation are rarely discussed (Brendel & Mandrella 2016). This lack of in-depth investigation of infrastructures is not unprecedented. People tend to take infrastructure for granted, and it only becomes visible only when there is a breakdown (Star & Ruhleder 1996). The process of designing, implementing and maintaining infrastructure remains largely hidden, and the politics, struggles, and choices involved often remain unpacked (Bowker et al. 1995; Hanseth & Monteiro 1997). Researchers have called for deeper examination, emphasising that “understanding the nature of infrastructural work involves unfolding the political, ethical, and social choices that have been made throughout its development” (Bowker et al. 2010). Studying infrastructure requires investigating it "in the making" (Star & Bowker 2002), and foregrounding its elements or using “infrastructural inversion” (Bowker 1994).

This section introduces the concept of information infrastructures (IIs), which represent the kinds of complex information systems needed to build innovative mobility systems. By reviewing the literature on IIs and examining their features, the section aims to bring elements of the e-mobility II to the foreground and provide a basis for understanding its development. The section has four subsections:

Section 2.2.1 introduces the concept of IIs in the IS literature, highlighting their complexity and dynamism and the challenges of designing them.

Section 2.2.2 explains the influence of the installed base on II evolution and illustrates related issues such as the bootstrapping problem and technology lock-ins. It highlights the tension between managed and bottom-up infrastructure emergence as researchers try to understand II cultivation. It also discusses the role of materiality in IIs and the importance of having a theoretical framework that takes it into account.

2.2.1 The Challenge of Complexity in IIs

The defining characteristic of an II is its complexity. IIs are large-scale complex information systems with dynamic and interdependent heterogeneous components (Hanseth & Lyytinen 2010; Star & Ruhleder 1996; Hanseth & Monteiro 2008; Gal et al. 2008; Turner et al. 2006).

These components are socio-technical, which means they include organisations, humans, technologies and institutions (Kling & Scacchi 1982; Edwards et al. 2007). An e-mobility II is similarly complicated given the multitude and diversity of its components: stakeholders from sectors such as energy, transportation, government, and academia; users with differing preferences, needs, and habits; and a range of mobility modes such as car sharing, taxis, buses, and trains (Hildermeier & Villareal 2014).

“... information infrastructures are at any moment of time heterogeneous: they contain components of various sorts – different technological components as well as multiple non-technological elements (individual, social, organisational and institutional) that are necessary to sustain and operate the infrastructure" (Hanseth & Lyytinen 2004).

IIs represent ever growing ecologies of networks: they are recursively composed of other infrastructures and technical elements and are recursively organised from a social standpoint because they are both the outcomes and conditions of design actions (Hanseth & Lyytinen 2010). While diversity and scale are not unprecedented in other parts of IS research, IIs stand out for their "unbounded openness" (Hanseth & Lyytinen 2010). If complexity is the product of the number of "types of components, the number of types of links, and the speed of change" (Hanseth et al. 2006), then IIs exhibit significant complexity in their makeup. Researchers agree that this complexity makes it difficult to design or manage them using the classical model of IT management (Orlikowski & Hofman 1997).

Traditionally, the design phase is a time-bound event with the goal of building applications with predefined contexts, functional goals and predetermined developer and user groups (Ross & Schoman Jr 1977; Agresti 1986; Walls et al. 1992). However, IIs have distributed control (Star & Ruhleder 1996) that make top-down design specifications challenging (Edwards et al. 2007; Freeman 2007) and the success of managerial control unlikely (Hanseth & Monteiro 1997; Tilson et al. 2010a).

The primary driver of lack of control stems from the complexity of IIs: uncontrollable side effects occur when multiple socio-technical components integrate and interact with each other (Kallinikos 2005; Perrow 2008) causing unintended drifts (Ciborra & Hanseth 2000; Hanseth et al. 2006) due to interdependencies (Aanestad & Jensen 2011), which may themselves start a chain of other unexpected and unpredictable side-effects (Hanseth et al. 2006).

The complexity of integrating multiple systems into the II (Hanseth & Ciborra 2007; Kallinikos 2007) has made it necessary for IS researchers to rethink II development approaches, which have not adapted to account for this complexity (Henningsson & Hanseth 2011). IS researchers have consequently come to view II development as an evolutionary, rather than controlled, process (Edwards et al. 2009).

To understand II evolution, researchers need to explore how planned structures intersect and interact with locally emergent structures (Star & Ruhleder 1996). The nascent research in this area needs further investigation both from a theoretical and empirical perspective. Henfridsson & Bygstad (2013) write that "little, if any, research has been geared toward developing a comprehensive understanding of the range and contingencies of causal structures in [digital infrastructure] evolution." IS researchers should investigate the black box of II development just as they were once urged to open the black box of information systems development and closely examine IT development (Orlikowski & Iacono 2001).

This section next examines the installed base, one of the key concepts in IIs, to expose the inner workings of II processes.

2.2.2 The Weight and Cultivation of the Installed Base

The installed base is a core concept in understanding information infrastructures (IIs). It not only represents the technical components of an II but represents all the existing systems, people, organisations and practices upon which the information infrastructure is built (Hanseth & Lyytinen 2004; Star & Ruhleder 1996). The installed base is relational in that it only becomes real to different groups in the context of other systems, persons, and practices (Star & Ruhleder 1996; Orlikowski & Iacono 2001; Venters et al. 2014). In urban mobility IIs, the installed base comprises the existing IS systems, institutions and practices in the different sectors, such as train operators, energy providers, and car-sharing partners. The installed base has to be stable enough to allow expansion (Tilson et al. 2010b), and at the same time, it also needs to be sufficiently flexible to allow innovation. Such is the importance of the installed base that an II is defined as a shared, evolving, open, heterogeneous and evolving *installed base* (Hanseth & Lyytinen 2010) (emphasis added).

The installed base is practically difficult and economically expensive to replace (Rönnbäck et al. 2006; Jackson et al. 2007). Additions must have backward compatibility with existing technology components, neighbouring infrastructures and user skills and learning (Grindley 1995; Star & Ruhleder 1996; Hanseth & Monteiro 1997; Porra 1999; Edwards et al. 2009). The literature calls this "path dependency" (Hughes 1987; Star & Ruhleder 1996; Porra 1999), given the high level of integration and interdependence between an II's parts and its installed base.

An II is never built from scratch and always adds to the existing sociotechnical base. Edwards et al. (2007) suggest that instead of using the word "building an infrastructure," scholars should consider the term "growing" which would capture the existence of the installed base and the "sense of an organic unfolding within an existing (and changing) environment." Instead of II development, researchers refer to its evolution as II "installed base cultivation" (Hanseth & Lyytinen 2010), which draws attention to how IIs evolve incrementally over long periods of time with extensions and modifications to the installed base (Aanestad and Jensen, 2011). The concept of cultivation stands in contrast to any planning-based approach for IIs and "stresses how evolution is shaped by initial choices and how "what is already in place" (i.e., existing technologies, work practices, routines, assumptions, organizational structures) enables or constrains possibilites of adapting, interconnecting, or creating new components." (Grisot et al. 2014)

There are several implications of the weight of the installed base, which is considered both "a resource for creative design and innovation or a trap from which it is difficult to escape" (Lanzara 2014). On the one hand, it provides the basis for the II to grow, and on the other hand, it exerts inertia and is resistant to change (Igira & Aanestad 2009; Hanseth & Monteiro 1998). This means that an II will not "jump" between old and new versions but that the process will be one of cultivation or "gradual and step-wise transition" (Aanestad and Jensen, 2011). In fact, understanding and specifying the transition process is critical to the II's success, even more so than outlining any specific goals at the initial outset (Hanseth and Aanestad, 2003).

A cultivation approach is, therefore, useful because it "acknowledges the existence of the installed base, and it seeks to address change in an incremental and gradual manner" (Grisot et al. 2014). The next two sections describe the distinctive problems faced in working with the installed base due to its complexity and unpredictability.

2.2.3 Technology Traps and Lock-in

Technology decisions made without sufficient consideration can become impossible to unlock, constraining II cultivation and becoming technology traps or reverse salients (Hughes 1987). In regards to this study's focus, keeping a mobility infrastructure open to different types of modes (such as bike-sharing and autonomous vehicles) requires an adaptive architecture, and technology traps are dangerous to the longevity of the II. The two common strategies of using standards and modularisation to build information systems can paradoxically also lead to technology lock-ins for IIs.

IS research has long recognised standards as crucial building blocks for software development that increase interoperability (Star & Ruhleder 1996; Edwards et al. 2007). This is also the case in IIs where "layered interoperable standards and common definitions of application and service interfaces are essential for the infrastructure's use and growth" (Tilson et al. 2010b). In the case of the installed base, they are useful but can also paradoxically make the II resistant to change in the long run (Hanseth et al. 1996; Egyedi 2002). This inflexibility arises because a large installed base continually attracts complementary products by using established standards, and further reinforces the existing design (Grindley 1995). Such “self-reinforcing mechanisms” (Arthur 1989) increase the embeddedness of the current design as more organisations and systems use it, creating a lock-in of the existing form. One way to tackle this challenge is to use flexible standards that are regularly updated, which can help avoid design stagnation that may result from using standards that only cater to the needs of the global infrastructure instead of appreciating local contexts (Braa et al. 2007). Alternatively, policymakers can also use gateways that link systems on different communication protocols instead of standards (Hanseth 2001; Hanseth et al. 2006).

Modularization or the division of software into independent functional units (Hanseth & Lyytinen 2004) is another principle used in IS development to streamline combination and interoperability of different components. Modules make extensions easier as they have "the potential to remove the tight couplings between information types and their storage, transmission, and processing technologies” (Tilson et al. 2010b).The principle of modularity can also partially address the technology lock-in issue as new services are added locally and incrementally in small components, avoiding major changes that reverberate across the entire II (Hanseth & Lyytinen 2010; Aanestad & Jensen 2011).

However, a closer look at modularised digital objects reveals that their “functional simplification” (the basic function any other object can elicit from them) can potentially limit the kinds of complex functions they can participate in (Kallinikos 2006). Even as simplification enables modules to be chained together to form procedural sequences (Luhmann 1993; Nardi & Kallinikos 2007), it can also make them closed to diverse types of extension. One possible strategy to limit II inflexibility resulting from over-simplifying the interfaces to modules is by restricting modularisation to core elements that will not change and are relatively straightforward (Hanseth et al. 2006).

2.2.4 The Bootstrapping Problem

The ability to attract users to an installed base is essential to the II's growth. The II's value grows as its user base grows and attracts others, a phenomenon called the network effect (Shapiro & H. Varian 1998). The bootstrapping problem is the challenge of meeting the needs of early adopters so that they share and extend the II to attract more users (Hanseth & Aanestad 2003; Hanseth & Lyytinen 2010). If the initial design of the II does not appeal to users, the II will cease to grow and exist. Hanseth & Lyytinen (2010) advocate a design theory to meet the bootstrapping challenge. Their recommendations include designing initially for usefulness, drawing upon the existing installed base, deploying persuasive tactics to attract users, and making the architecture modular with layers and gateways. However, one or all of these intentions can be side-tracked because of the unpredictability of component interactions (Kallinikos 2005), and the design theory does not adequately explain the causal links that drive the II's development (Koutsikouri & Henfridsson 2017).

When II designers define II components to meet the needs for an initial set of users, they might also inadvertently make the infrastructure inflexible in meeting the requirements of future users not yet considered or encountered (Hanseth 2014). This tension is referred to as the adaptability problem of II design (Hanseth and Lyytinen 2010, Edwards et al. 2007).

The challenges of technology lock-ins, bootstrapping and adaptability make it difficult to use traditional management approaches to cultivate the II. The table below explains the characteristic features of IIs and the installed base, which “wrestles with the inertia of the installed base and inherits strengths and limitations from that base” (Star & Ruhleder 1996).

Characteristic	Explanation	Papers
Complex and unpredictable	IIs are complex and dynamic which leads to unintended consequences.	Hanseth (2006); Henningsson & Hanseth

		(2011)
Sociotechnical	The installed base is a concept that encompasses "all that is there" already including practices, technologies, skills, and people. II cultivation is more than just a technical concern. It is also "characterized by political and negotiation processes" (Sahay et al. 2009).	Bowker & Star (1999); Ciborra & Hanseth (1998); Hanseth & Lyytinen (2010)
Relational	Infrastructure is not an end state but emerges in practice as people are connected to activities and structures.	Star & Ruhleder (1996); Orlikowski & Iacono (2001); Venters et al. (2014)
Largely invisible	IIs are usually invisible, taken for granted and unnoticed by people, and only become visible when they break down.	Star & Ruhleder (1996)
Grows by network effect	The network grows with the number of users it has and this increases its usefulness for others as well.	Ciborra & Hanseth (1998); Shapiro & Varian (1998)
Grows incrementally	The installed base is usually extended and evolves in an iterative, incremental and gradual manner.	Ciborra (1997); Grisot et al. (2014); Hanseth & Aanestad (2003); Constantinides & Barrett (2014)
The installed base can both constrain and enable growth.	The installed base can cause inertia due to path dependencies and stimulate growth through extension on existing modules.	Aanestad et al. (2017); Bietz et al. (2010); Grisot & Vassilakopoulou (2015)
Faces bootstrapping problem	The bootstrapping problem is the challenge of meeting the needs of early adopters so that the II can grow.	Hanseth (2014)
Vulnerable to technology traps and lock-ins	Once an infrastructure starts along a path, those choices get "locked-in regardless of the advantages of alternatives" (Arthur, 1996) making adaptability difficult.	Arthur (1996); Hughes (1987)

Table 1: Characteristics of IIs and the installed base

2.2.5 Tensions Between Managed and Bottom-up Cultivation

Given the path dependency of the installed base, it is clear that "the installed base of the existing infrastructure and its scope and complexity influences how the new infrastructure can be designed" (Hanseth & Lyytinen 2004). As this installed base grows, network effects take over "and growth becomes self-reinforcing, through cultivation" (Bygstad et al. 2017). For this study, another key to understanding installed base cultivation is analysing when it is successful.

Before delving into this question, it is necessary first to define the criteria for successful cultivation. Rolland (2014)'s research on failure to cultivate an installed base provides a useful matrix by which to evaluate II cultivation. This study reframes his three criteria for II failure as prerequisites for success as below:

- *For II cultivation to be successful, all relevant parts of the installed base must be combined in new solutions.* "Relevant parts" here refers to the need that *both* the social and material aspects of the installed base must be cultivated and combined to grow the II. For example, while technical interoperability through APIs and gateways is necessary for combining parts of the II, so is cultural fit (Bartis & Mitev 2008).

- *For II cultivation to be successful, different modules of the installed base must be extended*. Developing new functionality through extension aligns well with IIs that have a "multi-layered character" (Hanseth & Lyytinen 2010). Extension can be achieved by using software modularisation, which makes it easier to add experimental new modules to the installed base and to coordinate stakeholders around specific outcomes (Grisot et al. 2014; Aanestad & Jensen 2011). This is akin to "structural deepening" of infrastructures (Arthur 2009) where the II is extended by adding new modules to enrich the functionality of existing modules.

- *For II cultivation to be successful, installed base modules that are reverse salients must be replaced.* It is necessary to replace technologies and design choices that are causing technology lock-ins or are reverse salient (Hughes 1987) which may regress the entire II. This is akin to the concept of "internal replacement" of infrastructures (Arthur 2009) where modules are replaced and connections rearranged.

Success in the long term for an II is driven by its continued existence and growth from a global perspective. However, localised success may be perceived differently by various social groups. For example, in an e-mobility II, bike-sharing users may find the booking module of the II more useful than the e-scooter users, which will result in one part of the II becoming stagnant while the other continues to grow.

Between the two extremes of completely replacing modules and combining existing modules, researchers have found that the installed base resists radical change and projects that have attempted to achieve replacement have met with poor results (Aanestad & Jensen 2011; Monteiro & Hepso 2001; Rolland & Monteiro 2007). Trying to replace the installed base has been referred to as installed base-hostile (Hanseth et al. 1996). On the other hand, extending the installed base or being installed-base friendly by working with existing components has resulted in better outcomes (Grisot et al. 2014). One potential issue is that being too installed-base friendly can also result in technology lock-ins and result in "over-fitting" (Aanestad et al. 2017) as the current version of the II's design gets reinforced. As discussed in the last section, this can be detrimental to the longevity and success of the II as it becomes less adaptable to new users and demands. These issues show that successfully achieving installed base cultivation by combining, extending or replacing (per Rolland (2014)'s criteria) the installed base is a complicated and uncertain undertaking, further underscoring the gravity of the question about how to manage it.

As discussed earlier, II scholars agree that given the complexity of IIs, it is impossible to manage them in the traditional top-down manner of strategic management advocated by scholars such as Weill et al. (2002). There is consensus that a preferable cultivation approach would include "monitoring and intervention activities over strict control and ongoing adjustments over rigid preplanning" (Aanestad et al. 2017). However, a literature review shows there is disagreement between the best way to intervene in II cultivation and the extent to which it is possible (Henningsson et al. 2017). On the one hand, there has been scepticism about the ability to have any control over the implementation of complex IT systems with many case studies of failed projects and unintended consequences (Ciborra et al. 2000; Hanseth & Ciborra 2007; Perrow 2008). On the other hand, there is also a stream of literature on strategic intervention that runs the gamut of papers that advocate a relatively top-down process of initial design principles (Hanseth & Lyytinen 2010) to a relatively bottom-up process of empowering users to contribute to design (Ghazawneh & Henfridsson 2013). Table 2.2 categorises these different intervention approaches below.

Strategy	**Cultivation Strategy**	**Paper**
Manage strategically	Top performing managers can identify initiatives to invest in that create agility.	Weill et al. (2002)
Design for bootstrapping	Growth can be driven and users acquired by using simplicity, usefulness and persuasiveness (Hanseth & Lyytinen 2010) Stakeholders should invite and persuade the most motivated users to join and show them immediate benefits so that they can spread the word for others to join. (Hanseth & Aanestad 2003)	Hanseth & Aanestad (2003); Hanseth & Lyytinen (2010)
Develop standards	Standardisation increases compatibility between heterogeneous modules (Hanseth et al. 1996). However, standards should be flexible so that they can streamline integration in the present, but are checked at each stage for their adaptability and alternative ways are kept open for discussion	Edwards et al. (2007); Hanseth et al. (1996)

	(Edwards et al. 2007).	
Design for openness	The growth of the installed base is incremental and adaptive, which requires a technical design that supports openness.	Vassilakopoulou & Marmaras (2017)
Generate contextual triggers	Guide infrastructure growth by pursuing actions that create generative impulses, including by adding service value, creating design attractors, and lowering infrastructure barriers. *The paper by Koutsikouri* & Henfridsson *(2017) is one of the few IS studies on digital infrastructures for urban mobility as it examines the digitisation of the Stockholm public transport system*.	Koutsikouri & Henfridsson (2017)
Pursue modularity and incremental strategies	Decouple components to reduce complexity in implementation (Hanseth & Lyytinen 2010). Create a modular implementation strategy that lowers costs and stakeholder hesitance by relying on "stable intermediary" solutions in a step-wise growth plan (Aanestad & Jensen 2011).	Hanseth & Lyytinen (2010); Aanestad & Jensen (2011)
Develop gateways	Develop interfaces or APIs that connect different parts of the network achieved through facilitating coordination amongst stakeholders.	Jackson et al. (2007); Hanseth (2001)
Remain flexible to accommodate politics	Appreciate interplay of political and technical configuration of IIs and develop flexible configurations needed to adapt to changing power relations (Sahay et al. 2009).	Sahay et al. (2009)
Use grafting	Actors in control of certain parts of the infrastructure should effectively merge goal-oriented information system innovation with existing socio-technical arrangement.	Sanner et al. (2014)
Exercise controlled devolution	Strategically give control to actors and then let them relinquish control to others when the responsibilities to build the technology becomes too much to handle (to prevent inertia).	Nielsen & Aanestad (2006)
Adopt polycentric governance	Use bottom-up governance of information infrastructures through engaging stakeholders. (This strategy may increase complexity and lead to a divergence from the initial vision, and "spillovers" as one stakeholder's governance affects another).	Constantinides & Barrett (2014)

Find balance between local concerns and global requirements	An II's success lies in maintaining balance: developers must balance the local needs of consumers with the global requirements for standards and uniformity.	Rolland & Monteiro (2002)
Employ infrastructuring	Improve II cultivation by blurring the distinction between users and designers and integrating the creative activities of users.	Pipek & Wulf (2009)
Transfer design capability to users or third party providers	Trigger involvement from an eco-system of partners in service development.	Ghazawneh & Henfridsson (2013)

Table 2: Different cultivation strategies explored in the literature

The debate on different cultivation strategies outlined in the table above shows that the study requires more in-depth exploration of *how* cultivation or the coordination of integrating sociotechnical components into the installed base occurs. The CSCW literature has focused on the coordination of large-scale information systems and the next section reviews this literature to examine the cultivation process more closely.

2.3 CSCW Research on IIs

The integration of sociotechnical components to the installed base involves collaboration between different stakeholders and investigating this coordination is crucial to understanding the cultivation of e-mobility IIs. The CSCW literature broadly addresses the coordination problem of information systems (Schmidt & Bannon 2013), and this section reviews the literature to gain insights into II cultivation in four sub-sections (described below).

Section 2.3.1 shows how researchers can conceptualise II cultivation as emergent coordination which is highly dependent on its context. The section highlights the impact of four contextual aspects on II cultivation: the role of people, materiality, temporality and the urban environment.

Section 2.3.2 describes how emergent practices of people contribute to emergent cultivation, and how people change practices to find alternative ways to meet their projected goals.

Section 2.3.3 describes the importance of materiality on II cultivation, where materiality refers not only to the technology components in their present form but also the weight of II's installed base (Star & Ruhleder 1996). The section discusses how to consider materiality as constitutive of emergent coordination instead of distinct from it.

Section 2.3.4 reviews the influence of temporality on II cultivation. It reviews how temporality has been considered in the CSCW and II literature and the tensions between the influence of project time and infrastructure time, identifying a critical gap and highlighting the need for deeper examination.

Section 2.3.5 describes why building IIs in cities that have deeply entrenched infrastructures makes it particularly hard to bootstrap the II and motivate stakeholders to align efforts. The next section (Section 2.4) examines the strategic niche management (SNM) literature on the urban context and its impact on II cultivation.

2.3.1 II Cultivation as Emergent and Highly Contextualised

The context of II development is a dynamic, distributed and fast-moving environment where uncertainty and unpredictability are typical. There are several factors that underscore the dynamism of a multi-stakeholder II's context. First, geographically dispersed teams of multiple stakeholders develop an II, each working within the confines of its offices, adding features to the installed base. These stakeholders must coordinate their activities despite being distributed across a city or farther. Second, each team's work depends heavily on the business ambitions, product lifecycle and state of technologies within its organisational boundaries. The work in each local structure is highly contextualised and not managed at the II's global level. Third, there is a high level of dependency on the response from other teams across the multi-stakeholder ecosystem as IS products must integrate with each other to add to the II, which also perpetuates unpredictability. Fourth, an II's environment is relatively fast-paced since specific components of the II must be built within the timeframe of a project, especially as further funding is often dependent on showing results at each stage. Finally, the nature of technologies can change during the project and require specialists as new team members. Coordinating the activities of multiple stakeholders to contribute to II cultivation is extremely challenging in such a dynamic environment. The CSCW literature's work on the nature of increasingly complex and distributed work (Faraj & Xiao 2006; Okhuysen & Bechky 2009) is helpful in understanding how this occurs.

The CSCW literature has evolved over the years with the scholarly understanding of the workplace. Researchers began studying coordination formally with the emergence of railroads and large-scale manufacturing (Scott & Davis 2007). Initially, coordination was analysed using an information processing paradigm (Thompson 1967; Galbraith 1977) that assumed a predictable environment in which coordination models could be designed, shared and implemented across an organisation. Researchers believed that ICT technologies could significantly improve organisational coordination (Malone & Crowston 1990) and also emphasised managing interdependence amongst resources and activities (Malone & Crowston 1994; Malone et al. 1999). However, the environment in which actors interacted was unrealistically assumed to be predictable, with the belief that predefined mechanisms could aid coordination (Faraj & Xiao 2006). As organisations moved from manufacturing to service-based companies (Davis 2003), the limitations of this assumption became evident. A static view of the environment failed to account for the evolving and unexpected nature of work and its effect on coordination (Okhuysen & Bechky 2009).

Unexpected changes in the workplace could also derail meticulous planning, including the addition of geographically dispersed and interdisciplinary teams of specialists (Child & McGrath 2001; DeSanctis & Monge 1999) and new forms of collaboration devised on the fly as teams interacted with each other and with technologies (Faraj & Xiao 2006). Some environments were also, by their nature, unpredictable or "fast-response" (Faraj & Xiao 2006) where coordination emerged as specialists were brought together to work on a problem. Also, the nature of work itself could change rapidly with technology disruptions in the domain making it necessary for coordination management to change accordingly (Faraj & Xiao 2006). Formalized solutions to the problem of integrating work meant that there was no room to account for the work that resulted as unplanned contingencies in response to coordination challenges (Okhuysen & Bechky 2009).

This gap between the traditional view of coordination as structured and the reality of coordination as an ongoing process of interrelated actions in complex and highly contextualised settings has stimulated new research in the field. Researchers are moving away from studying how to optimise structures for coordination efficiency and instead focusing on coordination *as it happens* (Okhuysen & Bechky 2009). They began to view coordination as emergent and highly conceptualised. Based on the similarities between an II's context and the dynamic and fast-paced organisations described in recent CSCW papers, this study subscribes to the CSCW definition of coordination as a "temporally unfolding and contextualised process of input regulation and interaction articulation to realise a collective performance" (Faraj & Xiao 2006) and views II cultivation as an emergent process (Edwards et al. 2009). Two characteristics of emergent coordination are especially well-aligned with the conceptualisation of II cultivation (Faraj & Xiao 2006). First, coordinated actions unfold over time, constrained by the history of previous interactions. Such a view resonates with the recurring theme of path dependency in IIs as new components integrate with an installed base. Second, actor interactions drive coordination, which, as discussed earlier, is emergent rather than predestined. As discussed in the last section, it is almost impossible to design IIs in a centralised controlled manner due to the unpredictability of component interactions.

The CSCW literature on emergent coordination faces similar tensions between formal control and flexible interventions as found in the II literature on managing II cultivation. In fast-response organisations, formal mechanisms (Okhuysen & Bechky 2009) have been seen to coexist with improvised coordination (Kanawattanachai & Yoo 2007).

“the dilemma of coordination in such settings is that, on the one hand, there is a need for tight structuring …. but, on the other hand, because of the need for rapid action and the uncertain environment, there is a competing need to rely on flexible structures …” (Faraj & Xiao 2006).

To further examine the tension between control and intervention, the following sections examine the influence of different features of an IIs context on emergent coordination: the role of people, materiality, temporality and the urban environment.

2.3.2 The Role of People

The interaction of people with context, an essential part of understanding emergent coordination, is investigated in practice-based studies. Emergent practices drive emergent coordination in non-routine, dynamic and contextualised settings like IIs. Practice research (Orlikowski 2000; Brown & Duguid 2001) examines how knowledge and work coordination in such contexts do not rely on pre-identified interdependencies, and practices do not subscribe to the role of rules at the expense of actors achieving their end goals. In fact, actors are given the capacity to make "practical and normative judgments among alternative possible trajectories of action" (Faraj & Xiao 2006). Research studying emergent practices has investigated, among other things, the coordination mechanisms (interactions, tools, and technologies) that enable humans to enact a collective performance (Kellogg et al. 2006; Kling 1991). For example, coordination occurs when there is knowledge sharing through the emergence of boundary spanning competence and use of boundary objects (Levina 2005), the use of shared language (Okhuysen & Bechky 2009), and agile cross-boundary practices (Kellogg et al. 2006).

Scholars have also studied emergent coordination practices when teams have had to overcome traditional organisational boundaries, something that is particularly relevant to multi-stakeholder e-mobility IIs. In this context, studies have reviewed online communities (Faraj et al. 2011); new product development teams (Carlile 2004; Carlile 2002); cross-functional collaborations (Kellogg et al. 2006); emergent groups responding to disasters (Majchrzak et al. 2007), and emergency response teams (Faraj and Xiao 2006).

Practices in such contexts are generative in nature, emerging as they encounter new situations. Faraj & Xiao (2006) believe that in such contexts, practices can be viewed more as *modus operandi* (manner of working) than *opus operaturm* (finished work) (Bourdieu 1990). The coordination of this emergent collaborative work is itself emergent in nature (Kling et al. 2001; Faraj & Xiao 2006; Monteiro & Hanseth 1995). Many scholars believe that this emergence is essential to have a full picture of the process of coordination (Kellogg et al. 2006; Majchrzak et al. 2007; Okhuysen & Bechky 2009).

2.3.2 The Role of Materiality

One of the issues in the literature on emergent coordination has been limiting the role of technology to just a tool for collaboration. However, as discussed, IIs are relational in nature (Star & Ruhleder 1996; Orlikowski & Iacono 2001; Venters et al. 2014), and materiality is constitutive of this relational lens, not distinct from it. This study needs to examine the role of materiality in the emergent cultivation of the e-mobility II.

Materiality here is defined "the arrangement of an artefact's physical and/or digital materials into particular forms that endure across differences in place and time and are important to users," (Leonardi 2012) while material agency comprises "the ways in which a technology's materiality acts" (ibid).

Historically, most IS literature focused on the use of technologies as tools. It has largely considered technology as separate from practice and an enabling or constraining force on it (Beane et al. 2015). For example, studies have shown that technologies support coordination through community building (Kellogg et al. 2006; Malhotra & Majchrzak 2014; Nardi et al. 1995), through technologies that help temporally distributed teams (Bardram 2000; Chua & Yeow 2010) and by sharing knowledge across boundaries (Kanawattanachai & Yoo 2007; Jarzabkowski et al. 2012). Meanwhile, other research has studied ICT by identifying the coordination challenges that result from the use of technologies (Cramton & Webber 2005; Mortensen & Neeley 2012).

Recent literature, however, has argued for the examination of material agency in practice (Button 1993; Leonardi & Barley 2008; Orlikowski 2007). For these researchers, materiality is not a fixed and independent property (Barad 2003) that constrains, enables or prescribes practice, but inherent to how practice is materially enacted (Orlikowski & Scott 2008; Introna 2011). They subscribe to the view that "practice only exists as it is materialised in specific times, places, texts, artefacts, bodies, infrastructure, and so on" (Orlikowski and Scott 2014 as quoted in Beane et al. (2015)). The call to move away from a deterministic view of technology emphasises that the effects of technologies are a function of their use (rather than the technologies themselves (DeSanctis and Monge 1999; Kling 1991; Orlikowski 1992; Sahay & Robey 1996).

This study also believes that humans and materials are interlinked in II cultivation and technology is not just a tool for humans to generate outcomes. The technology in e-mobility IIs includes both software systems, such as timetabling systems for trains, and hardware technologies such as charging infrastructure stations for electric vehicles. Any investigation into II evolution must take all parts of the installed base into account. As discussed in the criteria for installed base success, "all relevant parts," i.e. *both* materiality and social practices must be taken into account when investigating cultivation (adapted from (Rolland 2014)).

Some studies that have examined the role of materiality by looking at aspects like digital infrastructure generativity (Henfridsson & Bygstad 2013), the integration of resources (Venters et al. 2014), and the increasing importance of algorithms (Galloway 2006; Lash 2007). This literature was critical in motivating the researcher to choose a theoretical framework that took technology seriously (Orlikowski & Iacono 2001) (discussed further in Chapter 3).

2.3.3 The Role of Temporality

A distinctive feature of II cultivation is its temporal context. IIs work at a completely different time scale than typical IT projects, which last anywhere from three to five years, whereas "IIs endure over periods of multiple decades" (Monteiro et al. 2012). The temporal scales of II cultivation extend beyond "project time" to include what Karasti et al. (2010) call "infrastructure time". Infrastructure time not only includes the history and path dependency of an installed base but also comprises an appreciation of the open-ended-ness of a project by taking into account future demands such as possible revisions and changes to the installed base. Karasti et al. (2010)'s work links the past-present-future continuum in what they refer to as an "extended temporal horizon" that forms an essential component of collaborative infrastructure development.

In the case of e-mobility IIs, the temporal horizon includes the history of the existing transportation infrastructure (e.g. roads, bridges, vehicles), the dynamics between the existing stakeholders (e.g. OEMs, public transport providers), and related habits of users, practices and institutions. It also includes the anticipated changes in mobility including the evolution of electric vehicles and battery storage, the changing demands of users, and the advances in artificial intelligence and driverless cars. Any investigation of II cultivation, therefore, must examine the impact of this temporal context. Given the scale and long duration of IIs, Williams & Pollock (2012) recommend that "[rather] than study technologies at particular locales or moments that we should follow them through space and time".

The CSCW literature has researched temporality for many years. However, Kallinikos (2004) points to the CSCW community as having a "here and now" problem which investigates practice-in-use rather than the examining the "biography" of IS artefacts and practices (Pollock & Williams 2010). This negligence also led (Reddy et al. 2006) to urge scholars to remember that "time also matters" in collaborative studies. Several studies have critiqued the digital infrastructure literature for not focusing on longevity and centring research around short-term aspects (Karasti et al. 2010; Monteiro et al. 2012; Williams & Pollock 2012), which limits understanding of IIs in the long run. Investigating temporality in IIs remains a gap with IS researchers acknowledging that there is a lack of theoretical and methodological frameworks that account for multiple temporal scales (Bowker et al. 2010; Karasti et al. 2010).

In response to these criticisms and to examine distributed coordination, interest in temporal coordination has grown (Ancona & Chong 1996; Ancona et al. 2001; Orlikowski & Yates 2002; Staudenmayer et al. 2002; Walther 2002; McGrath 1990). The notion of time has been researched in the context of collaboration occurs across time zones, teams that have asynchronous communication amongst members, as well as the use of ICT in the coordination of knowledge workers (Kellogg et al. 2006). Researchers are also starting to examine temporality in emergent coordination, and the ICT tools that support temporal coordination (Chua & Yeow 2010; Bardram

2000). Reddy et al. (2006), for example, have examined variable time horizons and temporal rhythms and their influence on coordination processes related to resource sharing.

Researchers are shifting the focus to "when" coordination happens from the traditional focus on "how" it happens (Constantinides & Barrett 2012; Faraj & Xiao 2006). The last section demonstrated that II cultivation could be conceptualised as emergent coordination and the CSCW research has also focused on how infrastructures emerge over time. The term "infrastructuring" (Star & Bowker 2002) has been used to define II cultivation as a "longitudinal, unfolding process" (Pipek et al. 2017) that is always in a state of becoming. The concept of infrastructuring focuses on the sociotechnical relations that comprise the II, advocating that to understand IIs, researchers must understand the work that goes into facilitating a productive relationship between people, organisations and technologies (Grisot & Vassilakopoulou 2017; Pipek & Wulf 2009; Karasti et al. 2010).

These "long-term, relational preoccupations" have led to a renewed interest in infrastructure development and about their making in more emergent terms (Karasti & Syrjänen 2004). However, the study of temporality in II cultivation is still nascent, and there remains "an urgent need to develop approaches, methods and tools for collaborative infrastructure development that would allow for and support different temporal orientations to ensure effective and productive collaborations" (Karasti et al. 2010). The tension between long-term concerns and short-term implementation tactics, for example, must be resolved in some way since infrastructure is "large" spanning time and space, but it is also "small" coming in contact with routine and everyday practice" (Bowker et al. 2010).

The sustainability of long-term change for an II has also been emphasised in research (Henfridsson & Bygstad 2013; Tilson et al. 2010; Ciborra 2000b) as scholars have tried to understand infrastructure change and evolution (Ribes & Finholt 2009; Tilson et al. 2010). Yet this section has identified a critical gap in the study of II cultivation related to the fact that "longitudinal ('biography') perspectives of collaborative technology are scant" (Monteiro et al. 2012). In particular, it has identified that the literature has weakly addressed frameworks that account for both short-term implementations and long-term infrastructure perspectives (taking into account the present and also the past dependencies and the future aspirations) (Karasti et al. 2010; Williams & Pollock 2012). Researchers have recognised this tension between short-term needs and long-term goals as a crucial challenge in II development (Karasti & Baker 2004; Ribes & Finholt 2009). Conceptualizing the process of II cultivation as a longitudinal process (Pipek et al. 2017) also has implications for this study's research methodology: a process-oriented approach must be used to examine e-mobility IIs "in-the-making" (Star & Bowker 2002) since "a process view exposes how an infrastructure comes into existence" (Grisot & Vassilakopoulou 2017).

This gap in the literature refines the research domain of this study to concentrate on the influence of temporality in the cultivation of e-mobility IIs and will focus on "addressing collaborative infrastructure development with a more explicit interest in temporality" (Karasti et al. 2010). The table below provides a summary of the different ways in which the literature conceptualises temporality in IIs.

Concept	**Explanation**	**Papers**
Longitudinal process	An infrastructure evolves over long periods of times and is the result of a cumulative process of incremental additions. Researchers should not ask *what* is infrastructure but *when* is infrastructure. Infrastructuring can be considered a "longitudinal, unfolding process" (Pipek et al. 2017).	Pollock & Williams (2010); Pipek et al. (2017)
Biography of artefacts	IIs should be examined against the entirety of their biography (past, present and future) instead of just at local points of implementation.	Monteiro et al. (2012); Williams & Pollock (2012)
Project time	Most projects are centered around short-term thinking that is limited to project	Karasti et al. (2010)

	management and funding cycles.	
Infrastructure time (or long term)	Infrastructure time includes both the long and short-term design and implementation, and long-term evolution and maintenance aspects of II cultivation.	Ribes & Finholt (2009); Karasti et al. (2010); Edwards (2003)
Long now	The long now calls for researchers to look across multiple scales of infrastructure temporality.	Brand (2008)

Table 3: How temporality is conceptualised in IIs

2.3.4 The Role of the Urban Context

The final part of the literature on emergent coordination requires focusing on another context of II cultivation that is especially relevant for this study: urbanisation. The deeply entrenched nature of urban transportation systems makes it extremely challenging to inspire stakeholders to contribute to the collective platform, and to understand the needs of users so that the II can be bootstrapped. Yet neither the CSCW or II literature address the II cultivation of urban infrastructures. The next section (Section 2.4) reviews the strategic niche management literature (SNM) on the prototyping of urban infrastructures after briefly summarising the main insights of the chapter so far.

Summary

Part 1 and Part 2 of this chapter have examined the IS literature related to large complex information systems called Information infrastructures (IIs) and the emergent coordination that comprises II cultivation.

The II literature review demonstrated that IIs are difficult to manage because of their complexity (Hanseth & Ciborra 2007; Kallinikos 2007). While researchers agree that the idea of top-down management is unrealistic, the literature revealed tensions between different levels of strategic intervention to successfully manage II cultivation. The process of II cultivation was next examined to examine this tension more closely by reviewing the CSCW literature.

The CSCW literature views II cultivation as an emergent unfolding process that is deeply influenced by its context and environment. The longitudinal nature of IIs underscores that II cultivation is not time-bound leading researchers to advocate that they should be studied against the broader history of their development instead of only at the point of local implementation (Williams & Pollock 2012). However, the literature revealed a gap in understanding the temporal context of II cultivation, refining the research focus of this thesis.

The table below shows the different ways in which the CSCW literature has conceptualised emergent coordination.

Context	**Strategy**
Static perspective on coordination: Traditional organization with a top-down structure and hierarchy providing a stable environment	This perspective believed that centralized decision making and rules-based processes can manage coordination (Thompson 1967; Galbraith 1977).
Dynamic perspective on coordination: High velocity or fast-response organizations	This perspective argues that coordination is emergent in environments where work is highly contextual and interdisciplinary (Faraj & Xiao 2006). Four aspects of the II's context are important to explore as below: ***The role of people and practice:*** • *Emergent practice:* Practices emerge in response to non-routine and dynamic work environments leading to emergent coordination (Majchrzak et al. 2007) ***The role of materiality:*** • *Technology as tool:* Technologies support coordination in various ways including community building and knowledge sharing (Kellogg et al. 2006; Bardram 2000; Jarzabkowski et al. 2012).

	• *Technology as constitutive of work:* This approach emphasises material enactment in practice and believes that technology is constitutive of emergent coordination. (Introna 2011; Orlikowski and Scott 2014). ***The role of temporality:*** • *Project time vs.infrastructure time*: Emergent coordination is perceived through a processual perspective, following the temporal storylines of IS artefacts (Ribes 2014; Monteiro et al. 2012; Pipek et al. 2017). The influence of temporality in II cultivation is under-examined in the literature and there remains a tension in understanding how to link II cultivation in the short-term with its longer biography (infrastructure time). ***The role of the urban environment:*** • *The challenges of bootstrapping and stakeholder alignment:* The deeply entrenched nature of urban transportation systems makes it uniquely difficult to cultivate a multi-stakeholder e-mobility II.

Table 4: How CSCW has conceptualised emergent coordination

2.4 Strategic Niche Management Research on Urban IIs

As discussed in the section on coordination and IIs, context is essential to understanding the evolution of IIs and the study must examine the context of prototyping innovative infrastructures specifically for cities. The problem of stakeholder alignment and bootstrapping is exacerbated when attempting radical innovation in a sector like transportation that has a deeply entrenched installed base. This happens for two reasons: first, the stakeholders are not motivated to collaborate and integrate their systems; and second, attracting users to an innovative mobility II is challenging since user needs are difficult to anticipate and understand. Even though the IS literature does not address prototyping for cities, there is comprehensive research on city-based experimentations with new types of infrastructures. This section, therefore, looks towards the literature on strategic niches where radical innovation for cities occurs to find valuable insights for investigating the design and development of urban e-mobility IIs.

This section has three sub-sections:

Section 2.4.1 reviews the concept of the strategic niche followed by an examination of frameworks used by researchers to understand them, focusing on the strategic niche management (SNM) literature and its treatment of technology design and development in infrastructure prototyping experiments.

Section 2.4.2 investigates the examination of coordination in the SNM literature including the role of ICT, highlighting the role of intermediaries and the black boxing of IS development.

2.4.1 The Concept of the Strategic Niche

Urban mobility infrastructures have a large installed base, including roads, vehicles, fuelling stations, rules and practices, and public agencies. Cultivating such a deeply entrenched installed base into a system that is sustainable with limited-to-none individual car ownership is extremely challenging. Several disruptions would have to take place in the current status quo including:

- New types of shared electric cars, bikes and scooters must be embedded into the existing spatial, social and cultural structures (Schneidewind 2011) and energy infrastructures must be extended to support electric vehicles (Dennis & Urry 2009; Mitchell et al. 2010).

- ICT systems related to a range of mobility services would have to integrate, including car-sharing, parking lots, bikes and public transportation (Vergragt & Brown 2007; Kemp & Rotmans 2005).
- Citizens would have to change their habits to adopt multimodal travel based on public and private transport, and prices would have to be competitive compared to traditional players.

Two things are clear: first, developing an integrated e-mobility II requires a broad set of stakeholders to cooperate (Elzen & Wieczorek 2005; Geels 2012), and second, this cooperation is not guaranteed and "cannot be taken for granted" (Bakker et al. 2014). This is because companies benefiting from the current sociotechnical systems resist any change that threatens their market dominance (Hekkert & Negro 2009; Smith et al. 2005). In the literature, such a sociotechnical configuration of existing practices, regulations, technology, infrastructure, markets, and knowledge is called a sociotechnical regime (Geels 2004). When innovation occurs within regimes in the transportation sector, it is usually incremental and does not challenge the basic architecture, power relations, and practices because of lock-in mechanisms and path dependence (Geels 2012). As a result, sectoral innovations have typically been related to end-of-pipe features, like fuel economy improvements in internal combustion vehicles (Banister et al. 2011; Unruh 2002). In contrast, reducing carbon emissions significantly requires "deep-structural changes in transport systems" (Geels 2012). What is needed to radically transform the mobility infrastructure are new technologies, the addition of non-incumbent actors, and a reconfiguration of the existing status quo. Regime actors may participate in such innovations to learn about new developments, but the inertia of the installed base is strong, and their commitment to a new system that threatens their market domination is usually limited (Bakker et al. 2014).

Governments who want to stimulate innovative mobility infrastructures often intervene and bootstrap the II themselves to motivate different stakeholders to collaborate with each other and build upon the installed base to attract an initial set of users. Governments have been proactively supporting and subsidising experimentation with urban infrastructures using the concept of a strategic niche. The idea of the niche was introduced to assist policymakers to devise ways of experimenting with radical innovations in a real-world setting. Niches represent protected spaces in which innovations can develop without the market resistance of regime players and with the input of citizens and public and private stakeholders (Kemp et al. 1998). Often, this protection is top-down and manifests itself in the form of financial support or favourable regulations (Hodson & Marvin 2009), and is created to motivate a pre-commercial market (Smith & Raven 2012).

The goal of a “technological niche” is to create heuristics that will drive innovation while reducing its risk and improving its performance (Schot & Geels 2008). It allows participants to learn how new infrastructure like an e-mobility system will play itself out in real-life applications: the price the market will bear; user expectations, needs and reactions; technical issues and problems; the possibility of innovative services and design refinements; and unexpected side-effects. In doing so, strategic niches reduce the challenges of bootstrapping and motivate collaboration.

Niches that are developed to motivate sustainable urbanisation have the clear political goal to “understand and influence the early adoption of new technologies with high potential to contribute to sustainable development” (Schot & Geels 2008). The niche experiment involves multiple public and private sector actors, and includes the participation and feedback of users. It tests the behavioural responses of users who show interest in sustainability and alternative forms of lifestyles to niche innovations to estimate the commercial viability of the new infrastructure (von Hipple 1986). Experimentation is considered “a method for constructing paths” towards sustainable infrastructures in the long run (Kemp et al. 2001). The study of sustainability transitions has become increasingly popular over the last decade and interested scholars have generated “an output of 60–100 academic papers per year” (Markard et al. 2012).

Two core theories for analysing innovation transitions in strategic niches dominate the literature (Markard et al. 2012): Strategic Niche Management (SNM) (Smith & Raven 2012) and Multi-Level Perspective (MLP) (Geels 2002). These frameworks have been used to build an analytical framework to review case studies and draw lessons on transitions, including those related to sustainable mobility (Petticrew & Roberts 2006).

MLP views the interactions between the micro (niche), meso (regime) and macro (landscape) tiers as structuring processes that lead to systemic changes over the long term (Geels 2005). The framework falls short as an appropriate lens for this study given it focuses largely on structuring relations between the different levels and not the process of infrastructure prototyping in the niche. The SNM literature (Hoogma et al. 2002; Kemp et al. 1998) is more relevant to studying niches for this study’s purpose since it specifically investigates the early phases of innovative technology prototyping (Weber & Truffer 1999). The remaining section focuses on the SNM literature for developing e-mobility systems.

The SNM literature examines niches related to new transportation systems such as the e-mobility II that is the focus of this study. These niches constitute “initiatives that embody a highly novel socio-technical configuration likely to lead to substantial sustainability gains” (Berkhout et al. 2010). Recent improvements in battery technology, the proliferation of car sharing fleet operators and alternative energy sources like solar and wind, and charging infrastructure, have reignited urban experiments and scholarly interest in sustainable mobility (Dijk et al. 2012). Researchers have shifted focus from just examining new car technologies to understanding “smart” mobility that requires ICT products in cars and infrastructure, and changes in consumer behaviour that present a transition pathway to sustainable mobility (Geels & Schot 2007). The literature divides technology into technological innovation systems (TIS), which concerns novel technologies and ICT, which concerns building information systems (Markard et al. 2012).

Despite innovation in transportation niches being driven by disruptive technologies, the SNM literature has focused on the influence of non-technical aspects of technology development. For example, articles have analysed the influence of factors such as geography (Xue et al. 2016), policy (Wee et al. 2012), competition (Bakker et al. 2012), innovative business models (Christensen et al. 2012) and market formation (Sushandoyo, D & Magnusson 2014) on the outcomes of transportation niches.

In the case of various car sharing experiments in Europe, for instance, articles assumed that technology was a static entity (Hoogma et al. 2002). This black boxing of technologies may be appropriate for technologies that have a relatively long development cycle that is not part of the niche activities such as electric car design. However, it is possible to investigate the development of ICT systems that can develop incrementally and rapidly during the duration of the strategic niche duration itself.

Specifically searching for articles in Google Scholar on strategic niches and ICT returns many results, but almost all of them fail to address ICT implementation and the factors that influence it during the niche. Empirical studies related to ICT tend to focus on value creation, such as from using NFC for mobile payments (Schilpzand et al. 2011) or using smart grids (Niesten & Alkemade 2016). Alternatively, studies may focus on user behaviour around IS systems, such as teleworking and teleshopping (Mokhtarian 2002), more than the specifics of the ICT development itself. The neglected analysis of technology design and development is evident both in theoretical and empirical studies related to strategic niches.

Brendel & Mandrella (2016) examined 58 publications in a systematic literature review related to next-generation mobility models. They found that "the qualities of IS are rarely examined" in the literature, with a focus on the benefits of using IS (Alessandrini et al. 2015; Wagner et al. 2015; Wagner et al. 2014) and not on how to design and develop IS itself. For example, articles related to technologies for multi-modal travel focus on aspects such as how to incentivise travellers through information sharing (Dacko & Spalteholz 2014; Schröder et al. 2014), algorithms for intermodal trips (Dib et al. 2015), route planning and optimisation (Guerriero et al. 2014; Parragh et al. 2010) or platform economics (Teubner & Flath 2015). For mobility modes relevant to this thesis such as flexible transportation like car-sharing or bike-sharing, technology analysis is again limited to aspects like algorithms (Lützenberger et al. 2014) or creating the business case for investment (d'Alessandro & Trucco 2012).

The omission of studying ICT in the strategic niche and mobility literature implies that even though strategic niches are essential for bootstrapping innovative urban IIs, the literature lacks an understanding of exactly how this happens at the design and implementation level and provides an opportunity for this study to contribute. The SNM literature does, however, provide insight into the coordination of strategic niches by studying the role of the intermediary, a critical role in government-funded strategic niches for multi-stakeholder projects. The next subsection reviews the literature on intermediaries in strategic niches to find any relevant insights for this topic.

2.4.2 Intermediaries and Coordination

Effective coordination to align stakeholders to collaborate and contribute is an essential aspect of strategic niche governance. The coordination aspect of strategic niche management is covered in the literature primarily by focusing on the role of "in-between" actors known as intermediaries that facilitate relationships between stakeholders (Medd & Marvin 2006; Moss et al. 2009). Studies have recognised their active and transformative role in facilitating innovation (Clarysse et al. 2014; Howells 2006), including strategic niche development (Kivimaa 2014; Hargreaves et al. 2013). They occupy a variety of roles such as consultants (Bessant & Howard Rush 1995), university transfer agencies (Macho-Stadler et al. 2007), science parks or innovation centres and scholars have categorised intermediaries depending on the function they play in a strategic niche. For example, an innovation intermediary is "[a]n organisation or body that acts as an agent or broker in any aspect of the innovation process between two or more parties" (Howells 2006). They are "actors who create spaces and opportunities for appropriation and generation of emerging technical or cultural products by others" (Stewart & Hyysalo 2008). Intermediaries essential for long-term and complex changes, including transitions to sustainability, are also called "systemic intermediaries" (van Lente et al. 2003), while "energy intermediaries" are those that help cities transition to low carbon energy (Bush et al. 2017; Hodson & Marvin 2010; Hodson et al. 2013). Socially skilled intermediaries that work across multiple industries, social worlds and cultures to translate requirements and facilitate collaboration are referred to as "border crossers" (Canzler et al. 2017). Such intermediaries are especially skilled in multi-stakeholder projects where they help parties focus on "evolving collective ends" (Fligstein 2001).

"Sustainability transitions are long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption. One particularity of sustainability transitions is that *guidance and governance* often play a particular role" (Smith et al. 2005). (emphasis added)

Despite the importance of intermediaries as influential actors in the reconfiguration of existing socio-technical relations (Guy et al. 2011), the full influence of intermediary actors remains under-examined in the literature (Bush et al. 2017; Kivimaa & Martiskainen 2016). Kivimaa & Martiskainen (2016) have criticised researchers for limiting the role of intermediaries mainly to brokering relations between the developers and users of innovation (Howells 2006; Stewart & Hyysalo 2008).The literature remains focused on aspects of this brokering function and related intentionality and actions (Howells 2006; Mike & Simon 2008; Randles & Mander 2011; Bush et al. 2017). For example, researchers have criticised the assumption that intermediaries must passively work with stakeholder relationships, citing evidence that intermediaries actively play a role in defining relationships (Medd & Marvin 2007). Even where studies acknowledge that intermediaries have a bigger role than just coordinating relations with the niche (Kivimaa 2014; Kivimaa & Martiskainen 2016), they only extend it to brokering relations outside the project and leave the larger influence of intermediaries in the project under-researched (Bush et al. 2017). Overall, the strategic niche literature views coordination as a function delivered by a narrowly perceived understanding of intermediaries as relationship brokers. Critically, nowhere in the SNM literature is the role of intermediaries related to ICT coordination studied in-depth, revealing a significant gap in the study of bootstrapping mobility IIs in cities.

Summary

In summary, this section has illustrated that radical innovations present path-breaking new technologies that are risky and difficult to manage, compared to incremental innovations, which represent refinements of existing technologies. Innovative mobility infrastructures require new technologies, both hardware such as charging stations and battery storage, and software that will connect all parts of the system to make a seamless experience for the consumer. Such radical innovation is possible in strategic niches which comprise the "creation, development and controlled breakdown of test-beds (experiments, demonstration projects) for promising new technologies" (Weber & Truffer 1999). They are spaces that are "protected" from the current nexus of socio-technical networks that resist innovations and exhibit inertia caused by path dependency. The strategic niche management (SNM) literature presents a comprehensive set of research on urban infrastructure prototyping. However, its examination treats ICT as a black box with no deeper investigation of its design and development. At the same time, the literature also limits its understanding of coordination to the role of brokering and project coordination and removed from a deeper role in II development. This study can provide valuable insights to help close some of these gaps in the understanding of II development in urban strategic niches.

2.5 Summary and Research Questions

This literature has examined the research relevant to the study of large-scale heterogeneous ICT systems for urban mobility. The domain of Information Infrastructures (IIs) is best suited to investigate this problem area as IIs, like large-scale mobility systems, are comprised of heterogeneous sociotechnical components that are owned by various stakeholders. With this focus in mind, the literature review focused on three areas in this chapter.

First, the chapter provided an overview of IIs, describing how their complexity and unpredictability makes them intractable to predetermined planning. Instead, IIs are cultivated and grow from an installed base of sociotechnical components (Hanseth 2006), emerging through the coordination efforts to integrate components in the installed based. The II literature illustrated the recurring challenge of directing II evolution due to their complexity, which distinguishes them from other types of information systems (Ciborra 2000b; Hanseth & Monteiro 1997).

Second, the CSCW literature confirmed that the working conditions for building an urban e-mobility II are dynamic, fast-paced and unpredictable (Faraj & Xiao 2006). Taking the environmental context that surrounds II cultivation seriously is essential to understanding II evolution. The chapter identified four contextual elements for further study: people, materiality, temporality and urbanisation. The examination of the temporal context of II cultivation revealed a gap in the literature. Researchers have yet to fully examine IIs against the full background of their history and anticipated evolution across the past-present-future continuum (Karasti & Baker 2004; Ribes & Finholt 2009). Examining the long-term biography of IIs presents a "new kind of temporal challenge for the field of Computer Supported Cooperative Work (CSCW)" (Karasti et al. 2010) and refines the focus of this study to a deeper examination of temporality and IIs.

Third, the strategic niche management (SNM) literature was reviewed to study research on II prototyping for cities. While the SNM literature helps understand how policymakers plan radical innovation in e-mobility IIs, the literature was found to treat the design and development of ICT systems as black boxes, providing an opportunity for this study to contribute.

In summary, the study seeks to understand the cultivation of IIs, which are open-ended (Orlikowski 2007; Orlikowski & Scott 2008; Yoo et al. 2010), have complex biographies (Monteiro et al. 2012; Pollock & Williams 2010) and are "always an unfinished work in progress" (Edwards et al. 2009). The literature was found to be grappling with two main tensions in II cultivation: (i) the nature of strategic interventions and decisions between intervening in a top-down manner or letting bottom-up processes dominate, and (ii) the challenges of II cultivation in the short term (project time) against the broader background of the biography of the II (infrastructure time). These tensions and gaps in the literature have helped refine the research questions as below:

RQ 1: How are IIs cultivated in strategic niches, and is it possible to strategically intervene and direct the II's development?

RQ 2: How do multiple temporal scales influence the process of II cultivation?

The literature review has also been helpful in refining the research approach of this study, underscoring the need for a conceptual approach that takes both materiality and temporality into account; and a research methodology that investigates IIs in-the-making as a longitudinal process.

3. Theoretical Framework

3.1 Introduction

The last chapter demonstrated how the IS literature is in early stages of examining the temporal context of II cultivation in strategic niches, revealing a gap that this thesis aims to investigate. The literature review identified the broad research question that needs examination: how are e-mobility IIs cultivated in strategic niches and how does temporality influence this cultivation?

This chapter describes the theoretical framework that will structure this investigation and analysis, providing a more precise set of research questions within the domain of II studies. The theoretical framework represents the prior knowledge that helps researchers to frame their thinking and understand and investigate the evidence. The concepts and relationships outlined in the theoretical framework are used to analyse the findings of the case study (in Chapter 6 and Chapter 7), which will then drive an explanatory framework on the influence of temporal rhythms on II cultivation.

The study bases the theoretical framework on sociomateriality informed by a theory of digital coordination and analytical concepts related to rhythmic temporality. The theory Trichordal Temporal Approach (Venters et al. 2014) examines digital infrastructure evolution as temporally embedded human and material agencies interact. The notion of temporality is then enriched with the concept of rhythms (Jackson et al. 2011; Lefebvre 2004) to form an extended theoretical framework for this study. This enriched approach helps to investigate the emergence of e-mobility IIs and formulate the specific research questions that will guide the thesis from this chapter onwards.

The chapter has five sections described briefly below.

Section 3.2 introduces the sociomaterial perspective that underpins the theoretical framework.

Section 3.3 discusses the Trichordal Temporal Approach (Venters et al. 2014), including how the authors extended the Mangle of Practice (Pickering 1995) with a theory of agency (Emirbayer & Mische 1998). Specifically, the section discusses the concepts of material agency and temporality as two critical parts of an investigation on II cultivation and identifies a gap in the theorisation of rhythms.

Section 3.4 delves more deeply into the notion of rhythmic temporality through a review of concepts related to rhythms and rhythms of collaboration (Jackson et al. 2011; Lefebvre 2004), highlighting among other things categories of rhythms and the tensions between them.

Section 3.5 presents the enriched theoretical framework that extends the Trichordal Temporal Approach with temporal rhythms and will be used to analyse the evidence.

Section 3.6 summarises the key concepts discussed in the chapter.

3.2 Sociomaterial Perspective

As discussed in the literature review, the sociotechnical components of the installed base include people and institutions, practices and habits, and various forms of materiality. In the case of e-mobility IIs, this materiality manifests itself in the different software systems (such as apps, APIs, databases and systems) and hardware infrastructure (such as electric vehicles, solar panels, wind turbines and charging stations). To examine IIs, this study's ontological approach (where an ontology defines the nature of reality) must acknowledge the influence of both the social and material components of the installed base.

In the past few years, there has been an increasing emphasis amongst organisational scholars on the role of materiality in work (Orlikowski 2007; Orlikowski & Scott 2008; Carlile et al. 2013; Leonardi & Barley 2010; Introna & Hayes 2011). Historically, the technology management literature had viewed reality based on an ontology of separateness, in which humans and technologies (non-humans) were separate with distinct existence and properties. However, scholars rejected technology's absence observing that in the "analysis of technological innovation everything is included … except any discussion of the technology itself" (Pinch & Bijker 1984). Orlikowski & Iacono (2001) found artefacts to be black-boxed and relegated to surrogates, while Barad (2003) famously noted that matter did not matter very much in organisational studies.

Researchers challenged the Cartesian dualism between humans and technology and advocated using a relational ontology instead in which nonhuman entities like technology must be acknowledged and seen in entanglement with human actors, not as separate realities (Pickering 1995; Knorr-Cetina 1997; Barad 2003; Latour 2005; Orlikowski & Iacono 2001; Schatzki 2002). Influenced by the sociology and science and technology literature (Barad 2003; Suchman 2007; Latour 2005), this conceptual approach stressed that the social and the technical are "ontologically inseparable from the start" (Introna 2007).

"It would not be incorrect to say that our existence has now become so entangled with the things surrounding us (if it even makes sense to use the notion of 'surround') that it is no longer possible to say, in any definitive way, where we end and they begin, and vice versa" (Introna 2009).

An II too is perceived as relational: it is not an end state but "emerges for people in practice, connected to activities and structures" (Star & Ruhleder 1996). This perspective provides a way to understand how IIs emerge as people experiment with locally-tailored applications and integrate them into the installed base (Star &

Ruhleder 1996) or embed some functions in other IIs (Vaast & Walsham 2009). If researchers take this approach seriously, then "the primary unit for research is not independent objects with inherent boundaries and properties but phenomena materially enacted in practice" (Orlikowski & Czarniawska 2016). To understand the relational ontology between humans and technology, researchers do not focus on independent objects with associated properties and boundaries, but instead, pay attention "to matters of practices/ doings/actions" (Barad 2003).

For social theorists, practice is not the act of doing something, but a "socially shaped arena in which activities are collectively negotiated" (Leonardi 2012a). Based on the theories of sensemaking and learning and work practices (Lave & Wenger. 1991; Engestrom 1990), the practice-based approach says that practices are dynamic and ad hoc, in which humans respond to the world (Schatzki et al. 2001; Knorr Cetina & Bruegger 2002; Reckwitz 2002). Humans and technologies are constitutively entangled as they enact practice and are interrelated and reiterated in evolving configuration (Suchman 2007). This "entanglement in practice" is referred to as sociomateriality (Orlikowski & Scott 2008; Orlikowski 2010), and practice is the space where humans and material are intertwined (Orlikowski 2010). However, sociomateriality is still a relatively new field and "scholars are just beginning to consider how such intertwinement occurs" (Leonardi 2012a).

Researchers perceive practices as performative, which means that practices "do not so much reproduce (in the sense of replicate) the world, but rather in their historical reconfiguration, they perform the world. Practices always have the potential to perform something different" (Scott & Orlikowski 2014). Performativity is an important concept related to relational ontology. It differs from performance in that whereas performance is the act of doing an activity, performativity is constitutive of reality itself. A classic example is the Black-Scholes formula of option pricing, which was initially devised to help economists understand how the market stabilises around an option price. However, over time, traders began to use the formula to price options, and it became constitutive of reality (MacKenzie 2006). Performativity emphasises process over structures and practices over representations, where identities constitutively emerge with reiterated performances (Butler 1990), a lens that extends beyond humans to matter as well (Barad 2003; Suchman 2007). In the science and technology literature, Pickering (1995) proposed a shift from "representational idiom" to the "performative idiom" when studying science, i.e. performance builds a constantly evolving reality, and action is not a mere representation, separate from being. To understand IIs, researchers must also examine them as dynamic and evolving, instead of stable and static entities.

This study conceptualises IIs as relational and frames II cultivation as a sociomaterial practice that is subject to performativity and entanglement. Based on this ontological foundation, the next section introduces the theoretical framework of this study.

3.3 Trichordal Temporal Approach to Digital Coordination

This study aims to understand the cultivation of the installed base, which is conceptualised as sociomaterial as outlined in the last section, and how multiple stakeholders collaborate to grow an II. The literature review discussed the evidence that IIs are difficult to manage given the dynamic interactions of multiple actors and technologies. This complexity makes it impossible to design them in a top-down manner: II cultivation is not the outcome of human decisions but the emergent result of the interactions between humans and technologies in practice. Researchers must examine IIs as a process "in the making" to understand its evolution. This study uses the Trichordal Temporal Approach (Venters et al. 2014) as the theoretical framework because it allows the researcher to investigate this sociomaterial entanglement in practice.

3.3.1 The Mangle of Practice

The sociomaterial interaction of human and material agencies is conceptualised as a mangle of practice (Pickering 1995) and forms the foundation of The Trichordal Temporal Approach. This section, therefore, starts with an examination of Pickering (1995). The central tenet of the mangle of practice is that when humans and materials interact, human intentions encounter material resistance, which derails design plans and requires humans to adapt. Pickering provides the analytical framework to view this interaction closely.

Pickering believes both humans and materials have agency. Human agency is defined as the intention and ability by humans to form and realise a goal (Emirbayer & Mische 1998). Humans are capable of making judgments and responding to situations they encounter with intention. Often, their actions and decisions are a response in the face of material agency. Here human agency refers to social agency, which is "a *group*'s coordinated exercise of forming and realising its goals" (Pickering as cited in Leonardi 2012a). (emphasis added).

Material agency is the capacity of nonhuman entities to act independently of human intervention. The weather, for example, has agency according to Pickering (1995) with actions like rain, heat, cold and wind, all of which do not involve human agency. "Much of everyday life, I would say, has the character of coping with material agency, agency that comes at us from outside the human realm and that cannot be reduced to anything within that realm" (Pickering 1995). In this study, materiality includes all the software and hardware components that comprise an e-mobility infrastructure.

One fundamental difference between human and material agency is regarding the notion of intentionality. Unlike human agency, material agency does not possess intentionality (Robey et al. 2012; Pickering 2001). "Machine artefacts have no inherent intentionality, independent of their being harnessed to or offering possibilities to humans," according to (Taylor et al. 2001). Material entities exercise agency "in the moment" through performativity (Robey et al. 2012): "the technology itself acts (exercises material agency) as humans with goals engage with its materiality" (Leonardi 2012a).

As time unfolds material agency can provide resistance to human intentionality in practice – "a failure to achieve an intended capture of agency in practice" (Pickering 1995). For example, physical phenomena in the laboratory resist the efforts of scientists to manipulate them. Using the case study of scientist Donald Glaser and his use of the Bubble Chamber, Pickering (1995) showed how Glaser went through a series of frustrating steps of using different gasses and iterations of the Bubble Chamber that in turn also shaped the goals of Glaser. In other words, the material resistance of the Chamber led to him change his methods and theories. Such alterations in human agency are called accommodations by Pickering as humans harness further technologies and materiality in response. It shows that humans are not at the mercy of material agency, but adapt their practices to respond to it (Leonardi & Barley 2010) and "there is, then, a temporal and posthumanist interplay here between the emergence of material agency and the construction of human goals" (Pickering 1995).

This process of resistance and accommodation is called tuning (Pickering 1995) and is an emerging dialectic that results in a continually evolving sociomaterial configuration. Human practice evolves "in a field of material agency, constructing machines that […] variously capture, seduce, download, recruit, enrol or materialise that agency, taming and domesticating it, putting it at our service" (Pickering 1995). This tuning continues until the outcomes are acceptable to humans and aligned with their intentions. Until this point of stabilisation, human and material agencies continue to unfold as resistance and accommodation occur, and the two agencies become constitutively enmeshed (Pickering 1993). Pickering refers to this "reciprocal and emergent intertwining" of human and material agencies as the mangle of practice (Pickering 1995).

Pickering believed that human agency is temporally embedded in the past and future and influenced by what he refers to as disciplinary agency and modeling. The past influences human action in the present through disciplinary agency, a distinct agency in itself, that imposes inertia in action. Disciplinary agency includes the habits, cultural and organisational routines, which have created widely accepted practices that are hard to change (Pickering 1995). Pickering cites the case of the mathematician Sir William Hamilton's work on quaternions to provide evidence of the impact of disciplinary agency. Hamilton, who meticulously documented his practices, was unable to reach the original goal he set out and the research mutated over time partially, believes Pickering, because of the disciplinary agency of Hamilton's conceptual beliefs and routine practices in algebra and complex geometry. As discussed in the last chapter, the inertia of the II's installed base has strong disciplinary agency on its cultivation including its practices and habits. However, Pickering does not delve deeply in the disciplinary agency of materiality.

Imagined futures also shape human intention and agency (Pickering 1990) through a process Pickering (1990) calls modeling. Modeling involves imagining different futures based on current resources and how humans can harness agency to make intentions come true. It has "no determinate destination as … [for] a given model … an indefinite number of future variants can be constructed" (Pickering 1995). As humans realise more possibilities for the future, both their intentionality and their actions are influenced, making intentionality temporally emergent as well. Material agency is similarly influenced by the past and the future as well, but Pickering focuses mainly on human agency in this respect as well.

Venters et al. (2014) found that Pickering does not deeply investigate the orientation of the agencies towards the past and future, and that "this orientation is only weakly theorised in his definition of modeling and disciplinary agency, and the link or interplay between these concepts has not been developed." To enrich the conception of temporality, and pay greater attention to their influence on material agency, they extended Pickering's work with the theory of agency (Emirbayer & Mische 1998).

3.3.2 The Trichordal View of Temporality

Venters et al. (2014) develop their Trichordal Temporal Approach by drawing on a trichordal view of temporality (Emirbayer & Mische 1998) to enrich the mangle of practice (Pickering 1995). The trichordal view of temporality focuses on the interplay of past, present, and future and argues that that agency is always "oriented toward the past, the future and the present at any given moment [in a] chordal triad of agency" (Emirbayer & Mische 1998). These three orientations are simultaneous, separate and may be divergent causing tension in the present. Infrastructure coordination emerges in the present as human and material agencies entangle amongst the "dynamic harnessing of past and future" (Venters et al. 2014). The theory adds to research in sustainable change in infrastructure (Ciborra 2000b; Henfridsson & Bygstad 2013; Tilson et al. 2010b) and challenges the belief that the emergence of infrastructure is a technical undertaking related to resource allocation and distribution (Crowston 1997; Chua & Yeow 2010). This section discusses the key elements of the Trichordal Temporal Approach.

The Trichordal Temporal Approach is an analytical theory to study digital infrastructure coordination. Venters et al. (2014) define three integrative conditions for digital infrastructure coordination: resource distribution, accountability and predictability, and develop a framework to analyse the influence of chordal tensions on these goals. This study chose the Trichordal Temporal Approach as the theoretical framework for studying the influence of temporality on II cultivation because of two main reasons. First, the theory rests on a sociomaterial perspective, which recognises the role of both human and material agencies in emergent coordination and aligns with the ontological approach of this study. Second, it theorises the role of temporality in infrastructure coordination by exploring how agency and temporality are linked in practice, a gap identified in the literature review.

An important contribution of the Trichordal Temporal Approach was incorporating Emirbayer & Mische (1998)'s definition of temporally embedded agencies into a framework based on the Mangle of Practice. According to Emirbayer & Mische (1998), "for each analytical aspect of agency one temporal orientation is the dominant tone, shaping the way in which actors relate to the other two dimensions of time" (ibid). Disaggregating the chordal composition is critical to understanding how emerging agencies recursively influence temporal agencies in any direction. Venters et al. (2014) provide this disaggregation by showing how the past, present and future link together.

The past influences the present through the installed base, the set of standards, legacy software components, practices and user familiarity, which are a "drag on innovation" (Venters et al. 2014). For example, developers may continue with a type of legacy system because of existing users, sunk costs already spent, and familiarity with implemented policies.

"Where multiple communities participate in the tuning process across globally distributed locations—each with the inertia of installed bases and conventions of practice—the integration of these diverse histories will influence the grid coordination" (Venters et al. 2014).

The anticipated future also influences coordination in the present. For example, software's generative features (Henfridsson & Bygstad 2013) have been shown to challenge planning for sustainable change in infrastructures (Ribes & Finholt 2009; Yoo et al. 2010).

According to Venters et al. (2014), all agencies are emergent, dynamically constituted and inseparable. Judgment in the present is inseparably and constitutively entangled with habits and inertias of past and the imagined technological progress and goals in the future as well. Not only is the future a set of multiple imaginings of what could happen based on people's experiences in the past (Emirbayer & Mische 1998), but ideas about the future can also colour people's memories of the past (Flaherty & Fine 2001). The interactions of these multiple interpretations of the past, present, and future (Emirbayer & Mische 1998) drive emergent coordination as the II is constantly "sociomaterially disciplined by the past as well as being revised in the emerging present" (Venters et al. 2014).

Emergence irreversibly affects all sociomaterial agencies (the past, present, and future) as the connections are dynamically constituted (Adam 2013a). According to the authors, "emergence refutes linear causality of change processes as being means-end driven and goes beyond classical theories on the separation of past, present, and future" (Venters et al. 2014). The present emerges as the past and future are dynamically harnessed in the performativity of the mangle, and emerging agencies in the past, present, and future link and influence each other.

"We define digital coordination as the temporally enacted tuning process involving multiple heterogeneous actors and across past, present, and future, where nonhuman actors are harnessed for achieving accountability and predictability in addition to resource distribution for the ongoing accomplishment of work" (Venters et al. 2014).

Another important aspect of the theory is that it does not privilege material agency over human agency, and analyses how both human and material agencies are embedded in multiple temporal dimensions during tuning. Material agencies also have a past, present, and future which is separate and distinct from human agencies (Ribes & Finholt 2009). Venters et al. (2014)'s sociomaterial approach takes all materiality that might occur in an II into account, i.e. it not only recognises the material agency of the IT artefact but also that of all its internal workings such as APIs, software code, the middleware, and databases. For example, the authors demonstrate in their case study that coordination can even be delegated to materiality: "accountability and predictability can be delegated to software as part of coordinating the grid" (ibid).

3.3.4 A Rhythmic View of Time

The Trichordal Temporal Approach demonstrates how the emergence of digital infrastructure is a complex and continually unfolding process. The theory defines coordination as an emergent tuning process that involves both human and material agencies. It demonstrates that while the digital infrastructure emerges in the present, it is entangled with orientations to the past and the future. By surfacing temporal tensions – transparency in the present, historical disciplining of social and material inertia, and modeling of future infrastructures through generativity, the theory provides a rich temporal framework to understand digital coordination and adds to the literature on temporality in infrastructure (Ribes & Lee 2010). However, the theory views time in only one way: linear clock time.

While conducting interviews for this study, the researcher noticed a recurring mention of another temporal structure: rhythms. The researcher returned to the Trichordal Temporal Approach to examine the analysis of rhythms and discovered that Venters et al. (2014) also make several observations where humans experience temporality in rhythmic form. However, these observations, some of which are described below, are not theorised and remain unexplored, necessitating an extension to the theoretical framework.

Venters et al. (2014) observed in their case study, for example, that particle physicists eager to win the Nobel Prize were keenly aware of a 3-year discovery cycle when the CERN apparatus generates new data. They realised that only discoveries in the first year would qualify them as contenders for the prize as analysis would become standardised and routine in the following years. This cycle drove them to quickly improve grid software to analyse the data as soon as possible.

The authors also noticed that physicists engage in “a rhythm of experiments and sporadic races.” They anticipate periods of scientific experimentation but also the inability of software engineers to expand the code base to accommodate new experiments (Venters et al. 2014). The physicists are then motivated to use “dirty” patches to reach quick software solutions when they encounter slow code development.

Another instance where temporal cycles impacted stakeholder behaviour was when exposure to futuristic prototype devices strengthened the software engineers’ belief in Moore's law (which states that computational power doubles approximately every two years). Anticipating the falling cost of computational power, the engineers delayed purchasing new hardware, which also delayed the infrastructure's evolution.

As discussed, these observations of temporal rhythms and their impact on human actions and the infrastructure’s coordination were noted but not theorised by Venters et al. (2014). Since the researcher also noticed interviewees discussing various rhythms during data collection, the theoretical framework is extended in the next section to enable the analysis of temporal rhythms in II cultivation.

3.4 Exploring Temporal Rhythms

This section introduces the concept of rhythm and describes a theory of how rhythms manifest themselves in collaborative work (Jackson et al. 2011). It starts this discussion with a brief overview of how humans perceive time and interact with temporal structures, which helps the researcher understand how stakeholders involved in II cultivation view time.

Several studies have examined rhythms over the past few decades. For example, (Johnson-Lenz & Johnson-Lenz 1991) describe how daily activities occur in regular patterns and Zerubavel (1979)'s research on temporality analyses social rhythms in hospital work. Humans try to achieve coordinated work through the alignment of disparate rhythms using tools and communication strategies (Im et al. 2005). Some scholars (Reddy et al. 2006; Reddy & Dourish 2002) have further examined the influence of rhythms on practices (seeking, providing and managing information). Reddy et al. (2006)'s study on medical workers, for example, demonstrates how knowledge of past rhythms and expectations of future activities help nurses manage their time. In their research, nurses organise their work in anticipation of when the information will become available or required for a common lab test. In this respect, the agency of nurses is temporally embedded as described by Emirbayer & Mische (1998).

Most studies on temporality, however, do not examine the influence of temporal rhythms from a sociomaterial perspective, which is the aim of this study. This study not only aims to explore the "important question: how do people respond to rhythms?" (Reddy et al. 2006), but also "how does materiality respond to rhythms?". The following section describes the analytical concepts used by this study to investigate time, rhythms and their interactions.

3.4.1: Perceptions of Time

Humans perceive time in two ways: objective or subjective. In classical times, the Greeks devised two terms for time: Chronos and Kairos (Bazerman 1994; Kinneavy 1986; Miller 1992). The term Chronos (from which the English language derives the word chronological) means “serial time of succession … time measured by the chronometer, not by purpose” (Jaques 1982). The term Kairos, on the other hand, places purpose or human intention as the measure of time and perceives “the time not of measurement but of human activity, of opportunity” (Jaques 1982). Organizational studies have also perceived temporality along this dichotomy between *clock time* (chronos) and *event time* (kairos) (Orlikowski & Yates 2002; Shen et al. 2014). Researchers have conceptualised these two temporalities as objective, absolute and measurable (Zaheer et al. 1999) or subjective, socially constructed and contextual (Glucksmann 1998; Jurczyk 1998; Adam 2013a).

In their seminal paper “It’s About Time” (Orlikowski & Yates 2002), the authors offer a view of time that is practice-based to demonstrate that people construct and reconstruct temporal structures. The authors believe it is essential to understand how people interact with time to comprehend how people perceive it. Influenced by practice theory and structuration theory (Giddens 1986), the authors perceive human action as being both shaped by and shaping temporality in life, a process Orlikowski & Yates (2002) call temporal structuring. Recurrent practices, like calendar meetings, grant deadlines, and product delivery timelines, create temporal structures that both enable and constrain human practices (Orlikowski & Yates 2002).

People experience time through these recurrent practices, and sometimes these temporal structures become so “real” in their minds that any attempt to change them fails. For example, when the French revolutionaries attempted to create a calendar of 12 fixed-size months of 3 ten-day weeks, it failed because society’s version of the 7-day week had become objectified and immutable through collective social practices (Zerubavel 1977).

“One of the most potent techniques we humans have for turning culturally arbitrary behaviour into social fact consists of our tendency to treat self-imposed temporal boundaries as inevitable external constraints” (Barley 1988).

At other times, people change temporal structures through their practices. For example, in software engineering, the traditional development cycles used the "waterfall" approach to build systems where engineers developed components sequentially. However, developers designing for the web slowly changed their practices and now use the agile approach where components are developed iteratively at "internet-speed" (Baskerville et al. 2003).

Humans experience time in two primary temporal structures: linear and cyclical. While many studies have analysed linear time, this study focuses on temporality in the form of rhythms. Rhythms represent patterns of repetition against which activities are experienced and come in a myriad of patterns, flows, and timelines. A rhythm is "the production and negotiation of temporal order… as a practical accomplishment of social actors" (Reddy et al. 2006). Examples of rhythms include work schedules, calendar meetings, holidays, seasons and product lifecycles (Ancona & Chong 1996).

Conceptualising temporality as described above has the following implications for the investigation of II cultivation:

- Any examination of collaborative work involved in II cultivation must investigate not only how activities are organised in time but also how people experience them in time.

- Temporal structuring, which views time through a practice-based lens allows researchers to understand both how temporality shapes and is shaped by human action. The objective view alone neglects the role of humans in shaping organisations while just using the subjective view overlooks how objectified time in organisations shapes human action.

- Temporalities are dynamic, enacted and emerge through aggregate individual actions and practices, and are at any given time “stabilized-for-now” (Shryrer 1993). Humans experience a multitude of temporal structures at any given time, including linear time and rhythmic time.

The next section delves deeper into the concept of rhythms to understand their features as temporal structures and illustrate how are used in organisational management studies.

3.4.2: Conceptualising Rhythms

A concrete understanding of rhythm and related concepts is required to use temporal rhythms as an analytical tool for understanding II cultivation. The roots of the concept of rhythm lie in music theory, although the construct has since been used in other fields like the life sciences as well. This section defines rhythms with examples of how it has been used in organisational management and IS literature.

Rhythms can be defined as “the temporal patterns and regularities that stem from and in turn help to frame and support ongoing forms of action in the world” (Steinhardt and Jackson, 2014). They represent the “regularities of practice” (ibid) that humans begin to structure their work around, and form related conventions and expectations. Examples include project planning, templates of innovation, expectations around customer behaviour and software development cycles.

Humans experience a great variety of rhythms over their lifespans with different temporal scales and types. Lemke (2000), for instance, identified twenty-two timescales in ecosocial systems that range from chemical processes that last only microseconds to universal changes that occur over billions of years. However, for this study, a subset of such rhythms related to collaboration described by Jackson et al. (2011) provides a good foundation to demarcate and investigate different types of rhythms (described below).

Organizational rhythms are rhythmic patterns institutionalised in organisational work. They are explicit temporal structures set by organisations such as strategic plans, performance review cycles, commercialisation timelines and quarterly financial reports. The IS literature has been critical of the goal to manage information systems top-down using plans and project goals (Ciborra & Hanseth 2000; Hanseth & Ciborra 2007). However, their influence as sites of negotiation has been recognised as well (Suchman 2007).

Infrastructural rhythms refer to the lifecycle of the built environment such as maintenance schedules or decline associated with legacy systems. The influence of the past and future of infrastructure has been discussed earlier in this study. The inertia of the installed base as a drag on II evolution is well-documented in the literature (Star & Ruhleder 1996) and the Trichordal Temporal Approach (Venters et al. 2014) demonstrates how the future generativity of software motivates developers. This study will enrich this examination with the further investigation of temporal rhythms.

Biographical rhythms refer to the flows of human life including people's "shifting roles, identities and career trajectories" (Jackson et al. 2011). While the authors refer to the biographies of individuals, this study extends the concept to collectives of people who work in a single organisation. It asserts that organisations that are stakeholders in strategic niches also have an evolving collective identity and organisations behave like individuals who spend time and effort in the ongoing construction of their life stories (Goffman 1959; Linde 1993).

Phenomenal rhythms are seasonal or episodic events that are beyond the control of individual stakeholders such as climate change or election cycles. Phenomena such as the development of battery storage technology and the political will of the government play a major role in e-mobility strategic niches, for example. Phenomenal and infrastructural rhythms represent the need to "account for the role of non-human forces and actors in the shaping of time" (Jackson et al. 2011).

Rhythm Interactions

Humans seldom encounter temporal structures in isolation. At any given moment in time, they experience multiple temporalities. In fact, one of the key contributions of the Trichordal Temporal Approach is highlighting how multiple and divergent temporalities simultaneously act on the mangle of practice, and that there is a chordal tension between the past and the future as it acts upon agencies in the present. This study needs a way to analyse rhythm interactions to understand their influence on II cultivation and a theory about why one rhythm dominates another. In his book "Rhythmanalysis" (Lefebvre 2004), philosopher Henri Lefebvre examines how the everyday rhythms of urban spaces impact the rhythms of the individuals who inhabit those spaces. Lefebvre (2004)'s names four ways rhythms interact with each other, which provide a guiding structure for this study to conceptualise such interactions and describe their use in the literature.

Eurhythmia

Lefebvre (2004) defines eurhythmia as the state when rhythms are constructive and reinforce each other. In music, the notion of ostinato as a base rhythm that reinforces other rhythms or music is common. An ostinato is a motif that is repeated persistently (Kamien & Kamien 1988). Ostinati are used to provide a base or background for the music to soar and surge forward. The idea is similar to the concept of a lyric in a song that is repeated (also known as a hook).

“If the cadence may be regarded as the cradle of tonality, the ostinato patterns can be considered the playground in which it grew strong and self-confident” (Lowinsky 1961).

Ostinato plays an important part in jazz and rock improvisation, where they are called riffs. A riff is defined as "short rhythmic, melodic, or harmonic figures repeated to form a structural framework” (Middleton 1990). They are short melodic fragments (a series of notes or chord pattern) that are repeated to fill an 8-, 12-, or 16-bar section of a tune. In jazz theory, riffing is a technique used to create melodies, while in songs, “riff structures help create a framework against which variation can take place” (Middleton 1990). Soloists often use riffs during improvisations or composers use them when writing new music. Riffing, “a favourite technique of contemporary jazz writers" has been a foundational technique during much of the history of jazz, and was popular in the 1930s and 1940s when many hits were tunes based on one or more riffs (Rawlins & Bahha 2005).

A riff personifies a simple structure or ‘a sequence of chords tied to a metric scheme’ (Kernfeld 1995) that gives musicians a sense of direction and allows them to improvise. This simple foundation is also sometimes called minimal structure. Jazz is unique “in the improvisational use it makes of structure” (Hatch 1999), and how jazz musicians “use structure in creative ways to enable them to alter the structural foundations of their playing” (ibid). When a piece of music relies on a repeated instrumental riff as the basis of its dominant melody, the piece of music is described as riff-driven.

“You can’t improvise on nothin’, man. You gotta improvise on somethin.” Bassist and composer Charles Mingus as cited in (Kernfeld 1995).

The organisation studies literature has used the concept of minimal structure to conceptualise improvisation in teams. They have suggested that “improvisational freedom [in organisations] is only possible against a well-defined (and often simple) backdrop of rules and roles" (Eisenberg 1990). Even though the structure or riff is simple, "small structures such as simple melody ... , general assumptions, and incomplete expectations can all lead to large outcomes and effective action" (Weick 1989a).

Similar to how soloists improvise on top of a riff, organisations can also improvise using analogous templates as minimal structures (Kamoche & Cunha 2001). The literature provides several examples of such templates including laying out broad product visions (Nonaka 1991), developing prototypes on which engineers can create variations (Weick 2002; Barrett 1998), or delineating project milestones (Eisenhardt & Tabrizi 1995).

Another way to reinforce an existing rhythm is to harmonise it. To harmonise music is to strengthen its sound and effect, for example when singers sing above or below the original melody enriching it. According to Lefebvre (2004), harmony relies on "on notes sounding at the same time."

Isorhythmia

Isorhythmia is the rare state where there is an exact equivalence of rhythms in terms of measure, frequency and repetition (Lefebvre 2004). Given that isorhythmia is extremely rare, this study focuses more on the related concept of entrainment, which provides a way to reach an approximation of an isorhythmic state.

In the 17th century, the Dutch physicist Christian Huygens noticed the phenomenon of "entrainment of frequency" or synchronisation between rhythms. Huygens observed how two wall clocks began to synchronise when they were on the same wall while remaining slightly out of step when they were on opposite walls. He concluded that there was something in the vibrations in the common wall that eventually caused the pendulums in both clocks to synchronise when they were on the same wall. Researchers observed similar phenomena when they studied how humans synchronise themselves with external rhythms like daylight and night time or when the chirping of crickets and flashing of fireflies become synchronised. Since Huygens discovery, scholars have widely applied the concept of entrainment in the natural and social sciences, including in biology (Aschoff 1979), physiology (Tang et al. 1999), economics (Larsen et al. 1993), and psychology (Fraisse 1963).

McGrath & Rotchford (1983) studied entrainment in the social sciences, showing how employees and their families entrain to different employee work shifts (e.g. night shifts). The authors described social entrainment as the "capturing and modification of human activity cycles by various social customs, norms, and institutions" (ibid). Ancona & Chong (1996) researched entrainment in teams and how teams adjust their rhythms to external rhythms. Researchers observed how teams begin to structure their work in alignment to each other as they interact over time (Brown & Eisenhardt 1997; Ancona & Chong 1996). Different functional groups also alter the pace of their work to match the velocity of their environment (Eisenhardt 1989) or develop a shared temporal rhythm and a new pace of work as they interact (Perlow 1999).

McGrath et al. (1984) developed the concept of zeitgeber or pacemaker in which weaker cycles entrain themselves to stronger ones. For example, the cycles of the sun drive many activities in humans who adjust their work and sleep schedules to them, or at the organisational level, powerful actors create zeitgebers such as industry leaders that innovate at a fast pace, or the tax authority that sets tax submission schedules. In their paper "Cycles and Synchrony" (Ancona & Chong 1999), the authors investigate the external environment or context as a rhythm setter. Political organisations, for instance, move in a four-year cycle where teams organise themselves in anticipation of the cycle and shift from election planning, to election time to post-election analysis. Another example is when accounting department entrains its phases to the fiscal year cycle or its production cycles to Christmas retail seasons. Zeitgebers can influence both the phase (when an activity occurs) and the tempo (the speed of the activity) of a phenomenon (Bluedorn 2002; Ancona & Chong 1996).

Arrhythmia

Lefebvre describes arrhythmia as occurring when there is dissonance between rhythms. In music, this is called syncopation and occurs when rhythms veer off in an unexpected way which makes part or all of the tune off-beat. Technically, it happens "when a temporary displacement of the regular metrical accent occurs, causing the emphasis to shift from a strong accent to a weak accent" (Reed 1997).

Arrhythmia occurs in organisations when different rhythms conflict and make it difficult to move the project forward (Jackson et al. 2011; Steinhardt & Jackson 2014). For example, organisational rhythms such as innovation plans may conflict with infrastructural rhythms related to legacy systems that resist change. When rhythms conflict, stakeholders can use their agency to change temporal rhythms or employ practices to align collaborative efforts, for example, by reorganising schedules and resources, prioritising modules and shifting personal time and efforts. How different stakeholders resolve tensions and even use rhythm to their advantage is one of the key questions of this paper: "the question of which rhythms are adjusted to which (and whose rhythms to whose) turns out to be a major site for the exercise of power and control" (Jackson et al. 2011).

Research on the subject of temporal rhythms has so far largely focused on the challenges of alignment for collaborative purposes (Jackson et al. 2011; Steinhardt & Jackson 2014) through ways such as Work Breakdown Structure (WBS) (Steinhardt & Jackson 2014). However, researchers still need further study on how the resolution of rhythmic dissonance occurs.

It is worth noting that Lefebvre (2004) has a final state in his theory of rhythm interactions which he describes as polyrhythmia or the state when rhythms peacefully or “symphonically” co-exist. While many rhythms may exist without dissonance with the rhythms in II development, these are *not* the focus of this study which is instead more interested in investigating the tensions between different rhythms and understanding why one dominates the mangle of practice, and the direction of II evolution. The concept of polyrhythmia is therefore not used in this thesis.

This section has conceptualised rhythms, including their key features, and introduced a broad categorisation to help organise and understand the discussion of rhythms encountered in data collection. The next section combines the Trichordal Temporal Approach with these concepts to create an extended theoretical framework for this study.

3.5. An Enriched Theoretical framework

The theoretical framework used in this study was originally the Trichordal Temporal Approach (Venters et al. 2014). However, early on in the data collection process, upon noticing the recurring mention of temporal rhythms by interviewees and a gap in how they were theorised in the Trichordal Temporal Approach, the researcher extended the theoretical framework to enable their examination. Using analytical concepts from scholarly work related to rhythms in organisational management studies (Jackson et al. 2011; Orlikowski & Yates 2002) and philosophy (Lefebvre, 2004), the study developed an enriched sociomaterial framework to examine II cultivation.

The purpose of the theoretical framework is to help investigate the influence of temporality on II cultivation. Temporality is considered a significant factor in work given its central role in our experience of the world and our interactions with each other (Reddy et al. 2006).

"Anyone who works in organisations thinks – has to think – of his or her work, and of the organisation itself, in temporal terms" (Strauss et al. 1985).

The framework developed in this chapter is illustrated in the diagram below and will be used to investigate and analyse evidence related to e-mobility IIs in strategic niches. The findings of the analysis will then be used to conceptualise further how temporality, specifically temporal rhythms, influence II cultivation.

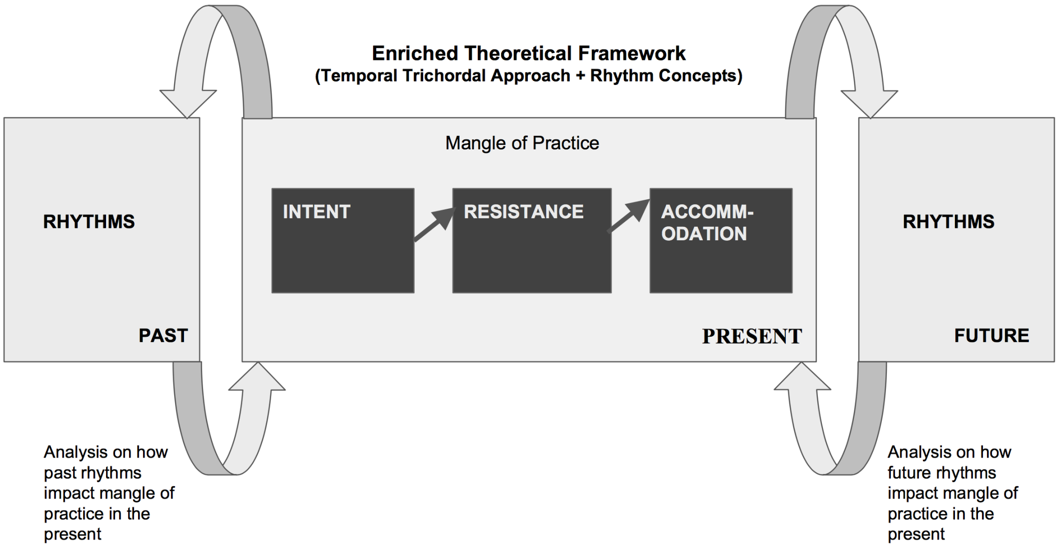

Figure 1: Enriched theoretical framework for this study

Key Theoretical Concepts

Concept	Definition
Mangle of Practice	When human and material agencies entangle and tune the emergent II through resistance and accommodation (Pickering 1995).
Trichordal Temporal Tensions	When human and material agencies are simultaneously oriented towards past, present and future (Venters et al. 2014).

Disciplinary Agency	When past habits, practices, and technologies are a drag on II cultivation (Venters et al. 2014).
Modeling	When imaginings of the future influence human and material agencies and motivate II cultivation (Venters et al. 2014).
Rhythms	The temporal patterns that support ongoing forms of action in the world (Steinhardt and Jackson, 2014).
Rhythms of Collaboration	Types of rhythms that influence collaboration: phenomenal, biographical, organisational, and infrastructural (Steinhardt and Jackson, 2014).
Rhythm Interactions	Three rhythm interactions are explored in this study based on Lefevbre (2004)'s matrix of interactions: Arrythmia: when rhythms are in discord and one chordal tension dominates for some reason. Euriythmia: when rhythms reinforce each other and can also be reinforced through riffing or through harmonising. **Isorhythmia**: when rhythms are exactly the same. This is a rare occurrence but when rhythms entrain to each other, they become more isorhythmic.

Table 5: Key theoretical concepts used in this study

3.5.1 Relationship between Conceptual Concepts

The theory of The Temporal Trichordal Approach (Venters et al. 2014) enriched by the concepts of rhythms and their interactions forms the theoretical foundation for this study. The main concepts and their relationships are outlined below:

- IIs are cultivated in practice through the sociomaterial entanglement of human and material agencies.
- Human and material agencies are temporally embedded, which means that there are multiple and divergent temporal tensions acting upon them at the same time.

- Rhythms are temporal patterns that influence the mangle of practice in the present when past and future rhythms impact human and material agencies.

- II cultivation occurs as rhythms interact with each other and the trajectory of this cultivation depends on which chord(s) dominates over others.

3.5.2 Refined Research Questions

The literature review revealed a gap in the study of temporality in II cultivation. The broad research questions outlined at the end of the last chapter can now be refined using the analytical concepts and relationships defined in this chapter. The original research questions focused on the influence of the temporal context on II cultivation and are now rephrased as a focus on temporal rhythms (see below).

RQ1 How do rhythms impact the process of II cultivation?

This research question aims to understand the influence of temporal rhythms on the mangle of practice between human and material agencies during II cultivation. Specifically, it seeks to investigate II tuning or the process of resistance and accommodation that leads to II cultivation and to see how past and future temporal rhythms influence this tuning.

RQ2 How do rhythms interact with each other during II cultivation?

Since human and material agencies are temporally embedded and "agency is always "oriented toward the past, the future and the present at any given moment [in a] chordal triad of agency" (Emirbayer & Mische 1998), there is a trichordal tension between the different rhythms. This study uses Lefebvre (2004)'s rhythmanalysis matrix in its investigation of the data to examine how rhythms interact.

RQ3 Why does one rhythm dominate and influence the II's trajectory when there is discord between rhythms during II cultivation?

In the Temporal Trichordal Approach (Venters et al. 2014), the authors state that while social and material agencies simultaneously orient towards the past, present and future, "one temporal dimension may be dominant in directing a particular action". However, the theory does not provide an explanatory framework for how one temporal chord may achieve this dominance. To study the influence of temporal rhythms on II cultivation, this research question aims at understanding why one temporal rhythm dominates over another when there is arrhythmia between rhythms.

3.6 Conclusion

This chapter describes the theoretical framework used in this study. It explains the sociomaterial perspective that technology and human actors are inextricably entangled with each other, constitutively "becoming" through performativity (Pickering 1995; Knorr-Cetina 1997; Barad 2003; Schatzki 2002). The study views IIs as sociomaterial and relational and uses the practice-based approach to understand their cultivation.

The researcher focuses on time within sociomaterial practice and draws upon recent work on the coordination of digital infrastructures (Venters et al. 2014) to develop a theoretical framework. The theory Trichordal Temporal Approach (Venters et al. 2014) is extended to include the notion of rhythmic time (Lefebvre 2004; Jackson et al. 2011), providing an enriched framework that examines the influence of the past and future on emergent coordination within the unfolding dynamics of multi-organisational practice. This extended framework is used to finalise the research questions and will be used to analyse the data collected in the case study. The next chapter introduces the methodology which will be used to collect and analyse the data.

4.Methodology

4.1 Introduction

The last two chapters outlined the problem domain and specific research questions around investigating the cultivation of e-mobility IIs in cities. The next step is to develop a methodological structure to investigate and answer the research questions and generalise the results. This chapter's structure loosely follows Crotty's (1998) four elements of social research.

Crotty (1998) recommends starting with identifying a theory of knowledge or epistemology that will underpin the research approach and illustrate the researcher's beliefs on how one can discover knowledge about the world. Section 4.2 introduces the epistemology of social constructionism as the philosophical lens to consider this study's research questions.

Based on the epistemology, a theoretical perspective is selected. Section 4.3 explains why interpretivism and process theory (Langley 1999) provide an appropriate theoretical approach for the analysis.

The next step is to choose a relevant research methodology within the theoretical perspective. Section 4.4 introduces the case study (Yin 1994) as the most appropriate method for this study. It also briefly describes why the researcher chose the BeMobility project as the single case study and the timeline of data collection.

Finally, the researcher selects data collection and analysis methods from the techniques available under this methodology. Section 4.5 provides details on the types of data collected and the methods of collection. Section 4.6 explains the analytical methods of thematic analysis and the processual approach used to interpret the data and outlines principles that aid in generalising and theory-building.

Section 4.7 summarises the chapter.

At each step, the chapter justifies why an approach is best suited to achieving the objectives of the study. The diagram below shows the sequence of steps structuring social research as outlined in Crotty (1998). Together, these steps form an internally coherent and consistent approach to investigate the phenomenon in this study.

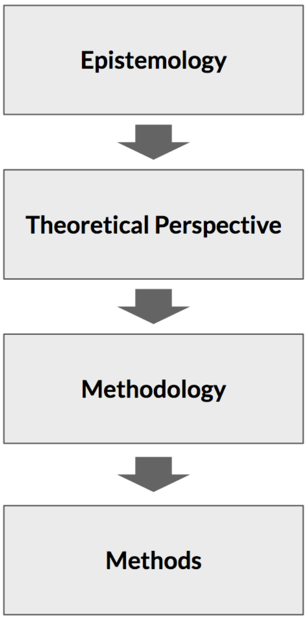

Figure 2: Structuring social research

Source: Crotty (1998)

4.2 Epistemology: Social Constructionism

Before starting a research project, researchers have to explicitly discuss their ontological and epistemological assumptions (Guba & Lincoln 1994). The last chapter explained this study's ontological approach and why the researcher chose sociomateriality as the ontology. This chapter defines how the study will gain knowledge about this sociomaterial world by selecting an epistemology.

Epistemology defines “how we know what we know” (Crotty 1998). It investigates the origins, methods, and limits of human knowledge (Creswell 2002; Strauss & Corbin. 1998), and guides research design, evidence gathering and its interpretation.

The researcher revisited the problem domain to guide the selection of an epistemology. As discussed in the literature review, II cultivation is an emergent process that needs to be investigated “in the making”. It is the result of the dynamic interactions of people and technologies and experienced in different ways by each stakeholder (Hanseth 2014). The epistemological approach known as social constructionism provides the researcher with the ability to understand this evolving reality. It subscribes to the view that “meaningful reality as such, is being constructed in and out of the interaction between human beings and their world, and developed and transmitted within an essentially social context” (Crotty 1998). Reality is dynamic and actively constructed through engagement with the world, and the researcher interprets this reality by understanding the perspectives of those engaged with it through her cognitive structures (Bogdan & Biklen 1998; Creswell 2002). This view stands in contrast to the more realist or positivist epistemology where reality is an objective truth that lies outside the researcher’s consciousness and can be measured (Crotty 1998).

One stream of researchers takes the constructionism perspective to an extreme. They believe in “strong” constructionism that takes the view that all reality including material objects, scientific constructs and physical laws are arrived through social construction (Latour & Woolgar 1991). This study disagrees with such a view and instead subscribes to the “weak” view of social construction, which holds that some social constructs are dependent upon “brute facts” (physical, biological, natural) (Searle 1995) that are objective “in the sense that they are not a matter of your or my preferences, evaluations or moral attitudes” (ibid). The weaker view of social constructionism allows for an external reality to which people adapt, assign functions, and come to terms with as they construct and reconstruct their reality in relation to it.

In the context of the research problem, this approach implies that the technological components of an II constitute a brute fact that different stakeholders and users grapple with as they aim to develop the II and assign functions to it. This view aligns with the theoretical framework of this study where materiality resists human intention, leading humans to accommodate it in various ways, in an on-going process of tuning (Pickering 1995).

4.3 Theoretical Perspective

4.3.1 Interpretivism

After choosing social constructivism as the broad epistemology for this thesis, the study needs a theoretical approach for conducting and analysing research. This study selected interpretivism, widely used within constructionism for formulating research design (Crotty 1998), and the processual approach as the theoretical models.

The theoretical approach must enable the researcher to investigate II cultivation, which is a dynamic phenomenon that emerges over time. The interpretive approach is appropriate as it perceives the world as "an emergent social process – as an extension of human consciousness and subjective experience" (Burrell & Morgan 1979). Knowledge about the world is discovered through the interpretations and actions of social actors (Orlikowski & Baroudi 1991; Crotty 1998) and is neither fixed nor given. This viewpoint presented a rupture with the previously popular positivist approach, which assumed one objective social reality and "the existence of a priori fixed relationships with phenomena" (Orlikowski & Baroudi 1991).

The theoretical approach must also help the researcher examine the context of II cultivation, an essential contributor to how the II develops. Context is significant in multi-stakeholder urban IIs where people, processes, and information systems form a complex sociotechnical background. Given that information systems are part of organisational reality, researchers cannot understand these systems without also examining their social context (Smithson & Hirschheim 1998). Interpretivism is useful to investigate this as its methods are “aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context” (Walsham 1995).

Interpretivism seeks to access the “meaning’ behind people’s actions by actively reflecting on and engaging with people in the social context to understand phenomena. Abstract patterns are deduced from social constructions, such as language, shared meanings, documents, and tools, that people generate as they interact with the world (Crotty 1998). These help researchers understand how members of a social group enact their particular realities and attribute meaning to them, and show how these meanings help constitute action (Orlikowski & Baroudi 1991). To understand II cultivation, the researcher would have to understand its process through the multiple interpretations stakeholders attributed to the project tasks and implementation (Boland 1985; Boland 1991; Orlikowski & Baroudi 1991).

There is another aspect of IIs that is necessary to investigate: the "becoming" of the II as it unfolds over time. The significance of temporality in II cultivation requires “a process-oriented understanding where it becomes crucial to trace and analyse the historical sequence of events and decisions that shape the forming of infrastructures” (Aanestad et al. 2017). The study needs a complementary interpretive approach that would help examine this dynamic, constantly evolving and “messy” process and make sense of how the II changes over time. This study uses the processual approach described below to help understand the temporal context of II cultivation.

4.3.2 The Processual Approach

The literature review found a gap in understanding the full breadth of the temporal context of IIs (Karasti et al. 2010) and its influence on II cultivation. As discussed in the last section, studying the influence of temporality is challenging as II evolution is complex, unpredictable and messy. The processual approach is useful here as it "draws on theorising that explicitly incorporates temporal progressions of activities as elements of explanation and understanding" (Langley et al. 2013). It is an interpretive approach that studies evolving phenomena and has become popular in the change management literature (Van de Ven 1992; Pettigrew 1997; Langley 1999).

"What happens, how it happens, why it happens, what results it brings about is dependent on *when* it happens, the location in the processual sequence, the place in the rhythm of events characteristic for a given process." (Pettigrew 1997) (emphasis added).

Processual researchers evaluate both how events unfold over time with different outcomes, and how these outcomes are differentially shaped by these events (Langley 1999; Pettigrew et al. 2001). They recognise that organisational change can be complex and chaotic with unplanned occurrences, and set out to catch reality "in flight with a past, present and future" (Pettigrew 1985).

Analysing data using a processual approach starts by paying attention to key events or episodes during the phenomenon under study. The approach allows the researcher to study temporal dynamics "within a broader contextual frame that accommodates the past (historical and retrospective analyses) and the future (analyses of future expectation before and after the event), as well as the current ongoing processes of change" (Dawson 2013). To analyse events, process theorists recommend a variety of evidence sources including interviews, observations, and temporally-embedded artefacts (such as project plans and reports).

For this study, the researcher chose several episodes related to accessing data to develop an e-mobility II as the anchor for starting the analysis (discussed in Chapter 6). The processual approach recommends different strategies for studying processes after event identification since analysing processes over diverse data types and variable temporal embeddedness (for example, short term, long term, rippling over time) (Dawson 1997; Dawson 2014; Pettigrew et al. 2001) can be challenging. This study uses Langley (1999)'s sense-making strategies of narrative and temporal bracketing for this analysis (explained in Section 4.5.2). In this study, temporal bracketing is used to divide the evidence into past, present and future phases. Unlike other processual studies, this study views the temporal structure of these phases as rhythmic. The use of rhythms presents an opportunity for the study to contribute to the research efforts of process-based studies on how rhythm organises process analysis (discussed in Section 9.3).

The analysis in process-based studies involves going back and forth between theory applied to the evidence and analysis of theoretical concepts emerging from the data (Langley 1999; Pettigrew 1997; Dawson 2014). This iterative induction (data-driven) and deduction (theory-driven) strategy allows the researcher to reconceptualise the phenomena as new evidence reveals itself and to incorporate it into the theory building. Langley (1999) believes that this approach provides researchers with the flexibility to fill the gap between data and theory starting at either end, and rigid adherence to pure inductive and deductive techniques is counterproductive to research. The analysis in this thesis also uses such an abduction approach (Locke et al. 2008): it examines the process of II cultivation using the enriched theoretical framework developed in Chapter 3 and theorises from the observed processes.

Having determined the theoretical approach to investigating II cultivation, the chapter next describes the case study method as the research methodology chosen for data collection and analysis.

4.4 Methodology: Case Study Research

An examination of intermodal e-mobility IIs, a relatively unique strategic niche concept, requires an interpretive methodology that allows for an in-depth understanding of the practices of stakeholders and their interaction with technology. This section explains the case study method and why it is appropriate for studying this phenomenon.

4.4.1 The Case Study Approach

Interpretivism is a philosophy that believes "understanding process involves getting inside the world of those generating it" (Rosen 1991). The case study methodology takes the researcher inside this world and allows the researcher "to answer 'how' and 'why' questions, that is, to understand the nature and complexity of the processes taking place" (Benbasat et al. 1987).

This study uses Yin (2003)'s three criteria to argue that the case study methodology is appropriate for investigating II cultivation. First, case studies are appropriate if they require explanatory answers to "how" and "why" types of questions (ibid). This study's research questions "how do temporal rhythms influence II cultivation?" and "why does one type of temporal rhythm dominate?" both fulfil this criterion. Second, if the investigator cannot manipulate the events in the field (as she could, for example, in an experiment), then she must use either case studies or historical data. Only stakeholders involved in strategic niches can take part in related II development, which means that the researcher could not influence II cultivation in any manner. Third, a case study is appropriate if the degree of focus is on contemporary as opposed to historical events (Yin 2003). While it is imperative to consider the path dependencies inherent to IIs and evaluating historical context is essential to processual analysis (Pettigrew 1997), the main focus of this study is on contemporary challenges to building urban IIs. Given that the phenomenon under study meets these three criteria, the case study method is the most suitable option for investigating this phenomenon. Researchers also recommend the case study method if the problem area involves sticky practices and investigating the behaviour of actors and the context of their practices are necessary to understand phenomena (Bonoma 1985). As discussed, an II is a complex, dynamic and unpredictable entity whose context is inextricably linked to its evolution.

While many authors have found the case study research method useful in examining complex IS phenomena (Walsham 1995; Creswell 1998) and generating theoretical frameworks (Benbasat et al. 1987), there has been “conventional wisdom” (Flyvbjerg 2006) and criticism about their rigour (Dubé & Paré 2003) especially about the bias that comes from conducting a single case study. However, several research studies counter the bias critique as their authors report that they were compelled to change their preconceived assumptions after conducting the case study (Ragin & Becker 1992; Geertz 1995; Wieviorka 1992).

Scholars can examine case studies from a positivist (Dubé & Paré 2003), interpretive (Walsham 1995) or critical realist stance (Wynn & Williams 2012). This study uses the interpretive case study perspective in line with its theoretical approach, which means that people’s interpretations in the form of interviews are used as the primary source of data and integrated with documents and observations for triangulation and validation (Lee 1991; Mingers 2001). The analysis of this data uses the interpretative technique of thematic analysis and the processual strategies of narrative and temporal bracketing. Sections 4.5 and 4.6 outline the data collection and analysis methods related to the case study.

4.4.2 Choice of Case Study

The BeMobility project in Berlin, an experiment in developing an e-mobility infrastructure, was chosen as the case study for this thesis. The project was a strategic niche funded by the German government with the goal of demonstrating the feasibility of building a sustainable transportation system. It aimed to provide end-to-end mobility to users (covering the last mile) while limiting individual car ownership and environmental pollution. The researcher found out about the project during conversations with the staff at LSE Cities (at the London School of Economics), a centre carrying out cities-related research and education activities in London and abroad, which was a partner of BeMobility. Upon visiting the project site in Berlin, it was evident that the ambitions and complexity of the project's information infrastructure (II) made it a highly relevant case study for this thesis. The researcher established contact with the Academic Director at InnoZ (the intermediary coordinating the project) in October 2011 who was supportive and secured permission to use BeMobility as the case study for this thesis. The duration of the project also motivated the interest of the researcher. The project had already completed Phase 1 over a two-year demonstration project and received Phase 2 funding from the German government when the researcher approached InnoZ. The potential of having both historical data and collecting data as the project unfolded was exciting. The duration of a four-year project also provided confidence that there would be sufficient data to analyse II cultivation.

To check if BeMobility was sufficient as the only case study, the researcher referred to the criteria outlined by Yin (1994) for choosing a single case study or multiple case studies to investigate the research question. Yin (1994) writes that while many research projects require multiple case studies, there are some situations where a single case study is appropriate. These conditions are (i) if the case is revelatory of a phenomenon that has not been accessible to the public before, (ii) if the case is critical for testing a theory, (iii) if the case is typical or (iv) if the situation is unique. The BeMobility case study fulfilled the first condition. At the time of the research (and even now), researchers had not explored the cultivation of e-mobility IIs and the BeMobility project qualified as a single revelatory case that could be used "to observe and analyse a phenomenon previously inaccessible to social science inquiry" (Yin 1994).

While the BeMobility project presented a desirable single case study to investigate the research questions for this study, the researcher faced a few challenges when using this methodology. First, it was hard to set boundaries and hone in on the research questions when the researcher encountered the full activity and complexity of the project. Myers (2008) discusses the difficulty of establishing the boundaries of what comprises the case and writes that "in case study research, it is, in fact, tough to separate the phenomenon of interest from the context, because the context itself is part and parcel of the story." Second, research questions had to be refined during the process of data gathering as the researcher gained more information about the project. For example, early in the data collection, it became apparent that all the stakeholders were referring to temporal cycles in justifying their decisions or complaining about resistance to their efforts. This realisation led the researcher to revisit the theoretical framework to find if it could accommodate the temporal rhythms that were being "experienced" by project stakeholders. As discussed in Chapter 3, while the temporal rhythms were noted by Venters et al. (2014), the Trichordal Temporal Approach did not theorise about them. The researcher then extended the theoretical framework with concepts related to rhythms (Lefebvre 2004; Jackson et al. 2011) and refined the research questions around the influence of temporality on II cultivation.

Risk Mitigation Techniques

Some scholars have criticised interpretive research, like case study methods, for its inability to be rigorous (Nandhakumar & Jones 1997). For instance, there can be differences between what interviewees say and do in a project. This discrepancy may be because of two things: (i) there is an element of secrecy and caution in what the interviewee is saying; and (ii) the interviewee is not aware of his actions fully as they are habitual and done unconsciously. Alternatively, the researcher may not be able to correctly interpret the interview due to differences in domain expertise or culture. To mitigate the risks to research quality related to these and other issues, the researcher added rigour to the research design by using the seven principles outlined by Klein & Myers (1999) to guide interpretive research. The principles are briefly described below with an explanation of their use.

The hermeneutic circle: The hermeneutic circle says that "we come to understand a complex whole from preconceptions about the meanings of its parts and their interrelationships" (Klein & Myers 1999). In the case of examining e-mobility IIs, it was essential to constantly move between the specific actions of stakeholders to the larger context of the project to correctly interpret the meaning of what people were doing and saying.

Contextualization: The historical background of the case study is critical because IIs rest on an installed base of historical practices, technologies, and institutions. Critical reflection on the social and historical context of the project was imperative to interpreting it well. For example, the study had to acknowledge the historical dominance of a few public and private players in the transportation sector that have a long influential history in Germany.

The interaction between researchers and subjects: During the interviews in Berlin, the researcher had to constantly reflect on her behaviour and biases, and ensure that she was not "leading" the interviewees to certain answers.

Abstraction and generalisation: As the researcher iteratively analysed the data, the application of the theoretical framework and concepts like agency, installed base, and rhythm, were essential to interpret and refine the coding of documents and interview transcripts. The processual approach was used to guide data analysis, and to interpret the findings for an explanatory framework.

Dialogical reasoning: Being aware of contradictions or inconsistencies between the theory and the data are critical in the analysis phase. For example, the study's initial assumptions about how every stakeholder viewed time was based on the Trichordal Temporal Approach (Venters et al. 2014). However, as interviewees articulated their conception of time, it surfaced that they saw time as bounded by their experiences, like organisational plans, skills evolution, and innovation cycles. This revelation was used to revise the theoretical framework and create an enriched framework that included socially constructed temporal rhythms.

Multiple interpretations: The interviews revealed multiple interpretations of several facets of the BeMobility project, including, for example, the neutrality of the role of the intermediary and intent of its staff. The researcher had to review all interpretations to draw a picture that was coherent and understandable from a holistic perspective.

Suspicion: Finally, data often includes the inherent biases that people have regarding any activity. Bias was evident in the charged environment of the BeMobility project, where traditional competitors joined hands to collaborate on a new mobility infrastructure. The researcher triangulated data to remove biases regularly.

Following these seven principles was useful in maintaining rigour throughout the data collection and analysis process, and in ensuring the quality of the interpretation. The next section describes the research design regarding the timeline of data gathering and analysis.

4.4.3 Research Design

The data collection for this thesis was carried out in three phases (November 2011 – July 2012, March 2013 – May 2013 and August – September 2016). The first two phases included five trips to the EUREF campus, which served as the headquarters for the BeMobility project.

Phase 1: Data collection was begun in November 2011 and lasted until June 2012. The researcher conducted 48 semi-structured interviews (45-60 minutes in length) with various stakeholders of the project during these months. These representatives had been assigned by their organisations to participate in BeMobility's working groups and to communicate findings and tasks to appropriate teams internally. The researcher conducted all but three interviews in English and used the services of a German interpreter for those carried out in German.

During this Phase, the researcher was provided over 200 non-confidential documents, which included minutes from each project meeting that occurred from the start of the project in September 2009 to June 2012, project plans, reports and social research related to citizen needs and behaviour. Almost all documents were in German, and the researcher translated relevant documents using Google Translate and occasionally used the help of the translator who assisted in the interpretation of interviews in German.

Phase 2: A break of seven months was taken between the first and second phases of data collection to work on the literature review and find an appropriate theoretical framework based on initial findings. This break also led to questions that would more precisely identify additional information needed to conduct the analysis. The stakeholders expressed support in accommodating further interviews and data collection in 2013 (barring information that was subject to national privacy laws or non-disclosure agreements).

The researcher conducted 10 additional semi-structured interviews from March 2013 – May 2013. The researcher had identified the need to have more detailed interviews with the teams specifically responsible for writing the functional specifications of new II modules and for negotiating standards and integration protocols. These interviews deeply investigated the practices of the intermediary involved in building the modules under investigation (BeMobility Suite, the Smart Mobility Card and the Smart Micro Grid) and the resistance of different technologies during this development. Further interviews were also conducted with the engineers at the Technische Universität (Technical University) or TU Berlin to understand the challenges they faced in building a smartphone application on top of existing information systems spread over several participating organisations. Relevant stakeholders also provided additional documentation specifically related to the project management, functional specifications, technical documentation, standards creation, and communications related to BeMobility Phase 2. The researcher could also access data from the online document repository for the project for which she was provided with a username and password for non-confidential documents

Phase 3: Finally, the researcher interviewed three more stakeholders in summer of 2016 to enrich understanding and fill gaps in details related to the second phase of the BeMobility project.

The researcher also visited the EUREF campus in April 2017 during a trip to Berlin. This visit provided an opportunity for her to meet the intermediary's staff and reflect on the project's achievements and challenges. These informal discussions helped in understanding what happened to the technologies and various stakeholders after the end of the project.

The researcher conducted the 61 interviews both in person in Berlin and over the phone, and on location at the project headquarters (EUREF campus) and at the offices of the stakeholders depending on what was most convenient for the interviewees. The researcher also observed the different stakeholders in a wide variety of settings including working at the project site or various corporate offices and participating in workshops and conferences at the EUREF Campus.

The study divided the stakeholders into four main types of participants and interviewed representatives from 35 different stakeholders involved in the project. In the beginning, the focus was to interview each of them once. However, over the course of the research, some stakeholders were interviewed twice or more to understand evolving actions and developments.

Private Corporations: Both phases of the project had corporate stakeholders that spanned various industries such as car manufacturers or OEMs like Daimler and Honda, energy providers like RWE and Vattenfall, and energy management software providers like Schneider Electric. Corporations also varied in size. For example, Deutsche Bahn AG is Germany's largest railway operator, and Solon is a relatively small solar energy company.

Intermediary Staff: The researcher interviewed the staff of the intermediary InnoZ involved in the various parts of the project including its founders, project coordinators, academic liaisons, user behaviour researchers, and technology managers. Some of the staff members were also members of Deutsche Bahn AG, which is an investor in InnoZ.

Public Agencies: The researcher interviewed representatives of two types of public bodies - public transport companies and government agencies - involved in the BeMobility project. For example, Berliner Verkehrsbetriebe (BVG) is Berlin's main public transport company and responsible for ticketing. Other government agencies include Berliner Agentur für Elektromobilität (eMO), an agency of the State of Berlin responsible for promoting Berlin's electromobility initiatives, and the Berlin Senate in charge of providing public space for charging infrastructure stations.

Academics: The researcher interviewed software engineers and professors at TU Berlin involved in the development of software modules in both phases of the project. The researcher also visited the research groups DAI-Labor, which participated in both

Phase 1 and 2 of the project, and the SENSE lab that was involved in Phase 2, at TU Berlin.

Participants involved	**Number of interviews**
Academics	7
Government Agencies	7
Corporations – Main Partners	23
Intermediary	24
Total	**61**

Table 6: Summary of interviews conducted

Research Questions Adapted to the Case Study

After choosing the case study, the research questions posed in the last chapter are tailored to inform the data analysis of the evidence from BeMobility as below:

RQ1 How did different phenomenal, organisational, biographical and infrastructural rhythms impact the process of developing the e-mobility II in the BeMobility strategic niche?

RQ2 How did these rhythms interact with each other during the development of the three II components: BeMobility Suite, Smart Mobility Card, and Micro Smart Grid?

RQ3 Why did one rhythm dominate another to lead to the trajectory that the BeMobility II took during the project?

These questions will guide the data analysis in Chapters 6 and 7. The next two sections outline the methods used to collect data and conduct this analysis.

4.5 Methods: Data Collection

II cultivation evolves over time, and in practice, this means that data must be collected over time as well. The processual approach uses a longitudinal qualitative research strategy, and data is collected using various methods like interviews, observations and archival data for historical context (Gehman et al. 2017; Hassett & Paavilainen-Mäntymäki 2013). For this study, the researcher collected data over several phases and visits to the BeMobility site following the recommendations of the processual approach "to mark out periods for fieldwork in arranging familiarisation visits, conducting interviews and observational work, as well as pre-planning follow-up and second and third phase data collection activities" (Dawson 2014).

The data collection centred primarily around semi-structured interviews and documents. Even though the study uses an epistemology that focuses on understanding phenomena through the interpretations of participants, it was important that the analysis not use interviews as the only source of information. The subjectivity of both the interviewer and interviewees can be a concern in interpretative research, and researchers are cautioned to remember that "they are reporting their interpretations of other people's interpretations" (Walsham 1995). To validate and enrich information, therefore, this study also relied on documents as a secondary data source.

Documents are not only helpful in corroborating insights collected during interviews and observations but can also reveal tensions and insights that people do not express in conversations. In other words, documents present a version of social reality in their own right. However, documents may also be subjective, and when reviewing documents, the researcher had to analyse their intertextuality and consider "how documents are produced, circulated, read, stored, and used for a wide variety of purposes" (Atkinson & Coffey 1997). Documents produced for a public audience, for instance, often offer a sanitised version of the truth.

This section provides a brief overview of the different kinds of data and sources used in this study, following the guideline to use multiple lines of evidence to corroborate information (Bryman 2012) and to mitigate risks of bias. The researcher meticulously noted all data reporting and arranged it systematically as recommended by Walsham (1995).

Primary Data Source: Interviews

Interviews were the primary data source for this thesis. They were conducted in a semi-structured way to allow the interviewer flexibility and the interviewee ease to recount his or her perception of the process. The interview technique rested on maintaining a balance "between excessive passivity and over-direction" (Walsham 1995). The researcher started with broad descriptive questions regarding BeMobility and then refined them iteratively as the interviewee began to describe his or her role and observations of the project. The general questions helped relax the interviewees who the researcher noticed were usually cautious in the first ten minutes. While listening, the researcher tried to adopt a "non-judgemental form of listening" (Zuboff 1988). Every interviewee's role was related to developing some part of the II, and the researcher probed further on specific experiences when they started to discuss technology development. In some cases, the researcher interviewed the same interviewee a few times over the course of the project enabling the researcher to notice evolving interpretations and actions.

The researcher also had several informal conversations with members of the various stakeholder organisations involved in the project, which included discussions carried out during meals or on the side during workshops, meetings and conferences. The informal discussions over coffee at TU Berlin, which was responsible for designing all the interfaces between participating stakeholder systems, were particularly revealing regarding the challenges they faced during the process.

The researcher transcribed each interview from recordings or notes taken during interviews and conversations in Microsoft Word. Later, the researcher stored all documents in ATLAS.ti software for coding and analysis.

Throughout the process of data collection, the researcher had to be self-aware about keeping her neutrality. The researcher's role can run the gamut of roles from involved participant to complete outside observer, and there are several advantages and disadvantages to both kinds of roles (Mumford 2006; Walsham 1995). On the positive side, the distance from the situation means that there is less danger that the researcher loses her ability to be critical; however, on the downside, active participation in the phenomenon allows a deeper and more intimate view of practices and beliefs. In this study, the researcher played the role of an outside observer and did not participate in the events unfolding before her in any respect. She chose not to be an involved researcher since she did not want the eco-system of partners to believe that she was loyal to any one participant. However, being an outside observer does not protect a researcher from biases or from influencing the object of study and the researcher kept Coffey (1999)'s cautionary note to ethnographers in mind, which was to be aware of the relationship between themselves (personal identities, relationships, and emotions) and field work when documenting observations.

An initial concern was the researcher's inability to speak German. However, almost all the participants interviewed spoke in English. The study also periodically employed an interpreter who helped translate any interviews and meeting proceedings primarily conducted in German. Google Translate was used to translate documents from German to English, and the same interpreter reviewed sections which were unclear. The researcher did not feel that her lack of fluency in German affected the quality of the analysis. This position is also taken by Walsham (1995) in his paper on interpretive IS research where he emphasises that lack of fluency in a foreign language should not deter researchers from undertaking field studies in other countries.

Project Documents, Meeting Minutes, Reports

The researcher was provided electronic copies of all (non-confidential) project documents from the beginning of the BeMobility project to its conclusion. The researcher was also provided access to the document-sharing cloud platform Alfresco where she was alerted of new document uploads and could view and download non-confidential documents. These included project vision documents, progress reports, meeting minutes for all the working groups and project-wide meetings, papers written by staff on lead user test results, and presentations made by various stakeholders. Documents also included technical papers related to the architecture (vision, UML and object diagrams) of the II. For example, business requirements for the BeMobility Suite, the smartphone application that was a critical II component in Phase 1, were stored in Alfresco. This documentation provided an uncensored account of the current state of the II, with earlier versions of the functional and technical specifications helping to provide insight into how the design evolved. All technical documents related to information systems behind the firewalls of stakeholder organisations were inaccessible.

Notes and quotes related to the documents were organised and coded to extract information regarding processes and interactions during the project. The study views these documents as important secondary data sources. They were useful in complementing primary data secured through interviews, corroborating information, and unveiling tensions between the official version of events and that which stakeholders revealed during the interviews. They also provided a historical overview of the BeMobility project, tracing an arc from its original conceptualisation to its evolution over the course of the two phases. The two most heavily used documents in this study were the final reports of Phase 1 (d8) and Phase 2 (d9), which were 300 pages and 667 pages respectively, and provided a full overview of the activities and results of each phase.

It is important to note that all documents provided to the researcher were subject to German federal privacy laws regarding consumer specific data and non-disclosure contracts between stakeholders regarding specific product information.

Participant Observations at Work, Meetings, and Conferences

The researcher participated in two project-wide meetings, attended a daylong conference, and observed members at work during her visits to the project headquarters and various stakeholder offices. The observations from these different occasions provided a richer understanding of the cultural context of the BeMobility project, as well as the social dynamics manifested by the interactions between different stakeholders. All observations were kept with "thick" or detailed descriptions and organised by theme in Microsoft Word. Thick descriptions (Geertz 1973; Holloway 1997) mean that not just the behaviour and quotes, but the context of the observation (cultural and social relationships, for example) are noted as well, which was critical in making the behaviour meaningful for the research.

Observing and Testing II Components

The researcher also tested the smartphone app developed during the project and the different technologies at the EUREF campus. This direct exposure to the II helped her ask refined questions and better understand responses related to its development. She downloaded the BeMobility smartphone app, one of the main II components studied in this study, from the Apple App store to review functionality on her iOS phone. During the visits to the project headquarters, the researcher could also see, touch and test various new technologies (cars, bikes, charging stations, solar panels, and plugs) used in the project. This was helpful in streamlining interview questions and valuable in understanding the documents as well.

Main Research methods		Examples	Data collection
Primary Data: Semi-structured interviews		Members of BeMobility 1.0 and 2.0 stakeholders including researchers, developers, intermediary staff and government officials.	Audio-recorded, transcribed, coded
Secondary data: Project Documents		Reports, presentations, meeting minutes, technology diagrams	Frequent consultations
Participant observations	Quarterly workshops and project meetings	Stakeholders from all major partners in the project presenting on progress	Notes taken
	Site visits	Visits to project headquarters on the EUREF campus	Notes taken

Table 7: Details of data collection activities

4.5 Methods: Data Analysis

The data analysis methods used in this study were a combination of thematic analysis (Boyatzis 1998) and the temporal bracketing and narrative strategies of the processual approach (Langley 1999). This section describes these methods and how the researcher applied them to the data collected from BeMobility.

4.5.1 Thematic Analysis

Thematic analysis is a qualitative analysis method used in "identifying, analysing and reporting patterns (themes) within data” (Braun & Clarke 2006) and was used in this study to interpret the case study data.

The analysis was begun at a high level early on during data collection. The preliminary analysis informed the subsequent field work and guided the direction of future interviews and document collection. Thematic analysis was used to identify patterns in how stakeholders perceived the cultivation of the e-mobility II and the different ways in which they expressed temporal awareness related to this work. The researcher studied the interview transcripts and documents and extracted relevant quotes for coding, which is “usually a mixture of data [summation] and data complication ... breaking the data apart in analytically relevant ways in order to lead toward further questions about the data” (Atkinson & Coffey 1997). The researcher applied themes to passages of text in the form of sub-sections and brief descriptions (Flick 2009). Themes were not chosen by isolating fragments of text but interpreted in the context of the interviews' meaning as a whole (Mishler 1995).

Themes can be generated inductively (data-driven) or deductively (theory-driven). Per Langley (1999)’s abduction strategy, this study interpreted the data using a combination of applying the theoretical framework developed in Chapter 3 to understand the data, and at the same time, using the data to re-conceptualise and enrich the theoretical constructs. An initial set of codes was sensed based on interesting features in the data informed by the theoretical framework. However, as mentioned earlier, when the researcher noticed that interviewees were mentioning temporal patterns, she enriched the theoretical framework to accommodate the analysis of rhythms and did a further round of coding. Themes generated from the codes enabled the researcher to interpret the data and form arguments related to the phenomena under examination (Boyatzis 1998). The flexibility of thematic analysis is useful as it allows both inductive and deductive methodologies to be used (Hayes 1997).

In general, the study followed the six phases prescribed by Braun & Clarke (2006) when applying thematic analysis: familiarising oneself with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes and producing the report. Thematic analysis is not expected to be a linear process but is a recursive one in which the researcher has a better understanding of the data as she moves iteratively between the six phases (Braun & Clarke 2006). Over time, the coding becomes more refined, which helps in capturing the richness of the phenomenon, connecting the dots, and identifying recurrent themes (Braun & Clarke 2006). The process of generating codes and themes in this study was also not a straightforward exercise and required three significant iterations.

The initial coding scheme was based on the Trichordal Temporal Approach (Venters et al. 2014). Upon discovering the importance of rhythms like German funding cycles and the lifecycle of future urban consumers, the researcher added temporal rhythms to the theoretical framework and conducted a second iteration of coding. After noticing the increasing technical sophistication of the intermediary and its role in negotiating tensions in II cultivation, the third coding exercise included classifying mentions of the intermediary's behaviour. All transcripts, notes and documents were stored and coded in Atlas.ti. The codes were also synthesised periodically to form more conceptual and complex codes and then aggregated into themes in Atlas.ti (Friese 2014). The researcher refined the number of codes from over 300 at the beginning of the analysis to just under 100 by the third iteration.

One of the critiques of thematic analysis is that it is not rigorous and is subject to the interpretations of the interviewer. As mentioned earlier, the researcher was aware that interpretations of interviews are vulnerable to her subjectivity to a degree, and used the principle of data triangulation and multiple site visits to improve the quality of data collection and interpretation.

4.5.2 Narrative Strategy and Temporal Bracketing

The thematic analysis was not sufficient by itself to systematically organise and analyse data with a strong temporal aspect. The researcher, therefore, also used processual approach strategies to make sense of the temporal interconnectedness of the past, present and future and its influence on II cultivation. These strategies are appropriate as they are based on "an understanding of the world as in flux, in perpetual motion, as continually in the process of becoming" (Langley & Tsoukas 2010). Langley (1999) provides several different strategies for analysing process data, yet does not prescribe any strict steps instead advising researchers to remember there is "no one best way to perform process research" (Gehman et al. 2017). For this study, the researcher employed a combination of temporal bracketing and narrative strategies: "temporal bracketing helps to recognise when and how changes are triggered; narrative strategies help to explain why" (Pozzebon & Pinsonneault 2003). Narrative strategy on its own is problematic as it can be too accurate to the specifics of the case study, while critics have said temporal bracketing on its own may miss details or incorrectly equate temporal phases (Langley 1999), which is why the combining the two is recommended by Langley (1999).

Temporal bracketing

The idea of temporal decomposition is a reference to Giddens' (1986) structuration theory and the idea that structures constrain individual actions, but that actions also shape those structures over time. The interactions between actors and context over time is cumulative. Since it is challenging to capture mutual influences at the same time, it is analytically easier to temporally "bracket" different processes and analyse them separately. By breaking down data into successive phases, the researcher can examine how actions in one period shape the context and action in the next period (Barley & Tolbert 1997; Langley 1999). The value of creating phases is to tease out feedback mechanisms and mutual shaping (Langley 1999).

Phases: In this study, the researcher bracketed events in past, present and future time periods and the influence of the past and the future was analysed separately on the present. This method is especially relevant when "analysing dialectical processes in which competing forces act in opposition to one another and for which short-term and long-term effects of action may be different" (Langley 2010). Rhythms of different temporal duration influence human and material agencies differently (for example, phenomenal rhythms will likely have a much longer duration than an organisational rhythm), and the resulting actions may reinforce or contradict each other.

Events: In each of the phases, critical sequential events or episodes of interest are identified by the researcher. This study chose five episodes to examine that are described and analysed in Chapter 6. In process studies, researchers usually analyse events sequentially across phases (Denis et al. 2001; Dutton & Dukerich 1991). However, in this study, the feedback mechanism is not only from the past to the present but also backwards from the future to the present as the study examines experienced rhythms in the past and imagined rhythms in the future.

After bracketing the evidence into different phases, this study used the narrative strategy to lend richness and nuance to events observed over time.

Narrative strategy

Narrative is used to organise and understand data about unfolding events in a systematic manner (Pettigrew 1985; Miles & Huberman 1994; Langley 1999). Contextualist researchers (Pettigrew 1990) and ethnographers (Van Maanen 1988) often employ the narrative strategy, and almost all process-based studies use it at some point in any research project. This study employed the narrative strategy to prepare an initial chronology of the phases and to analyse the sequences of phases and links between them (Langley 1999) making use of thick descriptions and vignettes as described below.

Thick descriptions: Throughout data collection, the researcher kept "thick" descriptions, which provided full contextual detail of any observation or interview. Thick descriptions are helpful in providing the "'vicarious experience' of a real setting in all its richness and complexity" (Langley 1999). Researchers must remember that narratives are not limited to just providing detailed descriptions, but should provide an overall sense of the arc of events and have embedded plots of themes that help make sense of the phenomena (Woiceshyn 1997).

Vignettes: This study also made use of vignettes to help organise and make sense of the flow of events. A vignette is a focused description of representative events limited to a time span, actors or space (Miles & Huberman 1994). The researcher created vignettes and storylines when examining interviews, observations and documents in the early phases of data analysis.

Influences and Interventions

Temporal bracketing and narrative strategies are used to analyse data and understand "how" and "why" II cultivation occurs in a certain way. The processual approach recommends a combination of data-driven deduction and theory-driven inductive strategies to imagine the "generative mechanisms" that explain the data (Tsoukas 1989). Mechanisms are useful to understanding "the set of driving forces that underlie and produce the patterns that we see empirically" (Gehman et al. 2017). However, even though Langley (1999) lists mechanisms as one method to use when using temporal bracketing and narrative strategies, there are no clear guidelines on how to generate them and "the explanatory basis of process research still lacks attention" (Vincze 2013). Mechanisms have been used widely in critical realism research (Myers & Klein 2011), but since critical realism is not the ontology used in this study, it uses thematic analysis to find influences and interventions in II cultivation rather than mechanisms. These influences and interventions are extracted in the analysis chapter through an iterative process of coding and developing themes. The researcher then further refines emergent themes and makes connections between them, using the emergent influences and interventions to develop an explanatory framework. Explanatory frameworks must then be generalised by the researcher to build a framework for II cultivation. The next section addresses how case study findings can be generalised.

4.5.3 Generalising and Theory-Building

Generalisation in qualitative research has been controversial and contentious partially because researchers have tried to apply the concept of statistical generalisation to case study research: “generalisations are sometimes mistakenly expected to be proven statements, rather than taken as well-founded but as-yet untested hypotheses” (Lee & Baskerville 2003). Walsham (1995) identifies four types of generalisations that are possible from interpretative research: “development of concepts, generalisation of theory, drawing specific implications in particular domains of action, and contribution of rich insights” (ibid). This study aims to generate the first type of generalisation which is the development of concepts (Lee & Baskerville 2003; Yin 2003) that are "part of a broader network or an integrated clustering of concepts, propositions and world-views which form theories in social science” (Layder 1993).

The case study methodology is capable of producing results that have implications and help analyse similar phenomenon beyond the research setting. In positivist studies, researchers base generalisation on taking results from a statistical sample and applying it to the wider population. In interpretive studies, they base it on moving from the case study to theoretical propositions (Lee & Baskerville 2003; Yin 2003).

'How can you generalise from a single case study?' is a frequently heard question ... The short answer is that case studies are generalizable to theoretical propositions. (Yin 2009).

Eisenhardt (1989) outlines three ways in which theoretical propositions are used in positivist case study research: as an initial guide for data collection and analysis, as part of an iterative process of data analysis, and as a final product of the research. This approach is also pertinent for interpretive case studies. This study used the theoretical framework developed in Chapter 3 as an initial framework that used previous knowledge and research on the topic to inform the data analysis. It is crucial that the initial theory not become a rigid framework, which limits exploration and interpretation of the data (Walsham 1995). To avoid inflexibility, researchers should “preserve a considerable degree of openness to the field data, and a willingness to modify initial assumptions and theories” (ibid). A flexible approach was also taken in this study where the initial theoretical framework of the Trichordal Temporal Approach (Venters et al. 2014) was enriched to accommodate new evidence that emerged during the analysis.

By extension, theory-building is not problem-solving but more an exercise in sense-making (Weick 1989b), requiring the researcher to go back and forth between intuition and data-based theorising. The iterative stance is distinct from Glaser & Strauss (1967)’s grounded theory where the theory is discovered directly through induction from the data collected. This researcher found the use of previous theoretical work on IIs very useful as a starting point to analyse the case, and so did not use the grounded theory approach. This study employed “disciplined imagination” in building theoretical concepts that “highlight relationships, connections, and interdependencies in the phenomenon of interest” Weick (1989b). Generalising to theoretical concepts is in this sense akin to an evolutionary process that emerges from trial and error (ibid).

4.6. Summary

This chapter explains the research design and methodology employed in this study. It describes why the social constructionist epistemology, which is the view that knowledge and meaningful reality is constructed from the interaction of humans with the world, is appropriate for this research. The chapter discusses how the epistemology guides the methodology and analysis of the findings. It introduces the interpretivism perspective as the theoretical approach since it helps access the “meaning’ behind people’s actions by actively reflecting on and engaging with the people in the social context. The study also uses a processual approach to understand emergent II cultivation as a longitudinal process. The processual approach is appropriate for studying IIs over time as “process researchers seek to understand and explain the world in terms of interlinked events, activity, temporality and flow” (Gehman et al. 2017). The chapter then explains the selection of the case study method (Yin 1994) as the interpretive methodology and the choice of a single case study for collecting evidence to investigate the research problem. A single case study is appropriate for this study given the uniqueness of the e-mobility II in a strategic niche and is a revelatory case for the phenomenon. Finally, the chapter provides the timeline of data collection, including the types of data collected and the principals by which the researcher ensured the rigour of the data gathering. It also outlines the data analysis methodologies of thematic analysis and temporal bracketing and narrative strategies. The research approach described in this chapter will be used to examine the case of the BeMobility project in Berlin, which is described in the next chapter.

5. Case Study

5.1 Introduction

This chapter introduces the intensive case study known as “Berlin elektroMobil” (BeMobility) used in this thesis. The study selected the BeMobility case because it represents a revelatory case about prototyping e-mobility IIs in cities. The researcher had significant access to the case study site including provision of project documents, permission to attend meetings, workshops and conferences, ability to conduct interviews with stakeholders (sometimes more than once if needed), and opportunities to inspect hardware (cars, charging stations, solar panels and so forth) and software documentation (code and databases). This access provided over time a deep understanding of the complex web of public and private stakeholders, and their associated information systems and data streams that had to be integrated to create the e-mobility II.

This chapter has the following sections:

Section 5.2 explains the background for setting up a strategic niche to prototype an e-mobility II and gives a broad overview of the vision for BeMobility. It illustrates the proactive involvement of the German government in driving e-mobility projects under the umbrella of “Energiewende,” a nation-wide policy effort towards sustainable mobility and an innovative mobility industry.

Section 5.3 describes the vision and stakeholders of BeMobility, including an overview of why Berlin was selected as the city to represent such an e-mobility experiment.

Section 5.4 describes Phase 1 of BeMobility and outlines its stakeholders and partners, goals and method of coordination. It focuses on the two II components driving the integration between public transport and car-sharing systems: the BeMobility Suite and the Smart Mobility Card. It reviews the necessary integration processes and describes the outcomes of the effort, and describes the results of the social research on the openness and reaction of consumers to the concept of integrated mobility.

Section 5.5 describes Phase 2 of BeMobility, highlighting the motivation for extending the project by adding the goal of integrating sustainable energy with transportation systems (as encapsulated in the development of the Micro Smart Grid). It explains the added complexity of the II given the wider scope of interested parties and systems, and the process of connecting additional layers of data and hardware to the installed base. Lastly, it reviews the results of the project regarding car-sharing rides taken, the integration of the microgrid and user behaviour and response.

Section 5.6 concludes the chapter by providing summary thoughts on the two phases of the project.

5.2 Energiewende

5.2.1 A National Platform for e-Mobility

Since 2007, the German government has taken a highly proactive approach towards e-mobility as Germany was determined to develop a globally competitive sector and to create a sustainable mobility infrastructure domestically.

A National Development Plan for Electric Mobility had been adopted by the government in August 2009 with the goal of deploying 1 million electric vehicles (EVs) by 2020. By 2020, it aimed for 5 million EVs deployed on the roads, and by 2050, for most urban transport to be powered only by renewable energy.

The Plan focused on two areas of research support: (i) research in battery storage for EVs; and (ii) the development of reliable and energy efficient systems for EVs[4].

It recommended achieving this long-term goal in three stages[5]:

- A *market preparation phase* lasting until 2011 with a focus on research and development (R&D), and demonstration projects that would prototype R&D.
- A *market escalation phase* lasting until 2016 that would focus on introducing EVs and developing infrastructure
- A *mass market phase* starting 2017 that would involve mass production of EVs with a viable business model.

The creation of the strategic niche called BeMobility has its roots in these recommendations and falls in the stage called "market preparation".

In May 2010, Chancellor Angela Merkel officially established the National Platform for Electric Mobility (NPE) that would deliver concrete proposals for the NPE's recommendations for the introduction of EVs in Germany. According to its website, the NPE had "set out to develop Germany into the leading supplier and lead market for electric mobility[6]." The aim was that this effort would result in an additional 30,000 jobs in Germany.

To formulate a comprehensive execution strategy, the NPE published three reports[7] that analysed the current state of electric mobility, made recommendations on how to

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[4] Germany Trade & Invest website (Source: http://bit.ly/2i1KYJh)
[5] Leurent, Fabien, and Elisabeth Windisch. "Triggering the development of electric mobility: a review of public policies." European Transport Research Review 3.4 (2011): 221-235.
[6] National Electromobility Platform (Source: http://nationale-plattform-elektromobilitaet.de/en/)
[7] Germany Trade & Invest website (Source: http://bit.ly/2gHiA2y)

stimulate the sector, and assessed progress respectively. One of the committee's chief recommendations[8] was coordinated measures to support the market start-up phase of innovative e-mobility technologies in so-called "showcase" projects.

5.2.2 Electric Mobility Showcases

The broader vision and strategy laid out by NPE at the federal level had to be executed by cities and local governments. The Electric Mobility Model Regions, a program launched to fund projects that would test and implement ideas in cities and regions during the market preparation phase, provided the funds for Phase 1 of BeMobility. The project secured funding through a national bidding process in which the Federal Ministry of Transport, Building and Urban Affairs (BMBVS) would award €130m (d8) to eight regions to create strategic niches for market preparation programs. Bids were a joint effort by public and private party stakeholders who collaborated to present proposals on how they would prototype e-mobility infrastructures in their regions. Each program was expected to comprise cross-sectoral experts from industry, municipalities, and academia to research and build experimental infrastructure. Their efforts would be coordinated by National Organisation for Hydrogen and Fuel Cell Technology (NOW) at the national level.

The ElectroMobility Model Region Berlin-Potsdam program funded Phase 2 of BeMobility. It was another promotional program launched with the aim of showcasing large-scale demonstration projects that used electric mobility technologies. Each of these projects would involve close cooperation between the central government, industry, and academia to coordinate the piloting of innovative e-

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[8] Nationale Plattform Elektromobilität, Zweiter Bericht der Nationalen Plattform Elektromobilität, Berlin (2011)

mobility solutions, serving both as a prototyping exercise to test such ideas and as a vehicle for generating public awareness and national and international demand.

In 2012, the federal government chose four showcase regions for e-mobility[9] based on the recommendations of an independent jury of specialists. About 140 projects in these regions would be supported by the federal and state governments along with the private sector over the period 2012-2015. One of the showcase regions was International Showcase of Electric Mobility (Berlin-Brandenburg) which also provided funding for the BeMobility project. The showcase projects were overseen by the Federal Ministry of Transport and Digital Infrastructure (BMVI), the Federal Ministry of Economic Affairs and Energy (BMWi), the Federal Ministry of Education and Research (BMBF), including the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMUB). The total amount of investment support for the program was Euro 300m with Euro 180m provided by the federal government.[10]

Even though the German government had a strong commitment to e-mobility, it came more into focus after the Fukushima nuclear disaster on 11 March 2011. An energy accident at the Fukushima Nuclear Power Plant, it was triggered by a tsunami following an earthquake. Deemed the largest disaster since the 1986 Chernobyl nuclear accident in Russia, it involved three nuclear meltdowns, the release of radioactive materials and several hydrogen-air chemical explosions. Almost immediately, the German government began to face mounting public pressure to reconsider its use of nuclear power in the country.

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[9] Germany Trade & Invest website (http://bit.ly/2z411B2)
[10] Schaufenster Elektromobilitaet website (http://bit.ly/2yNzDGh)

German Chancellor Angela Merkel’s government responded decisively by shutting down eight nuclear plants in Germany, with a plan to close the remainder by 2022. The government also made a renewed commitment to shift away from nuclear and fossil fuels to renewable energy sources to lower the risk of security hazards. Chancellor Merkel set a goal of reducing greenhouse gas emissions by 40 percent by 2020 and 80 percent by 2050 (compared to 1990 levels). The commitment to restructure the country’s energy sector to meet these goals took on the name of “Energiewende” or the “energy turn” in modern discourse, and the e-mobility strategic niches also began to be associated with this movement.

5.3 BeMobility for Berlin

The Berlin metropolitan made a compelling case to win the prize of building an e-mobility strategic niche for several reasons (outlined below).

1. Berlin had a famous public transportation system with an integrated transport policy under the Urban Development Plan for Transport, which provided a strong foundation for an e-mobility infrastructure reliant on public transport.

2. The city already had several years of experience with car-sharing programs, which showed that the concept was familiar to its residents. The first car sharing program StattAuto Berlin was launched in Germany in 1988 and Deutsche Bahn AG had been operating Flinkster, the largest car sharing network in Germany, since 2001in Berlin.

3. Berlin residents had a clear preference for shared transportation and personified the kinds of consumers that would value an e-mobility infrastructure. The population

of Berlin, approximately 3.5m people (the combined Berlin-Brandenburg metropolitan area has just over 4.9m people), had the lowest motorisation rate of any German city. Berliners owned only 324 cars per 1000 residents[11], while Hamburg, for example, had 611 cars for the equivalent number of residents. Cycling, walking, and public transportation were popular in Berlin, as were an increasing number of public and private car-sharing schemes.

4. Berlin had access to renewable energy with 45% of the electricity of the Berlin-Brandenburg metropolitan area already using wind and solar as its source, resources essential to building a sustainable transport system. The government aimed to have 100% of Berlin and Brandenburg's electricity demand fulfilled with renewable energy by 2020.

5. There was a strong foundation of research and development (R&D) in universities and research institutes such as TU Berlin, which was of interest to companies wanting to develop and test emerging mobility technologies

6. Berlin had a strong desire to become an innovation hub for different e-mobility solutions, and a living lab for prototyping and testing them[12]. It viewed the mobility and renewable energy sectors as an opportunity to attract capital and boost economic growth and employment in the city. The municipal government was also in the process of converting the site of Tegel Airport into an innovation centre for companies such as the energy and transport sectors.

Of the four projects planned in the Berlin Showcase, the largest one was BeMobility, which aimed at the integration of electric fleets (cars and bikes) into the public

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[11] P Rode, G Floater, "Going Green: How cities are leading the next economy", LSE Cities, 2012. Pg. 81
[12] P Rode, G Floater, "Going Green: How cities are leading the next economy", LSE Cities, 2012. Pg. 82

transport system providing multi-modal journey options. The goal of BeMobility was to prototype an e-mobility infrastructure that was flexible, affordable and sustainable.

A successful prototype of an e-mobility infrastructure would position Berlin as a quintessential "smart city" with sustainable transportation, and attract capital and talent to help Berlin develop similar systems for other cities. The demand for such innovative mobility systems was on the rise with rapid urbanisation. Cities, which occupy only two percent of the earth's surface, hold over half of the world's population of 7 billion people[13] with more people migrating to urban areas every day. The degree of urbanisation is expected to be over 60% by the year 2018 (World Bank, 2011). Against the background of increasing migration to cities and economic activity, a corresponding rise in motor vehicle registrations was putting intense pressure on urban transport infrastructures. Mexico City residents, for example, collectively spent 17 million hours in traffic[14] with traffic equally onerous in Asian cities like Jakarta, Bangalore, Beijing, Manila and Ho Chi Minh City. With an impressive e-mobility prototype, Berlin could become a role model for the rapidly urbanising world which was experiencing multiple environmental problems and transport bottlenecks. It would create the potential for Germany to become the leading supplier of e-mobility solutions for cities, a goal that highly motivated the government's support of programs like BeMobility.

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[13] P Rode, G Floater, "Going Green: How cities are leading the next economy", LSE Cities, 2012. Pg. 11

[14] Simon Pfanzelt, "Schleichende Massen" Der Spiegel 28 October 2014

5.3.1 Vision

The vision for future urban mobility involves replacing siloed modes of transportation, such as cars, bikes, buses, and trains, with an integrated system of shared mobility options that are powered by renewable energy. Citizens are urged to consider mobility services as opposed to vehicle ownership to encourage a more sustainable approach to reaching their destinations.

For example, a young woman on her way to work may ride a rented bicycle to the train station (powered by electricity) after which she takes the train to the stop nearest her office. From the station, she will have the option of taking an electric car (powered by solar energy) and park it near her office. The carbon footprint of her entire mobility chain would have been zero, and she would have used shared and public transportation modes. Such intermodal transport options could be provided by the public and private sector and made available at an acceptable price to the market.

The goal of BeMobility was to give urban residents multiple mobility options as described in the example above with an easy way to book journeys and make payments. Given multiple mobility players (such as car manufacturers or OEMs, public transport providers, charging infrastructure providers, energy suppliers, train operators, and parking space owners), an integrated information infrastructure (II) was necessary for systems from various stakeholders to seamlessly communicate. Computers within cars, for example, could continuously share and store information regarding their location, charging state and passengers, which in turn could drive business processes like auto-payments.

In addition to being sustainable, mobility could also be "personalised" to the needs of citizens. A smartphone application would enable users to decide on which route (and associated transportation modes) to take based on real-time information regarding a variety of factors including train and bus schedules, traffic conditions and delays, vehicle availability and charging state of shared bicycles and cars nearby, weather conditions and costs.

A selling point for citizens would be that investment in new mobility will create "intelligent" information infrastructures that will put the citizen in control of when and how he wants to travel in the city. Through a smartphone or tablet application, dedicated website or even a car dashboard, the citizen can preview his mobility route under a variety of conditions (such as cost or time of trip) and choose the one that fits his desires best.

From both the operator and user's perspective, the information layer of this mobility infrastructure constitutes a fundamental component of a successful multi-modal transport system.

5.3.1 Stakeholders

BeMobility involved over 32 stakeholders that were broadly representing four types of organisations: public sector (government agencies and associations), private sector (railway, energy and software companies), academia (university departments) and intermediary. Stakeholders either participated as Consortium Partners or Associate Partners, with the latter having a more limited role and funding contribution. The lead partner and primary sponsor of the project was Deutsche Bahn AG, Germany's largest public transport operator with subsidiaries that included railway, bus, and car-sharing and bike-sharing services.

The table below provides brief descriptions of the stakeholders (in alphabetical order).

Name	Description
Alcatel-Lucent	Alcatel-Lucent was a French global telecommunications equipment company focused on fixed, mobile and converged networking hardware, IP technologies, software and services, with operations in more than 130 countries. In

	November 2016 Nokia completed the acquisition of the company and it was merged into their Nokia Networks division.
Berlin Transportation Company (BVG)	The Berliner Verkehrsbetriebe (BVG) is the main public transport company of Berlin, the capital city of Germany. It manages the city's U-Bahn underground railway, tram, bus, replacement services and ferry networks, but not the S-Bahn urban rail system.
Berlin Senate	The Senate of Berlin is the executive body governing the city of Berlin, which at the same time is a state of Germany.
Buro Happold	Buro Happold is an international consultancy providing engineering, design, planning, and project management services for buildings, infrastructure and the environment.
Choice	Choice is a consulting, research and project development company in the area of innovative and intermodal mobility concepts.
Contipark	The Contipark International group of companies ("Conti Park") is an international organization that deals with the planning, financing, and management of parking facilities of all kinds.
DAI Labor (TU Berlin)	The Distributed Artificial Intelligence Laboratory (DAI-Labor) is a research institute of the Faculty of Electrical Engineering and Computer Science at the Technical University of Berlin.
Daimler	Daimler is a German multinational automotive corporation, which owns or has shares in a number of car, bus, truck and motorcycle brands including Mercedes-Benz. By unit sales, Daimler is the thirteenth-largest car manufacturer and is the largest truck manufacturer in the world.
DB Bahn Park	DB Bahn Park is the parking management company of Deutsche Bahn AG with the task of optimising parking at railway stations.
DB Fuhrpark	DB Fuhrpark is a subsidiary of Deutsche Bahn AG and provides mobility management services for the the DB Group's road vehicles. DB Rent (DB Connect as of 2017) is part of DB Fuhrpark and operates the car-sharing service Flinkster and the bike-sharing service Call-a-Bike.
DB Energie	DB Energie is the energy supplier of railways in Germany. DB Energie also supplied trade and commerce in and around railway stations with electricity and gas. It is the energy partner of the electric car-sharing service e-Flinkster operated by DB Rent.

eMO (Berlin Agency for Electromobility)	eMO is an agency of the State of Berlin that operates under the aegis of Berlin Partner for Business and Technology. It is the central point of contact for smart mobility in the Berlin.
GASAG	GASAG (Berliner Gaswerke Aktiengesellschaft) is the main natural gas vendor in Berlin.
Deutsche Bahn AG	Deutsche Bhan AG is the largest public transportation company in Gemany and has approximately 282,000 employees and generated sales of around Euro 32 billion in 2010. Its subsidiaries include DB Fuhrpark, DB Energie and DB Bahnpark.
HaCon	HaCon provides software solutions for public transportation, mobility and logistics from trip planning to mobile ticketing and fleet management.
Hiriko	Hiriko is a folding two-seat urban electric car that was under development by the Hiriko Driving Mobility consortium in the Basque Country of northern Spain.
Infra Wind Eurasia	Infra Wind Eurasia, founded in Berlin, is an initiative to flank the European-Asian cooperation in the field of renewable energy, smart grids, and the Green Economy.
InnoZ	InnoZ is a research and consulting company. It researches and consults on market and environmental trends and forecasts related to mobility.
LSE Cities (London School of Economics)	An international centre carrying out research, education and outreach activities in London and abroad dedicated to understanding the needs of contemporary urban society.
Netzgesellschaft Berlin-Brandenburg (NBB)	NBB is the network operator of the gas network infrastructure in Berlin and major parts of Brandenburg, and one of the largest local gas distribution company in Germany.
Reiner Lemoine	The Reiner Lemoine Institute is a research institute with the aim to scientifically support the processes for the long-term conversion of energy supply to 100% renewable energies.
REM+Tec	REM+Tec is the architecture firm responsible for designing parts of the EUREF campus.
RWE	RWE is a listed energy group and supplies electricity and gas to more than 20 million electricity customers and 10 million gas customers, principally in Europe. RWE is the second largest electricity producer in Germany.
Robert Bosch	Robert Bosch is a German multinational engineering and electronics company. It is the world's largest supplier of

	automotive components measured by 2011 revenue.
S-Bahn Berlin	S-Bahn Berlin operates the rapid transit railway system in and around Berlin.
Schneider Electric	Schneider Electric is a French multinational corporation that specialises in energy management and automation solutions, spanning hardware, software, and services.
SENSE (TU Berlin)	The Department of Sustainable Electric Networks and Sources of Energy (SENSE) at Technical University Berlin focuses on the study of energy and automation technologies.
Solon	Solon is a solar module manufacturer in Europe and a supplier of photovoltaic systems for large-scale solar power plants.
Toyota	Toyota is a Japanese multinational automotive manufacturer and as of 2016, the world's largest automotive manufacturer.
TUV Hessen (TÜV Technical Inspection Hessen)	TÜV Hessen is a service company with international operations and focuses on technical testing and certification in a wide field within the service sector.
Vattenfall Europe	Vattenfall AB is a Swedish energy company and is one of the largest electricity and heat producers in Europe.
Verkehrsverbund Berlin-Brandenburg (VBB)	VBB is a transport association run by public transport providers in Berlin and Brandenburg. Lines operated under the VBB fare structure include all local traffic in Berlin, such as the Berlin S-Bahn and Berlin U-Bahn. Common ticketing began in 1999 and services over 3 million passengers a day.
Yunicos	Younicos is a German-American technology company that develops and sells energy storage systems and control software.
Federal Ministry of Transport, Building and Urban Development (BMVBS)	A ministry of the Federal Republic of Germany responsible for governance of transport, building and urban development.
National Organization Hydrogen and Fuel Cell Technology (NOW)	NOW is responsible for the coordination and management of the Electromobility Model Regions programme of the Federal Ministry of Transport and Digital Infrastructure (BMVI).

Table 8: Stakeholders in the BeMobility Project

5.3.3 Project Coordination

InnoZ (Innovation Centre for Mobility and Societal Change), a multidisciplinary institute focused on mobility systems innovation, was the appointed intermediary and manager of the BeMobility project. InnoZ’s office is situated in a living lab for smart city and connected mobility projects called the EUREF Campus in Berlin-Schoneberg. Founded in 2006, InnoZ offers research, testing and consulting services in the field of innovative systems solutions for mobility. It has five equal shareholders including Deutsche Bahn AG. Andreas Knie, the Managing Director of InnoZ, along with other InnoZ staff members, also work for subsidiaries of Deutsche Bahn AG.

In 2013, it had 80 employees engaged in over 30 projects; had hosted 200 events and 6000 guests at its campus and had a €4.5m turnover[15].

In the BeMobility project, InnoZ had four main responsibilities:

- Coordinating and facilitating all project planning, reports and accounts management according to the requirements set by the government.
- Researching citizen needs and behaviour related to e-mobility.
- Leading public relations efforts including press releases, articles, website, events and conference participation.
- Providing a physical platform on its premises which served as an integration test environment for the different technological components (such as vehicles, smart grid, and charging infrastructures) before their deployment in the city.

InnoZ managed the project through the creation of work packages (called APs) for each type of activity. For example, in Phase 1, AP2 was for “User Requirements” while AP5 was for “User Interface/Infrastructure/Transport System.” During the

[15] ECCI Website, “Special Guests InnoZ Join us for a Pop-up Chat Room at ECCI”, 17 April 2015 (Source: http://bit.ly/2zCK2SI)

project, members of each AP communicated and met regularly, while the whole team met once a quarter for project update conferences at InnoZ's office.

5.3.4 Headquarters: EUREF Campus

InnoZ also operated a test site to showcase the latest technologies on the EUREF Campus, a 5.5-hectare campus in Berlin-Schöneberg. The EUREF Campus is a research and development campus for companies working in the fields of energy, sustainability and mobility. As of 2016, it is now home to 100 companies and research institutions with over 2000 employees. Companies such as Deutsche Bahn AG, Schneider Electric, Cisco, Alphabet, and General Electric and institutes as such as Mercator Research Institute on Global Commons and Climate Change and the Climate-KIC have built their offices here. InnoZ is located at the EUREF Campus, which meant it served as the project headquarters for BeMobility. The InnoZ offices and car park had several functions: as a place for stakeholders and media to come and view prototypes of future-forward mobility concepts including e-bikes, charging stations and ICT systems; as a site where the stakeholders could test, load and charge electric vehicles; and as the platform for a smart electricity network with a Micro Smart Grid. All quarterly meetings and initial experiments took place at the EUREF Campus.

5.3.5 II Components Under Investigation

The BeMobility project envisioned the future of urban transportation at the intersection of the mobility, energy and telecommunications (providing both ICT and payment support) sectors. Three main II components defined the envisioned e-mobility II: the BeMobility Suite smartphone app, a Smart Mobility Card for integrated payments, and a Micro Smart Grid. These three components are the focus of this study and are described briefly below:

BeMobility Suite: For consumers to plan their journey, they should be able to download a smartphone app that will plan the best multi-modal route for them given their origin and destination, providing them directions, pricing and relevant information such as where to charge and park electric vehicles.

Mobility Smart Card: For consumers to have seamless multi-modal travel, they should have access to an integrated payment card that allows them to easily and conveniently pay for all parts of their journey.

Micro Smart Grid: For the transportation sector to be sustainable, energy demand and supply should be intelligently managed using a Micro Smart Grid that produces energy via solar and wind power, as well as V2G (vehicle to grid) power from vehicle batteries.

The table below provides an overview of the goals and II components of Phase 1 and Phase 2 while the following sections describe how the stakeholders developed these components in each phase. Phase 1 lasted from September 2009 to November 2011, and Phase 2 lasted from January 2012 to March 2014.

	Phase 1	**Phase 2**
Goals	Integrating public transportation with electric and hybrid car-sharing networks.	Expanding the e-mobility II cultivated in Phase 1 to integrate it with energy networks.
Infrastructure	* Procurement of electric and hybrid car-sharing vehicles by Flinkster. * Construction of electric charging stations. * Designated parking spots in the city.	* Procurement of additional flexible sharing electric vehicles by MultiCity. * Set up of Micro Smart Grid including two small wind turbines, a combined heat and power plant, solar panels, three storage batteries, and a control room.
BeMobility Suite	* Development of a smart phone app that gives users a multi-modal journey route if they enter their	* Extension of the BeMobility Suite app with further integration of real-time data sources, testing of visibility

	origin and destination. * The App also allows users to search car-sharing vehicles, charging and parking spots, and to book car-sharing vehicles.	of battery level in electric vehicle, and ability to search charging station availability. * Improvement of routing algorithm. * Separation between production and the research versions of the app
Smart Mobility Card	* Development of a 3 month smart mobility card that allows users to pay for public transport in Berlin (underground metro, bus, urban rail), long-distance transport (railways) and short-distance transport (Flinkster car sharing and Call-a-Bike bike sharing).	* Development of a 1 year smart mobility card "BahnCard 25 mobil plus" that allows users to pay for public transport in Berlin (underground metro, bus, urban rail), long-distance transport (railways) and short-distance transport (Flinkster and Multicity car sharing and Call-a-Bike bike sharing).
Micro Smart Grid	N/A	* Development of a network management system that includes modules for data management, processing, optimising and forecasting. * Development of a data model for measurement, control, and forecast of data from wind turbines, solar panels, charging stations, and vehicles. * Ability to simulate consumer behaviour and optimise energy usage.
User Research	Research to understand the profiles of early adopters, how consumers use car-sharing, and their feedback on the BeMobility system. Results showed: * Car-sharing was used by homogenous group of highly educated males between the ages of 38-40 years who are employed with above-average household income. * Electric car sharing was used mostly for leisure trips and running errands. * Short range of electric cars did not deter customers.	Continue research to understand the profiles of early adopters, how consumers use car-sharing, and their feedback on the BeMobility system. Use surveys, focus groups and questionnaires to identify needs of future users. Results showed: * Early adopters were highly educated men around 40 years of age. * The findings showed that for 80% of users, range anxiety was not a concern as they needed car sharing

		for short rides and errands. * The surveys also surfaced a high sensitivity to price for users.

Table 9: Overview of BeMobility Phases

5.4 BeMobility 1.0

One of the main tasks of the BeMobility 1.0 project was to integrate all parts of the mobility infrastructure (services, vehicles, infrastructure) to create a seamless multimodal mobility chain for the user.

"The integration of different mobility, vehicles, and infrastructure (charging stations, parking lots) to provide and the information systems, was the core of BeMobility." [16] (Source: Project Website)

Specifically, Phase 1 of the project aimed to investigate the following facets of integration:

1. Whether integration was possible from a technical standpoint.
2. Whether there was any demand for such an integrated mobility offering.
3. Whether such a mobility infrastructure would improve the public transport experience for passengers.
4. Whether it was possible to have such an integrated offering in an urban setting.

InnoZ set up seven different work packages (APs) to manage the different themes and individual tasks. In total, there were nineteen partners divided into two types: consortium partners and associated partners with consortium partners both contributing and receiving more funding.

[16] InnoZ website (http://bit.ly/2zCgkNy)

Infrastructure Set-up

To introduce electric car-sharing, the project needed to organise three parts of the infrastructure: electric vehicles, charging stations and car parking spots.

First, the program had to procure the electric vehicles. Citroën C1, Smart Toyota, Prius plug-in hybrid and Citroën C-Zero. These vehicles were made available through Deutsche Bahn AG's existing car sharing scheme known as Flinkster operated by DB Rent. By the end of the project, 32 electric and hybrid vehicles were made available for car-sharing.

Second, the construction of charging stations was required, which needed the cooperation of private space providers, district offices that provided their parking spaces, network operators, utility providers and information and communication engineers. By the end of the project, 15 rental locations were made available with 25 loading platforms. Of these charging stations, nine belonged to DB Energie, fourteen to Vattenfall, one to RWE and one to Solon.

Drivers of electric vehicles received designated free public and private parking spaces where they could rent, charge, park and return cars. In cooperation with car park operators DB Bahn Park and Contipark, e-Flinkster users could park their cars for free and charge their vehicles in 9 DB Bahn Park car parks located at various Berlin railway stations and 17 Contipark facilities.

5.4.1 BeMobility Suite

The BeMobility project assumed that stakeholders would not be able to redesign hardware such as charging plugs and vehicles during Phase 1. However, the project required the development of a new smartphone application that would allow customers to easily search and book transport options, including on shareable e-vehicles. This prototype smartphone application was called BeMobility Suite. It was necessary both to deliver the integrated mobility service and to test the customer's reaction to the concept of shared e-mobility. The application needed to provide relevant information about public transport (stops, timetables and routes) and electric vehicles (vehicle location, charging stations, charging status, parking lots).

The project envisioned the BeMobility Suite as a real-time application, which would dynamically update relevant information as the user embarked upon a route based on his preferences. The application would integrate with the car-sharing application Flinkster operated by DB Rent, and enable booking, ticketing and payment of different transport options. The project would develop the app for both Android and iOS-based smartphones.

Project documents state that the initial goals of the app were to be user-friendly and to provide the ability for commuters to search, book and pay for intermodal journeys.

The key functionalities of the app are listed below:

Search and Book: The commuter would be provided multi-modal journey options from origin A to destination B by the BeMobility Suite app. The app would display all routes on a map to the user. The user would be able to view the timetables, delays and real-time status of public transport, availability of nearby electric cars and bikes, availability of parking spaces near a destination, see the charging state of the electric vehicles, and search location of charging stations along recommended routes. Public transport routes would be calculated using the VBB-Fahrinfo algorithm (journey planner provided by VBB, the transport association of Berlin) while individual multi-modal routes would be calculated using the Google Routing API.

Pay: The user should be able to view the price of the entire journey and provide his payment details and any other relevant information, such as senior citizen status.

The project plans stated that InnoZ would be responsible for the functional specifications and quality assurance testing of the BeMobility Suite, while Technical University (TU) Berlin would develop the application. Representatives of all the relevant stakeholders gave their input on the functionality including OEMs, public transportation service providers, and energy utilities. Based on workshops conducted with the partners, InnoZ drew a technical architecture that highlighted the integration of services and exchange of data for the BeMobility Suite. The final report of Phase 1 describes a plan to seamlessly retrieve the data needed for the BeMobility suite from the databases of various stakeholders (d8).

5.4.2 Smart Mobility Card

The BeMobility project created an integrated payment card called "Mobilitätskarte Berlin elektroMobil", which would allow users to pay for multimodal transport. The goal was to promote intermodal mobility by making it easier for users to switch between different modes of transportation (train, bus, electric car, bike and so forth)[17].

InnoZ collaborated with Deutsche Bahn AG and local public transport providers and associations BVG, S-Bahn, and VBB to develop and test this mobility card. The partners provided the following forms of transport:

- Public transport (Berlin metro underground railway, tram, bus, through the operator BVG).
- Public transport (urban rail S-Bahn through the industry association VBB).
- Long-distance transport (railways through the operator Deutsche Bahn AG).

[17] InnoZ, "BeMobility Berlin elektroMobil: Multimodal und elektrisch mobil", 2011 (http://bit.ly/2lf6Qpp)

- Short-distance transport (car sharing through the services Flinkster and bike sharing through the service Call-a-Bike, both operated by Deutsche Bahn AG's subsidiary DB Rent).

BeMobility launched the smart mobility card in Phase 1 as a three-month test where users took part in accompanying surveys. In return for participating in this research, users received free membership in Flinkster (car sharing) and Call-a-Bike (bike sharing), as well as free privileges of up to €50 for using elective vehicles with Flinkster and 30 minutes free rental with Call-a-Bike. The price of the card was €78.

The trial offer, valid for three months only, was taken up by 135 customers and InnoZ monitored its usage. The results[18] showed that the discount nudged users to adopt sustainable mobility patterns in the city. Amongst the users, there was a 10% decrease in personal car use per day, a 20% increase in bike rental per month, a 30% growth in car sharing usage per week, and an 11% increase in the use of public transport per day.

5.4.3 User Research

One of InnoZ's primary functions was to conduct research and provide analysis on customer needs and behavioural changes during the demonstration project. Quantitative surveys, qualitative interviews, and focus groups were used to provide insights into customer requirements for such an initiative.

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[18] Christian Hoffman et al, "Bewertung integrierter Mobilitätsdienste mit Elektrofahrzeugen aus Nutzerperspektive" 2012

In Phase 1, the survey group was chosen from interviewees who had subscribed to the electric car sharing scheme and were around 150-300 in number. The focus group members were specifically chosen by InnoZ, and represented early adopters or lead users in this domain.

InnoZ conducted quantitative surveys several times during the project: users were questioned on their expectations for e-mobility and vehicles before the rides were made available, on their experience after their first electric car ride, and their experience of frequent usage near the end of Phase 1.

The user research results showed that users of the electric cars were a largely homogeneous group: highly educated males between the ages of 38-40 years employed with above-average household income. Electric car sharing was used for leisure trips (32%), running errands (26%), business travel (17%), and shopping (13%).

InnoZ's user research results indicated that customers had a positive experience of e-mobility and valued the lower noise pollution and sustainable aspects of electric vehicles. The short range of electric cars also did not appear to deter customers. All social research results were compiled by InnoZ and presented to the project partners and government agencies.

5.4.4 Phase 1 Results

The results of Phase 1 included the following outcomes:

- Launch of electric vehicles in the car-sharing system Flinkster.
- The creation of a smart mobility card, which allowed residents to take local public transport in Berlin, rent cars from Flinkster (including electric

vehicles), and rent bikes from Call-a-Bike for three months using just one ticket.

- The launch of the BeMobility Suite smartphone app, that made it possible to search availability and location of different vehicle types in a multi-modal journey.
- Investigation into the behaviour of e-mobility users during the process, including the discovery that the short range of electric cars was not a hindrance to their usage.

At the end of BeMobility 1.0, the project had tested 32 electric and hybrid vehicles with 15 rental locations and 25 charging stations on the e-mobility platform in Berlin. During the duration of the project, customers borrowed electric and hybrid vehicles 2850 times.

5.5 BeMobility 2.0

BeMobility 2.0 launched in mid-2011 after receiving two years of further grant approval by the Federal Ministry of Transport, Building and Urban Development (BMVBS). NOW GmbH National Organisation Hydrogen and Fuel Cell Technology coordinated the program design at the national level and the TSB Innovation Agency Berlin coordinated it at the model region Berlin-Potsdam level. Phase 2 of the project was again led by Deutsche Bahn AG and was one of the projects of the "Berlin-Brandenburg International Showcase for Electromobility."

Along with the continuing integration of the electric car sharing fleet into the public transport system, Phase 2 aimed to integrate transport systems with energy networks as well. This phase built on the results of BeMobility 1.0, including the core group of stakeholders, the infrastructure set-up and the e-mobility II.

The goals of the project were:

- Expansion of the car fleet and introduction of flexible car sharing (where users could drop and pick up vehicles anywhere in the city instead of only at predesignated stations).
- Integration of the electric car-sharing and renewable energy networks using a Micro Smart Grid (MSG).
- Extension of the BeMobility Suite smartphone application with further integration of real-time data sources and information related to power availability and usage.
- Experimentation with new business models around electric mobility via the BeMobility Smart Card.

The number of project partners was also increased to 29 to reflect the expanded scope of the project. The two-year project would be carried out in three phases: training and build-up (2012); testing and research (2012-13); and evaluation phase (2013)[19].

Infrastructure Set-up

The major change in infrastructure set-up was the introduction of a new program called Multicity[20], which allowed users to pick up and leave their car anywhere in the Berlin S-Bahn circle and adjacent areas. The S-Bahn circle covers the city centre of Berlin where about 1 million of Berlin's 3.5 residents live (as of 2012). Previously, the Flinkster car-sharing program allowed users to rent both conventional and electric cars, but as a station-based offer, i.e. customers had to return cars to the spot where

[19] InnoZ, "BeMobility - Berlin elektroMobil: Multimodal und elektrisch mobil" (2001) (Source: http://bit.ly/2h6Qw5A)
[20] "Multicity - building a stationless, flexible e-carharing", InnoZ Website (Source: http://bit.ly/2yL5Yfj)

they rented them. Most of the parking spots were at public transport locations within the S-Bahn circle, and customers needed to book them in advance.

Developed through a partnership between Flinkster and Citroen, the Multicity program provided the new option of instant, open-ended and one-way trips within the specified area. The program catered to ultra-short-term rentals with one-hour trips within the city centre. All vehicles in the Multicity program were Citroen's C-Zero electric vehicles (d13).

The C-Zero vehicles could not be booked in advance and provided "instant access" or ultrafast rental. Customers could easily open MultiCity vehicles with an existing Flinkster customer card, and they were attributed fees on their Flinkster bill. The app estimated billing in 10-minute intervals, and billing rates varied for occasional and frequent users. The Starter fare (no monthly fee) was Euro 2.50 per 10 minutes while the regular user fare (with a monthly fee of Euro 10) was Euro 1.00 per 10 minutes. Pricing for the Flinkster station-based system depended on time (billed per hour), kilometres travelled and vehicle type.

Users would be able to use a smartphone application or the website to locate vehicles and charging stations in their immediate vicinity. All vehicles in the Multicity program were emission-free and supplied with 100% renewable energy. They could be charged using RWE's public charging stations and three fast-charging stations. Only those vehicles with sufficient charge to complete a typical short-distance drive in the city were rentable. If they did not have sufficient charge, a user was unable to rent them.

Any user with a Flinkster card had access to the entire fleet of 200 conventional Flinkster vehicles, 40 electric or hybrid-powered e-Flinkster cars and 100 flexible Multi City vehicles. After launching in August 2012 with 100 flexible car-sharing vehicles, another 250 electric vehicles were added in April 2013, bringing the total to 350 electric vehicles available in the program.

A service team would take vehicles to one of the RWE charging stations or use one of three quick-charging stations downtown. Any vehicle available for rent would always have enough load to complete a short-range trip in the city. During charging, the vehicles were also cleaned by the team.

Another significant addition to the infrastructure was the Micro Smart Grid (MSG) for controlled and bidirectional loading. Two small wind turbines were installed on top of the Gasometer Schöneberg in the EUREF Campus. The MSG also included a combined heat and power plant (CHP), solar panels, three storage batteries, and a control system that managed the distribution of storage of wind and solar power.

5.5.1 BeMobility Suite

The BeMobility Suite development was part of Work Package AP 4.3 called ICT Applications (d9). DAI-Labor did the software engineering, and the requirements were gathered and written by InnoZ. Participants took part in requirements analysis and set goals for extending the smartphone app based on customer feedback and experience of using the app in Phase 1. Extensions included real-time data on battery charge level, charging station availability and vehicle availability.

The three priorities of the app were service interconnection, adaptability, and interoperability[21]. The diagram below is adapted from the BeMobility Phase 2 report (d9) to show the different interconnections. The DB Navigator App provided

[21] DAI-Labor Website (http://bit.ly/2yMGfEB)

timetables and ticket booking for long distance trains, while the BVG Fahrinfo App provided the same information for short-distance within Berlin (bus, urban rail).

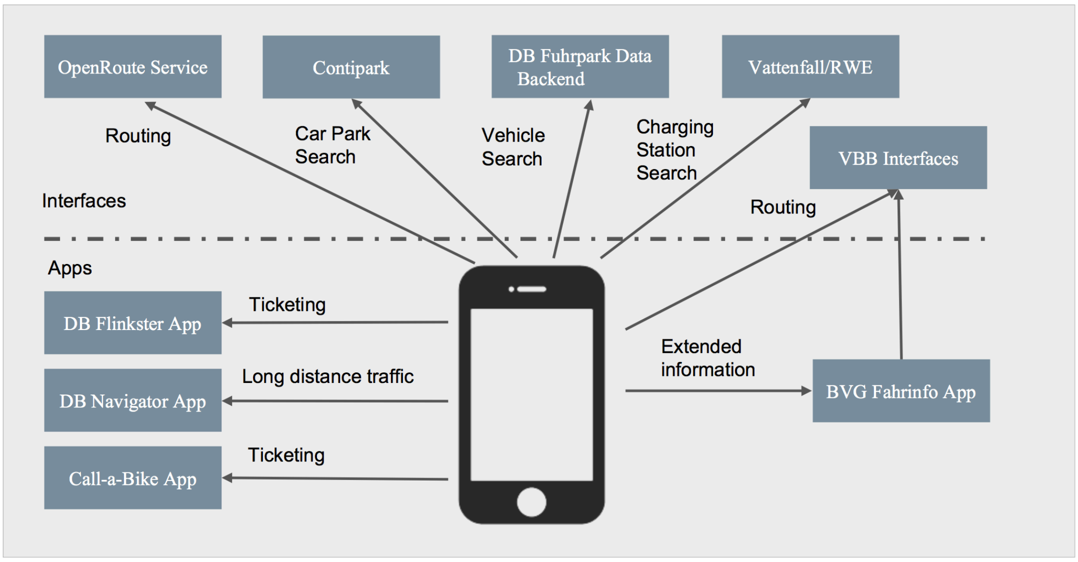

Figure 3: Integration of different functions in the BeMobility Suite

The ICT working group took a new approach to app development in this phase, which was the separation between the production and research versions of the app. The production version was available with all tested and polished services for users, while the research version was used to test new services and concepts. The group released the first production version of the app in October 2012 on Google Play, iTunes Store, and the website. The group periodically updated the app throughout Phase 2, after testing new services in the research version of the app.

The ICT working group added several new features to the BeMobility Suite in Phase 2 (d9). It extended the search function to allow users to search for charging stations and car parks and added a map display of routes and addresses. The routing service was significantly improved, and the user could now compile an intermodal route with recommendations on the pickup and return of car-sharing vehicles. Users could also now choose “favourites” to store regularly used addresses or routes. This information was also passed on to other services that were connected to the smartphone app to provide full journey personalisation. An iPad version was also made available and optimised for the iPad.

5.5.2 Smart Mobility Card

Based on customer surveys conducted by InnoZ, it was evident that Berlin residents were interested in multimodal transport and wanted a user-friendly way to pay for access to all different modes of travel. In a survey in 2012, InnoZ found that almost 95% of the 1,300 surveyed customers wanted to have several mobility options on one card (d10).

As a result, InnoZ proposed the creation of another integrated mobility card in Phase 2. The vision was that the card would provide access to the following means of transport on one card:

- Public transport (Berlin metro underground railway, tram, bus, through the operator BVG).
- Public transport (urban rail S-Bahn through the industry association VBB).
- Long-distance transport (railways through the operator Deutsche Bahn AG).
- Short-distance transport (car sharing through the services Flinkster and Multicity and bike sharing through the service Call-a-Bike, both operated by DB Rent).

In December 2012, the smart mobility card called "BahnCard 25 mobil plus" was launched by the BeMobility project. It was an extended version of the regular BahnCard 25 which is a prepaid card to ride the Deutsche Bahn railways (the 25 at the end indicates that buying the prepaid card gives commuters a discount of 25% compared to paying for individual rides). "BahnCard 25 mobil plus" by the BeMobility project not only provided usual access to the train but also included a €15 credit to use Flinkster and a monthly €10 credit to use Call-a-Bike. Users could add public transport tickets to the smart mobility card at the local BVG or VBB offices. The cost of the “BahnCard 25 mobil plus” was €79.

The core of the BahnCard was a magnetic strip which contained the VDV-DA chipset (d10), and different areas of the chip would allow users to pay for various means of transport. The card used a contactless Near Field Communication (NFC) chip, which meant that sensors could read the chip cards from a very short distance (d11).

Commuters could purchase the BahnCard 25 Mobile Plus at DB railway stations, the DB Mobility Centre in Berlin or online at the Deutsche Bahn website. The validity of each card was 12 months, and the card automatically expired after one year. It provided access to 600 car-sharing vehicles and 1250 bikes at over 80 stations and was valid at 13 short distance stops (bus, transport, underground, and rapid transit railway) and 5 railway stations for long-distance travel.

The BahnCard 25 mobil plus worked in the following way with Flinkster and Call-a-Bike: a user could find and book a Flinkster car via the internet, hotline or smartphone app. Using the card, the user could open the car, retrieve the key from the glove compartment and drive. Upon completion of the journey, the user would return the key to the glove compartment and lock the car with the card. Similarly, the bike could be booked via hotline, the Call-a-bike app or rented directly at one of the terminals.

5.5.3 Micro Smart Grid

One of the main goals of Phase 2 was to test the integration of the mobility and energy infrastructures to achieve sustainable transportation. A Micro Smart Grid was set up at the end of 2011 outside the InnoZ office on the EUREF Campus. The smart grid was a distributed electricity network where energy production, storage and consumption could be managed intelligently. The key was the matching algorithm in the network management system that would synch the fluctuating supply of renewable energy (wind and solar) to the consumption needs of the urban commuters. The connection with the public electricity network or the energy stored in the batteries could smooth fluctuations in renewable energy. The Micro Smart Grid setup included small wind turbines, solar panels, a power station and two large batteries network buffers. The grid was also connected to charging stations and the batteries of electric vehicles.

"We've built up complex system at Schöneberg: we have integrated 10-12 charging stations, photovoltaic panels, wind energy, stationary battery storage, in order to optimise charging of e-cars." (i11)

The aim was to use intelligent networking and control to decrease dependence on public electricity networks for electric mobility and generate electricity from local renewable sources. This study is specifically interested in the ICT systems related to intelligent load management in the Micro Smart Grid where "the work was divided into data modelling, the development of the control and simulation system and data analysis" (d9).

The ICT brain of the Micro Smart Grid was the network management system that included modules for data management, processing, optimising and forecasting energy usage. For load management and optimisation, the system used data from multiple sources (including renewable energy production and related forecasts, urban mobility consumption and related forecasts, and real-time charging column, vehicle battery charge and vehicle booking and usage data). Stakeholders created a local database where data from all relevant stakeholders was stored, and then retrieved to create an optimised control plan for the Micro Smart Grid. They specified a distributed modular architecture where different modules, such as processing car booking data, were allocated various functions. The diagram below is an amended version of the Micro Smart Grid architecture shown in the final report for the project (d9).

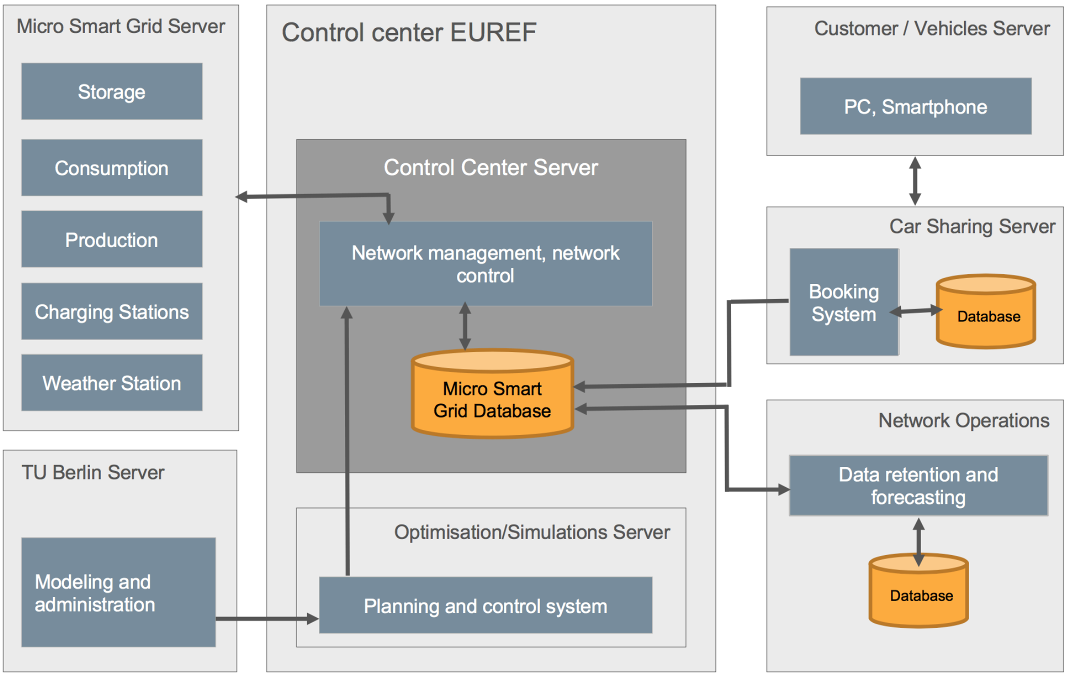

Figure 4: Micro Smart Grid modular architecture

"With the implementation of the MSG management system, the project team has succeeded in linking existing software systems of the stakeholders to an innovative smart grid application and in expanding new software components" (d9).

The working group included several stakeholders with the development of the architecture, data model and simulation algorithms led by DAI-Labor from TU Berlin[22].

[22] DAI Labor Website (http://bit.ly/2yHzMvz)

A control room was set up at the InnoZ offices with an interactive touchscreen table and multiple monitors to help stakeholders understand the energy flows and technologies. The control room allowed users to visualise scenarios that included interactions of renewable power generation, changing consumer needs and mobility trends using a Microsoft Tablet. It also highlighted the role of decentralised storage in the form of electric car batteries that could help balance peak loads and sinks.

5.5.4 User Research

As in Phase 1, InnoZ conducted social research in Phase 2 to understand the preferences, patterns of usage and feedback of consumers. Understanding the long-term commercialisation potential of electric vehicles and the e-mobility infrastructure, including whether range, price or the very notion of car sharing would be an issue for different demographics, was a critical outcome of the strategic niche. Not only did InnoZ conduct and publish user research for this purpose, but InnoZ also used it to inform the functional requirements it wrote for developing various II components.

There were three ways in which InnoZ conducted user research in Phase 2. First, it identified so-called “lead users” who were already following “new trends of living and working (co-working)” (i54) and conducted workshops with them to understand the needs of future users. Innoz based the social research into user behaviour on the “lead user integration defined by MIT's Eric von Hipple” (i38). This approach had predictive value to understand how these future consumers would live so that organisations could plan their mobility systems for such households.

Second, it carried out surveys using questionnaires. InnoZ conducted the questionnaires in three parts in Phase 1: before the trial in August 2012 (T0), in the middle of the trial from November 2012 to January 2013 (T1) and later in the trial from July to September 2013 (T2). A total of 2000 people participated in the three surveys. A final online survey was also conducted from July-September 2014 to gather information on how users felt after the program had been in place for two years.

Third, InnoZ helped generate user behaviour data based on the findings from the lead users and surveys. These simulations were used to forecast scenarios and consumption forecasting for the Micro Smart Grid with the help of DAI-Labor and Senozon, a consulting firm specialising in determining mobility patterns.

The results again showed that the lead users were “largely homogeneous”: predominately highly educated and gainfully employed middle-aged men. They also investigated several questions that concerned stakeholders including whether “range anxiety”, or the fear of using short-range vehicles, was an issue; whether user groups cared about specific car sharing providers or were more interested in a mobility platform; whether flexible car sharing was preferable to station-based car sharing; and the sensitivity of uptake to prices and discounts.

The findings showed that for 80% of users, range anxiety was not a concern as they needed car sharing for short rides and errands. These users were not loyal to any provider and instead focused on prioritising whichever offers and services met their individual needs best. In general, users significantly preferred flexible car sharing vs station-based car sharing and cited time savings, convenience, and flexibility as common reasons for choosing car sharing over public transport. Issues raised by users included time spent looking for car parking spots in the case of flexible car sharing, which did not have pre-assigned docks. The search for parking spots brought unpredictability to their mobility journey and made the platform less attractive. The surveys also surfaced a high sensitivity to price for users. While 90% of the surveyed users confirmed they understood the pricing of Multicity car sharing, only 60% of the interviewees found the offer cost-effective.

InnoZ published its results in magazines (d13, d14, d9) and the final report, presented them at conferences and shared details with all the project stakeholders.

5.5.6 Phase 2 Results

The results of Phase 2 included the following outcomes:

- The launch of flexible e-car sharing through a partnership with Citroen launched under the brand Multicity. Optimisation and expansion of station-based e-car sharing in continuing partnership with Flinkster.
- Optimisation of the BeMobility Suite smartphone app with the separation of "productive" and "research" segments, and extension of the BeMobility Suite smartphone application with further integration of real-time data sources, testing of visibility of battery level in electric vehicles, and ability to search charging station availability.
- The introduction of a year-long test for integrated payments through the development of the "BahnCard 25 mobil plus", which enabled discounted use of multi-modal journeys including using rail, car sharing (with Flinkster and Multicity), bike rental (with Call-a-Bike) as well as an optional inclusion of an annual ticket for local public transport in Zones A and B in Berlin.
- The establishment of the Micro Smart Grid with a demonstration of load management (storage and data processing) in a control room on the EUREF Campus.

This phase utilised more than 75 electric and hybrid vehicles including 50 C-Zero vehicles deployed in the flexible e-car sharing service and over 25 vehicles in the stationary e-car sharing service. Car models included C-Zero, Toyota Prius, Opel Ampera-e, Fiat Karabag, and Renault Kangoo. The parking infrastructure comprised of 15 car sharing stations. The energy infrastructure included a Micro Smart Grid at the EUREF Campus (which had 20 recharging points including a large-scale battery, wind turbines and solar panels); and 15 charging points that accompanied the car sharing stations (related to e-Flinkster).

5.6 Summary

This chapter described the BeMobility project, which is the case study used in this thesis. It introduced the motivations for setting up the BeMobility project by the German government as part of a larger effort to transition to a sustainable transportation infrastructure and make Germany a global leader in the emergent e-mobility industry.

The two phases of BeMobility (occurring between September 2009 and March 2014) had the specific goal of prototyping an e-mobility infrastructure, which involved the integration of electric car sharing with public transport and energy networks. The chapter described the plans to integrate the systems of over 32 public and private stakeholders and the results of each phase. Successful integration required a seamless exchange of data and the interoperability of various IS modules.

The chapter highlighted the complexity of such an undertaking by describing the large number and variety of stakeholders involved. It provided detailed descriptions of the goals, stakeholders, and outcomes of both Phase 1 and Phase II of the BeMobility project. The chapter focused on the development of three ICT components: a smartphone app, an integrated payment card, and a micro smart grid. The chapter also described the project plan and organisations involved in building these three components, setting up the stage for an in-depth analysis of the evidence from the interviews, documents, and observations collected from the case.

The BeMobility project provided a unique lens into the challenge of prototyping an e-mobility infrastructure in a strategic niche. Dr Knie, co-founder of InnoZ and a wellrespected expert in the field of future mobility, emphasised the complexity and unpredictability of developing the e-mobility II in his final speech. At the end of the four-year BeMobility project in March 2014, InnoZ held a concluding conference at the EUREF Campus. Summing up what had been a roller-coaster ride of success and disappointment, Dr Knie referred to the process as "Glanz und Elend der Elektromobilität" (the splendour and misery of electric mobility).

The next chapter outlines the analysis of the evidence gathered from BeMobility to address the study's research questions.

6. Analysis – Part 1

The Influence of Rhythms on the Mangle of Practice

6.1 Introduction

This chapter presents the analysis of information infrastructure (II) cultivation using the data collected from the BeMobility project in Berlin. The theoretical framework of The Trichordal Temporal Approach (Venters et al. 2014) enriched with the concepts of temporal rhythms was used to investigate the data. The overall analytical method was partly inductive (theory-inspired) and partly deductive (data-driven) as recommended by the processual approach (Langley (1999). This mixed approach allows "one to gain creative insight from the data, without necessarily denying or reinventing concepts that have been useful previously" (Denis et al. 2001).

Due to ethical considerations, the analysis chapters have anonymised all the names of interviewees as codes (with generic descriptions of their titles provided in Appendix A). The analysis also anonymised the names of the organisations with generic descriptive industry titles.

The study divides the analysis into two chapters that each address one or more of the research questions in the study. Both chapters contain analytical tables with evidence. The different iterations of analysis and methods representing each section are outlined below:

Chapter 6: Analysis Part 1 answers the research question "how do rhythms influence the process of II cultivation?".

Section 6.2: Key Process Events, in accordance with the processual approach, identifies episodes or events of interest in the project's II development that anchor the analysis.

Section 6.3: II Tuning in the Present investigates II tuning by examining the material resistance the project stakeholders faced as they tried to access, exchange and use data to build II components, and their efforts to accommodate it with the help of Intermediary. The theoretical framework is used to inspire codes and identify themes around resistance and accommodation in the mangle of practice. The analysis uses the narrative strategy (Langley 1999) for organising and sensemaking.

Section 6.4: The Influence of Past and Future Rhythms uses temporal bracketing (Langley 1999) to decompose the passage of time into past, present and future phases. Driven by the theoretical framework, codes were generated to tag iteratively (i) stakeholders' perceptions of what was causing material resistance (disciplining) and what was motivating them to contribute (modeling) to II cultivation; (ii) whether these causes or motivators were related to past or future rhythms, and if so, if those rhythms could be categorized as one of the four rhythms described in Chapter 3 (Jackson et al. 2011). The disciplining influences of diluting, stalling and blocking II cultivation were abstracted from codes related to technology lock-ins, bootstrapping, and lack of standards based on the II literature. The modeling influences of combining, extending and replacing II modules were abstracted from themes based on Roland (2014)'s paper on how to conceptualise II success and failure.

Chapter 7: Analysis Part 2 answers the research questions "how do rhythms interact?" and "why does one rhythm dominate another to direct the II's trajectory when there is discord between rhythms during II cultivation?".

Section 7.1: Rhythm Interactions uses Lefebvre (2004)'s rhythmanalysis matrix discussed in Chapter 2 to organise past and future rhythms and their interactions. However, while the analysis confirms that rhythms either reinforce each other (eurythmia) or are in discord (arrhythmia) when they interact, the result of this interaction and consequent II trajectory is unclear. The next section explores the possibility of Intermediary impacting this interaction.

Section 7.2: Intermediary and II Cultivation Trajectory investigates Intermediary in more depth given its recurring mention in interviews on technical decisions and accommodations. The first step involved thematic analysis by coding the evolution of Intermediary's technical skills that demonstrates how Intermediary had evolved its biographical rhythm through temporal structuring. The second step involved investigating Intermediary's role in rhythm intervention. Concepts related to rhythms such as entrainment inspired the codes for Intermediary's behaviour and actions. The section demonstrated that Intermediary intervened in rhythmic influences using the strategies of harmonising, composing and riffing.

Section 7.3: Summary summarises the findings of the analysis and presents observations on the role of temporal rhythms in II cultivation.

6.2 Key Process Events

In keeping with the processual approach, the first step to examining II cultivation was to identify certain events of interest. After the first round of interviews and reading initial documents, it became clear that data access, exchange, and integration was a core requirement of II cultivation, and it was only "on the basis of the data interfaces, [that] specific services could be implemented" in the project (d8). The researcher decided that examining events around data integration would help address the research questions on II cultivation.

The project required four types of integration, according to the project's website[23], all of which needed data integration to achieve the desired results:

- **Transport integration:** integrating car sharing (both regular and electric cars) into the public transportation system (buses and trains).
- **Services integration:** integrating maps, routeing, and timetables, to be accessed through the BeMobility smartphone application.
- **Offer integration:** integrating payment with all means of transportation (public, car, bike) in the mobility chain through one payment card.
- **Energy integration:** integrating a micro smart grid (MSG) with car sharing for local energy generation and sustainable consumption.

The software engineers from Academic-Team-1 who were responsible for ICT development confirmed that access to data was the key to integrating these different service components to the installed base.

"What we need to develop in the BeMobility suite is data interfaces to databases of the car (whether they are occupied, free); charging stations; parking lots; public transport timetables etc. We needed description of data interfaces to database of partners, to collect and compute them and to give customers right information." (i39)

As discussed in the last chapter, even though they were multiple components to the overall BeMobility project, this study focuses only on the three main components called BeMobility Suite, Smart Mobility Card and Micro Smart Grid. The data inputs required for these components (described in the table below) were reviewed to find

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[23] Kramer, Steffi, et al. "Electric Car Sharing as an Integrated Part of Public Transport: Customers' Needs and Experience." *Evolutionary Paths Towards the Mobility Patterns of the Future*. Springer Berlin Heidelberg, 2014. 101-112. (Source: http://bit.ly/1ZuYPXX)

key events of interest. Each data input had a different function to play in the development of e-mobility services. Other data types, such as user behaviour statistics, were also used in the BeMobility project but were collected from scratch and were not evaluated in this section.

Module	Types of Data
BeMobility Suite	**Car Locations:** required to search and book electric vehicles. **Parking information:** necessary to see if the allocated spots for the electric vehicle were free. **Timetable information:** necessary to inform users of the timetable of public transportation such as buses or trains that would form part of their multi-modal travel itinerary. **Battery information:** required to estimate how much energy was in the car's battery, and how far it could go as a result.
Smart Card	**User information:** required to understand payment made, discounts offered and bonus miles accrued for each type of transportation.
Micro Smart Grid	**Load information:** required to track local renewable energy creation and consumption from charging infrastructure.

Table 10: Data requirements for e-mobility II components

In keeping with the processual approach for interpreting the evidence and "understanding how things evolve over time and why they evolve in this way" (Langley 1999), the researcher identified five events or episodes to study related to the three II components under investigation. These events would be examined to understand the material resistance to coordinating data access and how stakeholders accommodated this resistance. While the project hoped for a seamlessly integrated data architecture that it documented in the BeMobility reports as shown below (d8), the next section will demonstrate how stakeholders found that accessing data was a formidable challenge.

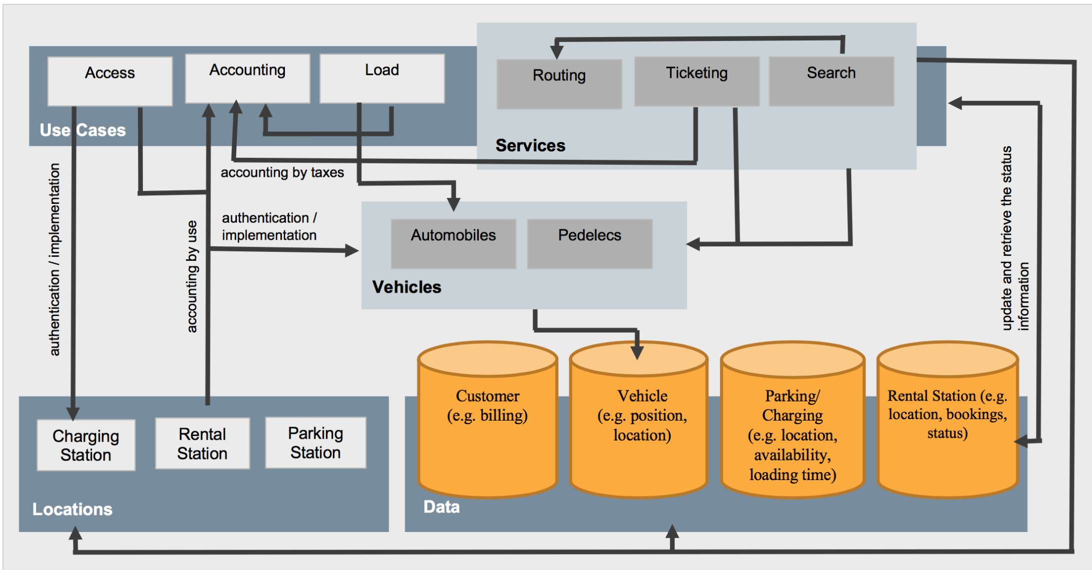

Figure 5: Planned seamless access to and integration with data sources

This chapter investigates the following five events:

1. Getting data from the car battery to estimate charge and remaining range
2. Getting data from the car park for car availability
3. Getting data for smart card integrated payment
4. Getting data for car search and book functionalities
5. Getting data for micro smart grid optimisation

6.3 II Tuning in the Present

This section investigates how stakeholders accommodated the material resistance they faced when they tried to access data related to these five specific episodes. It describes how Intermediary followed a pattern of actions that supported accommodation by pursuing alternative routes to access data, and which manifested itself as emergent II cultivation.

As mentioned in Chapter 4, all the interview transcripts, documents and observations were kept in Atlas.ti. The first round of coding on these documents was inspired by the theoretical framework of the Trichodal Temporal Approach (Venters et al. 2014) and used to find themes around high-level categories of resistance and accommodation during the mangle of practice. The researcher coded sub-categories under resistance and accommodation with codes such as “difficulty getting data from parking lots” and “solution for sharing data between apps” respectively.

The role of Intermediary surfaced early in the interviews as it featured prominently in how stakeholders accommodated material resistance. This mention was particularly prevalent in the explanations by the software developers who required assistance to access data for cultivating the II. Thus, an additional code of “Intermediary accommodation support” was added as well. The narrative strategy (Langley 1999) was used to start making sense of the coded data, and the researcher created vignettes from the thick descriptions stored in Atlas.ti. These vignettes were helpful in understanding the different ways the stakeholders accommodated resistance and in highlighting how this accommodation was reliant on Intermediary’s support. The vignettes were critical in enabling the researcher to trace the arc of what happened.

The thematic analysis revealed a pattern of the Intermediary choosing one of three actions – build, transfer or outsource –to support data access by the stakeholders. This foundational pattern of support is analogous to a riff, which is a repeated pattern as explained in the theoretical framework. The analysis of the cases of resistance and accommodation supported by Intermediary’s riffs are listed below with explanations on how the riff pattern created a minimal structure for improvisation by other stakeholders once the data became available. Without data, BeMobility could not build new services, but with full or even reduced access to data, stakeholders could accommodate resistance by improvising like jazz musicians improvise on top of a base riff.

Building New Modules

Accommodating material resistance in accessing data by developing new technology was an approach used a few times by stakeholders with the help of Intermediary, albeit not always successfully. Two instances of improvisation to build the BeMobility Suite demonstrated how Intermediary's support was essential. First, stakeholders faced material resistance in retrieving data from the car's black box, also known as the Controller Area Network (CAN), to gauge the energy levels in the battery to estimate charge and remaining range. OEM-1 blocked data access claiming all data went directly from the CAN to company headquarters in Asia, and it would require changing the code to reroute the data anywhere else.

"All the car sharing cars would come equipped with technologies that in theory would give the possibility to track driver patterns. However, later we learnt that this was not possible. Secondly, our [OEM-1] data had to be sent to Japan and analysed there. We only got back summary data." (i5)

All other OEM partners subsequently approached by Intermediary also refused to share the data and considered the request unusual and "controversial" (d8).

The resistance of the installed base in making data available meant that version 1 of the BeMobility Suite app did not have this critical information as the stakeholders had "no permission of the OEMs to access vehicle CAN" (d8). Later in Phase 1, Intermediary accommodated this resistance by partnering with Automotive-Parts-Supplier who improvised and developed a new telematics box as an alternate solution.

"We [Intermediary] tried to develop a car-sharing box with our partner Automotive-Parts-Supplier, which collects special data from the car like acceleration." (i40)

This new telematics unit was installed with Intermediary's help and could communicate information related to the voltage of the battery, charge status of the battery, and current capacity of the battery (d7), which was then used by Academic-Team-1 to find an innovative way to get this data into the BeMobility Suite App as explained by one of their members below.

"One problem in BeMobility was that it was hard to access data in the car. Automotive-Parts-Supplier built a small PC in the car that was now communicating with the car's black box through certain protocols. It was getting information on charging state of the car and the remaining range the car thinks it has …. We worked on the interface between their component in the car and our server, and for our server, our app got the information." (i20)

Stakeholders successfully tested the new box on two Citroën C-Zero cars in the second version of the app (d4).

Intermediary's Riff: Build new ICT modules with stakeholders that can access data.			
Goal	**Resistance**	**Accommodation**	**Riff-Driven Improvisation**
Display battery charge in an electric car so that consumers can calculate remaining range.	The telematics box of car manufacturers was set up to prevent others from accessing this data.	Intermediary worked with Automotive-Parts-Supplier to develop a new telematics box and successfully tested on a subset of vehicles.	Automotive-Parts-Supplier developed a prototype of a telematics box for the project.
Allow consumers to ascertain car availability for booking by searching for cars parked in Mobility-	Accessing the databases of Mobility-Operator was not allowed as it was considered a security risk.	Intermediary convinced Mobility-Operator to develop an API for its server	Academic-Team-1 would have improvised in taking data from the API minus some key information but this strategy was not

Operator.			successful as it was not built eventually due to budgetary constraints.

Table 11: Pattern of building to accommodate resistance to access data

The second instance of Intermediary's support was when Academic-Team-1 needed access to car location data to enable the search functionality of the BeMobility app. Mobility-Operator, the owner of the car parks where the electric vehicles were parked, did not have an API to access data and a direct database read was considered a "security risk" (i21). Intermediary helped accommodate this material resistance by convincing Mobility-Operator to build a new API for its server, which would allow Academic-Team-1 engineers to improvise and continue developing the BeMobility Suite without touching the Mobility-Operator databases directly. Despite this workaround, the interface between the Mobility-Operator's backend and the Academic-Team-1 backend was not built eventually. According to the Phase 1 final report, this was due to "high programming costs" and "capacity bottlenecks" (d8). The evidence showed that even though the Intermediary pursued the *build* accommodation strategy, it was not always successful.

Transferring Data

If the build strategy failed, Intermediary also had another accommodation strategy, which involved transferring data between stakeholders without touching any core systems that stakeholders preferred to keep secure and private.

For example, to book car-sharing vehicles, the BeMobility Suite app had to integrate customer information from Car-Sharing-Service (the system used to book cars owned by Shared-Mobility-Operator and the dominant player in the car sharing market in Berlin) with information on their location and availability. However, Shared-Mobility-Operator declined to share its customer data citing strict privacy laws in Germany that prohibit access and authority to use customer data easily. This was disappointing to Academic-Team-1 and Intermediary as the "car sharing system has all the data about the cars and the customers, and it was not allowed that we get data" (i39).

"Partners were difficult: on the one hand, we need exact description of data and they didn't have this nor did they have resources to provide this interface. They said we are working with you on this project but this is not in the scope of the project. Also, partners were explicitly worried about data security. For example, car sharing system has all the data about the cars and the customers, and it was not allowed that we get data on the customers. "(i39)

The material resistance to accessing this data delayed the release of the application. Intermediary accommodated this resistance through a workaround in which it harnessed the ability of apps on a smartphone to link to each other and share data. Intermediary conceived a way for the BeMobility Suite to pass on the booking request to the Car-Sharing-Service app "by providing an interim interface … [that can] use all its functionality without going directly to the Shared-Mobility-Operator server." (i40) This workaround was referred to as an "App-Familie" or App Family in the project (d8)

"With the Shared-Mobility-Operator, we [Intermediary] tried different ways to address this issue. We can't fix their interface, but we looked and provided alternatives, like enhancing the applications from Shared-Mobility-Operator so that they can be called directly from the BeMobility app. We were looking for technical alternatives so what we did was to … provide an interim interface. If we use a BeMobility suite, we can press one button and we can use the Shared-Mobility-Operator application (we can use all its functionality without going directly to their server)." (i40)

Intermediary's Riff: Transfer data from one stakeholder system to another to maintain process flow without data access			
Goal	**Resistance**	**Accommodation**	**Riff-Driven Improvisation**
Ability to search and book car-sharing vehicles on the mobile phone.	Shared-Mobility-Operator would not allow access to its customer data as it had no API for access and cited privacy laws as the reason.	Intermediary conceived of a family of apps which linked the BeMobility Suite to Shared-Mobility-Operator's Car-Sharing-Service app and allowed booking without touching Shared-Mobility-Operator's database.	Academic-Team-1 built the BeMobility Suite in such a way that the search and book requests could be passed seamlessly from one app to another in the app-familie.
The micro smart grid needed an energy management system and associated database of infrastructure charge levels, battery consumption and so forth.	None of the partners would let the project access their databases.	Energy-Management-Company built a new database that would store a copy of the data that the stakeholders would send to it to avoid touching any stakeholder database.	Academic-Team-1 used this interim database to develop algorithmic models of energy consumption.

Table 12: Pattern of transferring to accommodate resistance to access data

Another instance when Intermediary employed this strategy was during the set-up of the Smart Micro Grid. Optimising energy load balancing required getting data real-time from the charging stations operated by Energy-Utility-1 and City-Energy-Manager, and car utilisation and availability data from Car-Sharing-Service and Mobility-Operator. Academic-Team-2 would develop optimisation algorithms to manage and predict energy utilisation based on this data. However, the various stakeholders did not want to provide Academic-Team-2 engineers access to their databases, which made it impossible for them to develop a model. To accommodate this material resistance, Intermediary worked with Academic-Team-2 to create a central database on Energy-Management-Company's server that would duplicate the information kept in stakeholder databases.

"We have a lot of technical interfaces to charging stations, battery, and that all that integration has been done by Energy-Management-Company using the mBus (meter bus) protocol – all the devices can be integrated with this." (i21)

This approach was "absolutely not right for an urban scale information infrastructure" as admitted by Academic-Team-2 engineers, but Intermediary favourably supported it, which motivated other stakeholders to comply as well. The evidence showed that Intermediary either directly or indirectly supported the data *transfer* strategy to maintain process flows necessary for II cultivation. However, the Smart Micro Grid example also shows that the quality of this accommodation was not always optimal.

Outsourcing to Vendors

The third and final strategy tried by Intermediary to accommodate material resistance if the first two strategies failed was by working with the vendors and suppliers who built the information systems containing stakeholder data. In the creation of the App-Familie that linked apps to each other to transfer data, for example, the key to helping Shared-Mobility-Operator create an API for the BeMobility Suite was that Intermediary approached Shared-Mobility-Operator's software services vendor.

"We [Intermediary] had this idea because these apps … are developed by a third company, so we worked with that third party to enhance the apps and then we provided these enhanced apps to Academic-Team-1 so that they can create the interoperability between them." (i40)

Together with Academic-Team-1, Intermediary guided the vendor on how to build this interoperable layer between Shared-Mobility-Operator and the BeMobility server and created the "app familie" (i39). Without this alternative route, the app would not have had any booking functionality, a fundamental feature of an intermodal system.

Intermediary's Riff: Outsource work to stakeholder vendors and suppliers to share data.			
Goal	**Resistance**	**Accommodation**	**Riff-Driven Improvisation**
Create a smart mobility card that integrates payment for multiple modes of transportation including train, car, and bus on one card.	The smart card developed by National-Multimodal-Operator was not compliant with the national standards for integrated smart cards.	Intermediary worked with a licensed card supplier to develop a prepaid Mobility card that allowed customers to use multiple modes of transportation.	National-Multimodal-Operator improvised on the integrated payment card model by developing a prepaid customer card that allowed partners to add public transport on it without accessing National-Multimodal-Operator's customer data.
Search and book car-sharing vehicles on the mobile phone.	Shared-Mobility-Operator would not allow access to its customer data as it did not have an API for data access.	Intermediary knew Shared-Mobility-Operator's vendor and approached it to help build the API.	Academic-Team-1 could now directly link the apps to each other without touching any customer specific information using the App-Familie.

Table 13: Pattern of outsourcing to accommodate resistance to access data

The development of a Smart Mobility Card illustrates another instance of the outsourcing strategy. Building a single payment card for all transport modes required the stakeholders National-Multimodal-Operator (responsible for rapid transit railway system in and around Berlin and car-sharing and bike-sharing), City-Mobility-Operator (responsible for the city's underground railway, tram, bus, and ferry network) and Ticketing-Operator (the transport association in charge of common ticketing) to integrate their data. However, the current National-Multimodal-Operator card was not compliant with Germany's national standard for integrated payment. Intermediary accommodated the material resistance of the current version of the card by finding and working with a new licensed supplier who could add RFID to the card so that payments could be integrated (i23).

The project manager at the Intermediary commented that “the public transport has a national standard right now which only one company in Germany has the license to produce, which was *not* a National-Multimodal-Operator supplier … You need classical card, then you need a supplier for RFID card. It was a big deal to get these suppliers who were competitors to work together.” (i23)

The development of the Mobility Smart Card in both Phases 1 and 2 was essential to evaluate the interest and price sensitivity of customers to the concepts of electric mobility, car sharing and multimodal transportation. Once Intermediary had convinced National-Multimodal-Operator to agree to an integrated payment card, it built the card with a new vendor, allowing National-Multimodal-Operator to then improvise on how it addressed the issue of customer privacy. It solved this challenge by developing a prepaid National-Multimodal-Operator card on which customers could add public transport tickets by going to the City-Mobility-Operator office. This method ensured that City-Mobility-Operator never had access to the customer data, which was collected by National-Multimodal-Operator initially when the customer bought the prepaid card. (i57).

Outsourcing to a new card supplier was critical in overcoming the fact that National-Multimodal-Operator's original card was not compliant with the national standard necessary for developing integrated payments. Intermediary’s strong role in driving the development of an integrated smart mobility card led City-Mobility-Operator to later comment that “the important driver in shaping the [smart mobility card] project was InnoZ.” (i50)

6.3.1 Riffing: A Pattern of Accommodation

In summary, the stakeholders faced repeated material resistance in accessing the data necessary to integrate components and add them to the installed base of the e-mobility infrastructure. Stakeholders tuned the II through an emergent process of resistance and accommodation, supported by Intermediary's riff of either building new modules, transfering data to maintain flow, or outsourcing to vendors. This minimal structure formed a foundation for other stakeholders like Academic-Team-1and National-Multimodal-Operator to improvise and develop new services.

The next section describes the analysis to understand the influence of the temporal context on this accommodation and resistance process.

6.4 The Trichordal Tensions of Past and Future Rhythms

While the last section reviewed II tuning and showed the resistance and accommodation process to access data necessary for building II components, it is important to understand why there is material resistance, and why accommodation sometimes succeeds and fails. As outlined in the theoretical framework, human and material agencies are simultaneously oriented towards the past and the future at any given time (Venters et al. 2014) and must be examined in the flow of time to understand resistance and accommodation. In this study, the theoretical framework is enriched to perceive time not as linear clock time but as socially constructed temporal rhythms, whose trichordal tensions are evaluated next.

The processual approach studies this "intertwined relationship between agents and context over time" (Augustsson et al. 2010) by reviewing the sequential ordering of these interactions. This study employs the temporal bracketing strategy (Langley 1999) and divides the project into three phases: the past, present and future, and reviews interactions between the II and its temporal context from experienced past-to-present and imagined future-to-present. As the diagram below shows, the past, present and future are constitutively entangled, which means that the events that unfold in the present colour remembered experiences and future imaginings (Venters et al. 2014). Using temporal bracketing allows the researcher to understand II evolution in the present against the background of the II's longer biography (its past and future).

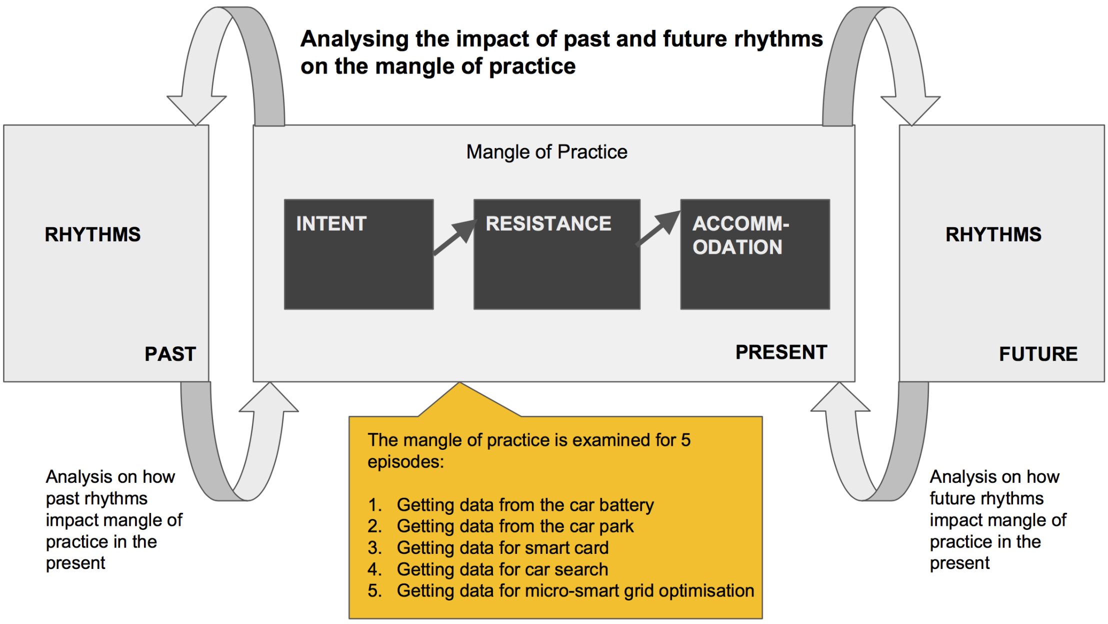

Figure 6: Analysing events using processual approach and theoretical framework

The researcher generated an initial set of codes inspired by the theoretical framework to iteratively tag text that indicated material resistance or accommodation caused by past or future rhythms. The researcher classified rhythms as one of four types: biographical, organisational, phenomenal or infrastructural (Jackson et al. 2011) where any inference of a temporal pattern as defined by Jackson et al. (2011) was tagged. If a rhythm held back II cultivation and created inertia, this study called it a disciplining rhythm, and if it motivated stakeholder contribution and alignment, the study called it a modeling rhythm, a nomenclature based on the theoretical framework (Venters et al. 2014).

6.4.1 Disciplining Influences of Past Rhythms

This section examines how the “social and material inertias of the past” (Venters et al. 2014) influenced the mangle of practice discussed in Section 6.3. It uses the issues associated with the installed base outlined in Chapter 2 (lack of standards, bootstrapping problem, technology lock-ins and inflexibility) to code the data and discover influences related to past rhythms associated with these potential results. It maps these issues to three kinds of influences that this study names as diluting, stalling and blocking as described below.

Diluting: Poor Quality II Cultivation

Diluting describes the process by which poor choices made during II cultivation lead to path dependency issues in the long run such as technology lock-ins (if the technologies chosen are not scalable) or the bootstrapping problem (if the product is not of commercial quality).

Since Academic-Team-1 and Academic-Team-2 developed the software, the researcher reviewed transcripts related to the decisions made by their engineers and the documentation and interviews related to the results of their choices. It emerged that the incentives of Academic-Team-1 and Academic-Team 2, and other stakeholders were not completely aligned around the goal of BeMobility to build a commercially viable prototype of an e-mobility II. Both Academic-Team-1 and Academic-Team-2 were part of the same department at the project’s academic partner.

“Technically, we are part of the faculty of information science at University-Partner so we do some teaching, and our focus is agent based communication (distributed agent intelligence). Since then we’ve done 3rd party projects like government and industry and a large part of our funding comes from these projects and we regularly publish research papers related to these projects. We are currently 100 students and fulltime workers and we have several different kinds of research directions of informatics." (i20)

Academic-Team-1 researchers were highly motivated by the past organisational rhythms of academia: a regular publishing calendar of "research papers related to these projects" (i20). This cycle drove Academic-Team-1 to choose innovative software solutions that could contribute to the literature in their field, sometimes at the detriment of the project's goals. Their motivation is rooted in the necessity to make *new* contributions to algorithms to get published, which is not the case in commercial applications of algorithms. The academics were always looking for challenges that were "interesting", "a research area" and "challenging" to contribute to existing literature as shown in the quotes below.

"The challenging point is the actual optimization algorithm. That is the interesting point where we all want to get to." (i21)

"Then we had research topics that we added because we wanted to do our research." (i21)

"Electric vehicles are of interest which is thinking about future grid as a research area. One part of future grid is the micro smart grid." (i20)

Stakeholders expressed concern about Academic-Team-1's work (i10) stating that they "do not see the technology developed in the BeMobility Suite adopted by the market" (i40). The lack of adoption by users would result in the bootstrapping problem where it is not possible to achieve the critical mass required to grow the e-mobility II.

Two other instances noted by stakeholders of poor technology choices driven by academic research interests also surfaced. One was the use of Semantic Web technologies in the BeMobility Suite search bar which Intermediary believed was unnecessarily complicated and untenable to support in the long run (i40).

"My feeling is that the Academic-Team-1 was just searching for a use case [for their research] where they could apply this technique into practice. It's a good idea but not perfect for the problems faced in the mobility sector." (i40)

"No, I don't see the technology developed in the BeMobility Suite adopted by the market. This is because service interconnection, which is part of Semantic Web or Web 3.0, is used by Academic-Team-1. This technique is more practical for internet browsers and not especially suitable for mobility information systems." (i40)

The second instance was the energy optimisation algorithm for the Micro Smart Grid, which Academic-Team-2 found very interesting and challenging (i21). However, the lead partner Energy-Management-Company felt Academic-Team-2's architectural choices were poor and that they "couldn't deliver these algos in an economical way" (i59). Developing complex code or computationally expensive algorithms both represent potential technology lock-ins that would be difficult to maintain and drag back II cultivation in the long run.

"Academic-Team-1 was the involved in the planning and control algos that they delivered – they were ok. In some cases they could have been better. That was one of the reasons why we decided to focus on how we could create algorithms ourselves with partners. Academic- Team-1 couldn't deliver these algorithms in an economical way." (i59)

"The IT they developed in my opinion, well there is better IT on the market. The output is one of the university and it is very different from the output of an IT company – if you are SAP or Microsoft, they will develop better products." (i10)

The social inertia of German federally funded programs meant that every project had to include an academic partner. However, this also meant the project was held hostage to the organisational rhythms of academic publications, and the biographical rhythms of tenure and PhD thesis awards. For BeMobility, this meant that the developed solutions for data integration were not always commercially viable or economically feasible.

Stalling: Slow II Cultivation

One of the keys to establishing an II is to use standards and gateways (Hanseth 2002), and a lack of such links and interfaces can cause delays or stall installed base cultivation. Stalling describes the influence by which the lack of interoperable gateways, APIs or standards slows down data integration and product development.

The theoretical framework explains that conventions of practice can cause material inertias (Venters et al. 2014). The German transport industry's conventions of practice caused material inertias because their innovation cycles never included work on interoperability. Their historical organisational rhythms as manifested by their product plans and development "never" (i1) included developing products that would one day integrate, converge or intersect.

"We're talking to PSA Citroen in France. PSA will come here with new prototype of car and they are thinking of how to open the black box, and thus give us access to the insides of the car. Perhaps we will get this access slowly: car companies never do this [give access] when they create prototypes or any products." (i1)

There were two reasons behind this traditional lack of interoperability. First, as strong players in the transportation sector, the OEMs, public transport and energy companies in Germany benefited from market dominance as entities whose products were built to be walled off from other players.

Second, there was a deep mistrust between the automotive and energy companies. Energy companies complained that "OEMs have a self-esteem that is close to arrogance" (i6) because "German car industry does not allow the energy companies to enter this black box (i1)". However, OEMs felt that their innovation was blocked because "we can't do anything more as a car company because we need the support of the energy providers" (i41). This mutual blame game had developed over decades of mistrust, a rhythm of interaction that led to reduced to no interoperability.

Third, there was no national standard developed for interoperability and exchange of data between different players in mobility industry and so building standard parts was something "nobody follows" (i2).

"We had different energy providers, and they had different cables and we had various types of cars, which are not compatible to all the energy provider's cables. Nobody follows a standard when they build parts…. at the National Electrical Platform, there is an understanding that there should be a consensus and standardized system. We are only at the bottom of this communication. This must be addressed at the national level and eventually at the European Union level." (i2)

The result of these three drivers was a historical pattern of never developing interoperable products, which meant that the BeMobility project consistently faced a data access issue that stalled and delayed II cultivation. Examples of poor data access included interfaces that were very slow (e.g. public transport data from Timetable-Services-Vendor) (i40), not real-time (e.g. data on parking spaces from Parking-Management-Company-1) (i20) or ill-defined (e.g. data from Shared-Mobility-

Operator to search cars) (i40). Past organisational and infrastructural rhythms had temporally disciplined stakeholders and their systems into a state that stalled II cultivation.

Issues related to Shared-Mobility-Operator: "They have no interface, no description of the interface developed over the years, and there is no definition about this." (i40)

Issues related to Parking-Management-Company-2: "Parking spaces... wasn't real time/dynamic – you would not know whether space is available or not." (i20)

Issues related to Timetable-Services-Vendor: "The problem is with Timetable-Services-Vendor. They provide an interface which is very slow. Sometimes you get timeout and get no public transport data." (i40)

Blocking: No II Cultivation

Blocking is the influence by which past rhythms make it very difficult to cultivate the II well, and may result in a new service not being launched or launched incompletely. In the BeMobility project, several past rhythms had a blocking influence on the development of the e-mobility II.

First, the phenomenal rhythms of German funding made it extremely difficult for start-ups to join, blocking access to the II and stifling potential benefits to it. The rhythms of German funding and associated requirements are "always the same" (i2) and out of the control of any one player.

"The German government has to put money into the system. It's always the same. The government gives a certain amount of money and then private companies have to add their own money, and this provokes development." (i2).

Germany's innovation funding cycles includes clear guidelines regarding the timeline of application, monitoring and review, which were carried out to the letter by Intermediary as part of its responsibilities (d8). Financially healthy companies were allowed in the project due to their established networks and ability to contribute to funding. National-Multimodal-Operator, the country's largest public transportation company, was selected as the consortium lead partner as it "already has connections to these [market] players because National-Multimodal-Operator is not a start-up" (i2). Some stakeholders felt that that the presence of only market dominating players constrained radical innovation and complained that "the government makes it hard for smaller companies with its funding model" (i16).

"Innovation projects are almost always driven by the economy- by the big big companies, who are very important, and employ thousands of people. … They want the big companies to be innovative, and that's why the government gives them more money." (i53)

This was proven true in the case of the solar company Energy-Utility-Startup, which could not find the money to contribute funding and had to limit its involvement in the project (i16).

"We had to scale down our participation in the project due to our [Energy-Startup] financial difficulties (even though 50% of the project was funded by the government, Energy- Startup found it difficult to provide the remaining 50%). " (i16)

It is generally believed that innovation comes from start-ups in countries like the US and yet the temporal cycles of German federal financing blocked the ability of start-ups to join instead leaving "a long list of large companies, each of them manifesting their agenda and traditional strategy," who "have the finances but not the spirit to be radical" (i16). This meant that data integration with startups was blocked as was their ability to contribute and benefit the II in the long run.

Second, sometimes integration efforts were not merely stalled by companies, but completely blocked due to historical policies of their market monopolies or mistrust between companies as discussed in the last section. These included the lack of APIs in sharing CAN data from the car's black box due to past infrastructural rhythms that disallowed interoperability efforts. The final report stated that the project had "no permission of the OEMs to access vehicle CAN" (d8).

"Every car is like a black box and its core CAN box which is the core IT of the car, and the German car industry does not allow the energy companies to enter this black box. (i1)

"[Car-Sharing-Service] has all the data about the cars and the customers, and it was not allowed that we get data on the customers." (i39)

The material resistance from the blocking influence of past organisational cycles stopped development of certain features in Phase 1 for the BeMobility app. However, the accommodations supported by Intermediary counteracted these influences in the subsequent phase as outlined in Section 6.2.

Disciplining Influence	Past Rhythm(s)	Impact and Evidence
Diluting Poor quality II cultivation will lead to growth issues	Organisational Biographical	Academic cycles make Academic-Team-1 and Academic-Team-2 prefer interesting research projects for publication instead of products for market consumption. Team members are focused either on finishing thesis or publishing a paper in a peer-reviewed journal. Several stakeholders complained about this.
Stalling Slowing II cultivation	Infrastructural	Data is not real-time.

	Infrastructural	Data access is extremely slow.
	Infrastructural Organisational	APIs are not developed as interoperability was not a priority in innovation cycles.
Blocking Stopping II cultivation	Phenomenal	Startups cannot participate in the project due to the rules of German funding cycles which require them to have raised and contributed a minimum amount of capital by a certain date.
	Infrastructural Organisational	OEMs will not give access to their CAN black box.

Table 14: Disciplining influence of temporal rhythms

6.4.2 Modeling Influences of Future Rhythms

Researchers have studied the importance of mapping the future for effective work and collaboration. When stakeholders lack clarity on the long-term direction of projects, time and effort can be wasted trying to understand and secure the resources for the project's future (Weedman 1998). Ribes & Finholt (2009)'s research showed that the preoccupation of domain scientists with current technologies and common pain points makes them "unable to articulate realistic novel applications" about the future of those technologies. Despite their inability to imagine the future themselves, "people organise their work with an orientation to the future" (Reddy et al. 2006) and project stakeholders who understand their relationship to the future information infrastructure (II) are more incentivised to build it (Venters et al. 2014).

The work of Rolland (2014) inspired the analysis of how future rhythms motivated II cultivation. Chapter 2 described the three ways in which Rolland (2014) states IIs will stop growing: failure to combine relevant parts, failure to extend relevant modules, and failure to replace existing modules. These failure criteria were inverted and rewritten as modeling influences for II growth, and used to code the themes in which future rhythms were found to motivate stakeholders to integrate existing parts (e.g. by connecting the charging infrastructure data to the energy management system), extending modules (e.g. by making their data real-time instead of static), and replacing modules (e.g. using electric vehicles instead of combustion-engine vehicles). The three influences abstracted from the thematic analysis of the data are listed below and named by this study as combining, extending and replacing:

- ***Combining***: Combining existing modules in new ways through existing or new APIs (using gateways and standards).
- ***Extending***: Extending current modules and building new ones (using the principles of modularisation and layering).
- ***Replacing***: Replacing old components and building entirely new ones (adding new functionality).

Combining: Using Existing Modules in New Ways

Combining describes how the installed base is cultivated by combining existing sociotechnical modules in ways that create additional services. This importance of existing or new APIs, gateways and standards are essential to this kind of growth (Hanseth 2001). There were several instances where the projected plans of companies incentivised them to integrate their services and data with other stakeholders. For example, National-Multimodal-Operator imagined a future in which it would combine all its different functions – railway, car-sharing, electricity in one seamless and sustainable journey.

"We [subsidiary of National-Multimodal-Operator] are thinking of building up a real public end-to-end infrastructure for railway stations, which is not provided by anyone at the moment." (i43)

“National- Multimodal-Operator offers customers mobility via car, bike or other means of public transport. To have these mobility solutions in one hand, so that he doesn’t need to think how he will get home, he has one card, and he can have all the offers in one mobility solution." (i2)

"Companies like National- Multimodal-Operator, for example. Because they have a lot of travel coverage and facilities that they can perfectly combine their existing assets into car sharing and car- pooling, I think they might have a really dominant role in this ecosystem." (i35)

This future organisational rhythm of integration and innovation motivated National-Multimodal-Operator to become a lead partner in BeMobility and to lend its support to integration efforts such as developing a Smart Mobility Card. In stark contrast, the OEMs were hesitant in changing themselves, and other stakeholders felt they were “definitely not interested that everybody should only share cars and not buy any individual cars” (i53).

The German government was a strong voice in wanting to combine the services of different transport and energy sector players to build an e-mobility II that would make the country a leader in future mobility services. The future phenomenal rhythm of Germany’s plans to “show to Germany, Europe and the world how the system of electro-mobility works in a global city” (i24) led the government to fund BeMobility for both its phases, thereby encouraging stakeholder participation.

“The role of the federal government related to e-mobility is very important because they have the goal of Germany to be leading market and leading provider of e-mobility by 2020.” (i44)

Extending: Adding New Modules

Extending describes the way the II is extended using modularisation (Hanseth & Lyytinen 2010) and new functionality is added to the installed base that builds upon existing service layers. An example is the BeMobility Suite that is built upon the information systems related to car sharing, car parks, public transport and energy. However, the historical belief that Germans loved their cars and that buying a car was a fixture in the biographical rhythm of any urban resident made stakeholders nervous. They worried about the commercialisation potential of the BeMobility concept and hesitated to collaborate and contribute to II cultivation.

Intermediary allayed their fears by demonstrating through social user research that the future biographical rhythms of consumers signalled a dislike of car ownership and a strong commitment to sustainability. The habits of future users were estimated by Intermediary using a variety of methods: surveys, focus groups, pioneer user analysis (von Hipple 1986) and simulations. Using such methods, Intermediary claimed they "are the voice of the users" (i4) who could identify "the "hidden" needs of users" (i4) that were inaccessible to other stakeholders.

"Our team here is also looking into identifying the "hidden" needs of users (view as citizen more than consumer). Regarding innovation cycles, I feel we are the voice of the users." (i4)

Stakeholders agreed that this user research was invaluable to their understanding the mobility patterns of future users.

"We rely on the input of Intermediary to tell us more about the mobility needs and patterns of the user. " (i11)

Intermediary published their findings in prominent magazines and academic journals and presented results at conferences and project update meetings at the EUREF

Campus. The result was that the stakeholders were inspired and incorporated the assumptions of Intermediary's user research into the functional requirements of the II itself, propelling the addition of new modules. This was the case for several of the II components including the BeMobiliy Suite and the Micro Smart Grid as they extended the current functionality of stakeholder products to develop the II. According to Academic-Team-1, all the user requirements for developing the BeMobility Suite were given to them by Intermediary, who based their requirements on two sources: first, a set of questionnaires that asked questions from people who used the services and second, a set of workshops with so-called "lead" users (as defined by von Hipple (1986)).

"Without these questionnaires, we would only know how many people use the cars, we wouldn't know why they used it and how many times they used it." (i20)

"I ran 3 workshops in total on lead user integration. My job was to identify people who are already interested in e-mobility … Lead user integration was defined by MIT Eric von Hipple. … A lead user is ahead of mass needs; he has needs that the rest of the market does not have right now" (i38).

Similarly, stakeholders working on the Micro Smart Grid also relied on Intermediary's research to model future consumer behaviour simulations to optimise energy load distribution, saying that the research "helps us understand what information we need for our ICT applications, and then we try to fulfil these needs" (i40). The extending influence of future rhythms was key to aligning and motivating stakeholders like Energy-Management-Company that was planning future product releases based on this understanding of users.

"Energy-Management-Company was focusing on finding out where market and customers will lead to in e-mobility and on the topic of smart grid, Energy-Management-Company wanted to understand where it can offer products (transformers, charging stations) and solution (data solutions for integration every component, visualizing it and controlling it)." (i59)

Replacing: Removing Reverse Salients

Replacing describes how future temporal rhythms motivate stakeholders to replace existing modules with entirely new ones. The influence of replacing is essential in driving radical innovation where stakeholders need to be persuaded of the technical viability of new technologies like electric cars. As noted in the literature review, replacing parts of the II is extremely difficult to do in practice (Aanestad & Jensen 2011; Rolland & Monteiro 2007).

Future organisational rhythms motivated some stakeholders as they imagined their products replacing those of competitors. This was why Automotive-Parts-Supplier was keen to build an independent telematics box for the BeMobility Suite's data needs: it imagined a future where its innovation cycles involved developing car parts usually provided by OEMs. An examination of Automotive-Parts-Supplier announcements related to product releases provides insights into their plans and incentives. In July 2010, it announced a plan to invest at least $507 million annually to develop EV specific components and cited BeMobility as a means to test their system. As cars became more modular and electric, Automotive-Parts-Supplier foresaw a higher market share for itself as a frontline player rather than lower on the supply chain serving OEMs.

"The best motivation is for the supplier to the automotive industry – like Automotive-Parts-Supplier ... Regarding the car, it was very complicated to build a car in the past. Building an electric car is much simpler. Thus, the competence of OEM industry is going down and it is the automotive parts that are becoming more important and complex. Thus, the parts suppliers are very motivated." (i24)

The Automotive-Parts-Supplier was very explicit in admitting that their motivation for participating in the project was how to successfully plan new products to integrate in the electric vehicles space (i30).

“100% - I would even say 110% -our primary goal was to see how we can see an electric car working in a major metropolis and to see what kind of product planning we would need to make it a success e.g. to get connectivity and telematics boxes. (i30)

In other cases, Intermediary stepped in to convince stakeholders of the plausibility of new technologies and the increasing speed of future infrastructural rhythms. Using a “living lab” approach on the EUREF Campus, it showcased different technologies by lining the walls of its office with pedelecs and scooters, batteries and simulation tables. It also placed electric cars, charging stations and the micro smart grid outside the offices to give stakeholders a realistic and tangible feel of the “future”. The story that the EUREF Campus told implicitly was that infrastructure rhythms and innovation cycles were accelerating and integration was fundamental to their success.

“The BeMobility project was able to accelerate the innovation cycle in the special area of integrated mobility services with EUREF campus.” (i58)

“You have to develop the narrative that describes the innovation vision and process, and postulates a long-range transformation path. This was the idea of the EUREF campus and platform.” (i15)

Interestingly, the Chinese Minister of Science and Technology Wan Gang saw the power of such an approach in convincing stakeholders to align and contribute, urging Intermediary to “build an intelligent story” (i1) to inspire project members.

“The Chinese Minister was with us 4-5 times and said you have to show the people how it works. You have to bring the wind and solar energy here into the building, and show it as part of a smart grid, and show in one place how it works. Build an intelligent story.” (i1)

A shared vision that aligns stakeholders is critical in strategic niches where one of the main barriers to new technology adoption is that the technology and its advantages are not understood well by stakeholders (Kemp et al. 1998). While the direct impact of this storytelling in the sociomaterial sense is not obvious at a granular level, interviews illustrate how stakeholders were more convinced of the project’s ambitions after visiting the EUREF Campus.

“There is something to be said having produced this campus that is real – EUREF – they have a smart grid, batteries, cars, bikes, … they are quite well-equipped for a platform, well-sourced, high levels of expertise, real technology on the ground.” (i49)

Many stakeholders were similarly favourable in their comments when they came for meetings or quarterly conferences to the EUREF Campus. The partners appreciated the campus because they could test each of the prototypes individually and together as a holistic system, making a mini-prototype of the larger infrastructure they imagined for city-at-large.

"The micro smart grid could really be an innovative idea and I have to stress that the platform EUREF is real – that I didn’t expect that it would become such a good platform and forum where every partner who is interested could come and look at it. It’s a forum in the real meaning of the word."(i12)

The replacing influence of future rhythms was critical in a project such as BeMobility given its vision of a radical transformation of the transportation infrastructure.

Modeling Influence	Future Rhythm(s)	Impact and Evidence
Combining Combining existing modules in new ways through existing or new APIs	Organisational	National-Multimodal-Operator imagines a new future in which it combines all its different functions – railway, car-sharing, electricity in one platform.
	Phenomenal	The German government forsees a future in which it has become a global leader of integrated energy and mobility transportation services.
Extending Extending current modules and building new ones (including apps, databases, and software modules).	Biographical	Intermediary's research shows that the biographies of urban consumers in the future will be different than today and will demand shared mobility platforms.
Replacing Replacing old components and building entirely new ones (like e-cars and their related ICT systems instead of diesel cars)	Organisational	Automotive-Parts-Supplier imagines future innovation rhythms that will develop products that will replace current OEM car modules and help them become more prominent in the industry.
	Infrastructural	Intermediary develops a living lab on the EUREF Campus that demonstrates to stakeholders that future technology innovation cycles will be faster and more integrated than today.

Table 15: Modeling influence of temporal rhythms

6.5 Summary

This chapter demonstrates that II tuning is influenced by the different disciplining and modeling influences of past and future temporal rhythms. The identification of the influences answers the research question on how rhythm impacts II cultivation. The next chapter will describe Part 2 of the analysis that delves into what happens when multiple rhythms interact at the same time, and why one rhythm drives II cultivation more than another.

The diagram below summarises the findings of this chapter in a pictorial format. It shows how temporal rhythms influence temporally embedded human and material agencies by disciplining (through the influences of diluting, stalling and blocking) or modelling (through the influences of combining, extending and replacing) II cultivation. In this way, the process of cultivation in the present can be investigated against the full background of the II's biography, extending from the experienced past and reaching towards the imagined future.

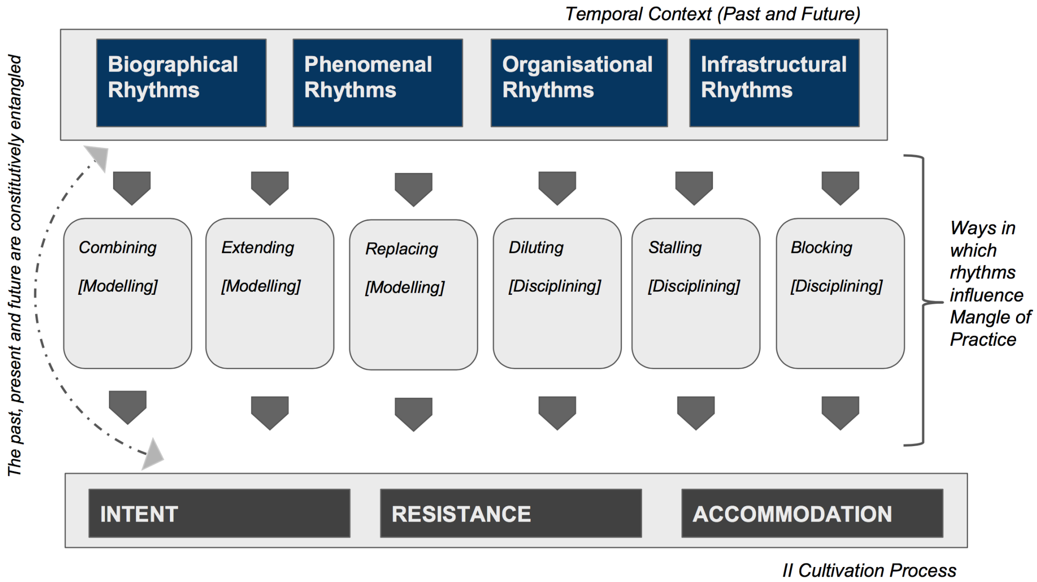

Figure 7: The ways in which temporal rhythms influence II cultivation

7. Analysis – Part 2
Rhythm Interactions and II Trajectories

7.1 Introduction

The findings on temporal dynamics in II cultivation underscore the complexity of rhythms and their influence on the mangle of practice in the present. This complexity increases when evaluating how rhythms interact and the assessment of their eventual impact becomes more difficult. For example, a scientist's tenure review date may conflict with the scheduling of an experiment, and she may prioritise one rhythm over others at such junctures. According to (Jackson et al. 2011), "the question of which rhythms are adjusted to which (and whose rhythms to whose) turns out to be a major site for the exercise of power and control." This chapter builds on the findings in the last chapter to investigation rhythm interactions and their consequences.

7.2 Rhythm Interactions

Rhythm interactions were analysed using Lefebvre (2004)'s rhythmanalysis matrix outlined in the theoretical framework, which categorised interactions as eurhythmia, arrhythmia, and isorhythmia.

7.2.1 Eurhythmia

In eurhythmia, when rhythms reinforce each other, the II cultivates in the direction of that eurythmic interaction. For example, the Automotive-Parts-Supplier and Academic-Team-1 collaborated on developing a black box and software for accessing battery charge respectively for the BeMobility suite. The two rhythms that reinforced each other were the future organisational rhythms of Automotive-Parts-Supplier (which imagined a future where it is more than a car parts supplier (modeling)) and the past organisational rhythms of Academic-Team-1 (which wanted to publish interesting research on for academic cycles (disciplining)). The two stakeholders worked closely together, and one Academic-Team-1 engineer commented that “for some of them like Automotive-Parts-Supplier, we are speaking to them every two weeks. With others like the car companies, we speak less, and it seems they are not interested in the needs of the customer” (i61). In cases of eurhythmia, and especially when Intermediary also supports the process, it is evident the II cultivates in the trajectory of eurhythmic interactions.

7.2.2 Arrhythmia

The study's findings confirm Jackson et al. (2011)’s assertion that “any given site, activity, or moment may be best thought of as a conduit or gateway through which multiple rhythms are flowing at once, many of which will be contradictory or dissonant.” Whenever human and material agencies entangle with each other in the present, multiple rhythms oriented towards the past and future exert their influence on these agencies. Many of these rhythms were conflicting in BeMobility, and this made it difficult to predict the II trajectory during cultivation.

For example, the historical Asian OEM product development cycles, similar to their German counterparts, did not include any time for creating interoperable interfaces. The car parts manufacturers, on the other hand, like Automotive-Parts-Supplier, which supplied car parts to the OEMs, imagined a future innovation cycle which involved data sharing and playing a prominent role in an integrated e-mobility infrastructure. These two rhythms came in direct conflict with each other during the attempt to capture data on the car's data for the BeMobility Suite. When the OEMs blocked the data access to the CAN, Automotive-Parts-Supplier devised a new telematics box to provide the same information and successfully tested it on a subset of vehicles.

Similarly, Energy-Utility-Startup wanted to join the project as a young solar energy startup to gain access to the market (modeling rhythm). However, German funding cycles prevented smaller companies incapable of contributing to the project for fear they will not attract consumers (disciplining rhythm). Ultimately, one of the rhythms dominated and this led to the II being developed in one direction versus another.

Type of Interaction	**II Component**	**Evidence**
Eurythmia Rhythms reinforce each other	**BeMobility Suite** BeMobility Suite needs car black box data to allow customers to know the level of battery charge and range in the car.	Automotive-Parts-Supplier and Academic-Team-1 collaborate on developing a black box for CAN access. Automotive-Parts-Supplier imagines a future where it is more than a car parts supplier (modeling rhythm) and Academic-Team-1 must publish interesting research to meet academic publishing cycles (disciplining rhythm).
Arythmia Tension between temporal chords	**BeMobility Suite** BeMobility Suite needs car black box data to allow customers to know the level of battery charge and range in the car.	OEMs do not want to create an app that allows access to data (disciplining rhythm). However, Automotive-Parts-Supplier wants to enable the app with this information (modeling rhythm).
	Micro Smart Grid Innovative technologies should be included in the BeMobility project to develop products that consumers value.	Energy-Utility-Startup wants to join the project as a young solar energy startup to gain access to the market (modeling rhythm). However, German funding cycles prevent smaller companies incapable of contributing to the project for fear they will not attract consumers (disciplining rhythm).

Table 16: Different kinds of rhythm interactions

Why does accommodation succeed in some cases and not in others? While II trajectories are obvious in cases of eurhythmia, they are difficult to predict in cases of arrhythmia. CSCW studies have documented the dissonance that occurs when temporal rhythms conflict (Begole et al. 2002; Reddy & Dourish 2002; Reddy et al. 2006) and the efforts of participants to resolve issues of temporal conflict by recrafting activities and reshaping organisations (Jackson et al. 2011). As Zerubavel (1985) finds in his research: “Many [rhythms] run independently of one another, and since there is not any attempt to coordinate them, conflicts arise.” This study is interested in the state of interaction related to discordant rhythms when there is tension between temporal chords, and it is unclear which chord will dominate and therefore determine the II’s trajectory. How temporal tensions resolve during II cultivation is the topic of the next section.

7.3 Intermediary and II Trajectories

The third research question on why some rhythms dominate over others to shape the trajectory of the II was the most challenging to address in this analysis. One clue lied in the recurring mention in interviews and documents of Intermediary’s role in decisions regarding ICT development. However, this influence was initially not taken seriously by the researcher as it was incongruent with Intermediary’s official job title of coordinator and social scientist. The first step in this analytical iteration was to investigate if and how a social science institute could heavily influence technical decisions.

7.3.1 A Changing Biographical Rhythm

The recurrence of Intermediary’s mention in accommodations to material resistance led to a new iteration of coding focused specifically on Intermediary’s role, skills and history. On re-examination of the interview notes, the researcher noted her comments that Intermediary was becoming more technical in its staff expertise and how it conducted itself in project matters. This study’s theoretical framework emphasises that “shifting roles, identities, and career trajectories are central constituents of biographical rhythm” (Jackson et al, 2011) of workers. As discussed in the chapter on the conceptual framework (Chapter 3), the researcher extends the concept of biographical rhythms to collectives of people who work in a single organisation. The change in Intermediary's biographical rhythm was unexpected as the framework assumed rhythms to be relatively stable during this time. This section describes the evidence and influence of Intermediary's evolving biographical rhythm on II cultivation.

At the beginning of the project, Intermediary staff followed the biographical rhythms of social scientists. Almost every staff member, starting with its co-founders, had a social science background (academic and work related). Having a social science edge increased the team's credibility given that since World War II, Germany has particularly emphasised the importance of sociology in science and technology projects (i49). One of Intermediary's founders had been a leading social scientist in the field of mobility in Germany for almost twenty years (i49), and the institute developed a robust reputation as a group of experienced social science researchers after its incorporation in 2006.

However, despite their deep knowledge of mobility trends caused by technological disruptions, Intermediary staff were following a biographical rhythm that had little to do with technology: their career path which included acquired skills, publications, position titles and promotions, all were related only to social science. In early interviews, Intermediary staff stated that they "don't have technical expertise, but we coordinate engineers" (i23), and stakeholders agreed that Intermediary did "not have the competence to further develop the technology" (i20).

However, it appears that Intermediary began to realise that its social science biographical rhythm was an impediment to its success. Intermediary was conscious that it needed to show technical expertise to prove its worth (i23) and technical skills were necessary to enable goals such as data integration. As projects like BeMobility provided the funding for Intermediary's operations, Intermediary was highly motivated to make the e-mobility II a success.

Slowly, Intermediary staff began to follow a new biographical rhythm, that of socio-technical scientists rather than just social scientists. Their skills as exemplified by their increasing expertise and technology involvement and their career trajectories as shown by the new types of technology related positions in the organisation, all indicated a new biographical rhythm for the organisation. Technology personnel numbers increased from three to eight to fifteen in the span of the project (i40 and i58) (when visiting in April 2017, the researcher discovered that Intermediary has an even larger technical department now).

"Originally, when BeMobility started, we were only 3 people in the media based group. Now we are 8 people and even that number will rise. I need more ICT experts." (i40)

"Yes, now in my [ICT at Intermediary] people I have at least 15 people and we developed different tools for analysis in mobility behaviour." (i58)

"We're always trying to challenge ourselves with new technologies and trying to adopt new things, and to try to do things that other people only talk about." (i13)

As the level of technical expertise increased in Intermediary, they imagined their "role increasing in the ICT part of projects across all of our projects." (i40). Stakeholders also noticed and agreed that the team became "technically more savvy" over time and began to heed Intermediary's suggestions for ways to access data.

"We have added a number of people with engineering background. We are becoming more technically savvy" (i15)

"Yes I would say that they are becoming technically more savvy between BeMobility 1.0 and 2.0. " (i21)

"This is the first time we've really got into technical solutions, and this is fine with City-Energy-Manager and Energy-Management-Company because they can see results and they can demonstrate to their boards that it's not just paper and talking." (i17)

This evolution was most evident in staff interviews from Phases 1 and 2 which became progressively more skilled and confident in technical language. The table below demonstrates this point with snippets from three different interviews taken over the years with the head of ICT at Intermediary.

Date	**Interview Extracts**	**Researcher Note Extracts**
24 January 2012	"I am a social scientist … My part was to coordinate this working package together with Academic-Team-1 …Partners were difficult: on the one hand, we need exact description of data and they didn't have this nor did they have resources to provide this interface". (i39),	"The tone is unsure and hesitant about how to access data. Language is very generic. They don't completely understand the technical details it seems."
11 March 2013	"Creating ICT technologies is an iterative process. If your goal is just to integrate all the data streams and put it on one platform then, in my opinion, you just double the complexity. With all this information on a platform, you need an information filter. All these layers of information [time, location weather] can be viewed as context sensitivity." (i40)	"Despite being a social scientist, he is speaking in far more sophisticated technical language than he was a year ago. Using words like information filters, context sensitivity and location based services. Even though he does not call it system architecture or information design, he is, in essence, talking about these things."

26 September 2016	Yes, now in my people, I have at least 15 people, and we developed different tools for analysis in mobility behaviour. We created different tools after the project of BeMobility 2.0 but the need for developing these tools started in BeMobility 1.0 … We have developed the tool a Modalyzer which is a smartphone app that can measure the mobility behaviour of people." (i58)	"Very confident tone and surprising that they are building complicated software apps in-house."

Table 17: Evolution of Intermediary's technical skills

Designing and developing the app that "that can track intermodal behaviour very exactly – distance, time, duration of trip" (i40) marks an important turning point for Intermediary as it underscores their capability to design and implement complex technologies themselves. Previously they were completely dependent on partners such as Academic-Team-1 and Academic-Team-2 to develop software.

"Yes, I see Intermediary's role increasing in the ICT part of projects across all of InnoZ's projects. At the beginning, we were focused on the customer needs, but now we are doing more and more in terms technical solutions." (i40)

As Intermediary began to identify itself more as a technical intermediary, some staff members even compared their role to that of information architects who "facilitate an innovation architecture and tech architecture, and we are very much building upon this architectural vision and bringing our partners into thinking that way" (i15).

"Absolutely, we are looking at information infrastructure design. There is definitely a clear vision what types of architectures we need to explore and optimize them" (i15)

Intermediary changed its biographical rhythm by evolving towards an imagined self that was a technical visionary and expert. This systematic repositioning of itself as having socio-technical skills instead of just social science expertise meant that Intermediary could intervene far more proactively in data integration processes. As the ICT group strengthened in Intermediary, its new biographical rhythm reverberated to the rest of the Institute confirming that "individual biographical rhythms may have profound effects on the nature of rhythm in larger collectives" (Jackson et al. 2011).

The deliberate intervention in one's biographical rhythms to enable reinvention is not unprecedented. Stakeholders can change rhythms as they accommodate the goals they set for themselves according to Steinhardt & Jackson (2014), including biographical rhythms and therefore their identities. While past experiences stabilise and sustain identities (Emirbayer & Mische 1998), Intermediary confirmed the notion of "temporal structuring" (Orlikowski & Yates 2002), which says that while individuals work through time, they can also work on time and change it. While other stakeholders in BeMobility could also have pursued this path, only Intermediary was observed to pivot its biographical rhythms during the project systematically (as shown in the table below).

Intermediary's Systematic Change in its Biographical Rhythm	Explanation and Evidence
Intermediary changes its biographical rhythm for reinvention	Intermediary changed its biographical rhythm. It pivoted from having the lifecycle pattern of a social science team to one of a more technical institution. This is a case of temporal structuring for an institution where rhythms can both change practices and be changed by practice, and was the only instance observed where the rhythm changed during the duration of the project itself. ***Example:*** It began to advise on accommodation strategies like app-linking and APIs more proactively. ***Example:*** It increased its ICT staff over the years from 3 – 18 people. ***Example:*** It started designing and building software in-house like the Modalyzer app.

Table 18: How Intermediary evolved its biographical rhythm

The next section describes how having reinvented itself, Intermediary more confidently intervened in how rhythms influence II cultivation, directly impacting the II's trajectory.

7.3.2 Interventions in II Cultivation

Having determined that Intermediary was consciously elevating its role as technical intermediary, the researcher next did a new round of coding to label texts that showed if and how Intermediary intervened in the disciplining and modeling influences of rhythms. Three interventions emerged based on this analysis, which described how Intermediary (consciously and unconsciously) intervenes in how rhythms influence II cultivation. These interventions are not necessarily rhythms themselves but are ways in which the influence of temporal rhythms can be reinforced or diluted. The three interventions of harmonising, composing and riffing were initially derived inductively and then aggregated and renamed inspired by the concepts related to rhythms in the theoretical framework.

Harmonising

Harmonising describes the reinforcement of temporal rhythms by Intermediary through various means of support, which helps certain rhythms dominate in case of arrhythmia. The researcher based the concept of harmonising on rhythm concepts, which state that to harmonise is to reinforce an existing song or rhythm. Intermediary used the harmonising influence to reinforce certain rhythms by supporting them selectively.

For example, when the Intermediary supported the development of a new telematics box by Automotive-Parts-Supplier to replace the CAN box by OEMs, it reinforced the *replacing influence* of future organisational cycles of Automotive-Parts-Supplier. In its future, Automotive-Parts-Supplier saw itself becoming a major player in the mobility industry by replacing OEM products with its own e-mobility products.

In another example, Intermediary supported National-Multimodal-Operator's plan to lead BeMobility and include its Car-Sharing-Service as the primary car-sharing service used in Phase 1. In doing so, Intermediary harmonised or reinforced the *combining influence* of future organisational cycles of National-Multimodal-Operator which saw all its subsidiaries (car-sharing, trains, energy) into a sustainable digitised mobility chain.

National-Multimodal-Operator "is 4th largest electric power generating company in Germany, and in the future they want to sell power to electric mobility and that's why they're interested in this car sharing project. (i47)

When Intermediary supported the rhythms of different stakeholders through the influence of harmonising, those rhythms became dominant in determining the trajectory of the II. For example, when it reinforced the vision of National-Multimodal-Operator to create an integrated mobility chain between its subsidiaries, the result was an e-mobility II that integrated the services of its subsidiaries Energy-Utility-2 and Shared-Mobility-Operator. Or when it supported the future organisational cycles of Automotive-Parts-Supplier, the result was the successful testing of an II with the potential to have integrated communication with telematics in Phase 2.

Even though the harmonising influence resulted in successful accommodation to material resistance, not all stakeholders agreed that the type of accommodation and resulting II trajectory was optimal. For example, in the case of its support of Academic-Team-1's recommendations for the BeMobility Suite and Academic-Team-2's work on the Micro Smart Grid, Intermediary was essentially supporting the past organisational cycles of academic publications that were motivating the decisions of the academic teams. In this case, both the products developed were subpar in their commercial quality according to some stakeholders (i59, i10), but given

Intermediary’s harmonising intervention, Academic-Team-1 and Academic-Team-2 continued to succeed in their ability to sway decisions in one direction.

Academic team members admitted that “in the more research based view, we are looking in a silo and not thinking about whether it can be used in a city wide area, rather to see whether these algorithms can be used." (i21)

Interestingly, some Intermediary staff admitted that they knew Academic-Team-1 “was just searching for a use case for their research … [which was] not perfect for the problems faced in the mobility sector” (i40). However, despite reservations, Academic-Team-1 continued as the main technical advisor, largely because it enjoyed strong support from Intermediary who both assisted and worked closely with them to create the software. A likely reason was that Academic-Team-1 was heavily influenced by Intermediary’s recommendations and relied on them wholly for functional requirements and “product images” (i20). Academic-Team-1 also depended on Intermediary for access to stakeholders like the car park company Timetable-Services-Vendor for the BeMobility Suite (i27) and the energy provider Energy-Utility-2 for the Smart Micro Grid (i21). Intermediary's blind eye to Academic-Team-1's weaknesses shows that intermediaries are not just passive actors but looking out for their interests as well (Medd & Marvin 2007).

The same self-interest was also evident in how Intermediary harmonised its activities with the disciplining of past phenomenal rhythms of traditional German funding cycles. Some stakeholders felt that traditional German funding cycles constrain radical innovation as it “makes it hard for smaller companies with its funding model” (i16) and blamed Intermediary, saying “Intermediary and the government are both looking only for big partners and big names" (i53). The analysis provides a cautionary note to the incentives and motivations of intermediaries when intervening in the disciplining influences of rhythms.

"The small companies have a hard time getting into such projects. I was at a meeting a few weeks ago where I saw a demo by a local company. There was a guy who has a small company with 7 staff members who had developed a foldable electric car bike. It looked very interesting …. I told him about [BeMobility] and asked, "why are you not involved at the platform at Intermediary?" And he said he wanted to but Intermediary didn't want him because he is too small. Intermediary and the government are both looking only for big partners and big names." (i53)

Harmonising (supporting some rhythms for reinforcement)	
Explanation	Intermediary selectively **reinforced** rhythms by supporting them.
Evidence: Context and Intervention	***Example:*** It following all guidelines given by the government including when companies must submit financial statements to show eligibility for project funding. ***Intervention:*** *Harmonising* reinforced the *blocking influence* of past phenomenal rhythms of German funding cycles that precluded small innovative start-ups from joining the project.
	Example: It supported Automotive-Parts-Supplier in developing a new telematics box. ***Intervention:*** *Harmonising* reinforced the *replacing influence* of future organisational cycles of Automotive-Parts-Supplier in which Automotive-Parts-Supplier saw itself as a major player in the mobility industry by replacing the OEM products.
	Example: It supported National-Multimodal-Operator's plan to lead the BeMobility project and primary role in the project such as the use of Car-Sharing-Service (its car sharing operator) as the main car-sharing service in Phase 1. ***Intervention:*** *Harmonising* reinforced the *combining influence* of future organisational cycles of National-Multimodal-Operator which saw all its subsidiaries (car-sharing, trains, energy) into a sustainable digitised mobility chain.

	Example: It supported Academic-Team-1's involvement and recommendations for software development. ***Intervention:*** *Harmonising* reinforced the *diluting influences* of past organisational rhythms of academic publishing cycles that prized interesting research over the commercial viability of products.
Results	The reinforced rhythms dominate chordal tensions and tilt the II cultivation in their favour.
Caveats	The II trajectory may not be optimal for the long-term viability of the II.

Table 19: How Intermediary reinforced rhythms by harmonising

Composing

Composing describes the creation of new rhythms by Intermediary that increased II cultivation by modeling future rhythms. For example, Intermediary researched future consumer mobility patterns that supported the commercial viability of car-sharing and e-mobility and created a living lab to showcase the latest technologies to show their technical feasibility.

The composing intervention mediated temporal rhythms by either reinforcing or countering their impact. For example, when Intermediary developed its living lab, it reinforced the *extending* and *replacing influences* of future infrastructure rhythms of stakeholders like Automotive-Parts-Supplier and Energy-Management-Company that imagined faster innovation cycles.

"And at Automotive-Parts-Supplier, Energy-Management-Company, and National-Multimodal-Operator, … they are already developing these techniques further, and they will do it anyway. So this research project is a chance to get paid 50% for their research." (i53)

One way the composing intervention was successful in motivating stakeholder alignment and contribution was by setting a rhythm for entrainment. Entrainment, defined as “the adjustment of the pace or cycle of one activity to match or synchronise with that of another” (Ancona & Chong 1996), means that the organisational and infrastructural rhythms of stakeholders accelerated as the temporal context of the rhythms they witnessed at the EUREF campus shaped their internal rhythms. In this sense, the campus rhythms acted as a pacemaker for stakeholder innovation cycles. Intermediary also realised this powerful narrative was successful in convincing stakeholders “to accelerate the innovation cycle in the special area of integrated mobility services” (i40). Entrainment countered the *stalling influence* of past infrastructure rhythms and organisational rhythms of stakeholders like OEM-1 and OEM-1 which were built on the conservative assumption of private car ownership and “a “don’t enter here” mentality in the car industry" (i1) that discouraged interoperability.

Innoz's “main role is to show the people how our project will work in the future. They have this e-mobility platform and their main part is to showcase the story and the project." (i31)

The composing intervention also manifested itself when Intermediary created scenarios of the biographical rhythms of future consumers. As discussed earlier, Intermediary did not only conduct user research surveys but also inserted the results directly into the functional requirements and specifications of II components like the BeMobility Suite and the Micro Smart Grid. When Intermediary worked with Swiss-Consulting-Firm to create consumer behaviour simulations that were used to optimise the Micro Smart Grid, it reinforced the *extending influence* of future biographical rhythms. This influence motivated stakeholders like Energy-Management-Company who worked with Intermediary “to understand where it can offer products (transformers, charging stations) and solution (data solutions for integration every component, visualising it and controlling it)." (i59)

"We have completed the simulation of the car sharing (we did it with a Swiss company called Senozon). We used the mobility and behavioural simulation software program MATSim, which was developed by the Swiss Federal Institute of Technology (ETH) Zurich and the technical university (TU) of Berlin with Senozon. In this stream, InnoZ offered data and knowledge about how flexible car sharing is used by the customer, how long and how often, etc, and this information was used to conduct the simulations jointly with Senozon." (i40)

Most stakeholders accepted the neutrality of Intermediary's social research and several affirmed their faith in the ability of Intermediary to correctly ascertain the behaviour of future users.

“ InnoZ is an important partner because they have been doing all the social science work regarding mobility … Without this information, it would not be possible to be successful" (i20).

However, some stakeholders complained that "a lot of [survey] questions were too strongly influenced by National-Multimodal-Operator, by their car sharing people, and they weren’t really as objective as they would have been" (i30). Others questioned whether Intermediary was biased in its research given its close association with National-Multimodal-Operator, the lead partner, saying “it’s hard to tell the difference [between them] for me sometimes" (i20). The composing influence thus serves as both a positive and cautionary note to the power of Intermediary, which successfully shaped the II by creating functional requirements based on its user research. However, the resulting II trajectory was considered biased to a degree by certain stakeholders.

Composing Influence (modeling future rhythms for entrainment)	
Explanation	Intermediary **composed new rhythms** that increased II cultivation by **modeling** the future.
Evidence: Context and Intervention	***Example:*** Intermediary researched future consumer mobility patterns that supported the commercial viability of car-sharing and e-mobility. ***Intervention:*** *Composing* reinforced the *extending influence* of future biographical rhythms that described the desire of consumers to have integrated services, and countered the *stalling influence* of past organisational rhythms of OEMs that were very conservative in their innovation cycles.
	Example: Intermediary created a living lab to showcase the latest technologies to show the technical feasibility of the technologies used. ***Intervention:*** *Composing* reinforced the *extending* and *replacing influences* of future infrastructure rhythms that imagined faster innovation cycles and new technologies, and countered the *stalling influence* of past infrastructure rhythms which resisted interoperability.
	Example: Intermediary worked with Swiss-Consulting-Firm to create simulations of mobility and energy consumption patterns that were used to predict and optimise the Micro Smart Grid. ***Intervention:*** *Composing* reinforced the *extending influence* of future biographical rhythms where consumers want to have apps for integrated mobility and sustainable living.
Results	These rhythms became **pacemakers** for stakeholder rhythms that **entrained** themselves to them.
Caveats	The neutrality of Intermediary is not always considered unbiased in generating scenarios of future rhythms.

Table 20: How Intermediary composed future rhythms

Riffing

Riffing describes the development of a base temporal rhythm or riff by Intermediary consisting of a pattern of always using one of three techniques – build, transfer, and outsource - to support the accommodation of material resistance to data integration as described in Section 6.2. The influence of riffing created a minimal structure, which "serves as a template upon which improvisation can take place" (Kamoche & Cunha 2001) for stakeholders like Academic-Team-1. Riffing intervened in various rhythm influences by supporting or countering their influence.

As described in Section 6.2, Intermediary worked with Automotive-Parts-Supplier to build a new telematics box to access the car's battery levels. This allowed Academic-Team-1 to improvise and get data for the BeMobility suite using the new telematics box. Riffing supported the *replacing influence* of Automotive-Parts-Supplier's future organisational rhythms that envisioned Automotive-Parts-Supplier replacing OEM car products, and countered the *blocking influence* of past infrastructure rhythms of OEMs which did not give data access.

Intermediary also supported Academic-Team-1's recommendation to transfer data from the Micro Smart Grid to a central database to avoid privacy and security concerns that allowed Academic-Team-1 to improvise on energy modeling algorithms. Here riffing countered the *stalling influence* of past infrastructure rhythms of energy providers which resisted interoperability since "they come from a monopolistic history and they are not trained to think like market-oriented entities." (i6)

Finally, to create the Smart Mobility Card, Intermediary worked with licensed vendors to outsource the creation of the smart card. However, it had to first persuade National-Multimodal-Operator that creating such a card was in line with its vision of being the leading player in an integrated mobility market. By convincing National-Multimodal-Operator through reinforcing the c*ombining influence* of its future organisational rhythms, Intermediary could also counter the *stalling influence* of past infrastructure rhythms of City-Mobility-Operator and Ticketing-Operator which resisted interoperability of payments. City-Mobility-Operator and Ticketing-Operator now had to follow suit given National-Multimodal-Operator's pressure even though Intermediary initially "couldn't bring them to sit together at one table" (i23). With everyone on board given the efforts of the Intermediary, National-Multimodal-Operator improvised on the idea of the integrated payment card by developing a prepaid card that precluded other stakeholders from accessing National-Multimodal-Operator's customer database. Without Intermediary's intervention, the Smart Mobility Card would not have been successfully developed and tested in both Phase 1 and Phase 2.

It is important to note that while Intermediary attempted to intervene in rhythms through the influence of riffing to enable data integration, it was not always successful in its efforts. The delay of Mobility-Operator's new API despite Intermediary's *build* intervention is an example of this.

Riffing (creating base rhythms for improvisation)	
Explanation	Intermediary developed a base temporal rhythm or **riff** of three techniques – **build, transfer, outsource** for accommodating material resistance by the installed base.
Evidence: Context and Intervention	***Example:*** It worked with Automotive-Parts-Supplier to ***build*** a new telematics box to access the car's battery levels. This allowed Academic-Team-1 to improvise and get data for the BeMobility suite using the new telematics box. ***Intervention:*** *Riffing* supported the *replacing influence* of Automotive-Parts-Supplier's future organizational rhythms that envisioned Automotive-Parts-Supplier replacing OEM car products, and countered the *blocking influence* of past infrastructure rhythms of OEMs which did not give data access.
	Example: It support Academic-Team-1's recommendation to

	transfer data from the Micro Smart Grid to a central database to avoid privacy and security concerns that allowed Academic-Team-1to improvise on energy modeling algorithms. ***Intervention:*** *Riffing* countered the *stalling influence* of past infrastructure rhythms of energy providers which resisted interoperability.
	Example: It worked with licensed vendors to ***outsource*** creation of a Smart Mobility card that integrated different modes of public and private transport that allowed DB to improvise on prepaid cards so that it would not have to share its customer data. ***Intervention:*** *Riffing* reinforced the *combining influence* of National-Multimodal-Operator's future organizational rhythms that wanted to be lead players in an integrated mobility market, and countered the *stalling influence* of past infrastructure rhythms of City-Mobility-Operator and Ticketing-Operator which resisted interoperability.
Results	This created a **minimal structure** for Academic-Team-1 and other stakeholders to **improvise** upon when they were building software components based on data integration.
Caveats	Riffing was not always successful. For example, even though it convinced Mobility-Operator to build a new API for data access, it was ultimately delayed due to project capacity and cost constraints.

Table 21: How Intermediary supported data integration by riffing

Summary

The study had set out to understand the influence of temporal rhythms on II cultivation. The findings in the analysis highlight that Intermediary tempers this influence by its actions, and researchers must not study rhythms in isolation without understanding the role of intermediaries as well. To succeed in its intervention strategies, Intermediary changed its biographical rhythm and imagined a future version of itself as a technical visionary.

The next chapter generalises these results to create an initial framework of information infrastructure (II) cultivation that conceptualises how intermediaries may intervene in temporal rhythms to influence the II's trajectory. From a practical perspective, the findings highlight the need for researchers to consider intermediaries in a more expansive and nuanced role than previously imagined. The diagram below illustrates how Intermediary's interventions of harmonising, composing and riffing mediated the disciplining and modeling influences of past and future rhythms on II cultivation in the BeMobility case.

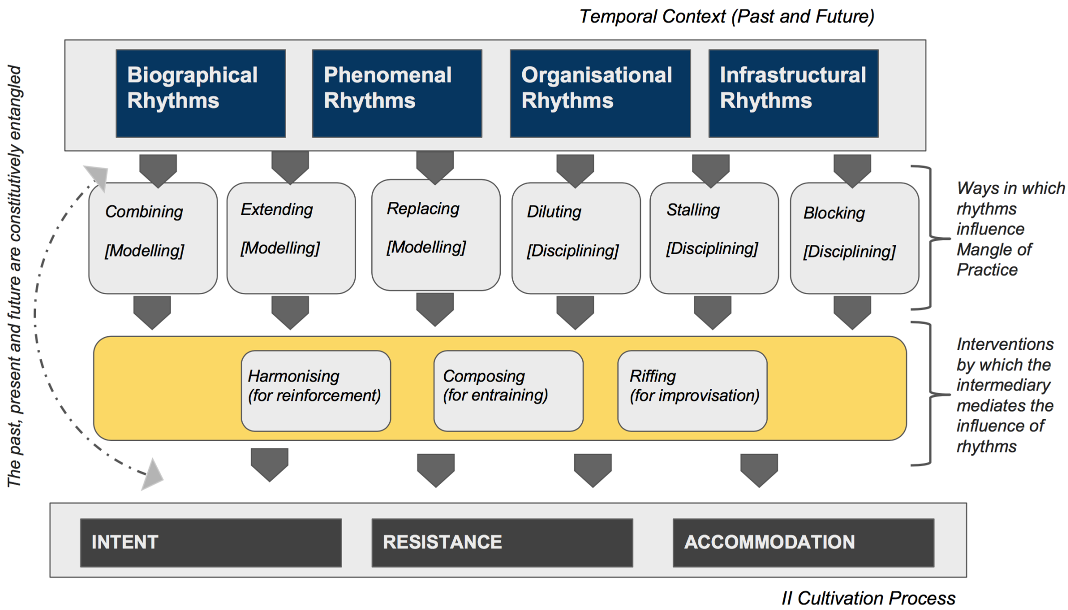

Figure 8: The ways in which the intermediary intervenes in temporal rhythms

The findings also tell a cautionary tale about the interventions of Intermediary to harness rhythms to influence an II's evolution. Given its central position in coordinating work between stakeholders, Intermediary not only sees the impact of rhythms on II development but can also elevate and de-emphasise rhythms to serve the project's goal. It can also create new temporal rhythms in the minds of project stakeholders that encourage more integration. However, while it may be successful in driving II cultivation, the resulting infrastructure may not always be optimal. It may be biased towards the needs of a particular stakeholder, such as when it appeared to cater to Intermediary's investor National-Multimodal-Operator in its research on future users. Alternatively, the II may develop at the detriment of being fully innovative, such as when Intermediary followed German funding rhythms and discouraged the inclusion of start-ups in the project.

Regardless of the eventual impact on the II, the influence of Intermediary and its use of temporal rhythms to achieve this influence is undeniable. This study gives researchers "a better understanding of power dynamics that might be invisible otherwise" (Steinhardt & Jackson 2014) in strategic niches.

The influence of Intermediary initially went unnoticed by the stakeholders who considered it merely a project coordinator. However, over time, project members began to appreciate the increasing technical skills of Intermediary, which was changing its biographical rhythms deliberately. By investigating how Intermediary intervened in temporal rhythms to influence II cultivation, the study's findings can provide practical recommendations to policymakers on both the advantages and disadvantages of partnering with intermediary organisations.

One of the issues in this line of examination has been that studying temporal rhythms do not always provide clear lines of influence between the sociomaterial interaction of agencies in the present and the rhythms themselves. While this study contributes to methodologies to study temporal rhythms, it also recommends further research in this area in Chapter 8.

7.4 Summary

This chapter analysed the findings from the BeMobility case study using a data-driven and theory-inspired iterative approach. This summary of observations is guided by how the chapter addressed the research question.

Temporal rhythms influence human and material agencies in the mangle of practice.

Past rhythms disciplined II cultivation through three influences: diluting, stalling and blocking while future rhythms modeled II cultivation through three influences: combining, replacing and extending. Rhythms can act alone or with others in disciplining or modeling the mangle of practice.

Rhythm interactions can cause tensions or reinforce each other.

Rhythms can act in cohesion in a eurythmic interaction, or in discord with each other in an arrhythmic interaction. Analysis of the interaction of rhythms using rhythmanalysis (Lefebvre, 2004) does not provide a clear answer on why the II cultivates in a certain trajectory.

When there are tensions between rhythms, Intermediary intervenes by mediating the influence of rhythms on II cultivation

Intermediary intervened (both consciously and unconsciously) in how rhythms influence II cultivation. Intermediary employed three types of interventions: harmonising, composing, riffing, to intervene in II cultivation and the last one to reinvent itself. Intermediaries exercise influence by reinforcing certain rhythms by supporting them to the detriment of others, creating new rhythms from scratch, and forming a minimal structure of a temporal pattern to help stakeholders improvise and accommodate material resistance to data access as outlined in Section 6.2.

These interventions are possible by an intermediary given its role in the project. In the BeMobility project, Intermediary had a birds-eye view of the whole project and could recognise rhythms that were motivating stakeholders better than participants who were engaged bilaterally with each other in working groups.

"I take part in the meetings of the sub-groups to understand what they are doing, to tell them my perspective, to always tell them the big vision, the big aims. Because if you are in the day-to-day work streams and the different interests of the company are coming together, they sometimes become too wrapped in other directions, so you have to bring them back." (i22)

Intermediary's interventions were not always best for the long-term goals of II cultivation. For example, Intermediary reinforced Academic-Team-1's efforts, but Academic-Team-1's software solutions were motivated more by interesting research than commercial viability and were weak in product development for end-users.

A contribution of this thesis lies in its identification of temporal rhythms as an influencer in II cultivation and the emergence of Intermediary as a stronger player than previously imagined. While researchers are encouraged to discover other ways of rhythmic intervention in future studies, intermediary intervention represents one explanation of how certain rhythms dominate and influence the trajectory of II cultivation. Features of rhythms that have significant implications for II cultivation are discussed in this chapter and add to the work on temporality and collaborative infrastructure development (Karasti et al. 2010). This research on temporality builds on the body of investigation on temporal rhythms in the CSCW domain (Zerubavel 1985; Steinhardt & Jackson 2014; Reddy et al. 2006; Reddy & Dourish 2002; Nilsson & Hertzum 2005; Kusunoki & Sarcevic 2015; Begole et al. 2002). The next chapter will discuss the themes and frameworks for II cultivation that emerge from this analysis.

8: Discussion

8.1 Introduction

The analysis used the theoretical framework defined in Chapter 3 to analyse the evidence and address the research questions. It also surfaced the intermediary's role in harnessing different kinds of rhythms to cultivate the information infrastructure (II).

This chapter discusses the major themes of the analysis in the last two chapters, bringing out the relevant points of the case study that can be generalised to the literature. It further develops these ideas into the sociomaterial concept of facilitated II cultivation and relates it to the theories in the theoretical framework. In doing so, the study contributes to the literature in several areas: first, it adds to the emerging literature on temporality in IIs; second, it expands the concept of the intermediary and its role in the strategic niche management (SNM) literature; and third, it adds some initial thoughts on how to integrate rhythms in the investigation of sociomaterial practice.

The chapter is structured as follows:

Section 8.2 revisits the research questions outlined in Chapter 3 and evaluates them in light of the findings in the analysis chapters. It also describes the two-step approach used by this study to generalise the analysis to theorise about II cultivation.

Section 8.3 introduces the concept of using rhythms in II research and demonstrates how the temporal structuring of rhythms can enrich current conceptualisations of time in this domain.

Section 8.4 outlines the concept of facilitated II cultivation based on the interventions of harmonising, riffing, and composing developed in this study to help conceptualise how intermediaries can intervene in the influences of temporal rhythms.

Section 8.5 develops the concept of a rhythmic intermediary, which is a new kind of intermediary that adds to the concept of intermediaries in the strategic niche management literature.

Section 8.6 discusses the place of rhythms in sociomaterial research and how it can contribute to a better understanding of II cultivation.

Section 8.7 summarises the chapter.

8.2 Findings and Generalisation

The literature review revealed two tensions that were a gap in the literature and of interest to the study of e-mobility IIs in cities.

First, the literature review demonstrated that IIs are challenging to manage because of their complexity (Hanseth & Ciborra 2007; Kallinikos 2007) and understanding how II design and development is a debate amongst researchers. While researchers agree that the idea of strict management is unrealistic, they disagree to the extent of strategic intervention that is possible: can II cultivation be managed with top-down design (Koutsikouri & Henfridsson 2017) or is it better left as a bottom-up process to users and third-party developers (Ghazawneh & Henfridsson 2013)? This tension between strategic intervention and impossibility to manage is a significant tension to explore for the study of II cultivation.

Second, the CSCW literature, which has researched the work of collaboration to build large-scale ICT systems, confirmed the importance of context in dynamic and fast-moving environments like IIs. The literature demonstrated that the study of temporality as a context is nascent and that there remains a tension on how to negotiate the long-term view of the infrastructure with short-term implementations (Karasti et al. 2010). Researchers argue that IIs should be studied as a process against the full backdrop of its history and as a biography rather than a moment in time (Monteiro et al. 2012).

The findings of this study address both these gaps in the literature. First, the demonstrates that strategic intervention in the II cultivation process is possible and II cultivation is not only a bottom-up process. Past and future temporal rhythms influence human intentionality and material agency mangling in the present through various influences that enable or constrain II cultivation. The intermediary can mediate these rhythmic influences through the interventions of harmonising, riffing and composing. Using these interventions, the intermediary can incrementally tilt the trajectory of II cultivation in the direction it wants.

Second, the study demonstrates the link between short-term implementations and the longer-term biography of the II. This biography does not only include the past and its experiences but extends into the intentions, aspirations and material possibilities of the II in the future. By demonstrating how past and future rhythms influence the mangle of practice in the present, the study connects project time to infrastructure time.

The research questions (refined by the theoretical framework) were addressed in the last chapter and will now be revisited to address the gaps in the literature discussed above.

8.2.1 Answering the Research Questions

RQ1 How do rhythms influence the process of II cultivation?

The results of the analysis confirm that “digital coordination can be understood as a temporally enacted process of sociomaterial entanglement” (Venters et al. 2014) of human and material agencies. As discussed in Chapter 3, human agency here refers to social agency, which is “a group’s coordinated exercise of formatting and realising its goals” (Leonardi 2012).

The analysis revealed how past rhythms discipline II cultivation through the influences of diluting, stalling and blocking. The conventions of the past exert disciplinary agency by creating inertia “through habit and repetition” (Emirbayer & Mische 1998). Past rhythms are not related only to human intent and actions, but also to materiality (such as software modules, APIs, and databases), which exerts resistance through path dependencies, and has its own distinct past, present and future (Ribes & Finholt 2009).

Imagining the future shapes group intentionality through the influences of combining, extending and replacing. These future models are “presently non-existent future states [that humans] then seek to bring…about” (Pickering 1995). Anticipated temporal rhythms can sometimes manifest themselves directly in the materiality of II when they influence the II’s functional requirements. This was the case in BeMobility when Intermediary researched the future biographical rhythms of consumers and used the results to write the functional requirements of the II.

The investigation of the anticipated future and its influence on II cultivation adds to the literature that has hitherto focused largely on the impact of the II’s path dependency (Hanseth 2014). The study disagrees that II “evolution is largely about managing network effects and path dependency” (Monteiro et al. 2012) and positions the future as being equally influential in impacting II cultivation as the past.

The table below connects the six influences of temporal rhythms extracted in the findings to the aspects of II cultivation discussed in Chapter 2. For example, the diluting influence of temporal rhythms manifests itself in poor design choices that lead to technology traps or lock-ins (Grindley 1995), and the extending influence manifests itself in developing modular extensions that add to the layers of the installed base (Hanseth & Lyytinen 2010).

Modelling influence of temporal rhythms	Disciplining influence of temporal rhythms
Combining: Rhythms that encourage building APIs and Gateways that lead to interoperability.	***Stalling:*** Rhythms that result in having none or slow interfaces that make interoperability difficult.
Extending: Rhythms that lead to design choices for adaptability through modular additions and flexible standards.	***Diluting:*** Rhythms that create lock-in features and make the II less adaptable.
Replacing: Rhythms that motivate removing sociotechnical components that will lead to reverse salients.	***Blocking:*** Rhythms that prevent the II from bootstrapping and attracting users.

Table 22: The relationship of rhythmic influences and II literature concepts

RQ2 How do rhythms interact with each other during II cultivation?

The findings demonstrated that multiple rhythms oriented towards the past and future exert their influence in different ways on II cultivation. They confirmed Jackson et al. (2011)'s assertion that "any given site, activity, or moment may be best thought of as a conduit or gateway through which multiple rhythms are flowing at once, many of which will be contradictory or dissonant."

The interplay of different rhythms was analysed using (Lefebvre 2004)'s rhythmanalysis matrix. In particular, the study examined the rhythm interactions of eurhythmia (when rhythms reinforce each other) and arrhythmia (when rhythms are in discord with each other). While the II's trajectory was evident in the case of eurhythmia, it was not apparent when there was temporal discord. Venters et al.

(2014) observed (but did not theorise) that certain chordal tensions dominate others. Analysing rhythm interactions using rhythmanalysis, however, did not help address this question, leading the researcher to shift attention to the role of the intermediary for answers.

RQ3 Why does one rhythm dominate and influence the II's trajectory when there is discord between rhythms?

The findings identified the critical role of the intermediary in guiding the II's trajectory as it intervenes in the influence of temporal rhythms, reinforcing some to the detriment of others. The findings showed that intermediaries use three main intervention techniques: composing, harmonising and riffing to help some rhythms dominate over others.

Composing future rhythms that validate the technical and commercial viability of an II motivates stakeholders to collaborate and counter the inertia of the installed base. CSCW researchers have noted that "people organise their work with an orientation to the future" (Reddy et al. 2006). People's interpretations of their context are termed "formative context" (Ciborra & Lanzara 1994) and comprise the organisational and cognitive dimension that influence the users' current and future understanding of the II (Augustsson et al. 2010). By modeling temporal rhythms that signal accelerating innovation rhythms for new technologies, or consumer biographical rhythms that will demand new services, the intermediary inspired stakeholders to entrain their innovation cycles to these rhythms.

The intermediary's future rhythms become a shared "temporal map" (Zerubavel 1985) for stakeholders who adjust the pace or cycle of their activities to synchronise with these imagined futures. In doing so, the intermediary effectively creates pacemakers, similar to those created by TV shows, for example. People coordinate their schedules around television shows thereby enacting a collective rhythm that is entrained to the rhythms of TV shows (Irani et al. 2010).

Harmonising occurs when the intermediary reinforces certain temporal rhythms by aligning its work in support of them. The alignment of work to different rhythms is "an important and under-recognised element within broader CSCW processes" (Steinhardt & Jackson 2014) and this study's findings demonstrate how strategic alignment influences the II's trajectory. It adds to the literature that analyses how practices and technologies are used to align work with temporal rhythms. For example, Hasvold & Scholl (2011) observed that nurses adjusted their activities to align with the informal work rhythms of their colleagues so that they could complete their interdependent tasks. Studies have also shown how technologies such as version control systems and different types of visualisations (Begole et al. 2002) have been used to help workers align and improve collaboration. In the context of the case study, Intermediary reinforced the phenomenal rhythms of German funding cycles by following the guidelines for stakeholder inclusion, and in doing so, tilted the II's cultivation in favour of the interests of larger companies rather than start-ups.

Riffing occurs when the intermediary provides a base rhythm or minimal structure on which different stakeholders can improvise to enable data integration. In the organisational management literature, minimal structures serve as "a template upon which improvisation can take place" (Kamoche & Cunha 2001) and have been shown to drive successful product innovation (Brown & Eisenhardt 1997). In information systems development, studies have demonstrated how minimal structures form "the support, freedom and safety net for people to explore through trial-and-error, improvise and innovate" leading to "collective agility" (Zheng et al. 2011). Minimal structures come in two forms: social structures and technical structures (Kamoche & Cunha 2001). In the case study, through various social actions (such as partnering with outsourcing vendors), or technical structures (such as creating technical strategies for apps to transfer data), Intermediary provided the minimal structure for other stakeholders to improvise and grow the II.

8.2.2 The Generalisation Process

“All research takes place in the form of single studies. The significance of any given study depends not only on the study's findings but also on the broader implications of the findings - the extent to which the findings can be “generalised” to other studies and other situations.” (Yin 2003).

The researcher chose BeMobility as the case study because it was a revelatory case (Yin 2010). The project was the first Mobility-as-a-Service pilot conducted in the world and provided “an opportunity to observe and analyse a phenomenon previously inaccessible to social science inquiry” (Yin 2003). This chapter uses Yin (2003)’s guidelines to extract the themes from the single case study analysis that can apply to a broader domain. As discussed in Chapter 4, case studies are generalisable to theoretical propositions. In this sense, they are different from quantitative studies that sample from a larger population and are generalised to that universe. This section’s goal is to explain how to “expand and generalise theories (analytic generalisation)” (Yin 2010).

Analytic generalisations are generated using Yin’s two-step process: first, the analysis is reviewed to see its bearing on the theoretical framework used in the study; and second, an argument is made on how the findings of the analysis can apply beyond the case study to analogous situations (Yin 2010). As shown in the last section, the theoretical framework can explain the findings and analysis from BeMobility to show how temporal rhythms influence II cultivation. Based on the strategy of abduction, the researcher extended the original theoretical framework with concepts related to rhythms, such as entrainment, that helped to explain how the intermediary mediated the influence of temporal rhythms through various interventions.

Researchers can make several types of generalisations from case studies (Walsham 1995), and this study focuses on generalisations related to the development of concepts, such as the concept of informate by Zuboff (1988) and knowledge communities by Walsham (2004). This study discovered and categorised rhythmic influences (diluting, stalling, blocking and combining, extending, replacing) and intermediary interventions (harmonising, composing, riffing), and used them to develop the concepts of facilitated II cultivation and the rhythmic intermediary.

This study uses recommended practices by Yin (2010) to ensure the analytical generalisability of these concepts. The reliability of case study research is based on its level of procedural transparency and the rigour of its research design (Klein & Myers 1999; Yin 2003). This means that researchers must be explicit about epistemological and analytical assumptions, and vigilant in data collection, analysis and reporting.

First, care was taken to make the interpretive and processual approach clear in the research methodology chapter, including the analytical approach of combining thematic analysis (Boyatzis 1998) with temporal bracketing and narrative strategies (Langley 1999). In the analysis, reference was made at critical junctures to demonstrate how the analytical assumptions were used to examine and generate themes from the data.

Second, principles of rigorous data collection were followed (Yin 2003) including the use of multiple data sources for data triangulation (Patton, 1987), creation of a case study database with all evidence stored and reported systematically and meticulously, extensive use of vignettes and thick descriptions (Geertz 1973), and maintenance of a chain of evidence (explicit links between research questions, data and conclusions throughout the chapters were described).

Another important criteria for judging the generalizability of a case study is to compare its findings with other case studies to check that the knowledge generated is not "context-dependent knowledge" (Flyvbjerg 2006). One way to meet this concern is to review other case studies to validate findings (Henfridsson & Bygstad 2013). The phenomenon of Mobility-as-a-Service is still relatively new, which means the researcher was unable to find similar case studies examining II cultivation in the literature. However, new strategic niches, such as those on integrated mobility in Singapore and Dubai, have been set up. Private companies such as China's taxi giant Didi, Helsinki's MaaS Global and Alphabet's Sidewalk Labs are also setting up similar initiatives. Any of these projects would provide an opportunity to further validate the initial concepts of facilitated II cultivation and the rhythmic intermediary developed in this study.

8.3 Using Rhythm in II Research

One of the main contributions of this study is highlighting the importance of temporal rhythms in the study of information infrastructures (IIs). Rhythms are important in collaborative work as they "punctuate the continuous flow of activities with periodically recurring events and thereby offer ways of condensing myriad individual events into patterns exhibiting at least some regularity and predictability" (Nilsson & Hertzum 2005). While CSCW researchers have examined the influence of temporal rhythms on collaboration processes (Reddy et al. 2006; Jackson et al. 2011; Chen et al. 2016), scholars have not extended the analysis to the sociomaterial cultivation of IIs.

The lack of attention to rhythms in II research is not surprising since the examination of digital infrastructure evolution is still nascent with researchers urging a more comprehensive understanding (Henfridsson & Bygstad 2013). Even though the relevance of temporality to understanding II cultivation has been surfaced by researchers (Ribes & Finholt 2009; Karasti et al. 2010), they have focused on linear time and the issue of temporal scales. According to Aanestad et al. (2014), one of the "pervasive challenges of infrastructuring include … dealing with multiple temporal scales simultaneously, such as project time and infrastructure time." This study proposes that one way to understand how temporal scales are linked in the biography of an II (Pollock & Williams 2010) is to examine it through the lens of temporal rhythms.

This study perceives rhythm as temporally structuring, both as driving events and the results of events, which means that temporal rhythms and events are mutually constitutive. Temporal structuring is evident in the way past and future rhythms influence the mangle of practice during II cultivation, and how an organisation alters its practices to change its own biographical rhythms (such as was the case with Intermediary in BeMobility). The use of rhythmic structures enriches the concept of temporal structuring related to linear time (Orlikowski & Yates 2002) and complements research by Venters et al. (2014) showing that rhythmic time (like linear time) is also constitutively entangled with II coordination.

Chapter 2 illustrated how researchers still lack a full understanding of time that is interpretive and experienced (Shen et al. 2014). While the CSCW literature has studied temporal rhythms, it has often focused on how rhythms influence collaboration (Reddy and Dourish 2002; Kusunoki & Sarcevic 2015). This study adds to the literature on the examination of rhythms as an analytical lens for understanding II cultivation and trajectories.

8.4 The Concept of Facilitated II Cultivation

Installed base cultivation is an incremental process that transitions the installed base to new versions of itself over time, and governing this transition process is critical (Hanseth & Aanestad 2003). This study proposes the preliminary concept of facilitated II cultivation as a strategic intervention strategy, which adds to the literature exploring the tension between planned and emergent infrastructure work (Ribes & Finholt 2009).

The literature review demonstrated that "managerial urges to curb complexity, mitigate risks, and facilitate interoperability across II parts are in constant tension with the need for local flexibility to accommodate situated practices" (Sanner et al. 2014). This thesis adds to efforts to fill this gap in the literature by developing the concept of facilitated II cultivation in which an intermediary can mediate the influences of temporal rhythms to direct the II's trajectory. The goal of facilitated II cultivation is to reinforce temporal rhythms that will increase interoperability and integration in the present to grow the II.

The framework (illustrated in the diagram below) shows how the intermediary can intervene in temporal rhythms. Past and future rhythms exert influence by disciplining agencies or by modeling the future for them. The intermediary mediates the influence of these rhythms through the three interventions of harmonising (by which it reinforces rhythms), riffing (by which it creates a minimal structure for improvisation) and composing (by which it creates new rhythms for entrainment).

The possibility of intervening in II cultivation adds to the literature on interventions and on-going practical work of expanding the installed base. Strategies include explicit design principles for complexity (Hanseth & Lyytinen 2010), continuing design (Karasti et al. 2010), using standards (Henningsson & Hanseth 2011; Edwards et al. 2007), designing for usefulness to acquire new users (Grisot et al. 2014; Skorve & Aanestad 2010), rafting (Sanner et al. 2014) and blurring the lines between designers and users – also called infrastructuring (Pipek & Wulf 2009). This study's findings support these views that adopting incremental interventions can guide II cultivation. It runs counter to the view that bottom-up bootstrapping may be the best way forward in an inherently unstable and dynamic environment like IIs (Hanseth and Lyytinen 2010). This study subscribes to the belief that "rather than design in the conventional sense, dealing with the evolution of infrastructures requires strategies to intervene and influence ongoing processes" (Aanestad et al. 2017).

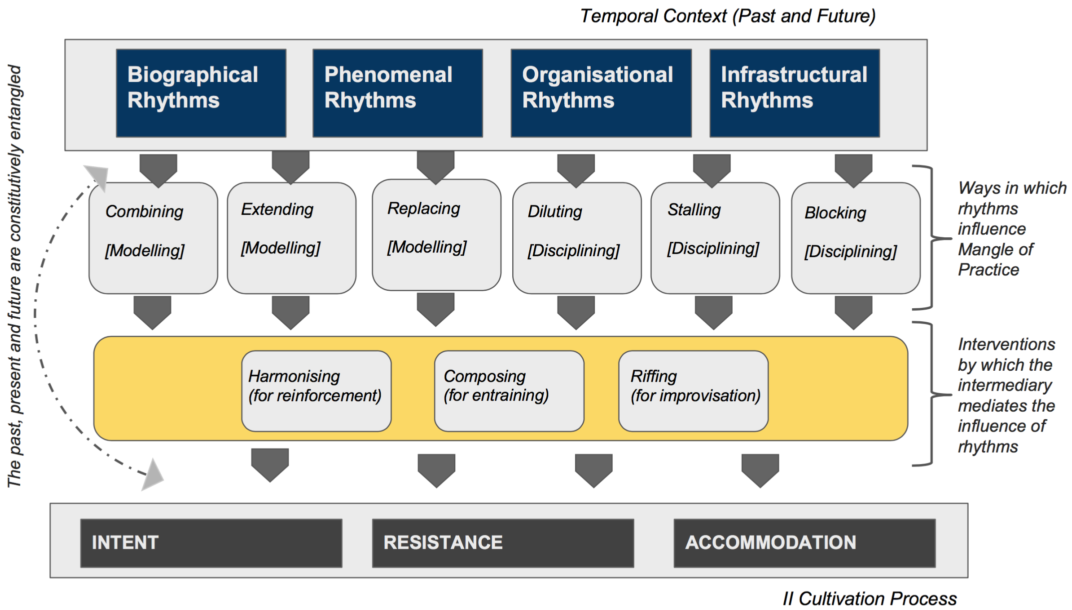

Figure 9: The concept of facilitated II cultivation

The concept of facilitated II cultivation also provides a framework to link short-term implementation with the long-term view on II cultivation. Authors such as Ribes & Finholt (2009) have pointed out that infrastructure time thinking (Karasti et al. 2010) must combine short-term design concerns with long-term maintenance concerns. While the short-term constitutes the length of a strategic niche, the long-term stretches both in the past and in the future beyond the limits of the project. The long-term is open-ended including infrastructure path dependency, design, maintenance and evolution (Brand, 2008; Ribes and Finholt, 2009; Karasti et al., 2010). The theory of facilitated II coordination contributes to the literature on longitudinal perspectives of II cultivation (Monteiro et al. 2012) by linking II cultivation during the project with its longer past-present-future temporal background.

The framework was developed by generalising the findings of the case study and identifying the "shared patterns, processes and emergent lessons" (Jackson et al. 2007) of the process of II cultivation. However, the revelation of the intermediary's role in mediating the influence of temporal rhythms was an interesting find, and ultimately critical to understanding why some temporal rhythms dominate and direct the II's trajectory.

II cultivation is complicated because it involves "the opposing logics around centralised and distributed control" (Tilson et al. 2010a). This study recommends strategic interventions by the intermediary to negotiate this tension. It responds to the call that ICT solutions like IIs are so complex that we need "radically new approaches" to developing and managing them (Hanseth 2014) and agrees that installed base "interventions are attempted in an active interplay with it" (Vassilakopoulou & Marmaras 2017).

Relevance to Current Trends

The research on temporality in IIs has significant implications for researchers trying to understand how large technology companies influence IIs by harnessing rhythms.

For example, Apple has held annual developer conferences (known as Worldwide Developers Conference) since 1983[24], a landmark event for any developer or company developing products on Apple's iOS operating platform. These developers *entrain* their product innovation rhythms to Apple's regular releases and especially to the mega-releases of new Apple products announced at the main conference. This approach has since been followed by other companies as well including Facebook, which holds the annual FX conference, and Google, that annually holds its I/O

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[24] Wikipedia: https://en.wikipedia.org/wiki/Apple_Worldwide_Developers_Conference

conference. At Facebook's announcement of its messenger platform in 2016, hundreds of thousands of developers began developing chatbots for Facebook. These conferences act as *pacemakers* for stakeholders developing an eco-system of products around these platforms. While platforms have certain restrictions like design and audit, they still exhibit many of the features of IIs (excluding unbounded openness).

Large technology companies have also started using open-source libraries to provide *riffs* for developers to *improvise* and develop new ideas. In its attempt to become a market leader in artificial intelligence (AI) and become an "AI-first" company, as stated by its CEO Sunder Panchai, Google released TensorFlow in 2015, an open-source software library for machine intelligence tasks such as training neural networks. Along with the libraries themselves, the company also releases training wikis and tutorials, all of which have enabled Google to set up a base rhythm of AI skills acquisition and development time, on which other companies and developers can improvise as they build products and services.

By composing new rhythms that developers can entrain to or riffs as minimal structures to improvise upon, large technology companies intervene and influence the direction of products built in the market, and increase their impact significantly in the process. The concept of facilitated II cultivation can help researchers understand these trends in the market.

8.5 The Rhythmic Intermediary

Developing an e-mobility II is a long-term transition goal that requires a wide range of stakeholders to collaborate, each one of which may "pursue different interests, e.g. opposing such a transition or advocating a different direction" (Meadowcroft 2011). The study has demonstrated that this is particularly true in a strategic niche where stakeholders with a history of mistrust come together, like in the case of various players in the transportation sector. Governments usually allocate an intermediary in such cases whose responsibility includes motivating stakeholders to align and contribute to the II.

Intermediaries have been recognised in the strategic niche literature for their transformative role in facilitating innovation processes (Kivimaa 2014; Hargreaves et al. 2013; Howells 2006). Referred to by several monikers including "innovation intermediaries", "go-between" agents, and "systemic intermediaries" (Medd & Marvin 2006; Moss et al. 2009; Howells 2006; van Lente et al. 2003), they have been critically examined as players in the innovation eco-system (Clarysse et al. 2014). However, their role has been limited in the literature to an examination of whether they effectively brokered relations between the developers and users of innovation (Kivimaa & Martiskainen 2016; Howells 2006; Stewart & Hyysalo 2008). Broadly, the types of roles identified for intermediaries fall in the three categories of facilitating, configuring and brokering (Stewart & Hyysalo 2008). However, researchers realise that the intermediary's role could be more nuanced and extensive, and the full extent of their influence is "still an under-researched area" (Bush et al. 2017).

Scholars have called for more research on intermediaries and facilitation work in general, saying that team members in positions of influence could use their knowledge of temporal rhythms to manage work better. For example, Ancona & Chong (1999) believe understanding temporal patterns could potentially make boundary spanners or intermediaries more effective, Zellmer-Bruhn et al. (2004) asked managers to decipher key rhythms as they "can both reinforce desired routines and change problematic ones" to meet their goals and Venters et al. (2014) posited that "for practitioners, then, an intimate knowledge of the past, and imagination of the future, may be central to their success in innovation."

One of the contributions of this study is to surface some ways in which the intermediary can "manage and orchestrate the multiple rhythms transacting any form of distributed collective practice" (Jackson et al. 2011) and as a result exercise some control over II cultivation. The ability to intervene and influence infrastructure trajectories has been highlighted by studies that show the importance of being able to control parts of the installed base (Nielsen 2006; Elaluf-Calderdood et al. 2011).

An intermediary that harnesses temporal rhythms by using intervention strategies such as harmonising, composing and riffing represents a new type of intermediary that this study calls a rhythmic intermediary. Rhythmic intermediaries mediate the influence of temporal rhythms on II cultivation by either reinforcing them (harmonising), modeling new rhythms for the future (composing), or creating a base rhythm for stakeholders to use as a basis for improvisation (riffing). Interestingly, rhythmic intermediaries can also intervene in their own biographical rhythms by evolving their technical skills and expertise, which enables them to influence the II's cultivation further.

Rhythmic intermediaries are needed since temporal rhythms interact in unexpected and discordant ways, and stakeholders experience rhythms in different ways. Aligning them by modeling the future, for example, results in "the convergence of actors' expectations towards a common view [which] is crucial for the emergence of an innovation niche" (Lopolito et al. 2011). Having intermediaries harness rhythms is similar to an approach by Nielsen & Aanestad (2006) who prescribe thoughtfully employing control devolution as a design strategy for IIs. By selectively relinquishing control, management will find that there will be fewer unexpected side effects, even as creativity and innovation are encouraged. This study agrees with two of the points raised by Nielsen & Aanestad (2006): first, that control in II development is "not an 'all-or-nothing' proposition" and that some kind of control is possible in IIs; and second, that by finding the right balance between empowering the periphery and keeping the reins in the centre, strategic alignment is more possible.

Many intermediaries may not be rhythmic in their character. However, one of the recommendations of this study is to encourage all intermediaries to become temporally aware. By narrowing their understanding of how time impacts II cultivation to only clock time, stakeholders may be “ignoring or undermining the opportunities for exploration, learning, innovation, and improvisation which are more likely to accompany a broader range of temporal structuring” (Orlikowski & Yates 2002).

The concept of facilitate II cultivation does not put a value judgement on whether this influence ultimately benefits the longevity of the II. In the immediate term, it moves the II forward in one direction. However, as the analysis has shown, in some cases, the intermediary’s intervention could lead to more flexibility and in others, it could lead to technology lock-ins. For example, the intermediary may support a temporal rhythm that dilutes, blocks or stalls II cultivation. It may reinforce such a rhythm inadvertently, or it may do it consciously as a strategy to increase its influence and power in the project. While this study does not examine the intent of the intermediary, this is an area of future research discussed in the Conclusion chapter.

Relevance to Current Trends

In the last decade, there has been growing interest in the reconfiguration of urban infrastructure systems (Coutard 1999; Graham & Marvin 2001; Guy et al. 2001) particularly around infrastructure experiments called strategic niches. The results of initial mobility experiments were disappointing with the inability of the niche to translate into the regime after the experiment ceased, with limited range and high price being two leading causes of low demand by consumers (Dijk 2011). However, since the last decade, improvements in battery technology, charging infrastructure, the proliferation of car sharing fleet operators and alternative energy sources like solar and wind, have reignited the interest in and potential for success of sustainable mobility infrastructures (Dijk et al. 2012). Policymakers now recognise that the development of “smart” mobility requires supporting ICT products in cars and infrastructure, which comprise an integral part of the pathway to sustainable mobility. The relevance of intermediaries to help align stakeholders to make such strategic niches a success by developing ICT is greater than ever for reaching sustainable mobility goals.

8.6 Temporal Rhythms in Sociomaterial Studies

An interesting side aspect of this thesis lies in the way it conceptualises temporality in sociomateriality and enriches it with the concept of rhythm. As discussed in Chapter 3, this study uses a relational ontology seeking to privilege neither technology nor humans (Orlikowski 2010).This study defines sociomateriality as a genre where "humans/organisations and technology are assumed to exist only through their *temporally emergent* constitutive entanglement" (Orlikowski & Scott 2008) (emphasis added). Sociomaterial practice is the space where humans and material are intertwined (Orlikowski 2010) and "human and material agency are reciprocally and emergently intertwined in this struggle. Their contours emerge in the *temporality of practice*, and are definitional of and sustain one another" (Pickering 1995) (emphasis added).

Yet scholars are still grappling to fully understand this intertwinement (Leonardi 2012). Studies on the temporal context of this entanglement are also at a nascent stage. Leonardi (2013) and Mutch (2013) criticise the ability of the relational approach or agential realism as providing the ability to understand how practices are sustained and changed over time. Leonardi (2013) recommends using critical realism as the ontological basis of sociomaterality and separating social and material to an extent to untangle the mechanisms that lead from intentionality to practice over time. He calls this approach imbrication and takes materiality as fixed at certain stages of analysis. Scott & Orlikowski (2013) respond to Mutch's criticism that the inseparability of social and material is "precisely" the point of sociomaterialty.

While this study does not address this debate directly, it provides a way to understand

II cultivation by combining the relational view of IIs with the processual approach. It shows how sociomaterial practices are influenced by temporal rhythms across the history and anticipated future of an II by extending the work of Venters et al. (2014) to understand the influence of temporality on sociomaterial practice.

Another issue called related to the study of temporality is that "the time span implied in sociomateriality generalisations is often unclear" (Alter 2012). Alter (2012) divides time-spans into three main categories, minutes-to-hours, days-to-weeks, and months-to-years, and recommends the "work system life cycle" model in understanding sociomaterial phenomenon over time. This study also contributes to the understanding of how sociomaterial practice in the short-term II cultivation in the present is linked to the long-term influences on this practice from the past and the future. In doing so, it addresses the question by Alter (2012) on whether sociomaterial phenomena "vanish an instant after they occur, or do they persist over years" with evidence that they persist over the long-term. While this study does not delve into this question deeply from a theoretical perspective, it offers initial insights that researchers can use while exploring this debate.

Finally, this study also makes a small contribution to the nascent research on understanding the role of materiality in temporal structuring (Steinhardt & Jackson 2014). By demonstrating the influence of rhythms on sociomaterial practice, it shows how the cultivation of the II in the present is mangled with the experience of past and future infrastructural rhythms. The findings show that the experiences of how materiality had been developed, such as lack of APIs and databases with latency issues, and how stakeholders imagine it developed in the future, with accelerating innovation cycles and entirely new forms like micro smart grids, significantly influence human and material agency in the present.

This section outlines how this study responds to the call to develop sociomaterial theories that examine what "practitioners routinely did, with others and tools, for what purposes" (Sandberg & Tsoukas 2011), and provides preliminary insights to researchers looking to examine the consequences of rhythmic temporal structuring of sociomateriality for organizational processes.

8.7 Summary

This chapter demonstrated how this study adds to the research on sustainable change in infrastructure research (Ciborra 2000b; Henfridsson & Bygstad 2013; Tilson et al. 2010b). II cultivation is considered an emergent and open-ended process of sociotechnical negotiations (Hanseth & Aanestad 2003; Hanseth & Lyytinen 2010). The analysis investigated the intersection between rhythm and agency and abstracted how temporal rhythms influenced II cultivation and demonstrated how the intermediary may intervene to mediate this influence.

This chapter related the findings of the sociomaterial analysis in Chapters 6 and 7 to the literature on temporality and infrastructure (Ribes & Lee 2010). While Venters et al. (2014)'s theory contributed to the literature by examining the "dynamic interplay of generative material and social agencies, oriented to multiple dimensions of time," this study further theorised temporality in the Temporal Trichordal Approach (ibid) by including the notion of socially constructed rhythms to this investigation.

This thesis builds on recent interest in the development of IIs (Yoo et al. 2010) and the quest to understand the evolution of complex systems that are difficult to design in a top-down manner (Kallinikos 2005). The II literature views the development of IIs as a continual effort where technology is "cultivated" rather than built from scratch (Ciborra & Hanseth 1998; Freeman 2007; Nardi & Kallinikos 2007; Monteiro & Hanseth 1995; Edwards et al. 2009). The analysis demonstrated that II evolution is not the result of top-down technical management of resources (Chua & Yeow 2010; Crowston 1997), but is the result of emergent cultivation driven by the interaction of human and material agencies. At any given time, multiple divergent temporal rhythms act upon these agencies, and the intermediary plays an active role in supporting or creating dominant rhythms. It joins the nascent work by researchers to develop "analytical tools for capturing how technologies are shaped across multiple spaces and timeframes" (Monteiro et al. 2012).

The increasing use of strategic niches by cities to experiment with sustainable infrastructures requires a critical review of the multi-stakeholder collaboration needed to cultivate such IIs. This thesis contributes to a deeper understanding of this process by developing the new concept of a rhythmic intermediary that is capable of strategically directing the trajectory of the emerging II. The rhythmic intermediary stands in contrast with the typical views of intermediaries in the literature, which limits their role to policy, business and social relations brokering and does not investigate their involvement in ICT design and development. The study recommends that all intermediaries should be encouraged to become temporally aware since their unique position in the strategic niche empowers them to harness rhythms. However, while the intermediary's influence is strong and undeniable, the value of its contribution to the longevity of the II is questionable at times.

The next chapter provides, in conclusion, an overview of the study's theoretical and methodological contributions to the literature, and the practical contributions to the policies related to strategic niches. It also highlights areas for future research in the domain of II cultivation.

9. Conclusion

9.1. Introduction

This chapter concludes the thesis and presents final remarks on the PhD project. It summarises the main parts of the PhD project, outlines its key insights and implications, and provides areas of future research.

The thesis overall addresses the issue of time and structure within the emergence and evolution of large-scale multi-organisational information infrastructures (II) for urban transportation. It contributes to an understanding of time and rhythm within infrastructure studies. It adds to the literature that contrasts emergent infrastructure development with plan based "construction" approaches (Aanestad & Jensen 2011; Ciborra 2000) and extends understanding of II evolution building upon notions of the "installed base" and its "path-dependency" (Porra 1999; Star & Ruhleder 1996).

The purpose of this thesis was to examine the temporal dimension of II cultivation, recognising both long-term evolution (Edwards et al. 2007; Karasti et al. 2010) and the short-term dynamic practices based on different stakeholder intentions. Aanestad & Jensen (2011) argue that in designing infrastructures, we need to "deal with the challenges of organising, mobilising and coordinating multiple independent stakeholders." This study addresses this problem by focusing on the impact of time on such activity.

Theoretically, the study focused on time within sociomaterial practice and drew upon recent work on the temporality of infrastructures (Venters et al. 2014). Venters et al. (2014)'s theory of the "Trichordal Temporal Approach to Digital Coordination" was extended to include concepts of rhythm and categories of collaborative rhythms (Jackson et al. 2011; Lefebvre 2004), and to incorporate a linear rhythmic temporality of past, present, and future, within the unfolding dynamics of multi-organisational practice.

This theoretical extension was used to examine a strategic niche experiment in Berlin that aimed to evolve urban mobility based on integrated chains of shared electric vehicles and public transport. The study reviewed the social, material and organisational rhythms which influence the practice of infrastructure development. The transition to reliance on an e-mobility II within transportation infrastructure required the coordination and integration of complex information systems that spanned multiple industries and organisations, such as renewable energy, rail and car sharing. The study's approach was informed by practice theory but framed practice in terms of sociomaterial agency drawing upon Pickering (1993; 1995).

The study sought to examine the rhythms of the sociomaterial structures within which they occur and how they temporally condition material and human agencies. These sociomaterial structures represent collections which include stakeholder institutions. In this way, the study extends the analysis beyond individual actions to encompass collectives of human and material agency.

This study also picks up on the debate to critically explore the notion of design in IIs. On the one hand, scholars have argued in the past that a global infrastructure requires reduction of complexity and risk, and more control (Weill & Broadbent 1998). On the other hand, scholars have more recently pointed out that users adapt technologies to their own use and situation, making efforts for a standard design irrelevant (Suchman 2002; Ciborra 2000b). These extremes are challenged by Rolland & Monteiro (2002) who state that the realistic answer lies in maintaining balance: the local needs of consumers must be balanced with the global requirements for standards and uniformity, even as local users resist protocols imposed from the top. It attempts to answer part of the question asked by Monteiro et al. (2012): “What, then, are key qualities of the process of design—initiation, *cultivation* and growth—of IIs?" (emphasis added).

This chapter concludes the study by discussing its contributions to the literature, practical implications for policy-making and possible areas of future research. It is structured as follows:

Section 9.2 outlines the two main theoretical contributions made by the study. First, the study contributes to the II literature by developing the concept of facilitated II cultivation that provides insight into how intermediaries may intervene in II cultivation by mediating the influence of temporal rhythms. Second, the study contributes to the strategic niche management (SNM) literature by developing the concept of the rhythmic intermediary that describes a new kind of intermediary who is capable of harnessing rhythms to direct the trajectory of II cultivation.

Section 9.3 describes the methodological contribution made by this study. The enrichment of the processual approach (Langley 1999) to examine rhythmic temporality in the study of II cultivation represents a new method to organise processes. Given the loosely defined guidelines provided by processual researchers, this study used a combination of thematic analysis, and the strategies of narrative and temporal bracketing to investigate rhythms. It also added the notion of "imagined futures" that are rhythms to the temporal bracketing strategy. The notion of imagined futures enriched the method to not only examine the influence of temporality moving forward sequentially in time but also backwards from the future to the present.

Section 9.4 provides three practical recommendations made by this study that could help policymakers responsible for developing IIs in strategic niches. First, the findings of this research suggest that the intermediary's role should be expanded to appreciate its influence in directing II cultivation beyond the hitherto limited role attributed to it. Second, the study's analysis of the importance of future rhythms in motivating stakeholders leads to a recommendation for policymakers to invest in living labs that showcase technologies and user research that imagines the needs of pioneer customers. Third, the analysis surfaced the significant role of temporal rhythms in II cultivation, which implies that stakeholders should have temporal awareness when making decisions to anticipate the inertia they will encounter. Policymakers can publish relevant articles and hold workshops to increase temporal awareness amongst strategic niche stakeholders.

Section 9.5 provides three areas of future research that emerge from this study. Researchers should consider delving deeper into the role of the intermediary whose significance was highlighted by this study. Further aspects of the intermediary's role to examine include the extent of its power and its motivations and intent when intervening in temporal rhythms. Rhythms themselves provide a second area of potential research given that the study selected only a subset of possible rhythms to examine in this research. The area of Mobility-as-a-Service (MaaS) also presents a nascent research domain to study further, including by using other theoretical frameworks such as digital product innovation.

Section 9.6 outlines the limitations to this study. Some aspects of the case study used for the explanatory framework are tied closely to the German government's method of conducting strategic niches, and it would be useful to validate the findings with case studies from other countries as well. Also, the multi-stakeholder and distributed nature of the strategic niche made it challenging to spend significant time with all the participants, which means that some might have had more influence on the study than others.

Section 9.7 provides concluding remarks on the study including commentary on the mixed success of the *energiewende* movement in Germany and global trends in strategic niche development for Mobility-as-a-Service (MaaS) by governments and multinationals.

9.2. Theoretical Implications

Recent research in information systems has confirmed that ICT solutions like IIs are so complex that we need “radically new approaches to the way we develop and manage them” (Hanseth 2014). The examination of digital infrastructure evolution is still nascent in the literature and “little, if any, research has been geared toward developing a comprehensive understanding of the range and contingencies of causal structures in [digital infrastructure] evolution” (Henfridsson & Bygstad 2013). This study contributes to the literature on IIs and strategic niche management as described below.

Temporality in Infrastructure Research

The coordination of unpredictable, complex systems like IIs is garnering interest amongst IS scholars but research on coordination in digital infrastructures (Venters & Whitley. 2012; Venters et al. 2014) is still in its early stages. This thesis adds to the literature on II cultivation by focusing on time within sociomaterial practice and builds upon work on the temporality of infrastructures (Venters et al. 2014). Its theoretical contribution lies in extending the structure of time in the Trichordal Temporal Approach (Venters et al. 2014) to include socially constructed rhythms (Jackson et al. 2011). By examining time as the linear rhythmic temporality of past, present, and future, within the unfolding dynamics of practice, the study examines how orientations towards the past and future by human and material agencies impacted the II’s cultivation in the present. The findings demonstrated that past rhythms exert the disciplining influences of diluting, stalling and blocking, whereas future rhythms exert the modeling influences of combining, extending and replacing on II cultivation. The intermediary is shown capable of mediating these influences using the interventions of harmonising, composing and riffing. While the intermediary intended to enable II cultivation, the unintended consequences of its actions sometimes include dragging back the II in the long run. Consideration of temporal rhythms provides an opportunity for researchers to construct new perspectives and explanations around II cultivation. This study presents initial research in this area with further study recommended (as outlined in Section 9.5) to fully examine the complexities of the influence of temporal rhythms on II development.

ICT Development in Sustainable Mobility Experiments and Strategic Niches

The strategic niche management (SNM) literature has limited investigation into the role of digital technologies in radical innovation and instead has paid attention to organisational processes around strategic niche development. Researchers have focused on user behaviour around systems (Mokhtarian 2002) or shared learning systems (Elzen et al. 1996) rather than an examination of ICT implementation. The black boxing of ICT implementation in studies related to sustainable mobility systems prompted Brendel et al. (2016) to urge scholars to work on research that would "explore the effects of specific IS solutions (prototypes of IS)." While researchers examined the potential for innovative models like car-sharing to promote sustainability (Firnkorn & Müller 2012; Shaheen & Cohen 2013), they focused more on aspects such as policy and algorithmic approaches (Alessandrini et al. 2015; Wagner et al. 2014; Wagner et al. 2015) rather than II development. This study contributes to the opening of the black box of ICT development in the SNM literature on sustainable transportation by showing how e-mobility IIs are cultivated in niches by integrating ICT systems, people, and practices across multiple stakeholders.

Another area where this study contributes to the SNM literature is in examining the role of intermediaries. The SNM literature has acknowledged the critical place of intermediaries in coordinating innovation activities in the strategic niche (Howells 2006; Boon et al. 2011). However, even though van Lente et al. (2003) argued that intermediaries are necessary for complex changes such as sustainability transitions, the literature has not studied their in role in ICT development in detail (Kivimaa &

Martiskainen 2016). The SNM literature on intermediaries views them as arbitrators between innovators and users (Howells 2006; Stewart & Hyysalo 2008). Just like information systems are black boxes in the SNM literature, so is a nuanced understanding of the role of intermediaries in II development in strategic niches. This study adds to the sustainable transitions literature (Geels 2004; Geels & Schot 2007; Kemp et al. 1998) by describing the important role of intermediaries in innovation for urban IIs.

9.3 Methodological Implications

Researchers must study IIs as a process “in the making” (Star and Bowker 2002). The processual approach provides an interpretative methodology for studying sequences of events and their outcomes and investigating the influence of temporal context. As discussed in the research methodology chapter, the guidelines for using strategies such as temporal bracketing and narrative approach are deliberately kept vague by Langley (1999). This ambiguity is particularly in the case for rhythms, which are rarely analysed using process theory (with a few exceptions like the quantitative approach by Klarner & Raisch (2013) and qualitative analysis by Warner (1988)). This study contributes insights into how to combine thematic analysis with process theory to investigate the influence of temporal rhythms on II cultivation.

The researcher generated codes and themes from the narrative that unfolded over three different temporal brackets (past, present and future). The theory analysed the influence of temporal rhythms using both a data-driven and theory-driven approach (Langley 1999). It analysed the process using the theoretical framework developed in Chapter 3, and theorised from the process observed (and consequently extended the theory with concepts related to rhythms). The study used principals of thematic analysis (Boyatzis 1998) to analyse the findings, and abstract the influence of temporal rhythms based on an iterative analysis strategy. This approach offers researchers insights into how to investigate rhythms when analysing processes.

The study also contributes the idea of "imagined futures" (Venters et al. 2014) to the temporal bracketing method, which means that events are not analysed sequentially and chronologically but also backwards from the future through the lens of temporal rhythms. The notion of imagined futures has implications for using the processual approach to study IIs and adds to the work in organisational management literature in the areas of foresight planning to anticipate the impact of the future trends on the present (Tsoukas & Shepherd 2004). The ability to capture the influence of rhythms on dynamic II evolution contributes to the processual approach for similar research.

9.4 Practical Implications

The findings of this study have implications for policymakers engaged in building large-scale Mobility-as-a-Service (MaaS) infrastructures. Three recommendations (described below) may serve policymakers to manage and successfully prototype e-mobility IIs, which derive from an understanding of the influence of rhythms on II cultivation.

9.4.1 Choosing and Governing a Capable Intermediary

As this study has shown, the strategic niche intermediary is capable of far more than the literature's limited perception of its role. The intermediary is capable of recognising and leveraging temporal rhythms to further II cultivation. From composing future infrastructure rhythms with an innovation lab to countering the disciplinary agency experienced by some stakeholders by riffing, the case study demonstrated that Intermediary was instrumental in driving integration in more complex ways than just involved in coordinating meetings and keeping track of budgets. This insight supports the work of scholars such as Medd & Marvin (2007) who emphasise that perceiving intermediaries as passive coordinators is incorrect and that, in fact, intermediaries proactively shape stakeholder relationships and project goals. By exposing the inner workings of II cultivation, this study makes a strong case for policymakers to envision a more expanded role for the intermediary in urban II developments.

Given the technical nature of developing urban IIs, the analysis revealed that the intermediary becomes quite involved in technical decisions and it is necessary to choose intermediaries that have the right technical skills as well. These skills can vary from knowledge of digital services architecture and integration to big data analysis and artificial intelligence. At a minimum, the intermediary should be provided training in these foundational technologies of urban IIs if they are to lead the coordination of the work.

The findings also provide a cautionary tale of the influence of intermediaries. The analysis demonstrated that intermediaries sometimes make decisions for short-term success at the cost of the longevity of the II, for example, by reinforcing the disciplinary agency of past rhythms. When an intermediary's influence leads to poor decisions, sometimes by design, it is detrimental to the project and points to the necessity of governing the intermediary's work.

9.4.2 Leveraging the Power of the Imagined Future

This study highlights the need to demonstrate the technical feasibility and commercial viability of a multi-stakeholder II to its participants. This is particularly true of radical innovation like Mobility-as-a-Service (MaaS), which does not have any precedence in the market. As Christensen (1997) highlights in his book "The Innovator's Dilemma", established companies tend to prefer incremental change to radical innovation, largely because of their fear of failure. Without insight and some certainty into the future benefits they will accrue from the II, it is difficult to align stakeholders to contribute to its development. The analysis showed that when stakeholders can imagine a profitable and sustainable future for Mobility-as-a-Service (MaaS), they are highly driven to develop the II.

Policymakers can communicate the future to stakeholders in two ways. First, they should invest in an innovation lab where stakeholders can view the latest technologies and test integration outcomes, which leads to greater engagement. The concept of innovation labs is not new in the private sector, where companies such as Visa and Daimler fund spaces where they can showcase their latest products. However, setting up a lab that includes the most recent products of not just one but several companies, including some that may be competitors, is rare and must be funded and facilitated by neutral policymakers. While policymakers may sometimes undervalue the power of imagining future rhythms of innovation, this study has demonstrated that it has a strong influence on stakeholder motivation.

"Our collaboration with Energy-Utility-2, for example, is always difficult because we are both in the energy sector. Sometimes it's competition and we don't want them to see too much of our internal information. Companies always have a hidden agenda in a project. " (i10)

Policymakers should also pay attention to the value of social science research into the habits of future users, which is also a powerful tool to persuade stakeholders of the market for new technologies. The analysis demonstrates that Intermediary's research on the lifecycle of future users was important in communicating that Mobility-as-a-Service (MaaS) would have increasing demand over time. In the case study, the user research was not only critical in convincing stakeholders that future consumers would behave differently than current ones, but also formed the functional requirements for building the II. This study highly recommends that policymakers not treat II development as only a technical undertaking, and hire social scientists and data scientists to conduct user research at different stages of the strategic niche project to align stakeholders.

Both innovation labs and user research serve to validate the future trends that justify an investment of time and resources into cultivating the II. Communicating future rhythms is critical as inconsistencies between different versions of the future may exist, which in turn stalls II cultivation.

9.4.3 Making Participants Conscious of the Biography of the II

This study also makes a case for temporal rhythm awareness for stakeholders. By anticipating the disciplining influences of diluting, stalling and blocking, stakeholders can set up interventions that prevent them from affecting II cultivation. For example, by researching historical production cycles, stakeholders can anticipate and counter the disciplining agency of conservative infrastructure rhythms of some partners. Equally important, by appreciating the factors that affect an II's longevity, stakeholders would more critically review their decisions keeping in mind the impact on the long-term sustainability of the II.

Perceiving the II in such a way does not come naturally to stakeholders. The typical project is focused on the short-term project duration instead of infrastructure time (Karasti et al. 2010). Stakeholders tend to discount the importance of temporality and temporal rhythms because of two reasons. First, since cultivation happens incrementally in IIs (Star & Ruhleder 1996), stakeholders usually assess the benefit of a decision based on its immediate return-on-investment (ROI) as opposed to its impact on the full biography of the II. Second, IIs are often considered a technical undertaking only, a view that leads stakeholders to under-appreciate other influences such as culture, skills and temporality.

Making stakeholders aware of the complexity of IIs, the dependency on the installed base, and the influence of temporality requires corporate training. By documenting the influence of temporality, this study aims to inform policymakers about the importance of temporality, and how it can reinforce or derail project plans. In doing so, it provides impetus for corporate training on temporal awareness. As many more cities embark on strategic niches for transportation, it is essential that stakeholders receive training that helps them recognise and harness temporal rhythms.

9.5. Areas of Further Research

Deeply Examining the Role of Intermediaries

This study demonstrates the pivotal role of the intermediary in intervening in the influence of temporal rhythms. Further research can consider the extent of this power and their motivation, and how an intermediary uses its ability to "manage and orchestrate the multiple rhythms transacting any form of distributed collective practice" (Jackson et al. 2011). Also, while this study explored just one type of intermediary: an institute partially funded by government initiatives, intermediaries come in many sizes and forms (consultants, universities, and innovation labs, for example) (Canzler et al. 2017). It would be interesting to investigate how different types of intermediaries harness temporal rhythms in similar situations.

Investigating Multiple Aspects of Rhythms

This study uses four broad categories of rhythms (phenomenal, biographical, organisational and infrastructural) (Jackson et al. 2011) but "rhythms can represent hybridizations of these categories, and intertwine in variable and complex ways" (Steinhardt & Jackson 2014). Researchers can further reflect on questions such as the effect of hybrid rhythms on II cultivation and on ways these rhythms can interact besides the four interactions postulated by Lefebvre (2004)'s rhythmanalysis matrix.

Examining Mobility-as-a-Service (MaaS) Through Other Frameworks

The concept of integrated multi-modal chains of mobility pioneered by BeMobility is now called Mobility-as-a-Service (MaaS). Other terms used in research papers include “mobility-on-demand,” “transportation on-demand,” “multimodal mobility,” “multimodal transportation,” “intelligent transportation system,” and “flexible transport service" (Brendel & Mandrella 2016). Researchers have examined the phenomenon from different perspectives, such as examining algorithms that enable mobility (Dib et al. 2015; Guerriero et al. 2014) and evaluating sustainable outcomes (d’Alessandro & Trucco 2012). This study has studied IS development involved in Mobility-as-a-Service (MaaS) by using the lens of emergent II cultivation and temporal structuring. It would be interesting to investigate Mobility-as-a-Service (MaaS) using a different framework as well. For example, researchers can examine Mobility-as-a-Service (MaaS) through the analytical lens of digital product innovation in the transportation sector. This line of investigation would be of value to IS scholars who have recently become more interested in this topic as digitisation has spread to every aspect of daily life (Yoo 2010; Tilson et al. 2010a).

9.6 Limitations

As with any research, there are limitations to this study. One limitation is that several features of the case study are specific to the German way of funding innovation cycles and the dominance of the automotive sector. Both these features exerted strong disciplinary inertia on II cultivation and may differ in other countries. To overcome this limitation, future researchers should also study other case studies of strategic niches as demonstrated by Henfridsson & Bygstad (2013) to validate influences and interventions outlined in this study.

Another limitation of the study was the distributed nature of the work involved in multi-stakeholder IIs. While the researcher interviewed one member from almost every stakeholder organisation involved in BeMobility, she was unable to observe all teams at their offices or to meet all team members who were working on the II. This may have resulted in some interviewees having greater influence on the findings than others. Researchers can think of adaptations such as video conferencing to meet more members of distributed teams in future studies.

9.7 Summary

In conclusion, this study confirmed that II cultivation emerges as temporally embedded human and material agencies interact in a mangle of practice in the present. It contributes to the debate between two contrasting approaches to II cultivation - bottom-up evolution and top-down management of IIs, demonstrating that strategic interventions are possible to guide II cultivation. The study develops an initial explanatory framework of how the intermediary can mediate the influence of temporal rhythms that span the biography of the II, providing a way to combine short-term implementation plans within longer-term perspectives on II cultivation. From a policy perspective, this implies an elevation of the intermediary's role, illustrating that given its vantage point of overseeing the project, it can harness rhythms or counter their impact, and can also evolve its biographical rhythms to drive the project forward.

The urgency of addressing sustainable transportation given rapid urbanisation world-wide has resulted in a much greater interest in integrated mobility or Mobility-as-a-Service (MaaS). As discussed in the last chapter, there is an increasing number of projects such as BeMobility that are now being set up across the globe. These include government-led projects such as Dubai's integrated mobility efforts, and multi-national led initiatives such as by Google's sister company Sidewalk Labs. As one of the first PhD projects to examine Mobility-as-a-Service, this study provides a starting point for researchers to investigate this phenomenon more closely, potentially by using the afore-mentioned new projects as relevant case studies.

"Integration of all this information is what we now call Mobility-as-a-Service. BeMobility was one of the first projects in the world to attempt to do it." (i58)

In keeping with the principles of the processual approach that "'outcomes' are often rather artificial staging points amid never-ending processes and they can be analysed as such" (Langley & Montréal 2007), it is important to mention what has happened to InnoZ and the national goals for e-mobility since the end of the strategic niche experiment. The experimental e-mobility II that was developed as a "proof-of-concept" was dismantled after the end of BeMobility. However, the technical, social and business lessons from the project have been useful for other projects undertaken by stakeholders. It was interesting for the researcher to visit the InnoZ offices in April 2017 and meet with senior staff. Since BeMobility, InnoZ has expanded its work in integrated mobility infrastructures to include autonomous vehicles (AVs) and further work on micro smart grids. Its reputation as a convener and driver of ICT innovation has also thrived, with MaaS Alliance (that provides open data for the European Union) having contacted them at the time of the visit to host a hackathon. The staff also spoke enthusiastically about the number of start-ups that now co-locate in its offices in the EUREF campus, showing how it has also become more inclusive of younger partners.

While InnoZ's prominence has increased with the rising relevance of sustainable transportation in cities, Germany's *energiewende* attempts to reduce emissions have had mixed results. It has been successful in having renewables supply almost 30% of electricity in Germany (with much higher proportions on windy or sunny dates as it was in April 2017 when 85% of the country's energy came from renewables[25]), yet it is set to miss its ambitious 2020 target of 40%[26] with coal still dominant in the energy mix. Also, German citizens have had to bear the burden of subsidising renewable

[25] Charlotte England, "Germany breaks renewables record with coal and nuclear power responsible for only 15% of country's total energy" *The Independent* 5 May 2017 (Source: http://ind.pn/2qNajtY)
[26] Nick Butler, "The power behind the shift to renewable energy in Germany", *Financial Times*, 6 November 2016 (Source: http://on.ft.com/2fvlZfH)

energy with a "green surcharge" that has increased their power bills by almost 25%[27]. The program has disrupted the traditional energy sector with its biggest utilities posting $30 billion in losses over the past two years (including one of the participants in BeMobility)[28]. Now the government's continued mission of sustainable mobility threatens the traditional transport industry next, and in 2017, the Bundesrat, Germany's upper hour of parliament, passed a resolution that called for the EU to use vehicle duties and tax incentives to ensure that only emission-free will be registered[29]. In many ways, BeMobility and its stakeholders were prescient in anticipating that "the governments are forcing utilities and automotive industries to turn upside down and deal with paradigm shift" (i6).

This study represents a nascent field in the II literature with potential for future research to lend deeper insights into how e-mobility IIs are cultivated. For this researcher, the next academic exploration will be to investigate the integration of public and private transport on a Mobility-as-a-Service platform in another site. Led by Singapore's largest transportation company, SMRT, a consortium of partners is contributing to a project that includes a mobility services platform that integrates a variety of mobility modes (including autonomous vehicles, bike-sharing and e-scooters) with public transportation. The platform represents digital product innovation for SMRT as the company tries to find a corporate strategy to generate revenue in the face of increasing competition from firms like Indonesian car sharing startup Grab. The Singapore project represents an opportunity to both validate and extend the findings of this study.

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[27] Brian Park and Weixin Zha, "How Merkel's Green Energy Policy Has Fueled Demand for Coal" *Bloomberg Businessweek* 21 September 2017 (Source: https://bloom.bg/2w876r5)
[28] Jill Petzinger "Germany's renewable energy push has forced $30 billion in losses on its biggest utilities" *Quartz* March 15, 2017 (Source: http://bit.ly/2yJWVha
[29] Nick Butler, "The power behind the shift to renewable energy in Germany", *Financial Times*, 6 November 2016 (Source: http://on.ft.com/2fvlZfH)

The continuing importance of e-mobility IIs in sustainable transportation makes it imperative that scholars investigate the processes by which they are developed, keeping in mind that IIs must be examined against their full biography that "extends from the present to the future (prospective dimension) and also to the past (retrospective dimension)" (Karasti et al. 2010). The aim of this PhD was to make a contribution to this emerging field and to highlight the significance of studying temporal rhythms in this examination.

Appendices

Appendix A: Interview List

In total, this study conducted 61 interviews. The choice of interviewees was made based on their association with the BeMobility project: stakeholder representatives involved in the different working groups were interviewed, as were members of a range of teams working in Intermediary.

Semi-structured interviews between 45-60 minutes in length were conducted using the techniques outlined in Section 4.5 in the Research Methodology chapter. Interviews were conducted in-person at the project headquarters at the EUREF Campus, at the offices of different stakeholders, and on the phone. Almost all the interviews were conducted in English.

The following table provides the job descriptions of interviewees.

Code	Description
i1	Co-Founder, Intermediary
i2	Business Development Manager, National-Multimodal-Operator
i3	Customer Needs Analyst, Intermediary
i4	IT Project Manager, Intermediary
i5	Europe Manager, OEM-1
i6	Business Development Manager, Energy-Utility-2
i7	Customer Loyalty Manager, City-Mobility-Operator
i8	User Research Manager, Intermediary
i9	Junior Project Manager, Intermediary
i10	Project Manager, Energy-Utility-1
i11	Software Engineer at Academic-Team-2
i12	Marketing Manager, Parking-Management-Company-1
i13	Energy Management Team, Intermediary

i14	Partnerships Manager, Intermediary
i15	Partnerships Manager, Intermediary
i16	Manager, Energy-Utility-Startup
i17	Energy Grid Manager, Intermediary
i18	Energy Grid Manager, Intermediary
i19	Energy Grid Manager, Intermediary
i20	Software Engineer, Academic-Team-1
i21	Software Engineer, Academic-Team-1
i22	Project Manager, Intermediary
i23	Project Manager, Intermediary
i24	Head of Department, State-ElectroMobility-Agency
i25	Head of International Programs, OEM-Startup
i26	Science and Technology Researcher, OEM-2
i27	Project Manager, Timetable-Services-Vendor
i28	Manager, Software-Consulting-Company
i29	Representative, State-Government
i30	Business Development Manager, Automotive-Parts-Supplier
i31	Project Manager, City-Energy-Manager
i32	Architect, Architecture-Firm
i33	Co-Founder, Intermediary
i34	Planning and Passenger Information Manager, Ticketing-Operator
i35	Strategic Industries Researcher, Telecommunications-Company
i36	Software Engineer at Academic-Team-1
i37	User Research Analyst, Intermediary
i38	Pioneer User Researcher, Intermediary
i39	ICT Manager, Intermediary
i40	ICT Manager, Intermediary
i41	Science and Technology Researcher, OEM-2
i42	Project Manager, Parking-Management-Company-2
i43	Manager, Energy-Utility-3
i44	Head of Research Mobility, Research-Institute
i45	Program Lead, Electromobility, Government-Agency
i46	General Manager Engineering, Automotive-Testing-Service
i47	Business Development Manager, Energy-Management-Company
i48	Clean Tech Advisor, Energy-Storage-Supplier
i49	Research Director, Academic Partner

i50	Project Manager, City-Mobility-Operator
i51	Government Relations Manager, Automotive-Parts-Supplier
i52	User Research Analyst, Intermediary
i53	Associate Director, Strategic-Consulting-Company
i54	Mobility Research Manager, Intermediary
i55	Vice-President, European-Asian-Cooperation-Institute
i56	Research Director, Academic-Partner
i57	Project Manager, Intermediary
i58	ICT Manager, Intermediary
i59	Project Manager Smart Grid, Energy-Management-Company
i60	User Research Analyst, Intermediary
i61	IT Project Manager, Intermediary

Appendix B: Interview Protocol

As discussed in Chapter 4 (Research Methodology), the semi-structured interviews were conducted in a way that would make the interviewee comfortable. Questions started out with broad questions regarding the nature of their responsibilities in the project, their career history, and work practices. As the interviewee became comfortable, the researcher tailored the questions to aspects of II cultivation and their specific roles. Interviewees were probed for explanations and elaborations. Interviews were recorded (with permission) when possible and were transcribed by the researcher meticulously.

Examples of general questions at the start of the interviews:

- What are your responsibilities in the project? Which working package are you involved in most?
- What are you working on these days?
- How big is your team and how often do you work with members of other stakeholders?

Examples of tailored questions related to interviewees specific responsibilities in the project:

- What are some of the challenges you have faced in your role? Did you meet the planned objectives in time?
- Was it easy for you to get data when you needed it to develop your component?
- How useful was Intermediary in helping you reach your goals?

Examples of probing for explanation and elaboration of resistance they faced, and accommodations they did or noticed:

- Why do you think your partners could not share this data?
- How were you able to deliver this component despite the challenges you mentioned?

- What were some of the main lessons from the phases BeMobility 1.0 and/or BeMobility 2.0?

Appendix C: Document List

This study reviewed extensive documentation related to the project plans, meeting minutes, technical requirements, and working group presentations for different parts of the BeMobility II. Over 350 documents were provided to the researcher who iteratively categorised them into relevant codes for review and then chose a subset of 45 documents to review thoroughly. Of these 45 documents, heavy use was made of the two final reports of Phase 1 (300 pages) and Phase 2 (667 pages) to corroborate the interviews, and the various documents in the table below. All documents were in German and translated in Google Translate by the researcher. Note that the names of internal documents have been anonymised. Online sources may have changed.

Document/Group of Documents	**Description**	**Code**
BeMobility Project Website	All details of the BeMobility project phases were provided on this website with links to relevant publications *(Source: http://bit.ly/1Av2TNJ)*	d1
User Research Result Documents	"Results of the usability tests of the BeMobility-Suite" (internal document) InnoZ also published several articles on the user research and the following articles were particularly useful: "Experiences of three years of carsharing with electric cars" (*Wolter, Frank; Scherf, Christian: Nutzungserfahrungen aus drei Jahren vernetztes Carsharing mit Elektroautos, 2013, S. 15-23. Source: http://bit.ly/2lgSDrL)* "The BahnCard 25" (*Aljoscha Nick, Christian Scherf und Dr. Frank Wolter, "Die BahnCard 25 mobil plus" Deine Bahn 6/2013 Source: http://bit.ly/2yRNig0)*	d2
Frank Wolter, "eMobility: Integration of electric vehicles into public transport and the electric grid", March 2014	Presentation on eMobility project at conference in London in 2014 outlining the major learnings from Phase 1 and Phase 2 of the BeMobility Project (*in English*)	d3

(London)		
BeMobility Berlin elektroMobil: Multimodal und elektrisch mobil (final brochure)	Final brochure 2015 (Source: *http://bit.ly/2zEuLRk*)	d4
Final Presentations BeMobility 1.0	This set of documents contain final presentations by InnoZ and some stakeholders outlining the results of BeMobility 1.0 at the closing event on 8 December 2011 at the EUREF Campus (Source: *http://bit.ly/2i4LVQO*).	d5
Final Presentations BeMobility 2.0	This set of documents contain final presentations by InnoZ and some stakeholders outlining the results of BeMobility 2.0 at the closing event on 20 March 2014 at the EUREF Campus (Source: *http://bit.ly/2h8owOS*).	d6
InnoZ website	This website provides information on the roles of different team members in the Intermediary along with details of its projects (social science and technical). *(Source: https://www.innoz.de/)*	d7
Final official report of BeMobility 1.0	The final report contained detailed information on the goals, stakeholders, achievements, failures and challenges of every part of Phase 1 (categorised by Working Groups). (Source: *http://bit.ly/2gEzcnS*)	d8
Final official report of BeMobility 2.0	The final report contained detailed information on the goals, stakeholders, achievements, failures and challenges of every part of Phase 2 (categorised by Working Groups). Especially useful for understand extensions to BeMobility Suite and Smart Mobility Card. (Source: *http://bit.ly/2yR8mmx*)	d9

BeMobility 1.0 documents (anonymised names)	Useful set of documents for understanding activities in Phase 1: “Kick off document outlining roles and tasks for all parts of the document” (Powerpoint) “Project status updates for BeMobility Suite, Smart Mobility Card and User Research (including architecture, algorithms, and data integration)” (focused on 6 update Powerpoint documents)	d10
BeMobility 2.0 documents (anonymised names)	Useful set of documents for understanding activities in Phase 2 especially related to the Micro Smart Grid: “Controlled charging in the micro-smart grid: Tasks and roles of the partners” (Powerpoint) “Micro Smart Grid Network Logic” and “Micro Smart Grid Network Physical” (architecture diagrams) “BeMobility Suite Research and Production Testing Requirements” (Word document)	d11

Publications

Khanna, Ayesha, and Will Venters. "The Role Of Intermediaries In Designing Information Infrastructures In Strategic Niches: The Case Of A Sustainable Mobility Infrastructure Experiment In Berlin." ECIS 2013.

Khanna, Ayesha, and Will Venters. "Exploring the Rhythms of Information Infrastructure Coordination for Smart Cities: The Case of Building a Mobility Infrastructure in Berlin." ECIS 2014.

Khanna, Ayesha, and Will Venters. "Integrating digital systems to help city residents plan seamless journeys." iSCHANNEL 11(1): 12-13, 2016.

List of Acronyms

API	Application Programming Interface
BVG	Berliner Verkehrsbetriebe (main public transportation company of Berlin)
CAN	Controller Area Network (CAN)
CSCW	Computer-Supported Cooperative Work and Social Computing
DAI-Labor	Distributed Artificial Intelligence Laboratory at TU Berlin
DB	Deutsche Bahn AG
eMO	Berliner Agentur für Elektromobilität eMO (Berlin Agency for Electromobility)
II	Information Infrastructure
InnoZ	Innovationszentrum für Mobilität und gesellschaftlichen Wandel (InnoZ)
LSE	London School of Economics
MaaS	Mobility-as-a-Service
NOW	National Organization Hydrogen and Fuel Cell Technology (NOW)
OEM	Original Equipment Manufacturer
SENSE	Smart Grid Lab at TU Berlin
SNM	Strategic Niche Management
TU Berlin	Technische Universität Berlin (Technical University of Berlin)
VBB	Verkehrsverbund Berlin-Brandenburg (transport association run by public transport providers in the German states of Berlin and Brandenburg)

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