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Extending Digital Infrastructures: A Typology of Growth Tactics

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Abstract

Digital infrastructures enable delivery of information services in functional areas such as health, payment, and transportation by providing a sociotechnical foundation for partnership governance, resource reuse, and system integration. To effectively serve emerging possibilities and changing purposes, however, a key question concerns how an infrastructure can be extended to cater for future services in its functional area. In this paper, we approach such digital infrastructure growth as a challenge of aligning new partners whose digital capabilities spur innovative services that attract more users. We advance an initial typology that covers four growth tactics (i.e., adding services, inventing processes, opening identifiers, and providing interfaces) with the potential to set extension of infrastructures in motion. We then explore the proposed typology by investigating the ways in which its particular tactics successfully extended the scope of a digital infrastructure for public transportation in Stockholm, Sweden. Our insights invite IS scholars to engage more deeply in the development of growth tactics that achieve infrastructure extensions necessary for improving the durability of service delivery.

Keywords: Digital Infrastructures, Growth Tactics, Typology, Public Transportation.

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1 Introduction

Digital infrastructures provide an underlying sociotechnical foundation for information services in functional areas such as health, payment, and transportation (e.g., Hanseth & Lyytinen, 2010; Henfridsson & Bygstad, 2013; Tilson, Lyytinen, & Søørensen, 2010). As such, they govern collaboration between partners (Andersson, Lindgren, & Henfridsson, 2008; Malhotra, Gosain, & El Sawy, 2007), facilitate their reuse of common resources (Henfridsson & Bygstad, 2013; Lyytinen, Sørensen, & Tilson, 2018), and help to integrate heterogeneous systems (Lindgren et al. 2008; Saadatmand, Lindgren, & Schultze, 2017; Sahay, Monteiro, & Aanestad, 2009; Tilson et al., 2010). Hence, the viability of these infrastructures is key for service delivery in functional areas such as fleet management (Andersson et al., 2008), health (Sahay et al., 2009; Ure et al., 2009), telematics (Svahn, Mathiassen, & Lindgren, 2017), and traffic navigation (Lindgren et al., 2015).

Digital infrastructures have a long lifespan during which their environments change (Ciborra et al., 2000; Lyytinen et al., 2018; Silsand & Ellingsen, 2014). Such evolution of new service requirements means that it is challenging for any infrastructure to serve as a stable (yet flexible) sociotechnical foundation over time (Grisot, Hanseth, & Asmyr

Thorsen, 2014; Ribes & Finholt 2009). A digital infrastructure therefore needs to be dynamically adapted to better cater to the services its user groups demand (Hanseth et al., 2006; Rolland & Monteiro 2002; Silsand & Ellingsen, 2014; Tilson et al., 2010).

However, it is difficult to transform digital infrastructures in this way. Past research highlights the complexity that designers and managers alike face when assembling diverse actors, systems, and technologies (Ciborra et al., 2000; Grindley, 1995; Star & Ruhleder, 1995), and discusses the adverse implications for deliberate change interventions (Hanseth & Monteiro, 1997; Tilson et al., 2010). Not surprisingly, often relying on tenets of the complexity, network, or relational perspectives (Henfridsson and Bygstad, 2013), recent IS research has depicted the transformation of infrastructures as an evolutionary process being shaped by responses and adaptations to ever-changing environmental conditions (Edwards, Bowker, Jackson, & Williams, 2009; Grisot et al., 2014; Monteiro & Rolland 2012).

In this paper, we propose the notion of extensions to capture improvements in the scope of a digital infrastructure that can augment its ongoing adaptation. We define an extension of the scope of an infrastructure as an enhanced capacity to effectively serve emerging possibilities and changing purposes (cf. Agarwal & Tiwana, 2015). For example, an infrastructure characterized by inertia created by control mechanisms that are too tight (Ciborra et al., 2000; Constantinides & Barrett, 2014) often means that the adaptation dependent on contributions of multiple actors and technologies does not take off in the form of positive feedback loops and self-reinforcement (Hanseth & Lyytinen, 2010; Henfridsson & Bygstad, 2013). We surmise that in such situations, deliberate growth tactics for extending the scope of the infrastructure are necessary to overcome the impediments to its successful adaptation.

Accordingly, we address the following research question: *How can growth tactics help extend the scope of a digital infrastructure and thereby enable durable service delivery in its functional area?* By relying on an initial typology of growth tactics, we empirically investigate this question through the case of the city of Stockholm's digital infrastructure for public transportation. In short, over a 13-year period, four growth tactics were pursued for the purpose of continued delivery of relevant information services to its citizens. Our investigation of these deliberate interventions scrutinizes how each of them extended the scope of the infrastructure. Overall, we use this longitudinal case study to further develop our initial typological theorizing into a full-fledged typology[1] (Doty & Glick, 1994; Gregor, 2006; Rich, 1992) of growth tactics that can help shape the successful evolution of digital infrastructures.

The remainder of the paper is organized as follows. First, we explain the salient concepts around digital infrastructure evolution and introduce our initial typology of growth tactics. Second, we describe the research context, detail the study method, and explain the data collection and analysis. Third, in the findings section, we scrutinize four particular growth tactics and discuss how they extended the scope of the digital infrastructure under study. In the concluding sections, we synthesize our findings into a full-fledged typology of growth tactics, articulate research implications, and note the limitations of our study.

2 Conceptual Basis

To build digital infrastructures supportive of effective service delivery is tricky in the first place (Hanseth et al., 2006; Star & Ruhleder 1995); maintaining their relevance over time, however, often proves to be even more challenging for most stakeholders (Grisot et al., 2014; Monteiro, Pollock, Hanseth, & Williams, 2013). While the topic of bringing infrastructures into existence is a well-researched subject (e.g., Hanseth & Lyytinen, 2010; Ribes & Finholt, 2009), much less is known about the sociotechnical means that help them to continuously grow and thereby evolve successfully over time (Henfridsson & Bygstad, 2013).

In what follows, we review the available literature on the evolution of digital infrastructures and propose an initial typology that covers tactics suitable for achieving extensions to the existing functional scope of such infrastructures. In addition to identifying these tactics, we theorize about architectural and organizational control, respectively, to shape the contours of our empirical investigation of infrastructure evolution in the Stockholm public transportation setting.

2.1 Digital Infrastructures

In 2000, Ciborra and others popularized the idea that the evolution of large-scale systems such as infrastructures[2] is a complex process beyond rational managerial control (Ciborra et al., 2000). Information systems scholars have since spent considerable effort trying to explicate the very nature of this complexity,

[1] Gregor (2006) argues that the term typology is often used more or less synonymously for taxonomy and classifications in IS research.

[2] While notions such as digital infrastructure, information infrastructure, and IT infrastructure are often used interchangeably in IS research, we adopt the concept digital infrastructure as proposed by Tilson et al. (2010).

and their resulting theorizing can be categorized into three streams of research (Henfridsson & Bygstad, 2013). The network view (see e.g., Aanestad & Blegind Jensen 2011; Hanseth & Monteiro, 1997; Yoo, Lyytinen, & Yang, 2005), reflective of Callon's (1986) and Latour's (1987) early actor-network thinking, defines infrastructure evolution as "the process by which multiple human actors translate and inscribe their interests into a technology, creating an evolving network of human and nonhuman actors" (Henfridsson & Bygstad, 2013, p. 910). Hence, for a designer or policy maker, shaping the evolution of a digital infrastructure is about facilitating translation of stakeholder interests into technology inscriptions. Similarly, the complexity view (see e.g., Braa, Hanseth, Heywood, Mohammed, & Shaw, 2007; Hanseth, Jacucci, Grisot, & Aanestad, 2006) zooms in on the adaptation processes of heterogeneous actors and effective ways of enabling them. At the heart of the relational view, is an examination of how meaning-making can be strengthened within a community of practice (see e.g., Pipek & Wulff, 2009; Vaast & Walsham, 2009). According to this perspective, IT-mediated activities are key to the processes responsible for the emergence of sociotechnical relationships (Star & Ruhleder, 1996; Pipek & Wulf, 2009).

As noted above, past research has treated the idea of effectively intervening in infrastructure evolution with harsh skepticism (see e.g., Ciborra et al., 2000). Still, some ways of doing so have been recently proposed. For example, Hanseth and Lyytinen (2010) conceptualize a bootstrapping process through which an infrastructure evolves step-by-step, with additional steps capitalizing on the momentum created by previous ones—i.e., exhibiting the idea of positive self-reinforcement. In this vein, Hanseth and Lyytinen advance design principles that seek to generate early growth, including: (1) designing initially for usefulness; (2) building upon existing installed bases; (3) expanding the installed base by persuasive tactics to gain momentum; (4) making the design of IT capabilities as simple as possible; and (5) modularizing the architecture of a digital infrastructure.

These design principles seem to invite further thinking about ways to continuously grow a digital infrastructure, and hence, ensure that it evolves dynamically over time. Inspired by the works of Hanseth and Lyytinen (2010) and other infrastructure researchers in IS, we next build an initial typology that covers four growth tactics, each of which offers a particular approach to extending the scope of a digital infrastructure. We then complement this theorizing by explicating how the notions of architectural and organizational control can help refine our theoretical and empirical insights into a full-fledged typology of infrastructure growth.

2.2 Towards a Typology of Growth Tactics

The main argument of this paper is that growth tactics for extending the scope of a digital infrastructure are necessary to augment its adaptation to evolving user requirements (Henfridsson & Lindgren, 2005; Henfridsson & Lindgren, 2010). At the heart of such an evolutionary perspective (see e.g., Agarwal and Tiwana, 2015) is the idea that successful infrastructures are the most adaptive ones (rather than the largest or strongest (cf. Lindgren, Hardless, Pessi, & Nuldén, 2002)—i.e., these adaptive infrastructures have the capacity to anticipate and embrace the future (Hanseth et al. 2006; Hanseth & Lyytinen 2010). For us, adaptation improves an infrastructure's fit with an evolving environment by extending its functional scope to effectively serve emerging possibilities and changing purposes (cf. Agarwal & Tiwana, 2015). Indeed, for many stakeholders who invest in digital infrastructures, building such a capability is an urgent and hence worthwhile task that can provide concrete tactics for extending infrastructures in areas of future growth.

Based on our literature review, we advance an initial typology that covers four growth tactics with the potential to set the extension of digital infrastructures in motion. First, *adding services* to a digital infrastructure can help to increase actors' willingness to actively take part in its evolution over time. For example, as Tyre and Orlikowski (1994) argue, the introduction of new IT functionality creates windows of opportunity, which opens an infrastructure to influences from both internal and external forces, potentially igniting user excitement and promoting further emergence of effective service design and diffusion processes. Such functionalities are engineered artifacts and each function is capable of performing a set of actions automatically or interactively on a computational object or process (Hanseth & Lyytinen, 2010). While such functionalities offer the potential right for users or user communities to benefit from a digital infrastructure, their utilization must be defined and managed by a single designer or a small group of designers responsible for their local evolution.

Second, *inventing processes* can help to scale up activities that enable a digital infrastructure to reach a maturity level necessary for its continued growth and evolution. Such processes allow for complex coordination among individuals and groups, as well as between efforts, to spur infrastructure adoption or to implement alternative infrastructural solutions (Hanseth & Lyytinen, 2010). As such, they can embed novel control structures capable of significantly shaping the evolution of a digital infrastructure (Henfridsson & Bygstad, 2013). While these structures may offer appropriate means to increase the flexibility of an infrastructure to leverage its scalability, they also provide the organizational glue that binds together diverse sociotechnical elements and their inputs/outputs in predictable ways. Hence, processes are key to balance flexibility and stability as two contradictory goals of evolving a digital infrastructure (Feldman & Pentland, 2003; Tilson et al., 2010).

Third, *opening identifiers* offer a means of standardizing classifications and uses of names for objects that identify salient things in a functional area (e.g., locations in public transportation). Such structural change of already institutionalized objects represents a significant event in the creation of a digital infrastructure, which can significantly shape its future evolution (Eriksson & Ågerfalk, 2010). For example, given that this process opens up new reference points for meaning-making, some infrastructure modifications are promoted, while others are not. In this regard, opening identifiers can work as a tactic for growing a digital infrastructure by extending its functional scope. To avoid identification mistakes and classification errors, however, these identifiers must be both flexible and stable in their application across different contexts (Eriksson & Ågerfalk, 2010; Hanseth & Lyytinen, 2010).

Fourth, *providing interfaces* can help leverage service innovation and heterogeneous participation (Eaton, Elaluf-Calderwood, Sørensen, & Yoo, 2015; Ghazawneh & Henfridsson, 2013; Saadatmand et al., 2017), and thereby increase the functional scope of a digital infrastructure. In most situations, these interfaces represent a growth tactic featuring tight architectural control, while the organizational control is relatively decentralized. As such, these interfaces offer an approach to resourcing an infrastructure by allowing different actors to participate in and contribute to its evolution (Ghazawneh & Henfridsson, 2013). While these interfaces are usually implemented through a variety of technologies, such as XML and APIs, they force developers to format their input and output parameters so that services can send data to and receive data from heterogeneous components of an infrastructure (Andersson et al. 2008). In this way, they allow the infrastructure provider to maintain control over its services, but at the same time they spur additional contributions from third-party players (Ghazawneh & Henfridsson, 2013; Saadatmand et al., 2017).

Manifested through deliberate interventions to evolve digital infrastructures, these growth tactics reside within a particular sociotechnical network of actors, and they are often difficult to imitate. At a general level, they can be viewed as organizational behaviors and technological practices that underlie the ongoing governance to exert control over infrastructure growth. From an evolutionary standpoint (Agarwal & Tiwana, 2015; Tilson et al., 2010), however, there are few IS studies of practical attempts to achieve adaptive digital infrastructures by pursuing these different tactics. Even less attention has been devoted to the individual capacity of these tactics to specifically extend the functional scope of an infrastructure and hence enhance its fit with emerging service requirements in a changing environment. Nevertheless, there is some relevant work on digital infrastructures that differentiate different aspects of control, thus allowing us to elaborate the tactics further through our case study research.

Consistent with typological research (Doty & Glick, 1994; Gregor 2006; Rich, 1992), we take inspiration from Henfridsson and Bygstad (2013) to articulate our key theoretical dimensions; namely, a social dimension (decentralized vs. centralized organizational control) and a technical one (loose vs. tight architectural control), which together offer a sensitizing device for exploring what adaptations stakeholders can make to a digital infrastructure and its control structure to accomplish extensions over time. First, the organizational control dimension varies along a continuum from centralized to decentralized forms (see e.g., Broadbent & Weill, 1997; Ciborra et al., 2000; Rolland & Monteiro, 2002; Tilson et al., 2010). The former forms of control involve the ambition to shape the evolution of an infrastructure through a singular point of control, which is usually the approach taken in situations where its original implementation was initiated by a single strong actor. In contrast, the latter forms of control typically exist in the context of large-scale infrastructural systems comprised of multiple stakeholders (Aanestad & Blegind Jensen, 2011).

Second, the architectural control dimension operates along a continuum ranging from loose to tight coupling between the components of a digital infrastructure (Henfridsson & Bygstad, 2013). Essentially, it concerns an infrastructure's ability to afford further development based on already existing architectural components without exercising any direct influence on their inherent operations (Elaluf-Calderwood, Herzhoff, Sørensen, & Eaton, 2011; Hanseth & Lyytinen 2010; Tilson et al., 2010). One way to achieve this is to decrease the coupling between components by modularizing them (Baldwin & Clark, 2000, Henfridsson & Bygstad, 2013), which in turn caters to different degrees of architectural control. For example, an infrastructure may encapsulate and make available some of its components to integrating partners to reduce the coordination burden. Alternatively, it may provide standardized interfaces to previously well-hidden components, thus allowing for novel utilization of infrastructural resources (Saadatmand et al., 2017).

These two control dimensions have been separated in previous IS studies of digital infrastructure evolution. In our quest to develop a full-fledged typology of growth tactics, we seek to marry them to highlight strategic actions of heterogeneous actors and their preferences on modes of control. We consider each of the four growth tactics as a fundamental archetype with a unique combination of the control dimensions that we believe will determine the adaptation outcomes. Following is an explication of how we investigated the ways in which these tactics successfully extended the scope of the city of Stockholm's digital infrastructure for public transportation.

3 Research Method

There were two particular reasons behind our selection of Stockholm's digital infrastructure for public transportation as the case study setting. First, because of its leading position in public transportation in general, Stockholm has launched a number of change initiatives supporting the growth of infrastructure. As manifestations of different growth tactics, these initiatives included, among others, application programming interfaces (APIs), service innovation contests as well as open data standards. The growth tactics took off, with apparent positive impacts, and hence we gradually realized that the case would make a suitable venue for our research efforts. Indeed, when building typological theory, it is useful to examine an empirical situation that can be considered to be prototypical or paradigmatic of the phenomenon of interest (Doty & Glick, 1994; Rich, 1992). Given our ambition to develop a typology that covers ideal types of growth tactics, we reasoned that selecting Stockholm's digital infrastructure would allow us to empirically verify our initial typological theorizing.

Second, rich and longitudinal data was essential for us to trace and theorize underlying control dimensions (i.e., organizational and architectural respectively) that could potentially explain the events that extended the digital infrastructure and hence promoted its growth. We had useful access to a significant number of respondents who had firsthand experience of the different growth tactics as well as other data sources related to the evolving infrastructure. This condition for our data collection meant that we expected to generate enough empirical material for generating meaningful new theoretical insights into the growth tactics under study. Indeed, typological theorizing is a data-intensive endeavor (Doty & Glick, 1994; Rich, 1992).

3.1 Data Collection

We conducted our data collection over a four-year period (spring 2013–fall 2017) and centered it around several data sources, including semistructured interviews, participant observation, and archival studies. First, as our premier empirical source, we conducted 24 semistructured interviews with 23 respondents. We interviewed four senior managers at the Swedish Road Administration, two research institute directors, an innovation manager at a vehicle manufacturer, a manager at the city of Stockholm's transportation office, an IT project manager at Stockholm Public Transportation Company (two interviews in total), two technical project managers at a Gothenburg transport company, one innovation manager from the Swedish Transport Association (two interviews in total), a manger in Intelligent Transport Systems (ITS), one public transport analyst, an administrator of projects related to transportation at the Swedish Innovation Agency, a third-party developer of an iPhone travel application, four third-party developers (from the team that won an innovation contest in 2010), and four public transportation researchers. All these respondents had been actively involved in the development of Stockholm's digital infrastructure for public transportation in one capacity or another.

The overall focus of the interviews was directed towards growth tactics for digital infrastructures and their individual capabilities to extend the functional scope of an infrastructure to promote its continued evolution. More specifically, we invited the interviewees to detail their insights about the antecedents, actions, interventions, and outcomes that characterized the execution of the tactics they had been involved with. Our follow-up questions generally dealt with how these individuals perceived the transformational effects of the efforts that were undertaken to make the digital infrastructure grow over time. The interviews were audio-recorded and subsequently transcribed to facilitate our data analysis.

Second, we also engaged in intermittent participant observation during the second half of the study period to complement the interview data. Two authors of this paper spent 24 and 34 hours respectively to observe meetings and workshops related to third-party development platforms, innovation contests, projects in sustainable everyday traveling, and the future of public transportation. Third, we conducted a search for public transportation apps that were available in the Stockholm area. Our investigation into the application marketplaces of the three leading operating systems (iOS, Android, and Windows Phone) yielded 35 travel-planning and real-time apps in total.

Fourth, our study included a significant volume of archival data including company and project reports, press clippings, and online data resources. One significant type of such data was reports written by consultancy firms and research institutes that had participated in projects focused on building and maintaining Stockholm's digital infrastructure for public transportation. As such, these reports helped us identify change motives, review design visions, verify key events, and asses the outcomes of the infrastructure growth process.

3.2 Data Analysis

Consistent with typological theorizing (Doty & Glick, 1994; Rich, 1992), we carried out three distinct steps to develop a robust classification of growth types. In the first step, we identified four growth tactics from extant infrastructure research to build an initial theoretical platform for our typological theorizing. To develop our emerging typology further, we identified two distinct dimensions of control (organizational and architectural respectively) (Henfridsson & Bygstad, 2013) that could help us to be more specific in discriminating each ideal type of growth tactic. Inspired by Henfridsson and Bygstad (2013), our theoretical assertion here was that growth tactics have a social and technical side to them and that the implementation of a particular tactic depends on a specific combination of organizational and architectural control dimensions.

In the second step, we investigated the empirical basis of the identified growth tactics by investigating the evolution of Stockholm's digital infrastructure for public transformation. In particular, we relied on retrospective data to devise a chronology of the case over the 13-year study period (2000–2014). We carefully analyzed antecedents, interventions, and outcomes to develop more detailed insights into how and why certain actions played out. This provided us with a thorough understanding of conditions, behaviors, and consequences within the context of each individual tactic (see Figure 1). An important part of this was to scrutinize how involved actors had pursued interventions to extend the functional scope of the infrastructure. Based on this rich display, we were able to not only assert the existence of the a priori identified tactics, but also explore their capacity to accelerate the infrastructure growth process.

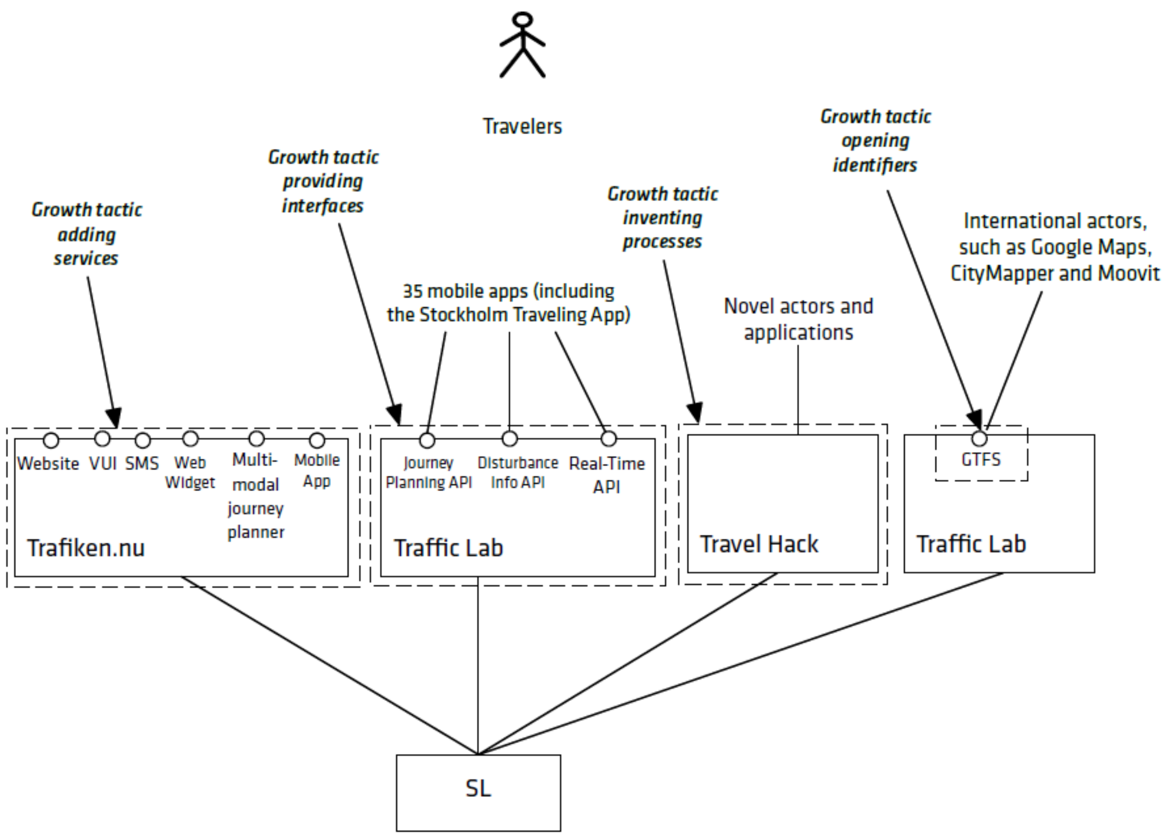

Figure 1. Sequence of Tactics to Grow the Digital Infrastructure

In the third stage, with the ambition to substantiate our typology, we further refined each growth tactic, debated their individual merits, and derived theoretical implications. This analytic procedure was repeated until we agreed that the resulting typology captured four distinct growth tactics, each embodying a particular configuration of control dimensions. Indeed, throughout our process of typological theorizing, we constantly challenged our emergent understanding of intermediate versions vis-à-vis other plausible tactics.

4 Results

Stockholm is a growing city that was recently ranked fifth among the most congested cities in Western Europe. Given that the population is estimated to increase by 25% in the next 15 years, newfound technological options (e.g., travel planning systems and real-time traffic services enabled by open data and interfaces) have been exploited to leverage digital infrastructure for public transportation. Indeed, changing contextual conditions have further spurred the continued evolution of the digital infrastructure. While citizens' rapid uptake of smartphones offered an for easy and effective means to access the digital infrastructure, the Swedish public transportation market was deregulated in 2012 to enable public-private collaboration. In what follows, we analyze four specific growth tactics that were executed over a 13-year period (2000–2014) to extend the scope of the infrastructure and to thereby make public transportation more effective and attractive to its users (see Table 1).

Table 1. Digital Infrastructure Extension: Overview of Antecedents, Interventions, and Outcomes

	Antecedents	Interventions	Outcomes
Adding services: Trafiken.nu	A sense of urgency to respond to the demand for information services in public transportation coupled with a strong belief that a service platform would stimulate interactivity among key actors.	This tactic was a concerted effort from Stockholm's traffic agencies to stay responsive to travelers' service preferences. To achieve this, the architecture of the shared platform required data to be decoupled from its origin and integrated into a common data model. Given this foundation, the platform was able to leverage innovative service development.	A range of new services to end users was developed, including a common website, SMS services, integration with newspapers' websites, and a multimodal smartphone travel planner.
Providing interfaces: External application programming interfaces (APIs)	Unsanctioned service development (i.e., scraping) by third-party developers caused problems, which highlighted the limits of the current traffic data control strategy and the need for a new one.	This tactic sought to allow external developers to extend SL's services to novel user contexts. The architecture sought to regain control of data delivery to third-party actors by intentionally lowering extant barriers to infrastructure access.	Increased number of third-party developers who used the APIs in new contexts. In August 2013, Traffic Lab had more than 1700 registered users and 35 externally developed smartphone apps (streaming real-time data from SL's APIs) were available for download.
Inventing processes: Travel hack	Readiness among actors to establish a new pathway for distributed service innovation.	This tactic was initiated, designed, and orchestrated as an innovation contest to encourage third-parties to develop new digital services for sustainable everyday travel. The new development process was enabled by specific resources such as personas, APIs, and prototype assessment metrics.	Development of 20 prototypes (15 of which were smart phone applications) supporting sustainable everyday travel, which involved new partners from outside the public transportation sector.
Opening identifiers: General transit feed specification (GTFS)	Incorporating new actors such as Google into service development required an adapted interpretation of what characterized the best travel option in public transportation.	This tactic was implemented to allow decentralized utilization of public transportation data (e.g., alternative travel routing options). Following the GTFS standard, the architecture decoupled travel planning algorithms from underlying network data, which enabled service development to go beyond SL's extant travel planning algorithm.	Partnerships with international players such as Google, City Mapper, and Moovit rendered more advanced travel services. These services broadened the scope of past domestic digital innovations.

4.1 Adding Services: Trafiken.nu

In the late 1990's, given the urgency to improve the utilization of the road system, the city of Stockholm, Stockholm Public Transport Company (SL), and the Traffic Administration introduced a framework for collaboration, which sought to specifically reinforce the exchange of traffic data between transportation actors.

This was a manifestation of their shared willingness to break with the institutionalized tradition to diffuse such data in silos and to build a digital infrastructure that would benefit public transportation at large. Recognizing the inherent potential of the ongoing industry digitalization, these actors envisioned an increasingly integrated transportation system that could offer services that fulfilled traveler expectations.

The launch of the service platform "Trafiken.nu" in October 2000 was the first concerted effort to enable travelers to plan their journeys using real-time information. As a result, a new breed of multimodal travel planning services generated considerable attention in the Stockholm area. These services were dependent on data exchange between transportation authorities and private organizations, which was explained by a transport researcher:

> *The new services were products of political confidence in and enthusiasm about emerging technologies combined with the Internet's capabilities to influence and shape public transportation demands . . . it also fulfilled a pressing need for an integrated and effective channel to provide traffic information to citizens.*

As a sophisticated service platform, Trafiken.nu was built upon novel architectural principles that conveyed the idea of providing everyday travelers with a unified view of the transportation situation. This required that the platform was fed by data from a variety of data sources provided by its member organizations. Indeed, the assemblage of high-speed Internet, intelligent cell phones, and ubiquitous sensors created a technological foundation capable of collecting, integrating, and providing traffic information requested by travelers.

Some four years later, Info24, a commercial data broker, engaged with Trafiken.nu to exchange transportation data. In short, this collaboration implied that the data broker provided traffic flow data from commercial road carriers and got traffic data from Trafiken.nu in return. With such a win-win deal in place, Info24 soon discovered the possibility of expanding the digital infrastructure further by instigating cooperation with media actors (e.g., newspapers, television), which led to an increased interest in services offered via Trafiken.nu.

Overall, Trafiken.nu was seen by many as a digital innovation, in that it gave travelers a dynamic picture of public transportation disturbances, parking space availability, traffic flow, and construction delays. The service platform, however, was still unable to provide travel-planning capabilities that covered different travel modes. To leverage the development of services embedding such functionality, it was deemed necessary to implement additional features such as automated speech response and SMS-based communication. This decision to extend the capacity of Trafiken.nu had a significant impact and its number of visitors kept rising beyond what was anticipated (exceeding 7.2 million in early 2008).

However, new requirements related to changing use patterns of cell phones, indicated that the service platform had not kept pace with the rapid digitalization of public transportation. In particular, everyday travelers increasingly sought to receive real-time transportation information in a mobile format. In an attempt to fill this gap, a new multimodal travel planner was launched in February 2009. It was generally well-received because its users could compare cost, environmental impact, and journey times across both private and public travel modes. Still this service failed to attract those users who preferred smart phone–based access to travel information. As a result, in 2011, the service owners provided a mobile version of the service called the "Travel Planner," with the immediate effect of user searches increasing four times over, but because of competition from other user-oriented travel applications (e.g., available via Apple's app store) its diffusion was limited. While the Travel Planner service was an indication of an increasingly viable digital infrastructure for public transportation, representatives of the organizations promoting Trafiken.nu still felt they had not taken shifting user behaviors seriously enough.

4.2 Providing Interfaces: APIs

In any case, it did not take long before the travel planning service provided by Trafiken.nu had sparked interest even outside the realm of Stockholm's transportation authorities. In fact, relying on scraping technology there were several independent third-party developers who exploited this newfound functionality to develop and diffuse unsanctioned smart phone applications. The most popular one, the "Stockholm Traveling App," was the result of an unpaid student project and had over a million downloads. According to the student leading the project, it was driven entirely by a motivation to develop a useful app that could fill a void experienced by fellow travelers:

> *It all started off as a true hobby project . . . and because I had the necessary technology and was eager to learn app development, I simply created the service I wanted to have, which at the time didn't exist out there.*

However, these illegitimate development practices caused problems for SL, including a fatal server overload. One of the staff members who resolved the server issue explained:

> *We've observed that developers were actually screen scraping our sites to gather the information and timetables necessary for building new mobile apps. This was something we hadn't experienced before . . . public transportation organizations like ours have traditionally owned and controlled such information and kept it as an integral part of their service innovation.*

> *These third-party apps, however, quickly turned out to be quite popular with the public and people increasingly rely on them.*

Apparently, SL was caught in the conflicted middle and it faced a delicate dilemma. Either it could seek to adjust third-party development through legal action and hence exclude popular and useful services, or it could continue to allow third-party development that potentially would extend the service portfolio but at the same time compromise its influence over development practices. The head of Internet Services at SL commented on this situation:

> *A decrease in the number of visitors of our own websites would lead to concerns internally . . . simply because we've always strived towards getting more attention. It acknowledges that we're doing the right things and hence it gives us better opportunities to influence people to do their traveling with us. But when smartphone usage exploded, we started to notice that people really liked those unsanctioned apps and that we had limited resources for development. We eventually understood that we didn't have the budget or manpower to serve our customers . . . this meant we started to shift our mindset and appreciated these third-party developers as complementors rather than competitors. In fact, there're a number of solid arguments that suggest we should support such development rather than work against it.*

Together with other data owners, SL thus instigated an effort to learn more about digital innovation and appropriate strategies for data sharing. As a result, SL created an innovation platform called "Traffic Lab" in September 2011. To maintain consistency with SLs existing service offerings, the resources made available (journey planning, disturbance information, and real-time information) mirrored the functions on SL's website. Since SL sought to have the APIs accepted among developers, much effort was devoted to keeping the log-in process to a minimum, requiring only a verified email address and the acceptance of a click-wrap contract. In addition, the APIs were redesigned to convey data over the developer-friendly protocol REST and API parameters were reduced to a minimum.

Collaborators expected that the platform would help them capitalize on the emerging idea of open data release to successfully support third-party development. Traffic Lab assembled actors beyond SL, like the Swedish Association for Public Transportation Companies, and as such it provided a structure for cultivating an ecosystem comprised of actors who would secure the development of novel services tailored to traveler needs. The innovation manager at Traffic Lab was very pleased with the industry initiative:

> *It was an opportunity for the industry to start dealing with open data and open APIs in a more systematic way. We wanted to make data access simple and stimulate industry actors and third- party developers alike to have fun and enjoy the novel development opportunities afforded by the platform. It was key to keep this industry initiative together via one sophisticated site serving as a nexus instead of letting each public transportation entity creating its own channel to handle data sources, developer agreements, and development APIs.*

The developer platform, which hosted 26 different APIs from 12 different suppliers, including data owners from both the public and private sector, turned out to be a success. The Traffic Lab initiative also sought to influence information providers to go beyond conventional transport data, and therefore triggered its members to innovate their collaboration with third-party developers by offering them free use of APIs with limited restrictions. Because of this strategy Traffic Lab enjoyed a number of incentives in 2011–2012, which elevated its generative capability to shape innovative digital service development in the public transportation sector. By fall 2013, it had gained momentum among developers, boasting some 1700 were registered users and 35 third-party applications available in smartphone app stores that were mostly based on SL public transportation information.

4.3 Inventing Processes: Travel Hack

The success of Traffic Lab primed the participating actors to push forward and create even better conditions for the continued growth of third-party apps. With the overarching strategy firmly established it was deemed important to create new organizational processes that could bind together in predictable ways the heterogeneous sociotechnical elements and inputs during such distributed development. One such routine that Traffic Lab invented was prize-centric innovation competitions. In short, originating from a general-purpose hackathon held a couple of years earlier in Stockholm, the idea was to host events where data publishers presented their current APIs in a systematic way to participating contestants. The fact that the team that won this previous event was actually innovating based on public transportation data meant a lot to SL and the other members of Traffic Lab. The leader of the winning team said:

> *We actually got interested when SL talked about the open APIs that were emerging in the public transportation sector . . . we*

were simply keen to try them out and to see what that could possibly lead to. But it was unfortunate that we couldn't get access to vehicle positions. Their coordinates were simply not accessible. Still we decided to deploy the APIs and by relying on the real-time data available (mostly about delays) we could at least roughly calculate the position of a vehicle between predefined stops. Though we didn't have great ideas when we came here, we were soon inspired and educated by those people who engage professionally with travel planning. Especially their presentations that kicked off the event really energized us and shaped our design thinking.

Indeed, the winning app was seen by public transportation actors, SL in particular, as a tangible manifestation of the new service development logic that they all were seeking. Not surprisingly, given its innovative approach to exploiting public transportation data, the development team received considerable media attention that ultimately paved the way for similar future hacker events.

Relying on its new organizational process, Traffic Lab orchestrated a first dedicated publication transportation event, called "West-Coast Travel Hack," in October 2011. The rationale behind the event was to influence a shift to more sustainable ways of traveling (e.g., from car to public transport), and the team that developed the most innovative, best implemented, and most impactful service prototype was rewarded for its achievement (the participating teams competed for awards exceeding €10,000). During the event, nine data providers featured 19 APIs that contained public transportation data, environmental data, and data about commuting, disruptions, and ridesharing. By supplying the developing teams with instructional resources such as personas and predefined APIs, the organizers were able to exercise some control over the process while also allowing exploration. All in all, the 76 developers yielded 20 prototypes, 15 of which were smartphone apps. Winners and runner-ups were chosen by a jury comprised of professionals with different backgrounds—two representatives from the public transportation sector, one governmental open-data civil servant, and one business angel. The overall winner created a smartphone app that embodied gamification principles to present sustainable travel choices. The first runner-up integrated public transport information into a property listing website as a means of influencing potential property buyers to consider public transportation as a factor in relocation decisions. The second runner-up created an open API to collect crowdsourced disturbance information.

A contributing factor to the success of the event was that it attracted new partners beyond the transportation sector to embrace the idea of opening up previously controlled and protected data. Indeed, the cross-fertilization of perspectives made it easier for different stakeholders to converge and cocreate novel public transportation solutions enabled by digital technology. The research institute director responsible for the "Smart City" initiative in Stockholm was excited about what the event had rendered:

The Travel Hack contest increased the awareness of all the actors within the public transportation sector in terms of how to provide and leverage open data in a coherent and stimulating way. I also think it has been a key element in kick-starting service innovation within transport in general.

Accordingly, the event was repeated in early 2013. In addition, representatives from Traffic Lab made frequent visits to other similar contests related to digital innovation as a means of attracting an even wider range of actors who could dive in and innovate with open data. These efforts turned out to be successful and led to development events that further shaped the idea of structured data-driven innovation in the public transportation sector.

4.4 Opening Identifiers: GTFS

Having assembled most prominent public transportation actors in Sweden, Traffic Lab was determined to expand its reach in order to also incorporate international counterparts, and in early 2012 Google approached Traffic Lab. At this point, Google Maps had become widely popularity, in part because of its sophisticated routing service functionality, which allowed travelers to find the best possible route, irrespective of modes of transportation (e.g., walking, car, bicycling). For this service to also present public transport options, it was dependent on transport authorities supplying traffic data in accordance with the "general transit feed specification" (GTFS). The innovation manager at Traffic Lab commented on this requirement:

What we could offer in terms of APIs and other stuff simply didn't satisfy Google. They had already thought things through and that was manifested through its own algorithm for travel planning. What Google wanted was clearly specified and this GFTS format was at the heart of its approach.

The APIs provided via Traffic Lab were essentially extending the journey planning service functionality through boundary resources. As such, the APIs that could be useful for Google were based on the journey planning service that was used to provide travelers with transportation information (e.g., the official web page). Hence, to use this API, a developer was supposed to supply the service with the origin, destination, time of departure/arrival along with other optional preferences (such as accessibility requirements). Based on these parameters, the API returned candidate journeys comprised of one or more public transportation trips that were complemented with suggested walking directions to and from included stops.

In contrast, GTFS relied on architectural principles where the journey planning algorithm and the underlying data about the public transportation network (e.g. stops, routes and timetables) were decoupled. GTFS prescribed how core public transportation objects should be represented and published. Using this data, the developer subsequently needed to use the journey planning algorithm of choice to produce suitable candidate journeys. Given this more modular structure, it allowed for developers to enjoy a higher degree of flexibility. While the architectural principles of GTFS invited the use of different routing algorithms, public transportation could also be easily combined with other modes of transportation (e.g., cycling, walking, ride-hailing services).

The transition from its existing APIs to an open data logic that would accommodate GTFS turned out to be more demanding than Traffic Lab had expected. In particular SL was concerned because it had to rewrite its set of institutionalized identifiers and ultimately rethink the current approach to controlling its routing algorithm. The innovation manager at Traffic Lab, however, still maintained that the benefits of this newfound flexibility outweighed the immediate risks:

> *GTFS afforded the opportunity for anyone to devise travel planners that could then be adapted and fine-tuned based on individual preferences. However, this wasn't really what the industry was after at this point—.rather, it wanted to maintain its strong control mechanism. Actors probably feared that people would build travel planners incapable of delivering value to the end customer. But at the same time, this GTFS format enabled completely new ways of combining, filtering, and analyzing information sources relevant to the public transportation domain . . . this wasn't possible at all when we relied on the original APIs from the journey planning service.*

It was eventually decided that Traffic Lab would embrace the GTFS format and comply with this emerging global standard for identifiers of public transportation information. Needless to say, this structural change effectively propelled the development of a wide array of new digital apps, including services for disabled travelers, analyses of transportation network accessibility, and predictions of actual arrivals (based on artificial intelligence). Analyzing what effects the shift to GTFS had caused, the innovation manager at Traffic Lab recognized not only the positive service growth, but also the alignment of prominent international players:

> *Right from the start GTFS has had an incredible impact on innovation and value-creation . . . the services we've seen would never have materialized if we had instead decided to stick with our initial set of APIs. That's one side of its success. In addition, it has enabled us to dramatically expand the number international actors. Now we have CityMapper and Moovit, as well as other actors who create value based on our data . . . and it's so easy to align these new players. They seek data-driven innovation opportunities and they all rely on GTFS.*

Apparently, the growth of Stockholm's digital infrastructure for public transportation was shaped through four specific tactics, which were ultimately orchestrated as interventions to extend its functional scope. Overall, these interventions helped to align new partners whose capabilities were needed to innovate services that attracted more users.

5 Discussion

Digital infrastructures are extremely scalable because their components can be upgraded or replaced with relative ease and low cost. This allows for new combinations of infrastructural capabilities and associated services that are produced at unprecedented speed (Saadatmand et al., 2017; Tilson et al., 2010). While these digital infrastructures may appear durable for a time, however, their scalability fosters extraordinary growth in their functional scope (Hanseth & Lyytinen, 2010). The process of extending the scope of such infrastructure has therefore been depicted as a gradual sociotechnical process (Henfridsson & Bygstad, 2013), where stability invites enrollment of new actors, artifacts, and services, and flexibility allows for unbounded growth (Tilson et al., 2010).

This inherent complexity makes direct managerial intervention tricky (Ciborra et al., 2000; Grindley, 1995; Star & Ruhleder, 1995), and received theory tells us that it is difficult to control the growth of digital infrastructures (Yoo et al., 2005). Hence, it is important to explore how different tactics can incept successful growth of digital infrastructures by extending their scope over time. Since no previous IS research has accounted for such growth tactics in a coherent, systematic way (Tilson et al,. 2010), this motivated us to synthesize and clarify the nature and impact of these growth tactics. In what follows, we draw on our initial theorizing and empirical insights to substantiate a typology for conceptualizing how control can be exercised in digital infrastructure growth. With this typology, we aim to contribute not only to the conceptual discussion, but also to empirically realistic and pragmatically useful types of growth tactics.

We define growth tactics as deliberate interventions to make improvements in the scope of a digital infrastructure that can augment its ongoing adaptation and thereby allow it to grow. That is, an extension of the scope of an infrastructure enhances its capacity to effectively serve emerging possibilities and changing purposes (cf. Agarwal & Tiwana, 2015). As such, these tactics are unique within a particular sociotechnical network of actors and they can be viewed as organizational behaviors and technological practices that underlie the ongoing governance to exert control over digital infrastructure growth. Consistent with typological research (Doty & Glick, 1994; Gregor, 2006; Rich, 1992), our initial theorizing identified four such tactics and made explicit the key theoretical assumptions in this study. Beyond these tactics, we also identified two previously separated dimensions that differentiate various aspects of control in the IS literature (cf. Henfridsson & Bygstad, 2013)—namely, a social dimension (decentralized vs. centralized organizational control) and a technical one (loose vs. tight architectural control). Our typological theorizing marries these two dimensions in order to highlight the strategic actions of heterogeneous actors and their preferences concerning modes of control related to growth tactics.

On the social side, we refer to the first dimension as organizational control, because it captures the distinction between organizational capabilities needed to support the pursuit of decentralized control as an alternative to a centralized approach (Broadbent & Weill, 1997; Ciborra et al., 2000; Henfridsson and Bygstad, 2013; Rolland and Monteiro, 2002). A particular growth tactic may require sequential switching between these control modes at different points in time. The value of another tactic can reside with the extent to which these modes are pursued simultaneously over time.

On the technical side, we refer to the second dimension as architectural control because it captures the distinction between exercising loose and tight control over the designs that make up the architecture of a digital infrastructure (Aanestad & Blegind Jensen, 2011; Henfridsson & Bygstad, 2013; Tilson et al., 2010). In practice, an organization may need strong control over a small part of an infrastructure's architecture to pursue a certain growth tactic, while it seeks weaker control over a larger part of an architecture to exploit another tactic. Such architectural control can shift among organizations, varying in strength with respect to the digital infrastructure as a whole (Baldwin & Woodard, 2009). Suggesting that control involves defining and managing a set of connections in a sociotechnical system, our typology thus accommodates multiple (but certainly not all) dimensions that are relevant for analyzing growth tactics. At the same time, however, it assumes that these dimensions are logically separate. Indeed, their interconnectedness presents an empirical question.

To demonstrate the utility and integrative potential of our typology, we have carried out an in-depth case study of a digital infrastructure for public transportation in Stockholm, Sweden. The analysis explicates how four particular growth tactics successfully extended the scope of the infrastructure by uniquely aligning each type of tactic with our control dimensions.

The service platform "Trafiken.nu," an initial manifestation of a growth tactic, materialized through a close-knit collaboration between SL, the Swedish Transport Administration, and the city of Stockholm. This interorganizational initiative relied on a strict coordination mechanism and sought to enable a new wave of service development in the public transportation domain. Given the objective of the alliance, the technical architecture was designed to decouple the data from the providing organization by integrating it into a platform-specific data model. The combination of a centralized approach to organizing and a loose architectural control made this growth tactic very effective. As a result, a wide array of services was rapidly deployed, including a novel multimodal journey planning engine that was well-received by citizens in and around Stockholm.

The initial tactic focused on adding new services and sparked significant interest among external actors who were involved in application and service design. Relying on a scraping approach, however, their development practices caused organizational and technical problems for SL, which hampered the growth of the digital infrastructure. In response, SL decided to regain control of its architectural data resources by establishing Traffic Lab, which comprised a pool of boundary resources (i.e., interfaces) intended for third-party developers. This second growth tactic, however, meant that the service innovation process was ultimately organized in a more decentralized fashion.

Providing interfaces to external actors helped SL and its partners better control the architectural core of the digital infrastructure. In this situation, however, it was necessary for them to continue expanding the pool of developers, but at the same time find ways to align their actions with organizational goals (as formulated by Traffic Lab partners). To that end, an innovation contest was launched that would serve as a novel process for governing the exploitation of boundary resources by third-party players. As a manifestation of a third growth tactic, it paved the way for intensified external development efforts and hence many new prototype applications and services materialized rapidly. Indeed, following its successful effect, the invented organizational process soon became part of SL's digital innovation portfolio.

Even though the increased number of third-party actors had successfully impacted the service production process, Traffic Lab partners still experienced an external pressure to facilitate yet another new wave of digital innovation. For example, Google Maps sought to utilize data resources emanating from actors in the Swedish public transportation domain. Given that it could not benefit fully from the boundary resources (and the underlying journey planning engine) already provided, its proposed architectural strategy was a modular one that involved decoupling data resources and the algorithm that was making calculations based on them. Manifesting a fourth growth tactic, SL decided to open up and expose core identifiers (i.e., institutional objects—for example, routes, schedules, and stops) based on the GTFS standard prescriptions. The loose architectural control this tactic implied, however, meant that the organization of the innovation process had to yet again adjust. Indeed, breaking with institutionalized procedures was deemed essential to managing previously unknown development partners and thereby unleashing the inherent potential of the newfound referential system.

By juxtaposing our empirical insights in Figure 2, we present a two-by-two typology that yields four fundamental types of growth tactics.

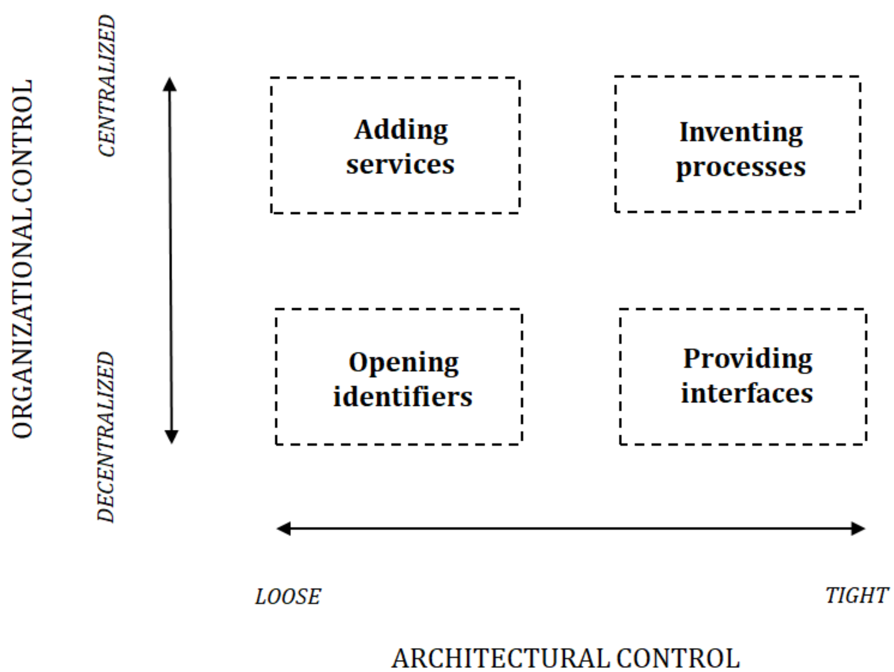

Figure 2: A Typology of Growth Tactics for Digital Infrastructures

We consider each of these growth tactics as a fundamental archetype that encompasses the various control dimensions that have been separated in previous IS literature. More specifically, each tactic represents a unique combination of the control dimensions that are believed to determine the outcomes. Table 1 indicates that these different combinations were almost equally effective in terms of promoting infrastructure growth. As Figure 1 suggests, however, a surprising finding was that the initial (i.e., adding services) as well as the final (i.e., opening identifiers) growth tactics relied on loose architectural control, although the structure of their organizational arrangements varied greatly in nature. Indeed, it appears to be a false assumption to explain successful infrastructure growth by linking decentralized organizational control and loose architectural control (cf., Ciborra et al., 2000; Henfridsson & Bygstad, 2013).

Our typology is a shorthand device through which growth tactics may be compared. It provides organizations a means for identifying and ordering tactics and clustering them into categorical types without losing sight of the underlying richness and diversity that exist within the type. As such, it becomes an analytic tool that may be applied as an instrument to stimulate thinking in alternate directions, helping decision-makers to manipulate their digital infrastructures. The results might trigger them to make adaptations they would not otherwise attempt, which in some situations may mean switching from one type of tactic to another. These tactics are applicable under different kinds of conditions. Mixed types are also possible under mixed conditions—and when the conditions destabilize or change, the mixed types should also change congruently. Our typology can help to map the rates and directions of movements among tactics with respect to each other. Overall, it captures the different choices organizations make in governing the growth of their digital infrastructures.

Turning now to research implications, our experience of using the typology as an empirical analysis tool highlights some areas where more work is needed. Indeed, one of the main virtues of our typology lies in its potential to guide more focused and systematic investigations into growth tactics. First, adding services entails a tactic through which actors can exploit opportunities offered by new technologies to meet user expectations and thereby ignite user excitement. Such opportunity exploitation may involve providing timely services that the infrastructure users realize that they need once they encounter them. This oftentimes quickly builds a user base, which is typically seen as a critical aspect of infrastructure growth (Grindley, 1995).

Second, providing interfaces denotes a tactic which infrastructure stakeholders often seek to stimulate service development. As recent platform and infrastructure research shows (Ghazawneh & Henfridsson, 2013; Tilson et al., 2010), transferring design capability to users, or end user service providers, can be essential for triggering the involvement of multiple actors in such development. However, little is known about how infrastructure actors may unite to lower the barriers to entry for new partners as they expand the network of actors around which the ecosystem is formed (Saadatmand et al. 2017).

Third, processes that embed tactics into organizational practices are at the heart of the successful growth of digital infrastructures. While these tactics enable new standardized behaviors and the regulation of the service delivery (Tilson et al., 2010), their implementation is distributed in time and space and involves a large number of heterogeneous actors at different levels. Digital infrastructure studies are needed that explain how growth tactics can be orchestrated to cut across multiple levels and multiple contexts.

Fourth, to successfully evolve a digital infrastructure, stakeholders need to develop a comprehensive take that includes the orchestration of a complex set of growth tactics. At the same time, they must be attentive to the conditions that pave the way for tactics to instigate infrastructure growth (Henfridsson and Bygstad, 2013). We hope that future research will explore what a capability might look like that helps infrastructure providers to identify and shape the conditions that ultimately lead to value-adding service outcomes.

Fifth, our typology suggests four growth tactics that vary in their control structures, and differ in their antecedents and outcomes. However, little is known about the dynamics of how each tactic emerges and unfolds in digital infrastructure efforts. We suspect this is because extant research on infrastructure growth has lacked longitudinal studies that observe the processes underlying types of tactics within an organization as well as across organizations. In particular, such studies promise to provide additional insight into the differential outcomes associated with each growth tactic.

Given its exploratory character, our study has at least two limitations. The selection of Stockholm as the main case affected which growth tactics emerged as relevant. Even though the identified tactics explain how infrastructure growth is instigated, the extent to which we can generalize them and their generative impact requires additional research. In fact, R&D investments and industry-academia collaboration funding for digital infrastructure initiatives are comparatively high in the Stockholm setting, which raises the risk that the conditions under which the four tactics were identified are different compared to conditions characterizing other public transport infrastructures located in other cities (where the same tactics may be observed). This means that other efforts on digital infrastructure growth may not be likely to follow the exact same trajectory. A much larger study would have allowed for additional analyses considering different countries, requisite variations in how growth tactics were launched, and what effects they rendered.

Finally, we concede that the granularity of our analysis of growth tactics is at a relatively high level. This suggests that we may not have discovered all of the tactics relevant for igniting the growth of digital infrastructures. It would therefore be worthwhile to pursue additional research that more carefully scrutinizes the nature of these tactics and thereby specifies their respective characteristics. Indeed, it would have been interesting to investigate what makes a specific tactic possible in the first place and to identify under what conditions such a tactic becomes effective.

6 Conclusions

The literature on digital infrastructure growth is complex and disparate. Prior research efforts to identify the antecedents and trace the outcomes of growth tactics have been limited by the absence of a comprehensive theoretical framework. As a result, there is no coherent body of material to guide research and practice, and there is little that ties together the different forms that growth tactics may take. In this paper, our objective has been to rely on the current body of knowledge and understanding to further specify the notion of growth tactics and develop a full-fledged typology to focus this line of research.

To that end, we first synthesized past insights on how to extend the scope of infrastructures to make them grow. Drawing on our empirical study, we then developed a parsimonious yet coherent typology that delineates four types of growth tactics, reflecting two primary dimensions that underlie previous IS research in the domain of organizational control and architectural control. While these dimensions have remained separate to date, our proposed four-cell typology of growth tactics marries them. Our typology thus helps to unify the various conceptualizations of control dimensions into a more holistic understanding of their nature and role in digital infrastructure growth.

We suggest that this typology reflects the different choices organizations make in governing the growth of their digital infrastructures and we have offered several recommendations and promising avenues for future investigations that proceed from it. We hope our literature review, typology, associated discussion on growth tactics, and research implications will help set the stage for an abundance of new and exciting IS research on digital infrastructures.

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Ola Henfridsson is a professor and the head of the Information Systems and Management Group at Warwick Business School. His research interests relate to the transformative potential of digital technology as it pervades modern business and entrepreneurship. Ola teaches digital business strategy and digital innovation at the MSc, DBA, and PhD levels. He is the director for the upcoming Executive Diploma in Digital Leadership program taught in the Shard in London. The diploma includes modules on platform strategy, artificial intelligence, data analytics, and digital transformation.

Daniel Rudmark works as a senior researcher at RISE Viktoria on issues relating to open transport data and third-party development, focusing on creating innovation. He has worked with several actors in the public transport sector in Sweden, but also internationally with public transport in cities such as Rio de Janeiro, Dar es Salaam and Bangalore.