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# Learning processes in municipal broadband projects: an absorptive capacity perspective

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# CAN A CITY MANAGE BROADBAND INFRASTRUCTURE DEVELOPMENT? AN ABSORPTIVE CAPACITY PERSPECTIVE

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# CAN A CITY MANAGE BROADBAND INFRASTRUCTURE DEVELOPMENT? AN ABSORPTIVE CAPACITY PERSPECTIVE


## ABSTRACT

This research extends the absorptive capacity theory to examine the dynamic of knowledge activities concerning ISD process in the context of municipal wireless networks. We ask three research questions: (1) How can we extend the absorptive capacity theory to explain the dynamic of knowledge activities involved in the ISD process?, (2) What are the ISD events that trigger knowledge activities during the course of municipal wireless network development?, and (3) How does a city create and utilize new knowledge in the development process? By framing ISD process as a dynamically emergent social process and knowledge is embedded in social actions, we develop the absorptive capacity model for information system development process and use it to analyze the role of prior knowledge, ISD events that trigger knowledge activities, and the dynamic of knowledge activities in three case studies (Chaska, MN, Hermosa Beach, CA, and Fredericton, Canada). The results suggest a pattern of ISD events that trigger knowledge creation across three cities including assignment of personnel, physical system construction, performance problems, resistance, and reassignment of organizational roles. The cities engaged in cycles of knowledge creation related to technology implementation, customer service, and revenue models, among others. This research extends the absorptive capacity theory by suggesting four new constructs that shapes the complexity of learning processes in ISD development. These constructs include the dynamic of technology development, partnership commitments, the roles of external knowledge, and learning-by-doing.


**Keywords:** absorptive capacity, information system development, infrastructure, broadband technology, municipal wireless network, Wi-Fi, public organization

**1. Introduction**

Access to basic telecommunications services is considered as one of the necessities for individuals and organizations in the global information society (Crandall et al. 2007; Lee et al., 2003; Wilhelm, 2003). The current U.S. broadband market is primarily dominated by a duopoly of the telephone and cable companies. As a result, broadband access and usage is concentrated among individuals and businesses in large cities and other economic booming cities (Horrigan et al., 2006). The lack of competition does not provide incentives for private operators to expand coverage to rural areas, lower prices, and upgrade the speeds (Daggett, 2007).

Following the ideology of the government's role as infrastructure developer (Gillett et al., 2004; Sawyer et al., 2003), many cities in the U.S. have considered deploying municipal wireless networks (citywide networks) with the goals of universal, affordable access to broadband infrastructure for all. Jain et al. (2007) defined municipal wireless networks as "wireless Internet access networks developed with active local leadership and involvement". Weill et al. (2002) classified the needs for infrastructure development into three levels: business unit, firm, and public infrastructure. By following this classification, municipal wireless networks are viewed as public infrastructure with the goal to provide fundamental telecommunication services to the general public. According to muniwireless.com, the number of U.S. counties and cities that are in the deployment or planning stage of wireless broadband networks substantially grew by 240% from 122 in June 2005 to 415 in August 2007.

Municipal wireless network projects provide an interesting study context and should add new theoretical insights to the ISD and knowledge management literatures. This is because there are a number of challenges associated with a municipal wireless network project in addition to those found in traditional ISD. First, several cities have an ambitious goal to have broadband coverage for the entire city area, thus making their project large in scope, and increase in complexity. The Wireless Philadelphia project (http://wirelessphiladelphia.org), for example, has planned to cover 135 square mile area. Second, there are a number of stakeholders, some of whom may have conflicting goals and interests. Mandviwalla et al. (2008) reported at least 13 diverse stakeholders involved in the Wireless Philadelphia project ranging from state and city government, community residents, businesses, telecoms and ISPs, to public schools and higher educational institutions. Third, several have expressed serious concerns regarding wireless broadband technology including the scalability of the technology which was originally designed for small-sized hotspots, the lack of standards for the mesh technology required to install wireless broadband networks in large areas, and the possible rapid obsolescence due to new innovations and standards (Jain et al., 2007). Fourth, some critics casted doubts on the capability of local government to develop and manage technology infrastructure including its lack of market discipline and technology capability (Feiss, 2007), the overlook of major elements in the operation costs including maintenance and network operations center costs (McClure, 2005), and its lack of resources to maintain the network in the long run (Cox, 2004).

Research in IT infrastructure and ISD has emphasized that experience, knowledge, and skills are critical to convert IT components into valuable services (Armstrong & Sambamurthy, 1999; Byrd & Turner, 2000; Fink & Neumann, 2007). However, most studies in the IT infrastructure literature focus on examining existing IT infrastructure and its components as antecedents of strategic organizational value including organizational agility (Fink & Neumann, 2007; Sambamurthy et al., 2003), organizational performance (Bharadwaj, 2000; Bharadwaj et al., 1999; Brown et al., 1995), and process performance (Froehle, 2006; Karimi et al., 2007; Ray et al., 2005). Similarly, studies in the ISD literature concentrate on using the variance approach to indentify antecedents of successful ISD projects (Sabherwal & Robey, 1995; Sambamurthy and Kirsch, 2000). Several researchers suggest that studies concerning ISD process are required to advance our knowledge of the complex social process concerning systems development (Hirschheim et al., 1991; Sabherwal & Robey, 1993).

The purpose of this paper is to extend the absorptive capacity theory to examine the dynamic of knowledge activities concerning ISD process in the context of municipal wireless networks. We frame ISD as a dynamically emergent social process of complex interactions among stakeholders that shape the outcome of the development process (Hirschheim et al., 1991; Newman & Robey, 1991; Sambamurthy & Kirsch, 2000). Following the guidelines for process research in organizations (Poole et al., 2000) and information system development process approach (Kling & Iacono, 1984; Newman & Robey, 1992; Sabherwal & Robey, 1993), we conceptualize ISD process as a sequence of events by highlighting critical events that are unfold during the broadband network development process among selected U.S. from the knowledge management perspective.

The specific research questions are:

- How can we extend the absorptive capacity theory to explain the dynamic of knowledge activities involved in ISD process?
- What are the ISD events that trigger knowledge activities during the course of municipal wireless network development?
- How does a city create and utilize new knowledge in the ISD process of municipal wireless network development?

## 2. Absorptive Capacity Model for Information System Development Process

Sambamurthy and Kirsch (2000, pp. 400-401) conceptualized ISD as a complex social process concerning "the tasks that developers build technical artifacts and make technical choices within a complex social process that involves multiple stakeholders engaged in multiple agendas and transactions in their interactions with each other." Research has identified a number of factors that influence the successful outcome of the ISD process: user participation (Ives & Olson, 1984; Kirsch & Beath, 1996), top management support (Howell & Higgins, 1990; Jarvenpaa & Ives, 1991), and IS developers' expertise (Aladwani, 2002). More recently, ISD organizations have experienced significant shift in their external environment with the demands of high global competition that requires flexible and fast paced delivery of information systems (Lyytinen & Rose, 2006). Consequently, the ability to learn new technical changes and business opportunities and use them in IS delivery has become increasingly critical for ISD. More specifically, a number of research suggests that absorptive capacity broadly defined as the ability to learn and apply new knowledge to improve performance (Cohen & Levinthal, 1990) is an important determinant of effective learning and knowledge transfer, one of the key factors contributing to successful ISD process (Hovorka & Larsen, 2006; Ko et al., 2005; Tiwana & McLean, 2005).

Pentland (1995) suggested that knowledge must be understood in the context of embedded social activities. Therefore, in our study, we situate knowledge activities in the context of ISD process in order to derive theoretically meaningful findings. The absorptive capacity theory seems to be an appropriate lens for this study because it provides a broad process framework of knowledge activities that enables us to develop theoretical insights of knowledge activities in ISD process. In addition, the absorptive capacity also emphasizes how an organization integrates new knowledge with knowledge accumulated through prior experience and applies it to increase the performance. Such theorizing is consistent with evidence in ISD research that prior knowledge about technical and IS development process and tasks increases the likelihood of ISD project success (Faraj and Sambamurthy, 2006; Kirsch, 1996; Kotlarsky et al., 2007).

To study knowledge activities embedded in ISD process, we use a recent framework by Zahra and George (2002) who conceptualized absorptive capacity as a set of dynamic capabilities consisting of four knowledge activities: acquisition, assimilation, transformation, and exploitation. The model also suggests that prior experience shapes knowledge activities. As discussed earlier, knowledge activities are embedded in ISD process, therefore, we theorize that events that trigger knowledge activities come from activities related to ISD. We modified Sabherwal and Robey (1993)'s classification of ISD activities as a guideline to identify relevant ISD events. In their extensive analysis of ISD projects in 50 organizations and more than 1,000 actions, Sabherwal and Robey (1993) classified detailed actions into 15 categories ranging from assignment of personnel to the project, submission of proposal, to reassignment of organizational roles. Figure 1 illustrates our absorptive capacity model for information system development process. Although the diagram depicts the model using boxes and arrows similar to those found in the variance approach, this study focuses on emergent knowledge process embedded in ISD process. The model suggests that ISD activities trigger knowledge activities and knowledge activities, in turn, shape subsequent ISD actions. Prior knowledge related to technical and management of ISD development process influences the extent of knowledge activities. The theoretical concepts and their definitions are presented in Table 1. Next, we provide a brief overview of the concepts in the model.

**Insert Figure 1 about here**

**Insert Table 1 about here**

*ISD Activities*. Zahra and George (2002) suggested that events that trigger knowledge activities are those internal or external triggers that induce efforts to seek knowledge to develop appropriate response mechanisms. Examples of internal triggers are performance failure, redefinition of an organization's strategy, as well as other forms of organizational crises. External triggers are those events that emerge as changes in an environment including technological shifts, radical innovations, and changes in government policy. The formulation of internal and external triggers is conceptually similar to events that arise throughout ISD process (e.g., user complaining about a system, cancellation of an IS project, vendors going out of business, and key IS personnel resigning). Sabherwal and Robey (1993) classified micro-level ISD activities into 15 event types. We modified their classification by removing events that are considered knowledge activities according to Zahra and George's definitions. These events include seeking technical knowledge, training, and reassignment of organizational roles. Consequently, twelve events are maintained to activate knowledge activities: assignment of personnel to the IS project, submission of proposal, approval or authorization, project definition, assessment of performance, vendor selection, system construction, performance problems, successful performance, resistance, acceptance or cooperation, and others.

*Prior Knowledge*. Argote (1999) suggests that prior knowledge is embedded in people, technology, structures and routines. The ability to absorb new external knowledge depends on the level of prior related knowledge. This suggests that the development of absorptive capacity is a path-dependent process (Cohen & Levinthal, 1990). Customer interactions, alliances with other firms, and learning-by-doing are some of the ways an organization can gain its experiences (Lane & Lubatkin, 1998; Nonaka & Takeuchi, 1995). In the ISD context, several studies reported that prior knowledge in forms of IS development process, technical capability, domain knowledge, and project management is critical to project performance (Faraj & Sambamurthy, 2006; Kirsch, 1996; Slaughter & Kirsch, 2006).

*Knowledge Acquisition*. ISD knowledge can be acquired from internal or external sources. Internal knowledge acquisition occurs through knowledge sharing among ISD stakeholders including users, project managers, business unit managers, and IS specialists in different work units such as development specialists, maintenance specialists, and quality assurance specialists. The complexity of IS projects increasingly requires organizations to rely on external consultants and multiple technology partners for help in developing and implementing these systems.

*Knowledge Assimilation*. Knowledge assimilation refers to routines and processes that allow an organization to interpret and understand new ideas learned from external sources (Zahra & George, 2002). An organization faces several challenges in comprehending knowledge acquired from external sources. For example, external knowledge may have heuristics that depart from those used by an organization (Leonard-Barton, 1995). The tacitness, specificity, and complexity of external knowledge can generate causal ambiguity between knowledge and outcomes which can prevents others from replication (Reed & DeFillippi, 1990). In addition, interorganizational learning research also suggests that the ability to assimilate new external knowledge is greater when the two firms share similar systems for processing knowledge (Lane & Lubatkin, 1998). In the IS context, Hovorka and Larsen (2006)'s findings suggest that knowledge assimilation is related to IT attitudes, prior experience with IT, and training.

*Knowledge Transformation*. Once an organization interprets and understands new knowledge, the next challenge it faces is how to absorb the new knowledge into the existing knowledge system. Knowledge transformation involves an organization's capability to develop routines to combine new knowledge with the existing knowledge (Zahra & George, 2002). Cohen and Levinthal (1990) suggest that internal organization mechanisms that enable knowledge sharing across organization members are necessary for the new knowledge to be integrated into an organization. In the ISD environment, Slaughter and Kirsch (2006) identified several mechanisms for internal knowledge sharing including meetings, bulletin boards, internal training classes, transfer of personnel, and informal demo. Ko et al. (2005), in their study of knowledge transfer between consultants and business users in ERP implementations, found that knowledge-related, communication-related, and motivational factors influence the extent of knowledge transfer.

*Knowledge Exploitation*. The new absorbed knowledge has to be applied for an organization to derive associated benefits. Knowledge exploitation refers to an organization's capability to extend its competencies, enhance performance, or increase innovation by incorporating transformed knowledge into operations (Zahra & George, 2002). Cohen and Levinthal (1990) suggest that the ease of knowledge utilization depends on the extent to which an outside knowledge is targeted to the needs and concerns of a recipient firm. Lane and Lubatkin (1998), in their study of alliances between pharmaceutical firms and biotechnology firms, found that the experiences in which two organizations share in solving similar types of problems make it easier for a recipient organization to find applications of the new knowledge. Similarly, Malhotra et al. (2005), in their study of supply chain partners, found that joint decision making helps firms to develop a deep understanding of the knowledge needs of their partners.

## 3. Research Methods and Data

### *3.1 Case Study Method*

Municipal wireless networks have been recent efforts by several cities to address the lack of affordable broadband services offered by private companies. Our objectives are to understand the required knowledge and associated knowledge activities and to help generate theory to better support the learning processes. At this stage of municipal wireless network development, a comparative case study is an appropriate methodology for three reasons. First, the case study is a viable method for studying areas that are underdeveloped in the literature (Benbasat et al., 1987). Second, the case study method is particularly well suited for studying phenomena that cannot easily be distinguished from its context (e.g., ISD process, organizational structure, prior experience). Third, multiple case studies also increase the validity and generalizability of the findings as well as theory development and testing (Benbasat et al., 1987; Yin, 2003, p. 46). Inductively generalizing from a single case study is epistemologically problematic and runs the risk of being easily falsified by a single counterexample (Benbasat et al., 1987).

We chose *Chaska, Minnesota*, *Hermosa Beach, California* and *Fredericton, Canada* for four reasons. First, these cities have varying levels of experience on ISD and broadband technology, thus making them theoretical diverse from the absorptive capacity perspective. Second, the three cities were among the early adopters of municipal wireless networks; therefore, they have relatively long term data and offer richer insights into the development process. Third, the fact that these cities located in different geographical locations with different socio-economic and political conditions can help increase the generalizability of our findings. Fourth, the three cities do not necessarily share the same goals for their municipal wireless networks. Such diverse goals may shape different knowledge activities during their development processes.

*3.2 Data Collection*

We use a retrospective research method by relying on interview data, archival documents, and related articles and interviews published in the popular press. Sabherwal and Robey (1995) suggested that the accuracy of the data from the retrospective inquiry is preserved when there is a reasonably short elapsed time between the completion of the ISD project and the start of data collection. In our case, all three cities finished the development process around 2005 and our data collection period was done between February and July 2007, representing an average of 14 - 19 months elapsed time.

We collected evidence from multiple sources for each case study. The interview transcripts, city council minutes, prior interviews given by city personnel, popular press coverage of the projects, and public discussion forums are used as the source to identify ISD events. For each of the three case studies, we interviewed key personnel who participated in strategic development, network architectural design, and implementation of the municipal wireless projects. Table 2 summarizes our data collection efforts.

Archival data constituted more than 250 pages of rich and detailed information through the entire development process of the municipal wireless projects.

**Insert Table 2 about here**

*3.3 Data Analysis Strategy*

Since the objective of this research is to develop an understanding of the complex knowledge creation in municipal wireless network projects, we use a process research method to analyze the data. Process research is appropriate for this study for a number of reasons. First, the process approach offers an inquiry mode that allows us to develop theoretical explanation to indicate how the learning process unfolds over time and identify causal inferences of the mediating steps through which causality acts through an initiating event and subsequent events. Second, the process analysis shares similar ontological assumptions with the absorptive capacity concerning the role of prior events. That is, the absorptive capacity argues that learning is path-dependent (Cohen & Levinthal, 1990) and process analysis suggests that "an entity's current state can be understood only in terms of the history of events that preceded it" (Poole et al., 2000, p. 12). Third, process analysis enables researchers to develop theoretical contribution through unanticipated events discovered during the process analysis (Whetten, 1989)

Poole et al. (2000) suggested that process researchers should use an appropriate analysis method depending on the number of cases and the number of events in the chosen cases. In this study, where there are three cases and each case does not have a large number of events, summary case studies that highlight the focal ISD events and dynamic of knowledge creation is justified. Events were coded according to Sabherwal and Robey (1993)'s classification of ISD events followed by coding of knowledge activities that were triggered by ISD events.

Next, we provide an overview of the wireless mesh technology that all three cities chose for their municipal wireless networks before we present the findings.

## 4. The Wireless Broadband Technology: Wi-Fi Mesh

In recent years, Wi-Fi technology (IEEE 802.11 a/b/g/n) has become an attractive choice to provide broadband Internet access. The proliferation and adoption of wireless technology has been successful for three reasons (Bar and Galperin, 2004; Bar and Park, 2006). First, the FCC did not require a license for the 2.4 GHz and 5 GHz spectrum; the airwave spectrum in which Wi-Fi works. Second, standardization as specified by the Wi-Fi Alliance and the IEEE organization led to an interoperability standard. Third, the large scale production of Wi-Fi chipsets resulted in low unit costs for Wi-Fi equipment, fueling the technology's integration as standard equipment in portable computers.

More recently, new developments have enabled Wi-Fi technology to be implemented in a large geographical area through adds-on mesh technology. In Wi-Fi mesh technology, Wi-Fi routers are typically installed outdoors by mounting on external structures such as buildings or lampposts to get a broad coverage throughout a city. The Wi-Fi routers (or access points or nodes) communicate with each other wirelessly through a mesh routing algorithm to allow users to connect to the Internet, thus minimizing the need to have each router connecting directly to the Internet. Wi-Fi mesh network requires a selected number of access points to be attached to the backbone network that connects to the Internet. These access points are often referred to as backhaul nodes. The rest of the access points can connect to the backhaul nodes by taking multiple hops from one access point to another wirelessly. Figure 2 illustrates Wi-Fi mesh network architecture.

**Insert Figure 2 about here**

## 5. Findings

### *5.1 Municipal Wireless Network Projects*

The three cities chosen for this research are diverse in terms of geographical locations and perhaps their goals related to their municipal wireless projects but they share some similarities in terms of being relatively small cities and they are all considered pioneers in their municipal wireless broadband efforts. Chaska is located 20 miles southwest of downtown Minneapolis in Minnesota. According to the metropolitan council estimates, Chaska's population was 22,467 with 8,194 households in 2005. The estimated per capital income was $44,137. About 3.4% of families and 4.7% of the population were below the poverty line. The city's area is approximately 14.5 square miles. The objective of developing a municipal wireless network (Chaska.net) highlights the concept of community: "… develop a high quality, low cost, high speed Internet service for Chaska's public, business, and residential entities, thereby enhancing Chaska's vision of being a connecting community", according to the Chaska.net's mission.

Hermosa Beach is located in the South Bay region of the greater Los Angeles area. The city's area is approximately 5.9 square miles. As of the 2000 census, Hermosa's population was 18,566. There were 9,476 households, and 3,553 families residing in the city. The per capita income for the city was $54,244. About 1.7% of families and 4.6% of the population were below the poverty line. The mayor gave two reasons for building the municipal wireless network known as Wi-Fi Hermosa Beach. First, he stated "When we first came up with the idea for a citywide network, we did it because there were only two choices, Cable and DSL. Both provided poor service, especially video and were really expensive. We knew we could do it better and cheaper. Second, he firmly believes that broadband Internet should be treated as a public service or utility and offered by the city, paid for by tax dollars.

Fredericton is a small urban city, located in southern New Brunswick, Canada. The city is a regional center for knowledge-based industries, with more than 70% of the province's high-tech economic activity. According to the 2006 census, the city of Fredericton had a population of 50,035. Among the population, 37.2% has a university degree. The average family income was $70,000 per year. The area of the city is 50 square miles. The city projects its municipal wireless network known as Fred-eZone as a part of infrastructure to become a smart city. The executive director of the city's economic development department stated "As a municipality, we already provide infrastructure—roads, sidewalks, and water distribution systems—we're just adding connectivity to the list. Projects like Fred-eZone contribute to Fredericton's image as a smart, progressive city, a place where people want to live, play, learn, and work."

Table 3 provides a summary of the key features of these projects.

**Insert Table 3 about here**

Next, we analyze the three case studies according to the theoretical framework in Figure 1. Our analysis highlights the role of prior knowledge in new knowledge creation, ISD events that trigger knowledge activities, and the dynamic of knowledge activities.

*5.2 The Role of Prior Knowledge*

All three cities had some prior experience with broadband development. At the beginning of its wireless broadband project, Chaska had about four years experience providing Internet services to the school district and businesses. In 2000, the city partnered with the school district to construct and maintain fiber optic connections. The school district agreed to pay all the costs associated with the construction and ongoing maintenance of the system with the condition that the city owns the fiber lines. Around the same time, the city also partnered with KMC (now CenturyTel) by granting KMC the right to utilize the city's right-of-way in their fiber optic installation with the agreement that KMC would construct a public fiber network to serve several city facilities.

Later in 2001, the city began expanding their high speed fiber network service to Chaska businesses. In 2002, the city decided to expand to more affordable broadband services through a line of sight 2.4 GHz point-to-multipoint wireless network. In 2003, the service was expanded to other nearby cities including Victoria, Waconia, Norwood, Young America, and Shakopee. The city had 71 business customers for their fixed wireless network services in April 2004. On one hand, Chaska's experience and knowledge that they had as an ISP as well as its existing backhaul infrastructure makes it easier for the city to implement the wireless network as the city manager puts it "That was the advantage that we had. We had been an ISP. There were a small number of customers but all the backroom kind of stuff – connection to the Internet, we had all that." However, at the implementation level, some of the prior knowledge proves to be contradictory to the requirement of Wi-Fi mesh technology. For example, the IS manager stated "As a fixed wireless operator, we kept on thinking along the lines of how high can we get those antennas to have a clear line of sight. But with a mesh system, that is not the right approach to take. Tropos recommended keeping the nodes … around 15 to 20 feet off the ground."

Unlike the city of Chaska, the city of Hermosa Beach did not have direct prior experience and knowledge to draw on. The city leased telephone connections from a telecommunications provider to support city operations. However, the mayor at that time had two years experience with a Wi-Fi hotspot in his own local bakery and café. With that knowledge in hand, he and the city manager presented the idea of operating a citywide Wi-Fi network to the city council in 2003. Since the two individuals did not have in-depth knowledge about the network and its implementations, they worked with a company, Wireless Facilities Inc., to draft details about the network and its benefits to the city. During the course of the Wi-Fi Hermosa Beach development, it appears that the knowledge they need is related to revenue models of the network operation.

Similar to the city of Chaska, the city of Fredericton had extensive experience and knowledge as an ISP prior to its wireless network development. In 1999, Fredericton responded to the problem of the lack of affordable broadband connectivity by investing in a fiber ring that delivered high-speed connectivity to the city and other businesses. Under the regulations of the Canadian Radio and Telecommunications Commission (CRTC), a broadband provider requires a license to operate the business. To address this regulatory requirement, a city-owned company staffed by city employees, e-Novations, was created and received accreditation as a non-dominant telecommunications carrier. The company allows the city to own the infrastructure and provides a means for local businesses to pool their resources to lease bandwidth on the city-owned fiber optic cables. The network infrastructure consists of a combination of fiber optic and point-to-point wireless technology by Motorola which serve as an important asset for Fredericton to easily expand the broadband services to the public.

*5.3 ISD Events and the Dynamic of Knowledge Creation*

Table 4, 5, and 6 presents the ISD events, description of events, timeline, and related knowledge activities triggered by those ISD events for the cities of Chaska, Hermosa Beach, and Fredericton respectively. There appears to be a pattern of ISD events that triggered knowledge activities across the three projects. These ISD events include the assignment of personnel, physical system construction, performance problems, resistance, and reassignment of organizational roles.

*5.3.1 Assignment of Personnel*

Assignment of personnel to begin the project prompted the project leaders in all three cities to acquire knowledge to identify an appropriate technology choice in the case of Chaska and Fredericton and to write an RFP in the case of Hermosa Beach. Note that the cities engaged in various means to acquire and integrate knowledge from different sources to make their decisions. For example, the cities of Chaska and Fredericton learned in-depth technology knowledge by following the industry and talking to a number of vendors. The mayor and city manager of the City of Hermosa Beach chose to adapt background knowledge they learned from municipal wireless conferences to write their own RFP.

*5.3.2 Physical System Construction*

Since the city of Hermosa Beach outsourced the design and implementation to an outside company, LA Unplugged, and their first phase implementation was relatively small (9 outdoor routers covering 35% of the city area), they did not have to deal with various issues arising during the physical system construction. The city manager stated, "LA Unplugged bought the equipment from Strix Systems (http://www.strixsystems.com) and assembled the boxes and the network. After that they provided one year of operational maintenance. I think the company folded since then."

In contrast, the physical system construction for Chaska and Fredericton triggered them to engage in new knowledge creation around specifics of the Wi-Fi mesh implementation. Both cities integrated their prior knowledge as telecommunications or wireless operators to install the Wi-Fi mesh systems with helps from their partners and experienced consultants to translate generic technology knowledge (e.g., frequencies, number and locations of outdoor nodes, and number of hops from a given outdoor node to a backhaul node) to specific city conditions. For example, Chaska worked with First Mile Wireless, a reseller and integrator of wireless solutions and an authorized reseller of Tropos, to plan and install the network. The city completed the installation of 230 Tropos 5110 routers on city-owned assets predominantly street lights through out the 14 square miles of the city in June 2004. Backhaul was installed at 36 locations around the city using the existing city's infrastructure including the point-to-multipoint wireless links and fiber network.

Fredericton chose Cisco systems for their Wi-Fi mesh network and worked closely with the company. The city IT manager praised the working relationships they had with CISCO, "The CISCO team worked tirelessly with us to fine tune the signal overlays, resolve radio signal interference issues, and educate our people so we could sustain the network after it was completed." He described the city's learning as integrating pillars of separate knowledge provided by contractors, saying "how to create backhaul networks and virtual LANS and distribute IP addresses, that (expertise) you have got to bring in from the outside, but you have to understand how to maintain it."

*5.3.3 Performance Problems*

Later in the project, Fredericton and Chaska, in particular, had a series of performance problems (disappointing customer services, unreliable connections, interference problems, network abuse, and quality downgrade) that triggered knowledge creation to address those issues. Throughout its Wi-Fi mesh deployment, Chaska faced a number of challenges with the system. First, the city realized that Wi-Fi mesh technology requires significant fine-tuning according to the city's various topologies, buildings, street conditions, and dense tree neighborhoods. The city started out with 230 routers in early 2004. In August 2007, the city had 378 routers, with 148 routers added or a 64% increase from the original plan. The IT manager admitted in his interview reported by Hughlett (2007) that "There were a lot of preconceived notions that you could just blast Wi-Fi signals through walls and trees and everything. We discovered that wet, leafy trees absorb radio signals. Wi-Fi signals don't pass through stucco like they did wooden walls." The city also found that if the number of hops grows beyond 3 or 4 hops to a gateway, the speed significantly drops down to dial-up grade service or even worse. This has become a problem in neighborhoods that are a long way from where gateways are located. In summer 2005, the city replaced the routers in one neighborhood with the newer 5210 Tropos routers. According to the city's administrative service director, that neighborhood experienced improvement in the quality of signal coverage because the 5210 technology works at different frequencies and it supports greater distance. Second, the technology was new at the time the city begun its deployment. "We are being one of the first or even the first to do a complete city Wi-Fi. There were still bugs that need to be worked out. We had a number of issues that hardware suppliers and software suppliers had not really thought about." said the city manager. Finally, Wi-Fi mesh technology had been improving at a rapid rate between 2004 and 2005. Only in one and a half year into its operation, the city replaced all of its Tropos 5110 routers with the newer 5210 ones. The city's administrative service director explained, "Tropos created resolutions for some of the problems that we initially saw on 5110. We would be working on a problem and then we called Tropos and they said that the problem had been resolved in the 5210 model, or that is not available in 5110 but it is on 5210. There is a bit of frustration on our part. We were only into this for a year and a half, the new features that we help identify and we need were not going to be available in 5110."

In addition to the technical issues, Chaska also recognized that their customer service experience and knowledge with being an ISP to business customers did not prepare them for residential customers as the city manager admitted "As you move to residential customers, that is a whole different kind of customer service because they weren't as computer savvy and so we received more calls." Moreover, the city did not have the necessary tools to track and analyze calls to differentiate old problems from new ones. According to Hughlett (2007), Chaska had 1,100 residents signed up to use the service in 2005 but 800 of those left partly because of the lack of support and unreliable network access.

To respond to the immediate problem, the city hired additional temporary staff to extend the customer service hours. Eventually, the city discovered that the network connectivity problems were tightly related to customer services because most of the problems users called in for help were related to connectivity. Therefore, the customer service support needed to have necessary knowledge and information about network performance to respond to connectivity issues. However, the city did not have expertise and tools in these two areas. So, they made the decision to outsource the network operation center and customer service to Siemens.

Similar to Chaska, Fredericton encountered interference from other routers, as well as reliability issues related to applications used on the network. Initially, all of their routers were connected to one backhaul bandwidth point, thus overwhelming the antenna with “broadcast storms” leading to malfunctioning routers. To address this issue, the city fixed the design flaw of the network by separating the network into three virtual networks, each with its own broadcast tower connected to the fiber network. The three broadcast towers are located on the city water tower, a clock tower, and at the city’s Knowledge Park business park.

The Fred e-Zone does not require users to log in to begin a session. However, the system records users’ MAC addresses when they begin a session. The network was originally designed as a completely open network with no traffic shaping. When the popular application BitTorrent was launched, speeds on the entire network including the fiber backbone slowed incredibly due to Fred-eZone users exchanging files. The network managers introduced traffic shaping protocols that throttled peer-to-peer traffic According to the city’s IT manager, Fredericton was becoming known as an international hotspot for spammers. To address the problem, the city rate limited the peer-to-peer traffic and blocked virus ports. While ports that use mail sending proxies like SMTP are not blocked, there is a limit of 10 messages per day that can be sent using SMTP, and outgoing mail messages are intercepted and run through an anti-virus program. Therefore, the network managers can determine the number of spam messages sent through the network. The Fred-eZone blocks users who abuse the network by sending spam or using too much bandwidth, as well as limiting the amount of bandwidth allocated to the e-Zone during business hours.

*5.3.4 Resistance*

One of the ISD events that triggered new knowledge creation for Hermosa Beach is the resistance from some council members to the citywide deployment. In late 2004 to early 2005, the city considered expanding the current network to cover the entire city. The cost of the expansion was estimated around

$126,000. In November 2004, the city council received feedback from citizens and businesses about the usage and benefits of the current network and their opinions about the expansion during one of the council meetings. However, more information particularly a possibility of a franchise business model through a partnership with an ISP, and an estimated monthly cost-revenue plan is needed for the city council to make the decision. To satisfy the request, the city manager identified other cities in California (e.g., city of Cerritos, city of West Hollywood) that have planned to enter into a partnership with an ISP to offer a citywide broadband service. Internet service providers are motivated to partner with those cities because of potential revenues in the areas of cities where a telephone and a cable company do not offer broadband services. However, it is unclear if the same business model will work for the city of Hermosa Beach when its residents have several options of broadband services from the existing telephone and cable companies.

In addition, the city manager also consulted with the contractor to get a more accurate estimation of total cost, total revenue, and replacement costs and schedule. In the end, the citywide deployment proposal failed to gain approval. Finally, another external event that seems to put an end to the citywide project is the change from the former mayor who was enthusiastic about the citywide deployment to new mayor who strongly opposed to the project.

*5.3.5 Reassignment of Organizational Roles*

Finally, Chaska experienced the departure of a few lead personnel who are knowledgeable about the Wi-Fi mesh deployment in early 2006. The city manager stated, “It was a big deal and it was probably one of our ongoing challenges. There are limited numbers of people who understand how Wi-Fi system works.” A new IT manager was hired in late 2006. To get him up to speed with Wi-Fi mesh technology, the city sent him to a training course with Tropos. According to the new IT manager, “It was a very good week of exploration of equipment, how to configure 5210, how to perform installation of 5210, and what optimal deployment looks like from a geographical standpoint.”

Table 7 summarizes the prior experience, ISD events, and knowledge activities during their municipal wireless network deployment.

**Insert Table 7 about here**

## 6. Discussion

This research studies new knowledge creation activities embedded in the ISD development process in the context of municipal wireless networks. Faced with the new technology, the cities rely on external knowledge from their private partners to successfully deploy wireless broadband networks. Cohen and Levinthal (1990) suggest that the development of absorptive capacity is domain-specific and path dependent in which having some absorptive capacity in a certain area enables an organization to acquire and exploit related knowledge in the future. In addition, an exposure to new knowledge influences an organization's decision making (March and Simon, 1993). In our case, the knowledge developed through the citywide backhaul infrastructure development that the cities of Chaska and Fredericton undertook is valuable in at least two ways. First, it permits them to better understand and evaluate the potential value of wireless broadband technologies. Second, it offers the opportunity for the city staff to develop expertise and an understanding of the city's broadband needs. Beyond the knowledge accumulation, the investment in backhaul infrastructure and the availability of unused fiber capacity make it more economical to add the front-end wireless broadband services.

However, deploying a wireless broadband network involves complex knowledge that needs to be customized to the needs and physical conditions of a city. Our case study data indicate several areas where the absorptive capacity model should be extended to address the complexity of learning processes involved in ISD development. The four constructs emerged from our analysis are: *dynamic of technology development*, *partnership commitments*, *the limitation of external knowledge*, and *learning- by- doing.* The revised absorptive capacity model for information system development is presented in Figure 3.

**Insert Figure 3 about here**

*6.1 Dynamic of Technology Development*

In 2004, Chaska, Hermosa Beach, and Fredericton were considered pioneers in using Wi-Fi mesh technology for municipal wireless networks. Most of the technologies were still under development. There were a few industry players who offered Wi-Fi mesh products at the time. In addition, vendors had limited or in some cases no experiences in deploying Wi-Fi mesh in a large geographical area. In Chaska's case, Tropos had previously implemented Wi-Fi systems in selected applications including public safety, police, and fire usage. Similarly, Hermosa Beach had to adapt routers from Strix Systems that were originally designed for indoor use for their outdoor project. Later on in December 2004, Strix Systems introduced weatherized rugged routers with better coverage and improved power transmission specifically designed for outdoor use. If the second phase of Hermosa Beach Wi-Fi project had been approved by the city council, the city would have had to go through replacing some of the existing routers for the newer and better models. Chaska went through the upgrade like this in April 2005 when Tropos released its 5210 routers (801.11g) which are far better than the 5110 model (802.11b) in terms of capacity and enhanced multi-use network capabilities.

The continuing development of Wi-Fi and other related wireless technology has implications on learning and performance. First, cities have had to keep pace with technological development and have had to learn and evaluate new technologies that might offer better features or solve some of the current issues the cities experience. In addition, as early adopters of the new technology, cities are also involved in co-learning with their partners to identify problems with the current technology with the intention that the vendor partner will resolve these issues in the next technology generation. As a result, cities might not get the optimum performance that the technology has to offer in its current generation.

*6.2 Partnership Commitments*

Chaska and Fredericton worked closely with their private partners in the design and management of the networks while Hermosa Beach chose a hands-off approach by outsourcing the design and management to a private company. Chaska worked closely with Tropos and their staff to implement the Wi-Fi mesh network and integrate other solutions to deliver Internet services. All three Chaska key personnel whom we interviewed shared similar views of the strong partnership from Tropos. The city's administrative service director summarizes Tropos's commitment as follows: "The thing that I have to give Tropos a lot of credits is they really step up and provided us access to a lot of their systems engineers and some of their key field people to help us with the deployment at the time it was certainly one of the largest deployment that they had done and also the largest deployment of varying topologies." Similarly, the IT manager of Fredericton, attributes the project success to the partner, Cisco, who donated equipment and provided essential expertise developing the network.

In addition to a partnership with Tropos, Chaska also enjoyed a long, ongoing relationship with First Mile Wireless, who has partnered with the city on a prior line of sight wireless service for businesses. First Mile Wireless CEO is very knowledgeable in wireless technology and he has provided extensive assistance to help the city understand Tropos technology and how to transform the knowledge into practice including frequency allocations, effective coverage of routers in the field, and adaptation to topologies and challenges in the implementation environment.

Strong partnerships offer partners the opportunity to learn from and about each other. The notion of partnership commitment in our research relates to trust in strategic alliances and joint venture research (Koza & Lewin, 1998; Lane et al., 2001). Kumar (1996) defined trust as dependability by the partners and each partner is interested in the welfare of each other. Successful alliances and joint ventures exhibit trust between partners. Trust is also important to absorptive capacity because it stimulates open sharing of valuable information and tacit knowledge (Inkpen & Beamish, 1997).

*6.3 Roles of External Knowledge and Learning-by-doing*

Knowledge related to new technologies is likely to be located outside of an organization (Konsynski & Tiwana, 2004; Van den Bosch et al., 1999) The rapid change of Wi-Fi mesh technology and the limited experience in Wi-Fi deployment in the industry requires a city to try out knowledge learned from the industry, evaluate the performance, and readjust their knowledge based on feedback from actual experience. In the case of the city of Fredericton, the network was originally designed to be a completely open network with minimal control and security monitoring. After the first year of operation, the city discovered that peer-to-peer traffic and spam significantly slowed down the network speed for users. As a result, the city blocked known virus ports, limited a number of e-mail messages sent, and scanned outgoing e-mail messages for viruses.

The implementation of Tropos routers in Chaska also illustrates the feedback loop between the external knowledge available through private partners and knowledge discovered through practice (Saccol & Reinhard, 2006). Chaska learned from Tropos that every $5^{th}$ or $6^{th}$ routers needs to be connected via a gateway to backhaul connection. However, after implementing routers according to this standard rule, the city experienced problems in signal strength and unacceptable speeds leading to unreliable and low quality Internet services. This is because some areas in Chaska had dense tree lines and green vegetation, while other areas had no gateways close by. In addition, some materials used to build houses can also block out signals. The city worked closely with Tropos to resolve the issues by limiting the number of hops to 3 to 4 hops, adding gateways, and revising frequency plans. Chaska went through a process of iterative knowledge discovery and had to adjust knowledge previously learned according to various conditions of the city.

The city administrative service director described Chaska's learning experience as, "A lot of knowledge that we have obtained has been through our efforts of trying something, see how it is performed, looking at alternative solutions, trying these alternative solutions and working to create what is the best combination to meet the needs of a particular area… The first two years we continue to make a lot of discoveries. We know that it is not just drawing a circle and positioning these radios but we also have to take into account the topology."

The knowledge discovery process not only benefits Chaska but it also significantly benefits Tropos. Mr. Ron Sege, president and CEO of Tropos, in his comment article on muniwirless.com said "The lessons learned in deploying Chaska spawned many mesh software innovations and a new class of analysis tools that will dramatically decrease the time needed to optimize networks in the future."

The relationship between Tropos and Chaska and the mutual benefits that they share in new knowledge creation relates to the collaborator supply chain relationships studied in Malhotra et al. (2005).

In their study of RosettaNet consortium in the IT industry, they found that firms that engage in collaborator type partnerships achieved high knowledge creation by exchanging privileged information and engaging in joint decision making.

*6.4 ISD Development Process*

Our findings are also consistent with others who reported that IT personnel requires both technical and managerial knowledge and skills to facilitate transformation process of IT components into effective services (Basselier & Benbasat, 2004; Fink & Neumann, 2007; Melville et al., 2004; Ross et al., 1996). Key technical expertise includes hardware diagnosis and maintenance, application development, systems integration and maintenance, and network management and maintenance (Byrd & Turner, 2000; Melville et al., 2004). Managerial skills include the ability to plan, organize, and lead projects, work collaboratively in a team environment, and complete projects within time and budget constraints, among others (Byrd & Turner, 2000; Fink & Neumann, 2007; Lee et al., 1995).

The Hermosa Beach project that was led by the mayor and the city manager is similar to the user-led project in Sabherwal and Robey (1995)'s classification. This kind of project is characterized by low participation of IS personnel, early technical knowledge seeking mostly from those external to the organization rather than from in-house IS personnel, and the lack of explicit performance evaluation. Some of these conditions may explain why the Hermosa Beach project experienced technical difficulties and resistance from those who were not directly involved in the project. Note that all three projects employed the implementation process that Sabherwal and Robey (1993) referred to as "outsourced cooperative" in which the three cities cooperated extensively with external parties to provide technical knowledge, consultation on the implementation details, and network components and management software. As a result, the cities had little control over the project and were vulnerable to external events. Some of these events are the dissolution of the external partner in the case of Hermosa Beach and the obsolescence of routers within a short period of time in the case of Chaska.

## 7. Conclusion

This research extends the absorptive capacity theory to examine the dynamic of knowledge activities concerning ISD process in the context of municipal wireless networks. By framing ISD process as a dynamically emergent social process and knowledge is embedded in social actions, we develop the absorptive capacity model for information system development process and use it to examine the role of prior knowledge, ISD events that trigger knowledge activities, and the dynamic of knowledge activities in three case studies (Chaska, MN, Hermosa Beach, CA, and Fredericton, Canada).

This paper makes at least two contributions. First, we develop a theory of absorptive capacity for ISD development by using a sequence of events to explain the outcome of the ISD process. By doing so, we are able to preserve detailed information about actions and how they unfold over time that lead to different outcomes (Sabherwal & Robey, 1995). Consequently, our research answers the call by many ISD researchers for process research to offer richer insights to understand such complex social phenomenon (Sabherwal and Robey, 1995; Sambamurthy & Kirsch, 2000).

A second contribution is that we extend the absorptive capacity by suggesting that dynamic of technology development, partnership commitments, limitation of external knowledge, and learning by doing shapes the dynamic of new knowledge creation. We believe that these four constructs might be generalizable to other contexts beyond ISD such as new product development, new technology adoption, and new technology development.

From a practical perspective, the study also provides insights and learning lessons for cities that are in the process of planning and deployment their municipal wireless networks. It also offers more realistic expectations around Wi-Fi deployment taking into consideration that the technology is not a plug and play technology and that considerable efforts are needed to integrate the technology with other solutions to deliver broadband Internet services as well as to configure the system according to topologies, street conditions, buildings, density of trees, among others.

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**Figure 1. Absorptive capacity model for information system development process**

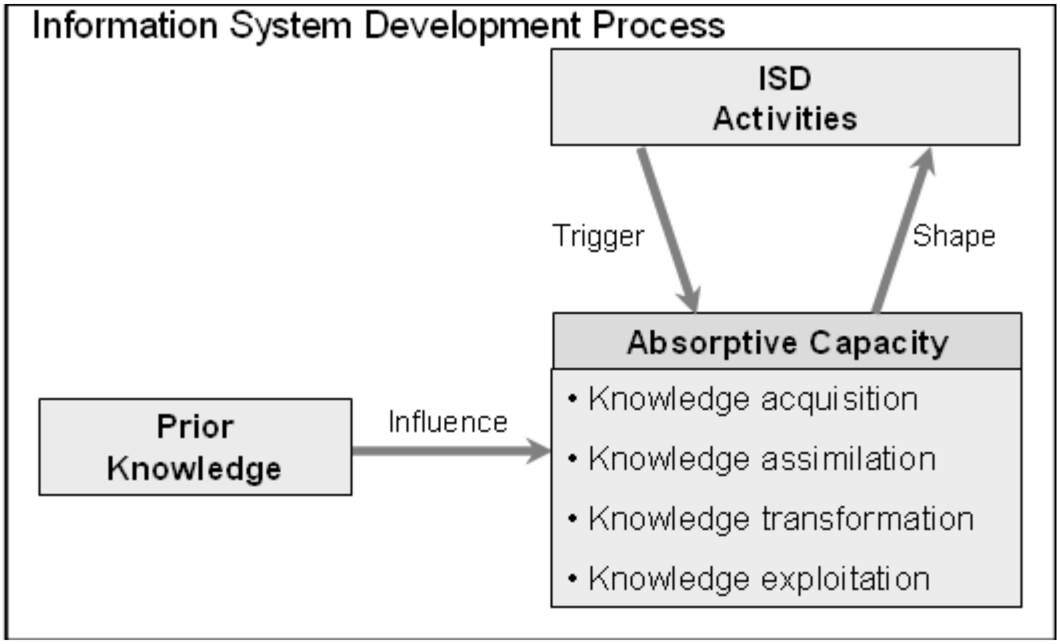


**Figure 2. An Illustration of Wi-Fi Mesh Network Architecture**

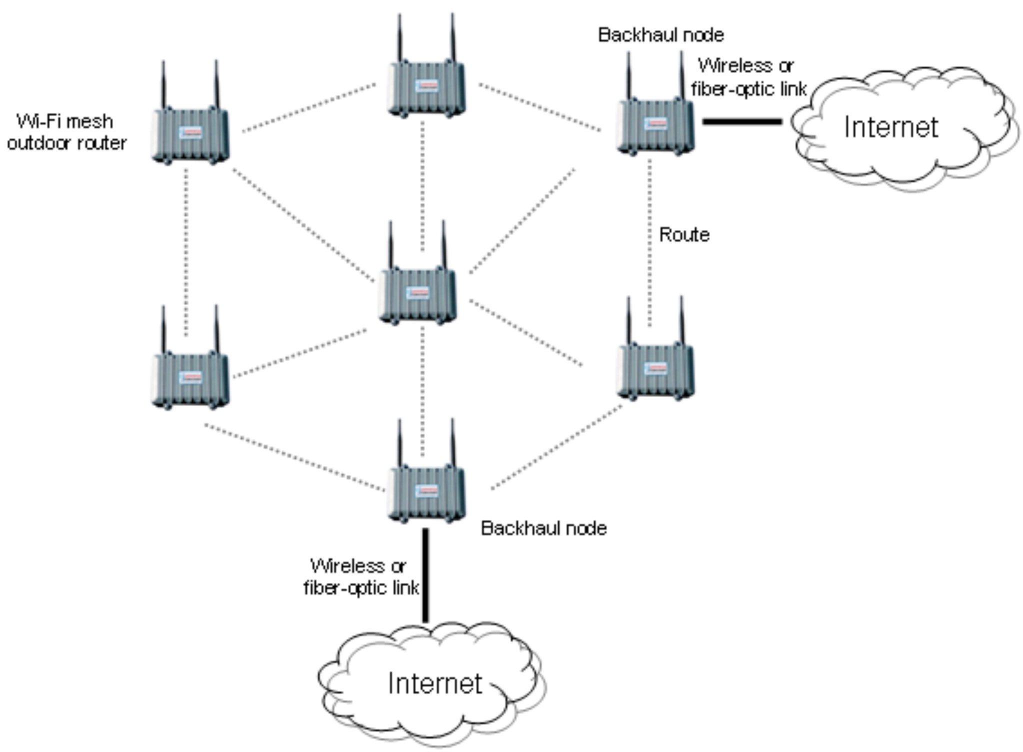

**Figure 3. An extended absorptive capacity model for information system development process**

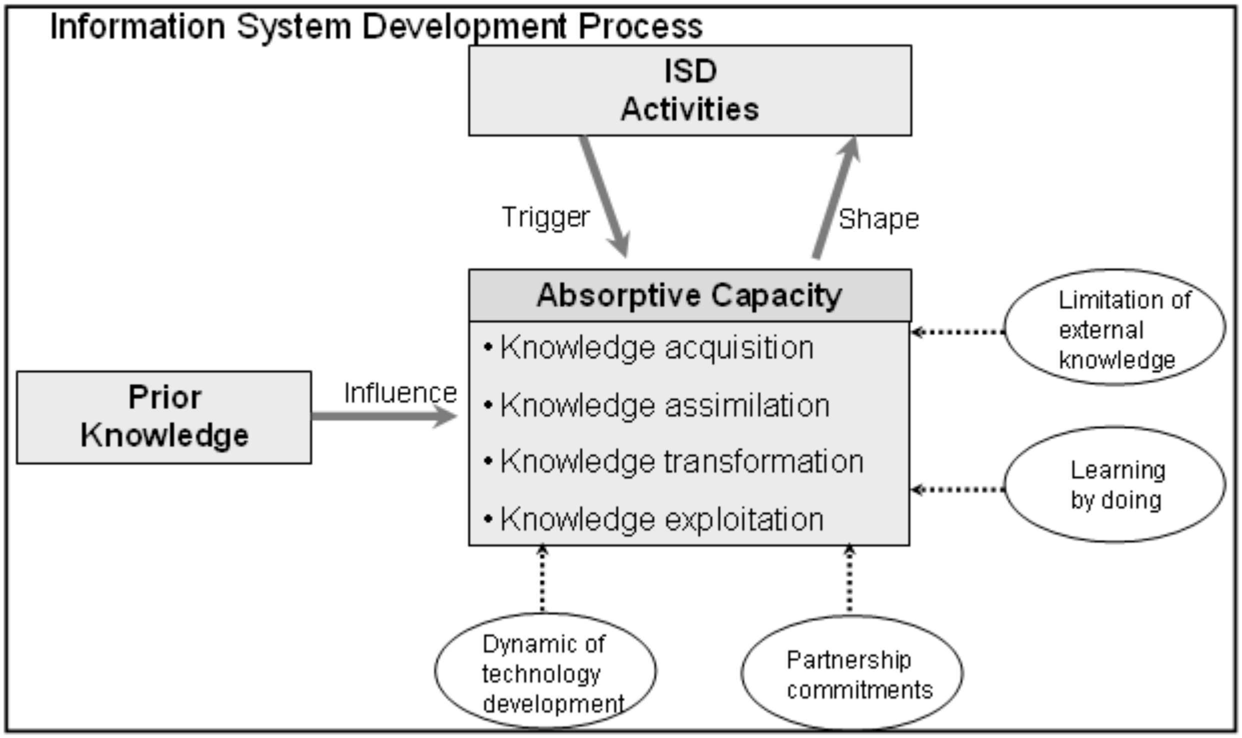

**Table 1. Definition of Research Concepts**

| COMPONENT | DEFINITION | REFERENCES |
|---|---|---|
| Prior knowledge | Prior related experience and knowledge about technical and IS development process and tasks | • Cohen and Levinthal (1990)<br>• Faraj and Sambamurthy (2006)<br>• Kirsch (1996)<br>• Kotlarsky et al. (2006) |
| Triggered events | Internal or external events from ISD process that trigger knowledge activities | • Haunschild and Ree (2004)<br>• Huber (1991)<br>• Sabherwal and Robey (1993) |
| Knowledge acquisition | Processes and routines to identify and acquire knowledge that is critical to ISD | • Lyytinen and Rose (2006)<br>• Zahra and George (2002) |
| Knowledge assimilation | Processes and routines to interpret and understand the new external knowledge | • Hovorka and Larsen (2006)<br>• Kim (1998)<br>• Szulanski (1996) |
| Knowledge transformation | Processes and routines to absorb the new knowledge into the existing knowledge | • Fichman and Kemerer (1999)<br>• Kim (1998) |
| Knowledge exploitation | Processes and routines to incorporate transformed knowledge into ISD process | • Cohen and Levinthal (1990)<br>• Lyytinen and Rose (2006)<br>• Szulanski (1996) |

**Table 2. Data collection**

| CITY | INTERVIEWS | DOCUMENTS |
|---|---|---|
| Chaska, MN | City manager<br>Administrative service director<br>Information systems manager | • Chaska.net web site (http://www.chaska.net)<br>• Prior published interviews given by city officials<br>• Press coverage of Chaska wireless network deployment |
| Hermosa Beach. CA | City mayor<br>City manager | • Wi-Fi Hermosa Beach web site (http://www.wi-fihermosabeach.com)<br>• City council minutes<br>• Wi-Fi Hermosa Beach support forum<br>• Press coverage of Hermosa Beach Wi-Fi network |
| Fredericton, Canada | City mayor<br>Chief Information Officer<br>IT manager<br>Economic development officer<br>System architect<br>Senior field technician | • Fredericton Wi-Fi web site (http://www.fred-ezone.com)<br>• Press coverage of Fredericton wireless network |

**Table 3. Summary of Broadband Wireless Deployment**

| FEATURES | CHASKA | HERMOSA BEACH | FREDERICTON |
|---|---|---|---|
| Technology | Wi-Fi mesh from Tropos | Wi-Fi mesh from Strix Systems | Wi-Fi radios from Cisco, Motorola Canopy backhaul (lily pad architecture) |
| Backhaul | Combination of fiber and wireless connections | Combination of fiber and wireless connections | Combination of fiber and wireless connections |
| Scale | Citywide network with 378 routers covering 14 square miles | Hotspot with 9 routers covering downtown, city hall, and selected neighborhoods | Network with close to 300 routers covering 65% of the city |
| Services | Paid services at $16.99 a month for residential grade service | Free service | Free service |
| Financial model | Supported by subscriber fees | Supported by advertising revenues | Supported by the city |
| Growth | Ongoing growth of subscribers and has potential for network expansion | The network has been considered completed with no future growth | No immediate plan to expand the network |
| Partners | Tropos, First Mile Wireless, and Siemens are the key partners with several other partners providing related solutions for Internet services. | LA Unplugged was the only key partner. | Cisco and the local Motorola vendor Eastern Wireless are the key partners. |
| City players | IS department has the key role with the support from city manager and administrative services manager. | IS department has little involvement. The mayor and city manager play the key role in the project. | IT and Economic development departments champion the project with strong support from the city council. |

**Table 4. ISD Events and Knowledge Activities: Chaska, MN**

| ISD EVENTS | DESCRIPTION | TIME LINE | KNOWLEDGE ACTIVITES |
|---|---|---|---|
| Assignment of personnel | The IS department was assigned to research wireless broadband technology to blanket the entire city. | Jan. – Feb. 2004 | The knowledge acquisition was done through talking to vendors and following the industry. The IS department carefully evaluated the advantages and disadvantages of different wireless broadband products in the market. At the end, they concluded that Wi-Fi mesh is the best choice with Tropos as a preferred vendor because Wi-Fi mesh is a non-proprietary system with relatively fast speed. However, some of their knowledge was developed by chance as stated by the former IS manager "We stumbled across Tropos web site, and we thought they might be able to offer us something of value." |
| Assessment of performance: On-site testing of equipment | The city had a satisfactory on-site testing of Tropos equipment and determined to move forward with this vendor. | Mar. 2004 | The IS manager stated "[Tropos] came out … and left us three of their nodes. We went out and built a kind of temporary network on the roof of a few of our vehicles, went out and tested the network." |
| Approval of project | The city council approved the wireless broadband network. | Apr. 2004 | |
| Selection of specific vendor | The city ordered 230 Tropos 5110 routers. | Apr. 2004 | |
| Physical system construction | The city installed Tropos wireless routers throughout the city area. | May – June 2004 | The city applied the prior knowledge that it had as a wireless operator to install the Wi-Fi mesh system in-house with some help in the planning and installation phases from First Mile Wireless, a reseller and integrator of wireless solutions and an authorized reseller of Tropos.<br><br>The IS manager stated "As a fixed wireless operator, we kept on thinking along the lines of how high can we get those antennas to have a clear line of sight. But with a mesh system, that is not the right approach to take. Tropos recommended keeping the nodes … around 15 to 20 feet off the ground." |

| ISD EVENTS | DESCRIPTION | TIME LINE | KNOWLEDGE ACTIVITES |
|---|---|---|---|
| Assessment of performance: Internal test of the network | The IS department successfully tested the performance of the network. | June 2004 | The IS manager stated "We have done testing indoors and outdoors. We are fairly confident it is going to work pretty well. I can sit in my office and log in to an access point a quarter of a mile away pretty reliably, and that is through a brick wall, trees, and another building. And I am still getting about 1.5 Mbps." |
| Assessment of performance: Public test of the system | The city opened the system for the public to test the network. There were 1,200 signed up to get free Internet access during the test period. | July – Nov. 2004 | |
| Performance problems: Unreliable service during the test period | The city received complaints from users regarding inconsistent coverage. | July – Nov. 2004 | The city used the information from complaints they received and took appropriate actions to solve the problems.<br><br>The IS manager stated "Even though we were free during our rollout, we lost some customers because at that point, we were not completely reliable." |
| Public launch of the system | The city launched Chaska.net's service which is owned and managed by the city itself. | Nov. 2004 | |
| Reassignment of organizational roles: Hiring | The city hired three full time temporary staff to handle customer support once the system was operational. | Nov. 2004 | |
| Performance problems: Customer services | The city received complaints from users about the unsatisfactory experience of customer services.<br>The city manager stated "We weren't able to respond to calls as they were coming in. Most of the times, callers ended up leaving a voice message and the support staff would have to respond on a return-call basisl." | | The city used what they learned from the complaints and addressed them with in the limit of city's resources.<br><br>The city administrative services manager stated "We didn't have in place the tools we needed to track and analyze the calls that were coming in so we could see which calls were about old problems and which were new problems." |
| Performance problems: Conditions in the environment | Wi-Fi mesh technology requires significant fine tuning according to | 2004 - 2005 | The city discovered several issues related to the technology through various connection problems |

| ISD EVENTS | DESCRIPTION | TIME LINE | KNOWLEDGE ACTIVITES |
|---|---|---|---|
| | various conditions in the environment. | | and most of the problems are related to conditions in the environment (e.g., building materials, trees).<br><br>The IS manager stated "We found out during build-out that we had underestimated the amount of dead pockets and dead air in our system. Chaska has a pretty dense tree population. As the altitude slopes up the further out you get from the river that runs downtown, the terrain gets pretty hilly." |
| Performance problems:<br>Unreliable connections | Customers complained about unreliable connections and reduced speeds.<br><br>One customer said "I live directly across the street from an antenna and can always connect to the network, but cannot actually get to the web. I'd say I can actually use the Internet about 10% of the time." | 2005 | The city The speed significantly drops down to dial-up grade services or even worse when the number of hops grows beyond 3-4 hops to a gateway. |
| Selection of a specific vendor:<br>Outsourcing to Siemens | The city outsourced the network operation center and customer support service to Siemens. | Feb. 2006 | The city evaluated a number of vendors and determined that Siemens Communications could deliver a comprehensive managed-services offering with all of the elements they needed. Siemens' venture capital investment in Tropos Networks in September 2005 also played a role in the decision. |
| External event:<br>Fast obsolescence of technology | The city upgraded all routers from Tropos 5110 to Tropos 5210. Tropos 5210 offers several benefits over Tropos 5110. While Tropos 5210 supports 802.11 b only, Tropos 5210 supports 802.11 b and 802.11g, thus offering greater capacity and enhancing multi-use network capabilities, among other things. | Mar. 2006 | The city experienced several problems with Tropos 5110 routers and reported the problems to Tropos. Tropos later released a new router, Tropos 5210, that solved most of the problems that the city experienced |
| Performance problems: | The city found out that a small number | 2005 | The city had to identify an appropriate solution to |

| ISD EVENTS | DESCRIPTION | TIME LINE | KNOWLEDGE ACTIVITES |
|---|---|---|---|
| Quality of service downgraded | of users who consume a lot of bandwidth through some applications (e.g., peer-to-peer file sharing system) can downgrade the quality of the entire network.<br><br>The IS manager stated "We were challenged with bandwidth-intensive application usage on the network by a small percentage of subscribers, as it was affecting the performance of the majority of subscribers using e-mail and Web applications, not to mention mission-critical business traffic". | | address the problem. They decided on the system from Ellacoya networks that performs bandwidth shaping and bandwidth usage control of the users on the system |
| Reassignment of roles: Resignation of key personnel | The IS manager and another staff in the IS department left the city to join Earthlink. | Mar. – July 2006 | |
| Reassignment of roles: Hiring a new IS manager | | Late 2006 | |
| Training | The city sent the new IS manager to attend a training course with Tropos. | Late 2006 | The new IS manager stated "It was a very good week of exploration of equipment, how to perform installation of that equipment, and also what optimal deployment of that equipment looks like." |
| Reassignment of roles: Creating new position | The city appointed the new IS manager to be Internet service manager for Chaska.net. | Late 2006 | |

**Table 5. ISD Events and Knowledge Activities: Hermosa Beach, CA**

| ISD EVENTS | DESCRIPTION | TIME LINE | KNOWLEDGE ACTIVITES |
|---|---|---|---|
| Project definition | The mayor presented the idea of operating a citywide Wi-Fi network to the city council. | July 2003 | The mayor worked with Wireless Facilities Inc. to draft details about the network and its benefits to the city. |
| Approval of project | The city council approved the budget for the city Wi-Fi network known as WiFiHermosa Beach project. | Jan. 2004 | |
| Assignment of personnel to the project | The mayor and the city manager are the two key individuals who are the champions for the project. | Jan. 2004 | The mayor and the city manager argued that there were no models out there for them to emulate concerning city-sponsored wireless programs.<br><br>The mayor stated "(The city manager) and I went to two conferences on municipal wireless about five years ago, one locally and one in Santa Clara. We came home and wrote our own." |
| Approval of vendor | The city council awarded the bid to a systems integrator, L.A. Unplugged. | May 2004 | |
| Physical system construction | LA Unplugged designed and install the network.The system has 9 access points/nodes placed in the commercial area along the Pier Avenue. | May – Aug. 2004 | |
| Assessment of performance: equipment test | LA Unplugged tested the equipment (the backhaul node installed on the fire station tower, a few mesh routers) and determined that the signal coverage is good. | May – Aug. 2004 | |
| Public launch of the system | The city launched Phase 1 of the Citywide Plan that cover approximately 35% of the City, providing free wireless Internet service to the Downtown, City Hall, and adjacent neighborhoods. | Aug. 2004 | |
| User training | The city offered Wi-Fi training classes to individuals and businesses who are | 2004 | |

| ISD EVENTS | DESCRIPTION | TIME LINE | KNOWLEDGE ACTIVITES |
|---|---|---|---|
| | interested in learning about the system. | | |
| Successful performance | The city manager reported the successful performance of the system base on the number of users. In particular, he reported that there have been 300 to 500 residential users and 20 to 50 visitors each day. | 2004 | The city manager uses the successful performance metric as a strong argument to ask the city to move forward with citywide deployment of the Wi-Fi system. |
| Resistance:<br>Citywide deployment | The city manager proposed the full citywide deployment of the Wi-Fi system and a plan to use advertising revenues to cover the ongoing costs. However, the proposal failed to gain approval due to the dissenting votes from a few city council members. | Nov. 2004 | The city staff did additional research to acquire knowledge in various areas and integrate them to determine the best course of action for the city. For example, the city staff evaluated that the business model that the city of Cerritos uses might not be appropriate to Hermosa Beach. City of Cerritos partnered with Airmesh to build and operate the system and charge $29.99 monthly fee for Wi-Fi broadband service. First, city of Cerritos residents do not have access to broadband services from the phone or cable companies, thus making the deal attractive for the private partner. Hermosa Beach is in a different condition because city residents and businesses have a menu of broadband service providers (DSL, cable broadband, fiber optics) to choose from.<br><br>The city staff also consulted with the current contractor and determined that the equipment replacement schedule should be 90 months (7.5 years) and use this schedule to calculate monthly cost associated with the equipment.<br><br>The revenue through advertising was estimated at $2,500 and the cost (equipment, T-1 line, and supports) was estimated at $3,317, resulting in a loss of $817 per month for the city. |

| ISD EVENTS | DESCRIPTION | TIME LINE | KNOWLEDGE ACTIVITES |
|---|---|---|---|
| | | | |
| Resistance: Evaluating citizens' opinions | | May 2005 | The mayor proposed the city to survey citizens' opinions regarding their willingness to pay for city Wi-Fi services. However, the proposal failed to gain approval due to the dissenting votes from the same council memebers who opposed to the project earlier. |
| External event:<br>Change of Mayor | The city had an election in Nov. 2005 and the new mayor was one of the council members who strongly opposed to the citywide deployment. | Nov. 2005 | |

**Table 6. ISD Events and Knowledge Activities: Fredericton, Canada**

| ISD EVENTS | DESCRIPTION | TIME LINE | KNOWLEDGE ACTIVITES |
|---|---|---|---|
| Project definition | The IT and economic development department staff presented a new vision to use the existing network capacity to provide broadband services for those who want to be connected all the time. | 2003 | The IT department had been experimenting with Wi-Fi technologies from various vendors in their testing lab. The IT manager and the executive director of the city's economic development came up with the idea of establishing a not-for-profit, community-wide, high speed, Wi-Fi wireless services. |
| Approval of project | The city council approved the project referred to as Fred-eZone.<br><br>The IT manager stated "The council members told us our timeline was not aggressive enough, gave us more money, and asked us to complete the project in half the time originally allotted." | 2003 | |
| Assignment of personnel to the project | The city IT manager who is also the president and CEO of e-Novations and the city's executive director of the economic development office are the project leaders. | 2004 | The executive director of Team Fredericton issued a formal "expression of interest" request to top networking vendors along with local telecommunications and cable companies.<br><br>The IT manager stated "We wanted someone that had a proven track record, the expertise, and the right product set." |
| Selection of specific vendor | The city chose the Wi-Fi mesh system from Cisco. | 2004 | After careful consideration, the city chose Cisco Systems, which donated equipment to the project, and Motorola Canopy backhaul, because local vendors already had experience operating Motorola products.<br><br>One IT staff stated "Proven, reliable, vendor. Cost is not the determining factor. Local presence, local support is important. Someone who can be down |

| ISD EVENTS | DESCRIPTION | TIME LINE | KNOWLEDGE ACTIVITES |
|---|---|---|---|
| | | | on the ground here." |
| Physical system construction | The city installed outdoor routers throughout the city. They installed more than 200 outdoor routers covering an area of almost 12 square miles. | 2004 | CIO Maurice Gallant stated "The CISCO team worked tirelessly with us to fine tune the signal overlays, resolve radio signal interference issues, and educate our people so we could sustain the network after it was completed." |
| Performance problems: Interference problems | During the built out of the Fred-eZone, the city encountered interferences from other routers, as well as from other devices that operate in the same frequencies of the Wi-Fi radio spectrum. | 2005 | One of the IT staff stated "Initially, we had problems with lots of interference over the network that was produced by having too many radios, and this happened before we broke down the network into separate networks." |
| Performance problems: Network abuse | Network speed was significant slower because the use of peer-to-peer file sharing usage. | 2005 | The network manager introduced traffic shaping protocols to control peer-to-peer traffic. |
| Successful performance | The two project leaders viewed that the project is a success according to a number of measures. According to the report by Cisco systems, the project was completed on budget and on schedule. The executive director of team Fredericton stated "The network is already being well-used. There are about 80 users on average log on each day. The most ever logged on simultaneously was 160." | May 2004 | |

**Table 7. Summary of Prior Knowledge, ISD Events, and Knowledge Activities**

| CONSTRUCTS | CHASKA | HERMOSA BEACH | FREDERICTON |
|---|---|---|---|
| Prior knowledge | The city had six year experience being an internet service provider to local school district and other businesses | The mayor had two years experience in providing a hotspot in his own private business. Neither of the two key personnel had any previous IT network experience. | The city had two year experience being a broadband provider to local businesses |
| ISD Events Trigger | • Assignment of personnel<br>• Assessment of performance<br>• Physical system construction<br>• Performance problems<br>• Reassignment of organizational roles<br>• Obsolescence of technology | • Project definition<br>• Assignment of personnel<br>• Resistance | • Project definition<br>• Assignment of personnel<br>• Physical system construction<br>• Performance problems |
| Knowledge activities | • The IS department worked closely with Tropos engineers to solve implementation issues<br>• The city staff worked closely with knowledgeable consultants<br>• Learning through feedbacks from trials and errors with different connections between routers and gateways and newer model routers<br>• Providing training to new IT staff<br>• Research for solutions | • Participating in several national and state-level conferences<br>• Exchanging knowledge with other cities in the development stage<br>• Learning from other municipalities and other institutions (such as a local university) and applying the lessons learned to the context of municipal wireless network project | • Going to conferences<br>• Integrating specialist knowledge from consultants including Cisco network engineers, RF specialists<br>• Learning through trial and error by responding to problems raised by network architecture choices |