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The Role Of Intermediaries In Designing Information Infrastructures In Strategic Niches: The Case Of A Sustainable Mobility Infrastructure Experiment In Berlin

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THE ROLE OF INTERMEDIARIES IN DESIGNING INFORMATION INFRASTRUCTURES IN STRATEGIC NICHES: THE CASE OF A SUSTAINABLE MOBILITY INFRASTRUCTURE EXPERIMENT IN BERLIN

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Abstract

This paper demonstrates the importance of intermediaries in the design of information infrastructures (II) in strategic niches, where urban infrastructures are prototyped to enable transitions to sustainable infrastructure. It shows how existing approaches to the study of such experiments fail to effectively address the design and development of information technology within them. Given the path dependency of initial design decisions in IIs, this literature gap leads to an under-appreciation of the influences that shape urban II design in the long run. The paper thus asks the question: "how are urban II prototypes designed?" In order to answer this question, the paper proposes that ICT within urban infrastructures can be conceptualized as information infrastructures (IIs), and that complex adaptive systems (CAS) provide a useful theoretical framework for examining the mechanisms that drive II design. In using this framework, the importance of facilitation and the intermediary in designing urban II prototypes becomes evident. The critical role of intermediation is illustrated through a case study of the development of an II in Berlin targeted with prototyping a sustainable mobility infrastructure, which integrates electric car-sharing into the public transport system. The paper contributes to the study of Green IT systems, providing an initial step in understanding the influence of intermediaries in urban II design, and also contributes to the examination of radical innovation processes in urban infrastructure and the development of so-called "Smart Cities".

Keywords: Green-IT, Strategic Niche Management, Information Infrastructure, Intermediaries, Complex Adaptive Systems.

1 Introduction

The world is migrating to cities and this rapid rate of urbanization means we need to both improve urban governance and build new cities1. This migration, coupled with the challenges of climate change, demands rapid innovation in urban infrastructures to avoid a precipitous increase in carbon footprints. Innovation is occurring in, for example, transportation infrastructure, transitioning it away from individual car ownership based on fossil fuel towards complex intermodal (e.g. car, bus, train, bike) transport based on renewable energy.

While considerable studies have been undertaken to understand such innovation in terms of large-scale sustainable infrastructure development (Markard, Raven, and Truffer 2012), very little work has deeply investigated the role of ICT in these efforts. Addressing this gap is vitally important if urban infrastructure is to achieve its sustainability targets. This paper addresses this gap by focusing on how urban infrastructures are prototyped in strategic niches or publicly funded experiments, which have multiple public and private stakeholders. The management of such strategic niches is a policy objective of many countries and cities and thus an area ripe for research.

The paper shows how the study of such experiments demands a deeper analysis of the role of information technology within the innovated urban infrastructure. The paper then illustrates how intermediaries play a significant role in shaping this ICT, using the theoretical framework of complex adaptive systems theory and by conceptualizing urban information systems as an information infrastructure (II).

The empirical investigation is based on a case study of a strategic niche (funded for the period Sep 2009 – Dec 2013) to innovate sustainable mobility infrastructure within Berlin, specifically integrating electric car sharing into the public transport system. The case study was conducted between November 2011 and June 2012, and was restarted in Jan 2013 and is on going, with 53 semi-structured interviews conducted and transcribed, and 200 documents examined so far. The paper is able to provide some limited recommendations for those involved in strategic niches around electric mobility, and provide a research agenda for the Information Systems discipline in studying the role of intermediaries in designing ICT for sustainable urban infrastructure.

2 Literature Review

Research on the innovation of large-scale infrastructures (e.g. power, water, transport) has been dominated by two research on socio-technical transitions (Markard and Truffer 2008). A transition has technological change at its core (Markard and Truffer 2008) and is seen as socio-technical in nature: the result of changes in, and interactions between, markets, infrastructures, cultural discourses, user practices, and institutional governance (Kemp 1994; Boelie Elzen, Geels, and Green 2004; F. W. Geels 2004). Transitions literature has formed a central component of studies of sustainable innovations in water, energy and transportation infrastructure. Within such studies, a number of theoretical frameworks have been used to explore the role of institutional structures and regimes, of which the strategic niche management (SNM) framework is most notable in accounting for niches. This review outlines the importance of the niche in sustainable infrastructure innovation, followed by a summary of SNM.

[1] KPMG, Infrastructure 100 – World Cities Edition. Link: http://www.kpmg.com/global/en/issuesandinsights/articlespublications/infra100-world-cities/pages/extended-cities-viewpoint.aspx

Niches[2] represent protected spaces in which innovations can develop through experiments without market pressures (Kemp, Schot, and Hoogma 1998) and the push-back from established business models, market players and processes. This paper draws upon the **Strategic Niche Management** (SNM) literature, which explores such **strategic niche experiments** (SNEs) in detail. SNM is a concrete 'strategic' policy intervention in the innovation process to nurture radical innovations (difficult and risky innovations involving path-breaking new technologies (O'Reilly III and Tushman 2004)) It is a response to known impediments to radical innovation – in particular the lack of knowledge of how the innovation will operate on an urban scale, the uncompetitive prices of innovations faced with incumbents capitalizing on economies of scale, and the actions of such incumbents when faced with innovations. SNM involves the "creation, development and controlled break-down of test-beds (experiments, demonstration projects) for promising new technologies and concepts with the aim of learning about the desirability (for example, in terms of sustainability) and enhancing the rate of diffusion of the new technology" (Weber and Truffer 1999).

The goal of strategically managing a niche around technology is to create heuristics that will drive innovation while reducing its risk and improving its performance (Schot and Geels 2008). This allows participants to learn how the new infrastructure will play itself out in real-life applications: how it can be priced in the market; user's expectations, needs and reactions; technical issues and problems; the possibility of innovative services and design refinements; and unexpected side-effects. The notion of path dependency is also core to the strategic niche management approach (Hommels, Peters, and Bijker 2007), and experimentation in the niche is considered is "a method for constructing paths" towards sustainable infrastructures in the long run (Kemp, Rip, and Schot 2001).

A strategic niche experiment involves multiple parties from the public and private sectors, and also critically involves the participation and feedback of users. Strategic niche management tests the behavioral responses of users who show interest in sustainability and alternative forms of lifestyles to niche innovations (Von Hipple 1986).There has also been recognition of the active and transformative role of intermediaries that facilitate strategic niche experiments, including more careful examination of the intentionality of their actions and role (Howells 2006; Hodson and Marvin 2008; Randles and Mander 2011). Researchers have criticized the assumption that intermediaries must passively work with stakeholder relationships, citing evidence that intermediaries actively play a role in defining relationships (Medd and Marvin 2007). In particular, the role of intermediaries in shaping ICT, as well as the design of ICT itself, remains unexplored in the study of niches. The following sections demonstrate this gap in the SNM literature.

The development of new technologies in the strategic niche management approach depends on interaction between the niche level and the global level (F. Geels and Raven 2006). Each niche experiment focuses on lessons learnt from deploying technologies in real-world settings. The technology, meanwhile, is considered *unchangeable* within each niche. The knowledge gained from each niche interacts with knowledge at the global level, which includes scientific visions and advances; with time, the results from niches are incorporated in global level technology developments and technological innovations occur over the course of many niches. While black-boxing technologies in experimental niches might be appropriate for several infrastructure technologies (e.g. electric cars, water treatment, power-generation) which have relatively long development cycles, it cannot apply to information systems which have the potential to develop incrementally and rapidly (Kautz, Madsen et al. 2007) and are central to many sustainable infrastructure innovations today.

This neglect of an analysis of information technology design and development within niche experiments is evident both in theoretical and empirical studies. For example, (B Elzen, Hoogma, and Schot 1996) identify three factors relevant to the strength of a niche (shared expectations, social networks and learning mechanisms) which emphasize the social and technical regime and the

[2] Key analytical terms are in bold to aid reading.

necessity for learning, but which underemphasize the capacity for ICT innovation to impact the wider urban infrastructure. Even when ICT is considered in empirical studies, the focus is mostly on changes in user behavior around systems that are included in the niche, such as teleworking and teleshopping (Mokhtarian 2002).

Studies on experiments in sustainable mobility infrastructure, including those with electric vehicles in Germany from 1992-1996, Switzerland after 1995, and Norway after 1991, have 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, Orsato, and Kemp 2012). There is recognition that instead of just focusing on new car technologies, the development of "smart" mobility or use of supporting ICT products in cars and infrastructure, and changes in consumer behavior, present an alternate transition pathway to sustainable mobility, which can be regarded as a reconfiguration pathway (F. W. Geels and Schot 2007). However, exactly how the "smart" infrastructure is built is yet to be deeply considered. Thus the literature on strategic niche management reveals a gap in its examination of information systems design in niche experiments.

3 Theoretical Framework

The literature on strategic niche management has not effectively considered ICT. Yet information technology forms an important and highly dynamic component of the heterogeneous sociotechnical network involved in large-scale infrastructure innovation. This section proposes conceptualizing urban-scale ICTs as information infrastructures (IIs), followed by an explanation of why the theory of complex adaptive systems (CAS) provides an appropriate lens with which to analyse IIs.

Sustainable urban infrastructures such as the mobility infrastructure require integration across multiple industries and organizations, which have previously existed completely separately. Urban-scale integrated information systems are different from traditional IS in many ways. For example, ICT in the transport sector comprises a large number of interconnected and interdependent components, is spread across many corporations, which cannot be controlled centrally, is comprised of new and unstable technologies like electric cars and batteries, and does not have any standards for integrating these heterogeneous components.

Given these complexities, this paper believes that urban ICT systems should be conceptualized as information infrastructures (IIs). Considerable research has been undertaken on the innovation of information infrastructures (II) (Star and Ruhleder 1996; O Hanseth and Monteiro 1997; Turner et al. 2006; Gal, Lyytinen, and Yoo 2008; Ole Hanseth 2010) which are defined by the following features (Ole Hanseth and Monteiro 2008; Monteiro et al. 2012): Their components are **heterogeneous** including organizations, humans, technologies and institutions (Kling and Scacchi 1982; Edwards et al. 2007). Further they are recursively composed of other infrastructures and technological components, and from a social perspective, they are recursively organized because they are both the outcomes and conditions of design actions (Ole Hanseth and Lyytinen 2010).They are **open and shared** being built to serve a number of different enabling activities, and are not tailored to any one particular function (Ole Hanseth and Monteiro 2008).They are open to a diverse range of users, developers, vendors and components (Edwards et al. 2007). Components present a coherent whole through the use of standard interfaces and gateways (Ole Hanseth 2001; Edwards et al. 2007) among heterogeneous components. They have an **installed base** as they are built through incrementally adding new socio-technical components (Star and Ruhleder 1996) to an already existing infrastructure. Such "path dependency" (Bijker, Hughes, and Pinch 1987; Star and Ruhleder 1996; Porra 1999) implies that any new improvements must have backward compatibility with existing technology components, neighbouring infrastructures and user skills and learning (Grindley 1995; Star and

Ruhleder 1996; O Hanseth and Monteiro 1997; Porra 1999). Finally they are **dynamic**, borderless and constantly evolving both in terms of expansion and in terms of its user base (Star and Ruhleder 1996; Freeman 2007; Zimmerman 2007). As the number of users increases, network effects increase the value of the II (Katz and Shapiro 1986). Our aim is to understand II design within the strategic niche, an important phase in the development of the evolving II given the strong path dependency linking to the installed base and initial design. This requires choosing an appropriate theoretical lens. We believe complexity theory, in particular complex adaptive systems (CAS) provides such an analytical lens for our research.

Complexity theory examines complex networks of interdependent components, which interact based on a set of rules, producing an emergent order; it is thus highly relevant to the study of II development. It consists of a broad set of approaches that explain complex phenomena that cannot be explained by mechanistic theories, which assume a centralized governing structure (Cilliers 1998). In particular, a subset of complexity scholars (W B Arthur 1994; Holland 1995; Kauffman and Macready 1995) study heterogeneous agents and their interactions and feedback loops in theories such as Complex Adaptive Systems (CAS). This seems particularly suited to the challenge of researching how information infrastructure development may create order within the complex networks of interdependent components that is the SNE itself.

This study uses CAS to provide a lens for examining such emergent phenomena by analysing the interdependencies and interactions of diverse socio-technical components (Anderson 1999) of ICT development within SNEs. CAS is consistent with studies of the development of IIs. Indeed (Ole Hanseth and Lyytinen 2010) have used the theory within a set of prescriptive design principles for IIs, arguing: "CAS helps characterize how the IIs can be initiated and how they grow and evolve while they self-organize"(p.6).

CAS investigates non-linear systems in which autonomous agents use rules to interact with and adapt to each other's behaviours and environmental changes in parallel, and in the process become self-organizing (Holland 1995). The overall behaviour of the system is a result of these interactions, which leads to an emergent order whose nature is unpredictable (but not random). The emergence of orderly patterns of agent behaviours and system states illuminate causal pathways or path dependencies in the system. The defining features of CAS are nonlinearity, the emergence of order from complex interactions, the path dependency of system states, and unpredictable system outcomes (Dooley 1996; Ole Hanseth and Lyytinen 2010). Amongst IS scholars, (Benbya and McKelvey 2006) have used CAS to develop a theory of evolutionary information systems development, while (Nan 2011)has used it the theory to capture bottom-up IT use processes. CAS thus complements the theory of IIs by providing a fine-grained lens to "describe II evolution as an example of path-dependent and nonlinear change" (Ole Hanseth and Lyytinen 2010).

Within our CAS analysis we draw upon three key CAS constructs (which while not universally agreed upon models certainly reflect the agreement (Gell-Mann 1994; Nan 2011)):

Agents: individual actors who represent diverse socio-technical entities such as individuals, organizations, technologies, and standards and are defined by attributes and behavioural rules. Attributes are internal states, which can be fixed (such as race) or dynamic (such as knowledge). Behavioral rules are the schemata, which govern an agent's response to feedback from interactions with other agents and the environment in an attempt to improve their alignment in the system (Drazin and Sandelands 1992). Agents learn from successful behaviours and repeat them in future interactions (Holland 1995).

Interactions: Interactions are the mutually adaptive behaviours of agents. For example, (Miller and Page 2007) explore how interactions move an audience from applause to a few members standing in enthusiasm to a full standing ovation. Interactions are a function of agents, connections and flows. The connections between agents are dynamic relational links, which evolve as the attributes of agents change. Agents alter links in reaction to attribute changes in other agents because they have bounded rationality: they constantly react to local information, whose source is primarily other agents

(Anderson 1999). Interactions also include the flow of resources such as information and knowledge through the system (Holland 1995),which help promote order in a CAS.

Environment: The environment of a CAS is defined by the structures in which agents operate and interact (Epstein and Axtell 1996).The relationship between agents and the environment is mutual and structuring, in that structures themselves are also influenced by the interactions of agents.

These complex adaptive systems are seen to be self-organizing because no individual agent or group can determine the state of the system (Anderson 1999). Systems self-organize at the "edge of chaos", which occurs when systems are balanced between stability and chaos or when both positive and negative feedback enable agents to learn how to adapt (Gell-Mann 1994; Anderson 1999). Positive feedback affirms positive payoff to agents from a choice, whereas negative feedback shows the opposite. Agents make decisions and learn in response to the local feedback they receive from other agents and the environment. While observations appear as logical consequences of the actions and interactions of agents in an environment, the system's overall behaviour is often "unintended and unforeseeable" (Nan 2011). This emergent behaviour is not random, but a result of the selections each agent made from a finite set of perceived choices, and the history of the agent's past choices. This causal pathway illuminates the mechanisms of path-dependency in IIs.

Based on this theoretical framework our research question is thus: **how are IIs prototyped or designed in strategic niches?** In addressing this research question we employ an empirical study of a strategic niche.

4 Case Study

The empirical investigation comprises a single case study (Yin 2003) of the BeMobility project in Berlin, which is an experiment in developing sustainable urban mobility infrastructures. BeMobility reflects the German government's proactive attitude towards the electric mobility industry. Its aim is to demonstrate the viability of integrating electric car sharing into Berlin's public transport infrastructure. Over 32 public and private stakeholders (e.g. car companies, electricity-generators, component manufacturers, car-park operators, transport authorities, and research institutions) were provided a protected space to experiment with new technologies and urban-infrastructure integration. The project is led by one of Germany's largest railroad consortiums, and coordinated by an intermediary to demonstrate the feasibility of integrating mobility services (public transport, car sharing), electric vehicles (electric cars, pedelecs), infrastructure (charging stations, parking lots) and information systems.

The BeMobility Project was carried out over two phases (Sep 2009 – Dec 2011; Jan 2012 – Dec 2013). This research project follows the project over the years with research conducted on both Phase 1.0 and Phase 2.0, and research is expected to go on until June 2013. The primary ICT related project of 1.0 was the BeMobility Suite, which was a smart phone application that provided the user information about car locations, booking and availability. In Phase 2.0, the ICT ambitions of the project were extended to include an enhanced smart phone application; the creation of an integrated micro-smart grid which allowed control and management of energy usage; the creation of a car black box which provided data about car usage; and finally, simulations were conducted on mobility and energy usage at the city scale based on information and knowledge gathered in Phase 1.0.

5 Analysis

Data was collected from 18 members of the intermediary and at least one representative of each of the stakeholders in the project (covering both Phase 1 and Phase 2). In total, fifty-three semi-structured interviews were conducted and transcribed. Regarding document analysis, primary sources of documentation were used and so far a total of 200 documents were reviewed (including minutes from meetings, project plans and reports) to corroborate the information gathered in the interviews. The analysis was carried out by first coding the themes extracted from the interviews and documents, and informed by the theoretical framework of CAS. The aim of the analysis was to understand how the different components of the information infrastructures (IIs) are designed and in particular, to examine the influence of the intermediary in this process. We now outline the main findings and analysis of the data collected from the empirical investigation.

The Bounded Rationality of Each Participant Makes Traditional Design Processes Impossible: The BeMobility project had over 32 stakeholders, and each organization has its own ICT systems, several of which had to be integrated and expanded to develop the integrated mobility infrastructure. Thus the installed base of the sustainable mobility information infrastructure had multiple dynamic and uncontrollable systems. In such an eco-system of moving parts, which could change unpredictably, it was difficult to imagine a way to build from scratch or even to design from a top down centralized manner. Each partner was primarily concerned with the partners it was interfacing with on a regular basis and thus exhibiting bounded rationality even though it was the mandate of the project to infuse a sense of the "whole". As one interviewee stated: "*In a way it seems that they are all working together, but in fact, each system is only locally responding to the one it is immediately interacting with. There is no central agent that controls it*". In addition, each participant organization was primarily interested in using the project to increase its own "fitness" or to its own advantage. For example, the academic partners used the project as a lab to test their specific research questions, and were focused on the predictive effectiveness of their algorithms and largely unconcerned the larger vision of an urban mobility infrastructure.

Designing an II is difficult, heavily influenced by the installed base and the heterogeneity and dynamic interactivity of its socio-technical components (Ole Hanseth and Lyytinen 2010). In exploring the design of innovative transport infrastructure in the niche, we therefore observe the same necessity to reject traditional assumptions of functional goals, predefined contexts and predetermined developers and users as we do in II design (Ross and Schoman Jr 1977; Agresti 1986; Walls, Widmeyer, and Sawy 1992). We believe transport infrastructure innovation is, like II innovation, decentralised and drifting (Ciborra 1996; Orlikowski 1996), involving distributed control, coordination and design mechanisms (Star and Ruhleder 1996). For example, a range of BeMobility stakeholders made top-down design specifications challenging (as argued by (Edwards et al. 2007; Freeman 2007) for IIs).

The Intermediary Fills the Niche of Business Analyst in a Multi-Stakeholder Integration Project: The level of integration and interface development required in such a project raises the need of a boundary spanner or business analyst (Levina 2005), a common member of a the project team in technology projects, responsible for defining the requirements and translating the needs and vision of the business to the technical side. However, in this case, the particular niche that the business analyst usually fulfills was not specified in that way in the project. Instead work packages were designed in which several partners were to collaboratively come up with functional requirements and design for specific parts components of the II. Over the two phases of the project, we see that the intermediary began to increasingly mimic the behavior of a business analyst, even though it is initially viewed as a non-technical entity. In particular, we see that it begins to acquire more and more technical skills, both in terms of physically expanding its ICT team from a start of 2 to 8 and still increasing, and also in terms of the efforts made to understand the technologies and to speak a language that is technically sophisticated. This mimicry (Holland 1995) is one of the ways in which agents are often seen to take on characteristics that become advantageous to their status in an eco-system. Indeed, as the intermediary becomes more technically savvy, others in the eco-system begin to appreciate its input and rely on it for more intermediation. For example, the intermediary begins to offer ideas for technical solutions, and discussing and convincing other partners of them. From being involved in just one technical project in Phase 1, it is actively involved in several of the ICT projects in Phase 2 .

Interestingly, the intermediary begins to extend its holistic vision of the mobility infrastructure to a vision of the II architecture as well, with team members using more technical language and design metaphors in interviews. Over the course of the time this research was conducted, the intermediary representatives began to speak in far more technical terms and exhibiting a sophistication that was not there at the initial stage of the project. “We are not just integrating data like a software company. Our partners are not aware of the complexity gains from the overall integration between multiple partners, which need to be reduced.” (manager at the intermediary). By Phase 2, the intermediary is thus thinking much more in II design and architectural best practices rather than just brute integration of data streams, even though this language is not specifically used in interviews.

The Intermediary Influences the Development Environment by Defining the Future User: It is very difficult for anyone to control the different agents in a complex adaptive system like an information infrastructure (II). One way to influence the behaviour of agents is to alter the environment against which they function (Holland 1995). In the case of the BeMobility project, the different participants organize their system components and integration according to the functional requirements of the “lead users”, also known as pioneers who exhibit the behaviour of future consumers. In the BeMobility project, the task of defining the lead users was taken on by the intermediary, who not only conducted research on the behavioral patterns of future users who will respond positively to new innovations (von Hipple 1986), but after each development phase of the application, also analyzed usage patterns and quality assurance testing from the selected “lead users” or those users who had already shown an inclination towards “green” living and car-sharing. With this new information on future users, the project stakeholders begin to adapt their expectations and their design, and in this way, the intermediary exercised great influence on the design of the II without directly controlling the design processes in any centralized manner. After over one year of development, the BeMobility Suite was first made available in the app stores from Apple and Android in June 2011, and the integration of different components was largely based on the perceived needs of the users as forecasted by the intermediary.

This knowledge did not only affect the smart phone application, but had a ripple effect on other parts of the II as well. For example, the creation of the control and management systems for energy usage from the micro smart-grid was based on the knowledge garnered from the intermediary on consumer usage and behavioural patterns.

The Intermediary Uses the Nature of Data as a Lever to Influence the Shape of the II: The mobility II has many facets, but the intermediary was recognized the value of data and was particularly focused from the start on the release of data from different participants. This recognition of the flexibility and range of data streams and digital objects (Kallinikos, Aaltonen, and Marton 2010), and the pursuit of opening information for the II showed a consistent strategy by the intermediary to use the nature of digital objects as a lever to influence the shape of the II. A lever is any relatively small effort that can have a large influence on a CAS (Holland 1995); given the granularity, modularity and mutability of digital objects (Kallinikos, Aaltonen, and Marton 2010), multiple extensions and services built on the II would benefit from each data stream made available. Their editability, interactivity, openness and distributive nature enables digital objects to be easily assembled as and when needed in granular and modular form within applications. “Digital objects are no more than temporary assemblies made up of functions, information items or components spread over information infrastructures and the internet” (Kallinikos et al, 2010).

Extracting information streams in a multi-stakeholder projct is subject to many constraints, however, including corporate politics and suspicion. For example, the BeMobility Suite was initially unable to provide real-time information about the state of the car’s battery since the car manufacturers restricted access to data that resides in the car’s computer. *“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 data had to be sent to Japan and analysed there. We only got back summary data.”* (Car manufacturer representative).

Despite the intermediary's efforts, the car data was not available to the II in Phase 1. In Phase 2, the intermediary began working with another participant, a car parts manufacturer, to build a prototype of a car box that would gather data from the car, such as its acceleration, and send it to the mobility II. Thus the intermediary actively sought to create new avenues to extract and expand the data streams in the II, recognizing that data availability acts as a lever that has far reaching consequences in the II's effectiveness to streamline intermodal transport.

Such work-arounds are evident again and again as the intermediary tries to convince participants toshare data but in failing to do so, thinks of alternative ways in which data can be released. For example, the question of "who owns the consumer data?" is a contentious topic in any integrated service offering to a consumer. The intermediary was able to devise a solution in which company specific smart phone applications were able to hand off data to each other without accessing the servers and private consumer information of any particular company's customer. This solution was then given to the academic partner to code into software programs, and resulted in successful data integration which respected the concerns of the participating stakeholders. A manager of the intermediary commented that *"Even if we don't know the actual software code, we know how it works, and we can come up with solutions for problems"*, a sentiment that was echoed by one of the partners who agreed, *"Yes I would say that they are becoming technically more savvy between BeMobility 1.0 and 2.0."*

The Intermediary Uses Narratives as Tags to Signal the Shape of the II: As discussed, it was very difficult to have any centralized design process for the emerging II in the BeMobility project. Instead the II began to take shape as a result of dynamic interactions between the different participating organizations. We identified several ways in which the intermediary was able to influence the II design despite having started out as a non-technical entity. One other way in which the intermediary impacted the design was to present a strong narrative of the value and vision for the project. It was able to create this narrative as a social "tag" that acted as an aggregation tool for the partners who began to coalesce around it. (Holland 1995) calls "tags" actors or symbols that serve as a rallying point for agents. Examples include leaders with strong personalities, professional identities, and product names or narratives (Marion 1999). In the case of the BeMobility project, this vision was not only articulated in meetings with the stakeholders but also manifested in the physical EUREF campus where all the technologies were demonstrated and simulations were shown. The intermediary considered it as one of its main responsibilities and almost all the partners agreed that the EUREF campus was particularly conducive in helping them come together around one vision, a vision that was largely shaped by the intermediary as the administrator of the EUREF campus. Apart from the campus, the technical vision was also used to persuade resistant parties. For example, the intermediary made many high level presentations to the board of a large public railway consortium to convince it of the value of having an integrated smart mobility card, a vision that was ultimately accepted and successfully resulted in the creation of a 1 year test card.

6 Discussion

As a Strategic Niche Experiment, the objective of BeMobility was to innovate around electric car-sharing. The aim was thus to design a large-scale urban mobility infrastructure through a collaborative participative process involving a large range of agents (from electricity generators to individual users). Within this larger effort, ICT innovation was considered a key component of project success

Yet creating an information infrastructure (II) for this mobility infrastructure was a difficult process: multiple existing systems had to be integrated which required coordination and interfacing at several levels: technical, organizational, processes. The II was heavily influenced by the existing transport infrastructure installed base – indeed it *"used what they already had"* (project stakeholder) in terms of cars, sites and locations. This existing installed base was complex and dynamic: *"There are so many moving parts and each part of the bigger platform is a module that needs to be innovated on. We have operators, user interfaces (web and mobile), charging facilities, cars etc."* (quality assurance analyst).

This complexity was compounded by the challenges of new technologies, mutual suspicion and competition between several of the stakeholders, and the difficult of establishing communication between industrial silos where no standards currently exist.

Is it then possible to steer this transport II infrastructure growth such that strategic niche's may be better understood and (potentially) make improved policy decisions? We believe that exploring the role of the intermediary, which is traditionally known as a non-technical and neutral facilitator, can unveil successful efforts to shape II design. Over the 2.5 years that this research has followed this project, ICT has been developed and an architectural design for the II prototype has *emerged*. It was the aim of this study to understand the forces that influenced this emergent design, and the analysis showed that facilitation and therefore the intermediary was a key mechanism, which drove innovation in urban IIs forward. We saw that just as the vision for the mobility infrastructure was driven by the intermediary to some extent, the architecture for the overall mobility II was also indirectly, and increasingly directly, influenced by the project intermediary. The important role of facilitation in the technical design was a phenomenon that both the intermediary and partners did not realize or fully appreciate even as they acknowledged greater technical skills within and technical direction from the intermediary.

This research has shown that not only is facilitation critical in II design, but it that facilitation is also reinforcing: the more the intermediary facilitates innovation in ICT, the more building blocks are built that can be used in combination with other ICT components to create new innovative smart products. This idea of recombinant building blocks is one of the principles of CAS (Holland 1992; Holland 1995) and discussed as particularly well-suited to the discussion of modular technology components (W. Brian Arthur 2009; Yoo et al. 2012). Given the absence of standards at the beginning of the formation of an II, such as during a strategic niche experiment, the need for the intermediary to once again facilitate the design of this next generation of ICT products becomes necessary. This was evident from the creation of a smart mobility card, which integrated rail ticketing with car sharing booking on the strong advice of the intermediary. The intermediary then further mediated the addition of other services, like buses, into the smart card, thus extending the II even further.

It is important to note that this study does presumes neither neutrality nor bias on the part of the intermediary. The intermediary, like all the other stakeholders involved in building the II, acts in a way that optimizes its own position. However, it is the nature of the intermediary's mandate to facilitate an integration of the processes and systems of the different participants, and this study highlights the influence and value of intermediaries in shaping the II given this mandate. In the case of BeMobility, the interventions by the intermediary resulted in a positive expansion of the scope and reach of the II, and for the most part, the principles of good design as outlined by (Ole Hanseth and Lyytinen 2010) were followed; however, this may not always be the case and we urge further studies on the outcome of intermediary influence on II design.

In conclusion, our analysis shows that facilitation can be regarded as a key driver and cause of II's emergent design in a strategic niche.

7 Conclusions

This paper set out to show the importance of intermediaries and the use of complex adaptive systems (CAS) in better understanding and conceptualising the design of ICT systems in urban infrastructure prototyping. Using CAS will enable researchers, policy makers, and those engaged in SNEs to better understand the pivotal role ICT can play within urban infrastructure development. Indeed, as such infrastructure becomes increasingly "smart" with embedded computer systems into, for example home energy meters in national power-grid infrastructures, and computer controlled cars in transport infrastructures, the importance of ICTs in "Smart City" niche projects will proportionately increase.

The paper argued that ICT can be conceptualised as an information infrastructure (II) within urban infrastructures. Analytical constructs from II theory such as installed base of heterogenous components and "growth" were used to understand urban infrastructure innovation. By conceptualizing II as a CAS, it becomes possible to examine the forces that influence the growth of the II as multiple stakeholders come together to integrate their heterogeneous and dynamic processes and systems. Modelling strategic niches using these three constructs: agent, interaction and environment, provided a simple means of highlighting and modelling the potential impact intermediaries on the design of II prototypes. In conclusion this paper defines a gap and recommends deeper research into the influence of intermediaries on the design of information infrastructures (IIs). Conceptualizing these IIs as complex adaptive systems is an important first step in viewing the role of facilitation in design, and thereby underscoring the critical role of intermediaries in urban infrastructure innovation overall.

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