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EXPLORING THE RHYTHMS OF INFORMATION INFRASTRUCTURE COORDINATION FOR SMART CITIES: THE CASE OF BUILDING A MOBILITY INFRASTRUCTURE IN BERLIN

Research in Progress

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Abstract

This paper investigates how the coordination of information infrastructures (II) emerges as a result of the dialectic between social and material agencies, whose interactions are tempered by both the objective and subjective flows of time.

Drawing upon the theory of the Trichordal Theory of Coordination (Venters et al. 2014), the study explores the process of coordinating the development of particular forms of II associated with Smart Cities. It redirects this theory to the study of strategic niches by including socially constructed temporal rhythms that frame organizational practice (Jackson et al. 2011; Orlikowski & Yates 2002). We show that the development of II projects, such as those undertaken in the creation of smart cities, can be understood through interacting social and material agencies that are embedded in multi-dimensional temporality.

The paper draws upon an in-depth study of the BeMobility project, in which a strategic niche had been created to prototype a sustainable mobility infrastructure in Berlin. The goal of the project was to demonstrate a future in which Berlin will have a multi-modal transport system dominated by electric car-sharing, which is fully integrated into the public transport system. The paper contributes to research on cooperative work in multi-stakeholder II projects for smart cities.

Keywords*: Strategic Niche Management, Information Infrastructure, Coordination, Intermediaries, Agency, Mangle of Practice, Trichordal Temporal Approach to Digital Coordination..*

1 Introduction

Innovations in urban transportation involve a radical reconceptualization of the notion of "transport". Today, transportation systems are heavily reliant on individual car ownership powered by fossil fuels, and transportation modes such as buses and rails, which operate in isolated silos. A sustainable mobility infrastructure would be based on an integrated chain of shared vehicles such as car, bus, bike and train, which are powered by renewable sources like solar and wind power. Smart ICT applications would help users map and navigate the city with features such as location of available vehicles, train timetables, fares and carbon footprint. The transition to reliance on such an information infrastructure (II) within transportation would require the coordination and integration of complex information systems that span multiple industries, like public transport, car manufacturers, and utilities.

This paper attempts to understand how this coordination may occur and asks the research question, "In developing an urban information infrastructure (II), what is the process of coordinating?"

The paper is organized as follows: Section 1 reviews the literature on strategic niches, coordination and mobility networks. Section 2 introduces the Trichordal Theory of Coordination (Venters et al. 2014) as the conceptual foundation of the study, and discusses how it might be extended to consider the subjective temporal rhythms of organizations. Sections 3 and 4 describe the research methodology and case study, followed by the analysis in Section 5 based on the aforementioned theoretical framework. The paper ends with a discussion on the contribution and implications of this research.

2 Literature Review

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) and scholarly work on sustainable transitions has risen to 60-100 academic publications per year (Markard et al. 2012). Many researchers focus on infrastructure experiments called strategic niches and their translation into new national infrastructures. Strategic niches are "protected" from the current socio-technical networks that resist innovation (Hodson & Marvin 2009), comprise multiple and varied stakeholders from the industry, government and research universities, and derive lessons from deploying technologies in real-world settings. Infrastructure niches often include the creation of an integrated large-scale information system that is built upon the existing systems of multiple stakeholders. The strategic niche literature, however, largely considers all technologies as static. While such blackboxing might be appropriate for innovations such as electric cars, which have a relatively long development cycle, it is inappropriate for technologies like information systems, which have the potential to develop incrementally and rapidly.

Studies specifically focused on experiments in sustainable mobility infrastructure, including those with electric vehicles in Germany from 1992-1996, Switzerland after 1995, and Norway after 1991, have also largely taken technology as a static entity (Hoogma et al. 2002). The results of several of these experiments were disappointing with inability for 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 late 90s, improvements in battery technology, charging infrastructure, 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 infrastructure (Dijk et al. 2012). There is recognition that instead of just focusing on new car technologies, the development of "smart" mobility requires supporting ICT products in cars and infrastructure, and

changes in consumer behavior, and present an alternate transition pathway to sustainable mobility, which can be regarded as a reconfiguration pathway (Geels & Schot 2007). However, exactly how the "smart" infrastructure is built is yet to be deeply considered.

In order to examine ICT development in such infrastructure projects, we turn to the literature of information infrastructures (II). IS scholars view complex information systems with dynamic and interdependent heterogeneous components as a new class of IT systems called information infrastructures (II) (Gal et al. 2008; Hanseth & Lyytinen 2010; Hanseth & Monteiro 2008; Star & Ruhleder 1996; Turner et al. 2006). Any integration effort must recognize that each organization has existing systems that cannot be controlled centrally. These features are characteristic of information infrastructures (IIs) (Hanseth & Monteiro 2008; Monteiro et al. 2012), including that IIs are comprised of heterogeneous components (Kling & Scacchi 1982; Edwards et al. 2007), are shared and meant to serve more than one enabling function and activity (Hanseth & Monteiro 2008), and have an installed base and new components are built incrementally over existing systems (Star & Ruhleder 1996). Coordinating the development of IIs is difficult given the heavy influence of the installed base, and the heterogeneity and dynamic interactivity of its socio-technical components (Hanseth & Lyytinen 2010). The increasing complexity of integrated information systems (Hanseth & Ciborra 2007; Kallinikos 2007) makes it necessary for IS scholars to rethink design approaches, which have not adapted to account for this complexity (Henningsson & Hanseth 2011).

The coordination and CSCW literature (Schmidt & Bannon 2013) provide insights into how multiple organizations collaborate to work on a project. The practice-based approach in the coordination literature emphasized the emergent nature of coordination and the evolution of related skills and processes. It emphasized knowledge sharing through use of shared language (Okhuysen & Bechky 2009), the emergence of boundary spanning competence and use of boundary objects (Levina 2005) and emergent cross-boundary practices in volatile and uncertain conditions, including through the use of web-based tools (Kellogg et al. 2006). However, this literature lacked an appreciation of materiality and its role in impacting the coordination activities. The CSCW literature also has yet to pay in-depth attention to IIs such as ERP systems (Monteiro et al. 2012). This study presents an opportunity to fill this gap in the literature on II development in strategic niche and CSCW research streams.

3 Conceptual Framework

The Theory of Trichordal Coordination (Venters et al. 2014) uses the Mangle of Practice (Pickering 1993) to understand digital infrastructure coordination through a performative lens. According to Pickering humans seek to manipulate the world through harnessing human agency in order to *accommodate* the material agency of things in the world. Material things however *resist* such attempts and further accommodations are needed in an temporally unfoldinginterplay between resistance and accommodation, referred to as *tuning* (Pickering 1993) and driving the development of scientific inquiry.

Venters et al (2014) extended the Mangle of Practice (Pickering 1993) to better account for the temporal dimension of infrastructure evolution. Pickering's acknowledgement of the influence of the past through the "disciplinary agency" of culture and past knowledge (Pickering 1993) and the anticipation of the future through the concept of "modelling" (Pickering 1990) are extended by Venters et al. (2014) augmenting the theory with a temporally embedded view of agency based on Emirbayer & Mische (1998)'s work, which views agency is always "oriented towards the past, the future and the present at any given moment [in a] chordal triad of agency" (Emirbayer & Mische 1998). The resultant Theory of Trichordal Coordination (Venters et al. 2014) asserts that both human *and* material agencies are better understood by analysing them in the flow of time. These authors state

that "digital infrastructure coordination can be understood as a temporally enacted process of sociomaterial entanglement, configured by the past … oriented toward the future … and emerging in the present" (Venters et al. 2014). For instance, the past can assert itself on material agency in the form of the installed base (Star & Ruhleder 1996) while the anticipation of the future is built into the material agentic tendencies in the form of the generativity (Henfridsson & Bygstad 2013) of software. Coordination emerges at the intersection of three tensions: the remembered past and its associated disciplining of social and material agencies, the imagined future and the agentic leanings towards it, and the entanglement of human and material agencies, also referred to as tuning, in the present.

This paper extends Venters et al (2014) to enrich understanding of the complexities of social agency involving large numbers of stakeholders organised into different organisations, (in urban infrastructure projects organizational stakeholders can sometimes be greater than 50 in number). Within these organisations, we believe, the motivations and actions of individuals are influenced by a shared socially constructed notion of time as well as the linear temporality of past, present and future.

This paper thus seeks to extend the Trichordal View of Coordination (Venters et al. 2014), to the study of complex multi-institutional settings with different subjective dimension of organizational time (Orlikowski & Yates 2002). In doing this the paper introduced four types of collaborative *rhythms* which reflect the collective temporality evident among the participants of the organisations involved – organizational, infrastructural, biological, and phenomenal, which frame temporal experience and practice in collaborative scientific projects (Jackson et al. 2011). Collaborative rhythms are influenced both by human and non-human factors. For example, the influence of the built environment plays a role in the choices organizations make, and their willingness to participate in an activity. At the same time, biological rhythms, which include the shifting roles and identities of organizations, also plays a part in how sincerely an organization participates in a strategic niche project. Organizational strategy and action is best understood through a multi-dimensional temporal lens (Kaplan & Orlikowski 2013), which in turn directly influences organizational alignment or coordination in a collaborative project.

4 Case Study

The BeMobility project was started in September 2009 as part of the German government's effort to become the market leader and key supplier in electric mobility markets. It was sponsored with the specific goal of demonstrating and investigating how electric car-sharing schemes could be integrated into Berlin's public transport system. The goal of the project was to provide end-to-end public transport to users while limiting individual car ownership and environmental pollution. The project was conceived with the hypothesis that users are agnostic about the particular mobility vehicle (bicycle, car, train, or bus, for instance) as long as it takes them directly from and to their home. This would require a chain of public mobility services, for example a rentable bicycle from home to the train station and then a train to the office. Such a multi-modal mobility service would be energy efficient if it was powered by renewable electricity, and would be effective if customers found it easy to use through an integrated infrastructure and a user-friendly application that provided them data on availability and payment

The lead partner of the project was Deutsche Bahn and InnoZ was given the responsibility to manage the development of this new infrastructure.

Multiple organizations participated from the following sectors: energy and charging infrastructure providers included Vattenfall and RWE; academic partners included TU Berlin and MIT ; car manufacturers included Daimler, Honda, Toyota, Hiriko; public transport companies included Deutsche Bahn, BVG, HaCon; car part suppliers included Bosch; electricity management included Schneider Electric; real estate providers (public and private) included City of Berlin and Contipark; government agencies included the federal government and EMU; and startups included Salon. Several new technologies (hardware and software), existing systems and new modules were planned. These

included: immature hardware technologies such as electric cars, pedelecs, micro-grids, charging infrastructure, plugs, cables, and simulators on EUREF campus; new hardware/augmented technologies such as smart cards with RFID chips and car boxes; existing information systems such as systems, databases, APIs, and modules; and new information systems such as smart phone applications, simulation programs, databases, APIs, and software modules

BeMobility 1.0: At the end of BeMobility 1.0, 32 electric and hybrid vehicles with 15 rental locations and 25 charging stations had been tested on the new platform in Berlin. The vehicles were made available through Deutsche Bahn's existing car sharing scheme known as Flinkster. Drivers of electric cars were provided designated free public and private parking spaces where they could rent, charge, park and return cars. The design of technologies such as charging plugs and vehicle design were taken as fixed in BeMobility 1. Innovation was pursued in the form of infrastructure integration, a new smart phone application called the BeMobility Suite and social learning. One of InnoZ's primary functions was to conduct research and provide analysis around future customer needs.

BeMobility 2.0: BeMobility 2.0 was started in January 2012 and finished in February 2014. This project has expanded upon the pervious phase to include: (i) an expanded fleet of cars including the Hiriko mini-foldable car which made its debut in Berlin in 2013; (ii) an examination of how the electric car-sharing and renewable energy networks can be integrated via a micro-smart grid (MSG); (iii) an extension of the BeMobility Suite with further integration of real-time data sources and information related to power availability and usage, and coordinated efforts to build further standards around interoperability of sub-infrastructures; and (iv) experimentation with new business models around electric mobility services. The number of partners of the project was also increased to 32 to reflect the expanded scope of the project.

5 Research Methodology

The BeMobility Project was carried out over two phases (September 2009 – December 2011; January 2012 – December 2013). This research project has followed the project over the years with research conducted on both Phase 1 and Phase 2. Interviews and documents were gathered in 3 stages: Nov – Dec 2011, May - Jul 2012, and Mar - April 2013. An additional stage is to be conducted in March - April 2014 to question a subset of participants (currently, the final report of the project is being written by InnoZ and various stakeholders).

We conducted 53 semi-structured interviews with representatives of all the different stakeholders, and were provided over 200 project documents (including minutes from meetings, project plans and reports) from Sep 2009 – Jul 2013. Initial thematic coding was done of all the interviews and of a subset of the documents. The interview data was corroborated and augmented by the documents. Preliminary analysis is currently being conducted by anchoring the findings in the Trichordal Theory of Coordination (Venters et al. 2014) and an extension through the inclusion of a multi-dimensional temporal lens (Jackson et al. 2011) of agency interaction.

The analysis phase was highly iterative and we have so far used a four-stage analysis to evaluate the interviews and documents. First, we read the different documents provided by InnoZ and available from media coverage to create a timeline of events that led up to and occurred during BeMobility I and II. The creation of summaries of these events provided contextualisation (Klein & Myers 1999), which was critical in understanding the project at a high level. We then created summaries of the project's various working groups that were formed to address specific goals of the BeMobility project. These timelines were useful in understanding the temporal unfolding of the case.

In the second stage, we used the Trichordal Theory of Coordination (Venters et al. 2014) as the foundational lens to understand the interaction of human and material agencies in context of the evolving parts of the II, such as the development of the BeMobility Suite. We thematically coded the

interviews and documents based on this theory, especially using the analytical constructs of its foundational theories of Mangle of Practice (Pickering 1995). We tried to identify and isolate the tuning of resistance and accommodation as they emerged in the data.

In the third stage, we began to integrate the influence of time on agency into the coding (Emirbayer & Mische 1998), which necessitated going back to several stakeholders to understand organizational motivations, interpretations and constraints. At this stage, we revised our theoretical framework by extending the Trichordal Theory of Coordination with a constructed view of temporal rhythms (Jackson et al. 2011).

Currently, we are working on analysing the data under this extended view of subjective and objective time, and analyzing organizational choices and alignment made in the present based on rhythms of time, which influence strategy and action. We are in the course of finding patterns amongst organizations using this new framework. We present initial findings in Section 6.

6 Case Analysis

This analysis deconstructs the way stakeholders (as collections of individual) interact with each other during II development in order to understand and analyze *coordinating*, which is viewed as a "temporally unfolding and contextualised process" (Faraj & Xiao 2006). We extend the practice-based view of coordination as an emergent process by further examining the chordal tensions when human and material agencies interact with each other, using the conceptual constructs of the Trichordal Theory of Coordination (Venters et al. 2014) and the temporal rhythms of collaborative practices (Jackson et al. 2011). The unit of analysis in this paper is thus the organization, taken as a collection of individuals with similar practices towards the coordination of the strategic niche.

6.1 Organizational Rhythms

Organizational rhythms are the overtly temporal rhythms set by organizations such as production cycles, strategic plans, review processes, commercialization and approval timelines. Organizations that are under deadline or over-stretched find it hard to participate in collaborative environments. Representatives especially assigned to niche can only contribute productively to an extent before he or she will require the authority or support of the organization. The opposite is true if the project calendar is aligned to the organizational rhythm. In our case, the release of software for the simulation and BeMobility suite closely matched the timelines for PhD research and publishing deadlines of the programmers who were coding the simulations and smart phone application. This made their interest and availability in working on the project very high.

6.2 Infrastructural Rhythms

The built environment, legacy systems and other non-human factors all constitute the infrastructural rhythms of an organization (Jackson et al. 2011). Getting data from the electric car's black box, for example, was necessary to know details about the car's condition including the amount of battery power left. This data was to be integrated into the BeMobility Suite smart phone application so that whenever a user was booking a car, he would know the state of the car and how far it could travel. One of the stakeholder, a leading car manufacturer said it would not be able to share the car's data saying that it was always sent directly to the manufacturer's headquarters in Asia. On the one hand, participants felt it was a political move by the car manufacturer not to share insights on consumer behavior with competitors. On the other hand, it was also a fact that the legacy systems had been set up for years to send the data to Asia, and any new data feed to the outside would require new software development which also included filtering company specific sensitive information. The project was

also constrained in being able to use other commercially available, manufacturer agnostic black boxes for the cars donated for the project. Infrastructural constraints came up repeatedly in the project and included issues as varied as batteries that froze in the winter, to parking lot information systems that could not convey if a particular parking spot was occupied or not.

6.3 Biological Rhythms

Whereas Jackson et al (2011) refer to the biological rhythms –"shifting roles, identities and career trajectories" (ibid) of individuals, we apply the same concept to organizations. Group interactions exhibited in the BeMobility working groups were influenced heavily by an organization's interpretation of its evolving identity over time and how the project related to its evolution. For organizations like InnoZ, for example, the success of the II and integration of constituent stakeholder systems was critical to establish itself as an intermediary, which could be hired again for such smart city pilots. For other companies such as a leading car manufacturer, the project was more of a research exercise since the company was in early stages of a production expansion from a diesel based to an electric or hybrid car. Many stakeholders complained that such participants were "spying" on the project, as one participant put it, and offered scant information and contribution. For participants who had decided that electric car sharing was a fundamental part of their future, we saw evidence of proactive alignment with others in the project to move it forward. This was true both of the largest railway organization in the project, which wanted to extend its services to the last mile for consumers through intermodal transport, and a car parts manufacturer, which saw an opportunity to move into the car manufacturing industry as cars become electric and more modularized.

6.4 Phenomenal Rhythms

Jackson et al (2011) refer to phenomenal rhythms as large-scale background trends that are out of the control of individual stakeholders. They give the example of natural phenomena that affect scientific projects, such as climate change. In our study, we also consider political decisions such as those taken by the German government to create a National Electric Mobility Platform and to set a goal of 1 million electric cars in Germany by the year 2020. For those companies that had a seat on the National Platform, the political will driving the project was reinforced and weighed heavily on their decisions. This included representatives from the intermediary, a railway operator and a car parts supplier. In interviews with its top executives, their participation in the Platform was always brought up. For others, natural phenomena such as the availability of wind in Berlin played a role in their alignment in a working group. This was particularly true in Phase 2 where renewable energy provide, including startups, were more interested in contributing to the micro-grid than the larger energy companies, one of which bowed out in Phase 2.

6.5 Emergent Coordination or Striving for Alignment in the Present

The social and material agencies that interact in the present are influenced by the four temporal rhythms of stakeholder organizations. For example, as discussed in the section above on infrastructural rhythms, the resistance of the installed base black box in the project cars in directly providing data to stakeholders meant that Version 1 of the BeMobility application did not have car data. Other participants in the working group, each of which is chosen to participate in the group due to market, expertise and indicated interest, were unable to provide counter support for this initiative. However, in Phase 2, InnoZ partnered with a parts manufacturer, who had begun experimentation with car black boxes to harness the material agency of its car parts to create a new box that could generate the needed data. This box was created in Phase 2 and some of the car data such as battery usage could be recorded and displayed in the application.

Our analysis is still at an early stage to provide deeper insight into patterns of alignment due to the interaction of different rhythms, especially when they are competing with each other. In addition, there are other subtleties that complicate our findings. For example, regardless of the biological rhythms, we found that the bureaucracies of the firm further increased or decreased the influence of this rhythm. These bureaucracies were often, although not always, related to the size, history and monopoly position of the firm in the market.

7 Discussion and Contribution

The development of urban scale "smart" infrastructures involves coordination between multiple public and private stakeholders within a range of different organizations. Increasingly, governments are encouraging the prototyping of such infrastructure by subsidizing projects known as strategic niches. Such efforts include the development of information infrastructures (II), which are complex, evolving and heterogeneous systems making it difficult to coordinate their design and development.

This paper set out to begin to show that II coordination emerges as a result of the dialectic between human and material agencies, whose interactions are embedded and influenced by both subjective and objective notions of time embedded in the organisations to which they belong.

The paper makes tentative steps towards extending the Trichordal Theory of Coordination (Venters et al. n.d.) to further our understanding of time in the coordination of strategic niche infrastructure initiatives. Drawing upon empirical data and analysis from a case study on the development of a smart mobility infrastructure in Berlin the paper illustrates that II coordination is an emergent process that results from the temporally embedded entanglement of human and material agencies. More significantly it shows that the concept of temporal rhythms may offer a useful means of reconciling analysis of organisations (and their temporality) with the performative analysis of coordination within Venters et al. This may allow the Trichordal Theory of Coordination to be used in a wider range of analysis contexts in which individuals strongly represent their organisational performance. While further work is needed to validate this extension to this theory, this paper shows that understanding temporality may have significant benefit in the analysis of Smart Cities in which multiple organisations' representatives interact in seeking to coordinate a large-scale complex information infrastructure.

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