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

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ABSTRACT

Effective knowledge management is important to the success of information technology projects. This research applies the integrated lens of the absorptive capacity theory and the social process model of information system development projects to examine the dynamic of knowledge activities concerning broadband infrastructure development in the context of municipal broadband networks. The research questions are: (1) What is the extent of the dynamic of knowledge activities involved in the development process?, (2) What are the events that trigger knowledge activities in municipal broadband development?, and (3) How does a city create and utilize new knowledge in the development process? This study examines municipal wireless projects in three cities (Chaska, MN; Hermosa Beach, CA; and Fredericton, Canada). Events that trigger knowledge activities are assignment of personnel, physical system construction, performance problems, resistance, and reassignment of organizational roles. Four factors that influence knowledge activities and project performance are the dynamic of technology development, partnership commitments, limitation of external knowledge and learning-by-doing, and political dynamics. The study has policy implications for cities that are in the process of planning and deployment. A good project planning, user expectation management, systematic performance evaluation, a careful partner selection process, and the use of service level agreements are important to project success. In addition, cities need to take 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 services as well as to configure the system according to topologies, street conditions, buildings, density of trees, among others.



## 1. Introduction

Access to basic telecommunications services is considered as one of the necessities for individuals and organizations in the global information society (Crandall, Lehr, & Litan, 2007; Lee, O'Keefe, & Yun, 2003; Wilhelm, 2003). In the U.S., for example, the 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 metropolitan and other economic

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booming cities (Horrigan, Stolp, & Wilson, 2006). The lack of competition does not provide incentives for private operators to expand their coverage to rural areas, to lower their prices, and to upgrade broadband speeds (Daggett, 2007).

Following the ideology of the government's role as infrastructure developer (Gillett, Lehr, & Osorio, 2004; Sawyer, Allen, & Lee, 2003), many cities worldwide have considered deploying municipal wireless networks (citywide networks) with the goals of universal, affordable access to broadband infrastructure for all. Mandviwalla, Jain, and Banker (2007) defined municipal wireless networks as "wireless Internet access networks developed with active local leadership and involvement". Weill, Subramani, and Broadbent (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.

Infrastructure development can be understood broadly as an information systems development (ISD) process. ISD is conceptualized 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" (Sambamurthy & Kirsch, 2000, pp. 400–401). Municipal wireless projects provide an interesting study context and should add new theoretical insights to both the ISD and knowledge management literatures. This is because there are a number of challenges associated with a municipal wireless project in addition to those found in traditional ISD. First, several cities have an ambitious goal to have broadband coverage for the entire city areas, thus increasing the projects' complexity in scale and scope. The Wireless Philadelphia project (http://wirelessphiladelphia.org), for example, is planned to cover a 135 square mile area. Second, there are a number of stakeholders, some of whom may have conflicting goals and interests. Mandviwalla et al. (2008) report that at least 13 diverse stakeholders are 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 express doubts on the capability and knowledge of local government to develop and manage technology infrastructure including its lack of market discipline and technology capability (Feiss, 2007), its exclusion of some operational costs such as maintenance and network operations center costs in the budget (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, Bharadwaj, & Grover, 2003), organizational performance (Bharadwaj, 2000; Bharadwaj, Bharadwaj, & Konsynski, 1999; Brown, Gatian, & Hicks, 1995), and process performance (Froehle, 2006; Karimi, Somers, & Bhattacherjee, 2007; Ray, Muhanna, & Barney, 2005). Similarly, studies in the ISD literature concentrate on using the variance approach to identify antecedents of successful ISD projects (Sabherwal & Robey, 1995; Sambamurthy & Kirsch, 2000). Several researchers suggest that studies concerning ISD process are required to advance the knowledge of the complex social process concerning systems development (Hirschheim, Klein, & Newman, 1991; Sabherwal & Robey, 1993). More specifically, the absorptive capacity theory (Cohen & Levinthal, 1990; Zahra & George, 2002) conceptualized as a capability related to four knowledge activities (acquisition, assimilation, transformation, and exploitation) should broaden an understanding on the influence of the knowledge processes in large-scale infrastructure development projects.

The purpose of this paper is to apply the integrated lens of the absorptive capacity theory and the social process model of ISD projects to examine the dynamic of knowledge activities concerning infrastructure development process in the context of municipal wireless networks. Note that the dynamic social process involved in infrastructure development emerges from complex interactions among stakeholders that subsequently shape the outcome of the development process (Hirschheim et al., 1991; Newman & Robey, 1992; Sambamurthy & Kirsch, 2000). In particular, the infrastructure development process is conceptualized as a sequence of events by highlighting critical events that unfold during the municipal wireless network development process among selected cities from the knowledge management perspective (Kling & Iacono, 1984; Newman & Robey, 1992; Poole, Van de Ven, Dooley, & Holmes, 2000; Sabherwal & Robey, 1993).

The specific research questions are:

- What is the extent of the dynamic of knowledge activities involved in the development process?
- What are the events that trigger knowledge activities during the course of municipal wireless network development?
- How does a city create and utilize new knowledge in the process of municipal wireless network development?

## 2. Infrastructure development process as a social learning process: an absorptive capacity model

Municipal wireless development can be viewed as a social process that involves multiple stakeholders and multiple agendas (Hirschheim et al., 1991; Sambamurthy & Kirsch, 2000). A stakeholder is "a person or group with a vested interest in the outcome of an ISD effort'' (Sambamurthy & Kirsch, 2000, p. 401). Stakeholders in traditional ISD projects may include a project manager, analysts, programmers, user liaisons, IS and user management, vendors, and consultants. Unlike these traditional ISD projects in organizations, most municipal wireless projects have broad goals to provide universal, affordable access to broadband infrastructure to all. Therefore, municipal wireless projects may involve a number of diverse stakeholders such as city government, community residents, businesses, telecoms and ISPs, public schools, vendors, and consultants (Gillett, Lehr, & Osorio, 2006; Mandviwalla et al., 2008).

Different stakeholders who involve in municipal wireless projects may have their individual agendas. An agenda is ''a set of goals, objectives, or expectations relative to the development effort'' (Sambamurthy & Kirsch, 2000, p. 401). A stakeholder's agenda may be implicit or explicit and may include political objectives. For example, wireless technology vendors have an explicit goal of earning profit from their involvement in municipal wireless projects. However, they also have implicit goals to use these projects to showcase their products, to solicit additional projects with other cities, and to promote the municipal wireless industry.

Since this research is focused on learning processes in municipal wireless projects, absorptive capacity is used as a theoretical lens to identify events and explain related learning processes during the municipal wireless development process. Absorptive capacity refers to an organization's capability to identify new knowledge, assimilate it with the existing knowledge, and exploit the integrated knowledge (Cohen & Levinthal, 1990). Absorptive capacity has been identified by a large body of research as a critical factor contributing to innovation (Tsai, 2001), interorganizational learning (Lane & Lubatkin, 1998; Lane, Salk, & Lyles, 2001), and knowledge creation in supply chains (Malhotra, Gosain, & El Sawy, 2005), among others.

A number of factors that may influence the successful outcome of the ISD process are 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 a 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, 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, Kirsch, & King, 2005; Tiwana & McLean, 2005).

Pentland (1995) suggested that knowledge must be understood in the context of embedded social activities. Therefore, this study situates 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 theory also emphasizes how the integrated knowledge from newly acquired knowledge and knowledge accumulated through prior experience can be applied to increase an organization's 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 & Sambamurthy, 2006; Kirsch, 1996; Kotlarsky, Oshri, van Hillegersberg, & Kumar, 2007).

This study uses a recent absorptive capacity framework by Zahra and George (2002) to study knowledge activities embedded in infrastructure development process. Zahra and George (2002) 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 infrastructure development process, therefore, events that trigger knowledge activities come from activities related to infrastructure development. Since infrastructure development is considered one type of ISD, this study modifies Sabherwal and Robey (1993)'s classification of ISD activities as a guideline to identify relevant knowledge triggering events. In their extensive analysis of ISD projects in 50 organizations and more than 1000 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.

Fig. 1 depicts the infrastructure development process as a social learning process using the absorptive capacity model. The model suggests that infrastructure development activities trigger knowledge activities and knowledge activities, in turn, shape subsequent infrastructure development 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, a brief overview of the concepts in the model is provided.

### *2.1. Social process*

An ISD process evolves through the social interplay of multiple stakeholders. Stakeholders use formal and informal means of interaction to achieve their agendas and accomplish the tasks in the development process. For example, an executive committee to develop an implementation plan, town hall meetings, and request for proposals (RFP) are some of the formal interaction mechanisms in municipal wireless projects. Since these projects involve many stakeholders, differences in collective interests and individual interests may lead to conflict and resistance. Social power, appeals to

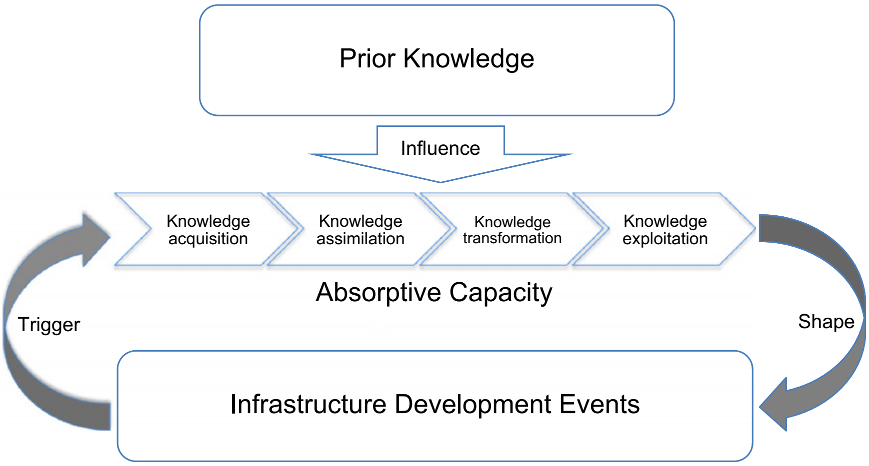


**Fig. 1.** Absorptive capacity model for infrastructure development process.

**Table 1**
Definition of research concepts.

| Component | Definition | References |
|---|---|---|
| Social process | Infrastructure development is a social process that involves the interaction of multiple stakeholders with multiple agendas | • Hirschheim et al. (1991)<br>• Sambamurthy and Kirsch (2000) |
| Prior knowledge | Prior related experience and knowledge about technical and infrastructure development process and tasks | • Cohen and Levinthal (1990)<br>• Faraj and Sambamurthy (2006)<br>• Kirsch (1996)<br>• Kotlarsky et al. (2007) |
| Triggered events | Internal or external events from infrastructure development process that trigger knowledge activities | • Haunschild and Rhee (2004)<br>• Huber (1991)<br>• Sabherwal and Robey (1993) |
| Knowledge acquisition | Processes and routines to identify and acquire knowledge that is critical to infrastructure development process | • 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 infrastructure development process | • Cohen and Levinthal (1990)<br>• Lyytinen and Rose (2006)<br>• Szulanski (1996) |

legitimate norms or policies, and distorting communication to prevent a fair and open debate are some of the ways that stakeholders can respond to conflict and subsequently reach consensus in ISD projects (Hirschheim et al., 1991).

### *2.2. Triggered events*

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 the ISD process (e.g., users 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. Their classification includes a mix of non-knowledge activities (e.g., submission of proposal, project definition, and assessment of performance) and knowledge activities (e.g., seeking technical knowledge, training, and reassignment of organizational roles). This study modifies their classification by focusing on non-knowledge activities as events that trigger knowledge activities according to Zahra and George's definitions. Consequently, twelve activities are maintained as events that 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.

### 2.3. 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 absorptive capacity development 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; Slaughger & Kirsch, 2006).

### 2.4. 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.

### 2.5. 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 prevent 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's (2006) findings suggest that knowledge assimilation is related to IT attitudes, prior experience with IT, and training.

### 2.6. 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 organizational members are necessary for the new knowledge to be integrated into an organization. In the ISD environment, Slaughger and Kirsch (2006) identified several mechanisms to share internal knowledge such as meetings, bulletin boards, internal training classes, transfer of personnel, and informal demonstration. 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.

### 2.7. Knowledge exploitation

The newly 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 any 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.

In the next section, research methods, data collection, and data analysis strategy are discussed.

## 3. Research methods and data

### 3.1. Case study method

Several cities view municipal wireless network initiatives as opportunities to enhance community economic and social development and to address the lack of affordable broadband services. 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, Goldstein, & Mead, 1987). Second, the case study method is particularly well suited for studying phenomena that cannot easily be distinguished from its context (i.e., infrastructure development process, social process, and 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).

The cities of Chaska, Minnesota; Hermosa Beach, California; and Fredericton, Canada were chosen for four reasons. First, these cities have varying levels of experience on infrastructure development and broadband technology, thus making them theoretically 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 are located in different geographical locations with different socio-economic and political conditions can help increase the generalizability of the 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

A retrospective research method is employed by relying on interview data, archival documents, and related articles and prior interviews given by city officials 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 project and the start of data collection. In this study, all three cities finished the development process around 2005 and the data collection period was done between February and July 2007, representing an average of 14–19 months elapsed time.

Data was collected 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 sources to identify infrastructure development events and the related learning process. In total, archival data consisted of more than 250 pages of rich and detailed information through the entire development process of the municipal wireless projects.

For each of the three case studies, the interviews were conducted with key personnel who participated in strategic development, network architectural design, and implementation of the municipal wireless projects. Table 2 summarizes the data collection efforts.

### 3.3. Data analysis strategy

Since the objective of this research is to develop an understanding of the complex knowledge creation in municipal wireless projects, a process research method is used to analyze the data (Poole et al., 2000; Sabherwal & Robey, 1995). Process research is appropriate for this study for a number of reasons. First, the process approach offers an inquiry mode that allows the researchers to develop theoretical explanation to indicate how the knowledge process unfolds over time. Second, it enables researchers to identify causal inferences of the mediating steps through which causality acts through an initiating event and subsequent events. Third, process analysis shares similar ontological assumptions with the absorptive capacity theory concerning the role of prior events. In particular, absorptive capacity theory argues that the knowledge process 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). Fourth, process analysis enables researchers to develop theoretical contributions through unanticipated events discovered during the process analysis (Whetten, 1989).

Poole et al. (2000) suggest 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 events and dynamic of knowledge creation is justified. Events were coded according to Sabherwal and Robey's (1993) classification of ISD events. Knowledge activities triggered by these events were also coded.

Next, an overview of the Wi-Fi mesh technology that all three cities chose for their municipal wireless networks was discussed before the presentation of the findings.

**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.wifihermosabeach.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 |

## 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 & Galperin, 2004; Bar & Park, 2006). First, most countries did not require a license for the 2.4 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 integration of Wi-Fi as standard equipment in portable computing devices.

More recently, new developments have enabled Wi-Fi technology to be implemented in a large geographical area through add-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. A 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 these backhaul nodes by taking multiple hops from one access point to another wirelessly. Fig. 2 illustrates Wi-Fi mesh network architecture.

## 5. Findings

### 5.1. Municipal wireless network projects

The three cities chosen for this research are diverse in terms of their geographical locations and their goals related to municipal wireless projects. However, they share some similarities in terms of being relatively small cities and they are all considered pioneers in their municipal wireless 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 8194 households in 2005. The estimated per capita 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. According to the Chaska.net's mission, the objective of a municipal wireless network highlights the concept of community by aiming to "… 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."

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 9476 households and 3553 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 at the time of network implementation 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 for video and were really expensive. We knew we could do it better and cheaper." Second, he firmly believed that broadband Internet should be treated as a public service or utility that is offered by the city and paid for by tax dollars.

Fredericton, Canada 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% have a university degree.

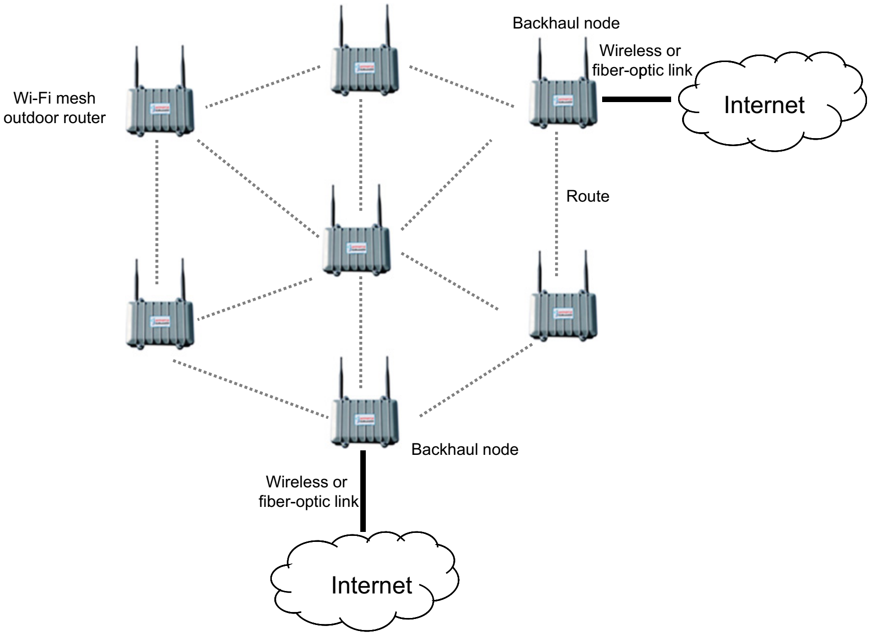


**Fig. 2.** An illustration of Wi-Fi mesh network architecture.

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.

Next, the three case studies are analyzed according to the theoretical framework in Fig. 1. The analysis highlights the role of prior knowledge in new knowledge creation, infrastructure development 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 owned 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. By the end of that year, the city had seven private businesses signed up for the service. 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 with monthly revenues of $16,400. On one hand, Chaska's experience and knowledge that they had as an ISP as well as its existing backhaul infrastructure made it easier for the city to implement the municipal 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 proved 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[3] recommended keeping the nodes … around 15 to 20 feet off the ground."

[3] Tropos (http://www.tropos.com) is a company that provides hardware and software solutions to Chaska to implement its municipal wireless network. Other solution providers are BelAir Networks, Cisco, Motorola, and Strix Systems, among others.

**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 | The original design involves a citywide network. However, in the end, the city created a 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 in 2007 and was recently increased to $19.99 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 | 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 needed 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 |

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 appeared that additional knowledge needed was related to appropriate revenue models for broadband services.

Similar to the city of Chaska, the city of Fredericton had extensive experience and knowledge as an ISP prior to its municipal 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 consisting of a combination of fiber optic and point-to-point wireless technology by Motorola serves as an important asset for Fredericton to easily expand broadband services to the public.

### *5.3. Infrastructure development events and the dynamic of knowledge creation*

The analysis from a careful coding of events suggests a pattern of events that triggered knowledge activities across the three projects. These events include the assignment of personnel, physical system construction, performance problems, resistance, and reassignment of organizational roles. More details about the infrastructure development events, description of events, timeline, and related knowledge activities triggered by those events for the cities of Chaska, Hermosa Beach, and Fredericton, respectively, may be found in the appendix.

### *5.4. 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 these 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. In particular, Chaska's IS manager at the time, Mr. Bradley Mayer, began exploring and evaluating technologies for wireless access to residential users in early 2004. The city evaluated at least three technology solutions from the Metricom/Ricochet system, the Motorola canopy mesh network, and the Tropos system. They eventually chose the Tropos Wi-Fi mesh system primarily because the Tropos system uses an open standard that offers high speed broadband connections with low end user costs for customer premise equipment. In March 2004, the city tested Tropos equipment and found that it provided reliable connections. As a result, the city council approved the development of the network. The equipment and software investment was projected at $535,000 with the assumptions that (1) the city would bill customers for the service through the utility billing system, (2) the city would provide modems to customers at no cost, and (3) the city would provide customer service support through hiring additional staff.

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. Note that these two city officials had no formal training in information technology. The city manager stated, "No, I have no technological background. I'm a manager. I'm a generalist." Similarly, the mayor stated that "I'm a business owner, a manager. I just like technology." Both the city manager and the mayor stressed the fact that there were no models "out there" for them to emulate concerning city-sponsored wireless programs. They stated that they did all of the fact finding, writing the RFP, evaluating the bids, and making a decision without training, experience, or consultants. The city manager stated, "Our RFP was only for building the network, not running it. We got 7 bids ranging from $35,000 to $200,000." The city eventually chose the lowest bid from a system integrator, LA Unplugged.

The city of Fredericton's IT manager, the CIO, and the executive director of the economic development office were the champions of the municipal wireless project. They presented the ideas of a free public wireless network (Fred-eZone) that used excess capacity in the fiber ring to the city council, who voted on each phase of the project as it developed. The city CIO and his team began by experimenting with various Wi-Fi technologies from various vendors. He concluded that "We could achieve our goals if we found the right partner. We wanted someone that had a proven track record, the expertise, and the right product set." The city approached top networking vendors and local telecommunications and cable companies and chose a solution from Cisco who donated some of the equipment in-kind in exchange for using Fredericton as a demonstration project to publicize their products.

### 5.5. Physical system construction

Although the city of Hermosa Beach planned to provide wireless services throughout the city, they took a more cautious approach by dividing the project into two phases. In February 2004, the Hermosa Beach city council approved $35,000 funding to implement the first phase of the project as a test area to evaluate signal strength and backhaul equipment. This phase involved an implementation of 9 outdoor routers and covered 35% of the city area in downtown, city hall, and adjacent neighborhoods. Local business sponsored some of the operation costs. The city hoped that this partnership was a sustainable business model for a citywide deployment in the second phase. In the meantime, the city council requested the staff to work with private companies to find out whether a cost effective wireless broadband system could be successfully deployed throughout the city. In addition, the city council asked the staff to provide monthly reports on the operations and usage of the system.

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, they did not have to directly 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." The first phase of the network was operational in August 2004. Between August and November 2004, there were about 300–500 residential users and 20–50 visitors each day. The city also relied on volunteers to teach Wi-Fi classes and to provide help to other users through an online forum (http://www.wifihermosabeach.com/support). The first phase of Wi-Fi Hermosa Beach appears to be a success. It received enthusiastic support from the city's residents as evidenced from the following quotes taken from residents who attended the city council meeting to support a citywide deployment in November 2004: "free Wi-Fi was the best thing the city had done", "my reception is wonderful", and "I attended the Wi-Fi classes and had never seen such excitement in the community."

In contrast, the physical system construction for Chaska and Fredericton triggered them to engage in new knowledge creation around specifics of Wi-Fi mesh implementations. Both cities integrated their prior knowledge as telecommunications or wireless operators to install the Wi-Fi mesh systems with help 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 closely 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 throughout 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."

### 5.6. Performance problems

Chaska experienced its first performance problems during the test period from July to November in 2004. During this period, 1200 customers signed up for free access to test the service. Throughout the test period, the city, particularly, the IS manager and his two staff members had to address several issues to get the system to work. It is important to emphasize that Wi-Fi mesh was a relatively new technology at the time of Chaska's implementation; therefore, there was not much existing knowledge in the industry for the city to draw from. The city's administrative services director explained, "We were not just deploying Tropos products. We had to figure out how to backhaul from gateways through fiber resources. We also had to ensure that we had some wireless backhaul in the area that we did not have fiber access. We had to work out some issues that we had in terms of inconsistent coverage. During that time, we were getting a lot of calls from people saying that this does not work." The city's manager concluded in his interview reported in Hughlett (2007) that "In hindsight, that was a mistake. That is because 1000 households made for too big of a test sample, considering the new network still had bugs. A lot of Chaskans peppered the city with complaints. A smaller sample size would have been easier."

Chaska also needed to acquire knowledge on the fly while the city experienced difficulty in integrating various components of the Wi-Fi mesh system. The city's administrative service director explained "We not only had to deal with finding an authentication product, we had to find one that could handle the scale of customers that we were anticipating but could also allow us to put up the portal page… We also had trouble with the authentication system so we had to take it down and we left the system open while we worked with Pronto to bring the authentication controller back on again. We also were doing a lot of things to get different pieces in place including an e-mail server and web servers. We had to get the customer premise equipment programmed and make sure that they could connect to the mesh and they could connect with the authentication product."

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 activities to address those issues. Throughout its Wi-Fi mesh deployment, Chaska faced a number of challenges with the system. First, the city realized that the Wi-Fi mesh technology required 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 at the time 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 began 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. After only one and a half years 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 providing services to 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 1100 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 appropriate tools in these two areas. So, they eventually made the decision to outsource the network operation center and customer service to Siemens in February 2006.

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-eZone 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[4] was launched, speeds on the entire network including the fiber backbone were incredibly slow because of peer-to-peer file sharing use among Fred-eZone users. 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 limited 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. In addition, 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.

Overall these cities' experiences offer several learning lessons for other cities. First, careful project planning is one of the important steps towards the success of the project. In particular, project planning needs to perform an analysis on realistic estimates of the number of subscribers, traffic pattern prediction, users' technical needs, and related security issues. Second, cities need to carefully evaluate the technology, understand its limitations as well as implementation details. Third, cities need to approach their wireless projects from a solution perspective. That is, cities need to think about all the components, both hardware and software required, to provide broadband services. Some of these components are outdoor routers, a backhaul system, servers, customer premise equipment, an authentication system, bandwidth shaping software, among others. Fourth, before launching broadband services, cities need to prepare necessary resources (e.g., helpdesk, network operation centers, and maintenance staff) to address connection problems and help users solve their usage problems.

### *5.7. Resistance*

One of the events that triggered new knowledge creation for Hermosa Beach was the resistance to the citywide deployment from some council members. In late 2004 to early 2005, the city considered expanding its Phase 1 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 was 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 planned to enter into a partnership with an ISP to offer a citywide broadband service. Internet service providers were motivated to partner with those cities because of potential revenues in the areas of cities where a telephone and a cable company did not offer broadband services. However, it is unclear if the same business model would work for the city of Hermosa Beach where its residents had several options for broadband services from the existing telephone and cable companies.

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. The city mayor cited lobbies from the telecommunication incumbents as one of the reasons for the approval failure. The mayor stated "We had a pretty good deal with one of our initial vendors. They were going to offer us all of the radios for free. The cable companies got involved. Some independent wireless people got involved. They sent e-mails to our council people and got them to turn against us. They said the technology is inferior and obsolete. I had a real battle with another councilman. He claimed that it's a horse and buggy technology." It is also important to emphasize that the resistance in the Hermosa Beach project reflects the interplay among technology issues, the uncertainty around the revenue model, the proper role of government, and municipal priorities (Cox, 2005). As reported in Cox, one of the council members who voted against the citywide deployment stated "We're not going to pay to improve your street, but we are going to give you free Wi-Fi. You have to prioritize your needs and wants. This free Internet stuff would be way down on my list." Finally, another external event

[4] BitTorrent is a peer-to-peer file sharing protocol for downloading high-quality files over the Internet. Some of the popular services are newly released movies, TV shows, music, and games. BitTorrent is considered bandwidth-intensive services.

that seemed to put an end to the citywide project was the change from the former mayor who was enthusiastic about the citywide deployment to the new mayor who strongly opposed to the project.

In terms of the future of the network, both the city mayor and city manager believed that there would never be a rollout of a complete citywide network. The mayor explained that, after the last council election, more of the council members were in favor of the network but it was no longer needed. He explained that with so many new options for broadband Internet in Hermosa Beach, particularly since the introduction of Verizon's FIOS fiber system in 2006, the need for city-sponsored wireless was disappearing.

### 5.8. Reassignment of organizational roles

As mentioned earlier, Chaska, Hermosa Beach, and Fredericton are early adopters of a Wi-Fi mesh system. Cities did not have opportunities to fully integrate the knowledge into their processes and routines. As a result, most of the knowledge related to system implementation, operation, and maintenance is embedded in people. Personnel turnover can be problematic and may have a negative impact on performance during this period of early knowledge development (Carley, 1992). Chaska experienced its personnel turnover when Brad Mayer who was the lead personnel throughout the testing and early deployment phases left Chaska in March 2006 to join Earthlink. Later, around July or August 2006, Chaska also lost another employee to Earthlink. This employee worked closely with Mr. Mayer and became knowledgeable with Tropos products, backhaul products, and the servers that support the operation center. 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."

Although Chaska did not experience any significant disruption in their municipal network project, their experience offers a lesson for other cities to have adequate planning and training programs in place to address personnel turnover.

Table 4 summarizes the prior experience, infrastructure development events, and knowledge activities during the municipal wireless network deployment.

## 6. Discussion

This study examines knowledge activities embedded in infrastructure development process in the context of municipal wireless networks. Although this study is not intended to offer a comprehensive set of factors that are important to the success of municipal broadband projects, it is argued that effective social learning process is important to understand why some projects fail and others succeed.[5]

During the course of municipal broadband projects, most cities are challenged with the daunting task to understand various technological choices; therefore, these cities tend to 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 & Simon, 1993). In this study, 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 learning processes because the required knowledge must be tailored to the usage needs and physical conditions of a city. The case study data offers evidence that there are at least four factors that influence a learning process and hence project performance. These factors are: the dynamic of technology development, partnership commitment, limitation of external knowledge and roles of learning-by-doing, and political dynamics. Table 5 presents the evidence from the three case studies to support the validity of these four factors.

### 6.1. Dynamic of technology development

In 2004, Chaska, Hermosa Beach, and Fredericton were considered pioneers who chose to use a new Wi-Fi mesh technology in municipal wireless networks. Most of the technologies were still under development. There were a few

[5] Some studies (e.g., Gibbons & Ruth, 2005; Goth, 2009; Hudson, 2010) suggest that a mixed public and government usage plan, well-planned risk sharing models with the private sector, realistic usage estimation, and sustainable business models are important to the success of municipal broadband projects.

**Table 4**
Summary of prior knowledge, infrastructure development 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 |
| Infrastructure development events | • 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 on network design<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 | • Attending conferences<br>• Integrating specialist knowledge from consultants including Cisco network engineers and RF specialists<br>• Learning through trial and error by responding to problems raised by network architecture choices |

**Table 5**
Factors that influence learning processes in municipal broadband projects.

| Factors | Evidence from case studies |
|---|---|
| Dynamic of technology development | **Chaska**: "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 …. 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."<br>**Hermosa Beach**: The city had to adapt routers that were originally designed for indoor use in its outdoor deployment.<br>**Fredericton:** "When the popular application BitTorrent was launched, speeds on the entire network … were incredibly slow." |
| Partnership commitment | **Chaska:** "… I have to give Tropos a lot of credits. They really stepped 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."<br>**Fredericton**: "The Cisco team worked tirelessly with us to fine tune the signal overlays, resolve radio signal interference issues, and educate our people." |
| Limitation of external knowledge and roles of learning-by-doing | **Chaska**: "There were a lot of preconceived notions that you can just blast Wi-Fi signals through walls and trees and everything. We discovered that wet, leafy trees absorb radio signals."<br>**Hermosa Beach**: "There was no RFP model. No other cities were doing this at the time. There was nothing to follow."<br>**Fredericton**: The initial design was based on a single network but when adverse weather conditions affected the radios and interference between radios grew, quality of service impacted the entire network. As a result, the city changed the design to include three virtual networks. |
| Political dynamics | **Hermosa Beach**: The citywide deployment proposal failed to gain approval from the city council. |

industry players who offered Wi-Fi mesh products at the time. In addition, vendors had limited or in some cases no experiences in deploying a Wi-Fi mesh in a large geographical area. In Chaska's case, Tropos 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 the Hermosa Beach Wi-Fi project had been approved by the city council, the city would have had to go through such an upgrade in April 2005 when Tropos released its newer 5210 routers (801.11 g) which are far better than the older 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 knowledge activities which in turn influence project performance. First, cities had to keep pace with technological development and had to learn and evaluate new technologies that might offer better features or solve some of the current issues that the cities experienced. In addition, as early adopters of the new technology, cities were also involved in co-learning with their partners to identify problems with the current technology with the intention that the vendor would 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.

How can cities cope with the fast changing broadband technology? The experiences from these three cities suggest that good project planning, user expectation management, and systematic performance evaluation are critical to project success. First, a good understanding of application needs and stakeholder expectations is required to develop an appropriate network design. Therefore, cities are encouraged to set up various task forces to study current broadband availability, pricing, and broadband needs and provide recommendations on technical and business solutions for the project. Second, an RFP should not commit the city to a specific technology platform. Instead, an RFP should have a detailed outline of technical requirements that emphasizes desirable performance metrics such as access and backhaul performance, coverage, security, reliability, redundancy, and scalability. Third, an RFP should explicitly state that a city anticipates technology upgrades to meet changes in increased bandwidth demand. Thus, vendors are required to provide their roadmap of product development and a plan for a technology refresh if newer technologies such as a new Wi-Fi standard and WiMAX become available. Fourth, it is important that a city uses public forums and committees to engage various user groups in order to set up the correct expectation about network performance regarding speed, reliability, and factors that may impact network performance. Fifth, it is important that a city develops a systematic performance evaluation once broadband services are offered. Following an industry trend and sharing information with other cities are some of the ways that cities can learn how to address any performance issues as they arise.

### *6.2. Partnership commitments*

Chaska and Fredericton worked closely with private partners in the design and management of their networks while Hermosa Beach chose a hands-off approach by outsourcing the design and management to a private company. More specifically, 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 shared similar views of the strong partnership from Tropos. The city's administrative service director summarized 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 to develop the network.

In addition to a partnership with Tropos, Chaska also enjoyed a long, ongoing relationship with First Mile Wireless, who had partnered with the city on a prior line of sight wireless service for businesses. First Mile Wireless CEO was very knowledgeable in wireless technology and he 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 this 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 the 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).

Partner selection and service level agreements (SLAs) are some of the mechanisms that are helpful to guarantee commitment from private partners. A comprehensive background check that covers financial stability and technical capabilities is important to the partnership selection process. For example, a city may want to check if vendors have experience with other municipal broadband projects. A city can also use the information from a vendor's response to an RFP to evaluate their technical capabilities. For example, a vendor's network architecture plan, its plan to mitigate interference issues, and system capabilities (e.g., throughput, latency, and jitter) to support voice, data, and video applications are useful information.

An SLA is a contract to characterize the service and specify the quality of service that a private partner will provide to a city (Lehr & McKnight, 2002). Service level agreements that focus on network performance metrics around key applications under a normal condition and under a high subscriber load for different type of traffic (voice, video, and data) will guarantee private partners' commitment to work with the city to meet its broadband service goals. In some cases, SLAs may also include customer service support, technical support, and performance management.

### 6.3. Limitation of external knowledge and roles of learning-by-doing

Knowledge related to new technologies is likely to be located outside of an organization (Konsynski & Tiwana, 2004; Van den Bosch, Volberda, & de Boer, 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 the 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). For example, Chaska learned from Tropos that every 5th or 6th 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 or 4, 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 muniwireless.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 the 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. Political dynamics

Bowker and Star (1999) argued that infrastructure development is not a smooth process because not all technologies develop into embedded infrastructures. Social and political negotiations have important impact on how the infrastructure is eventually built. These statements are certainly true for the Hermosa Beach case. Resistance and politics that led to the failure to build a citywide broadband network in Hermosa Beach primarily evolved from the complex interaction among local politics, beliefs about the role of government in broadband services, and technology limitations. On one hand, some level of resistance is good for the project because it creates additional oversight to the decision making process. In particular, resistance enables city champions of municipal broadband to find more evidence to support technology choice, address project sustainability, and find appropriate business models as evidenced in the case of Hermosa Beach. Another unexpected result is that the broadband, though partially complete, was viewed as a threat to the private broadband providers. As a result, they were pressured to offer high quality services at reasonable prices. On the other hand, some may argue that an abandonment of municipal broadband may result in a long-term opportunity cost to increase competition, lower prices, and drive demand for future deployments in both the public and private sectors (Scott & Wellings, 2005).

From a broader perspective, these early examples of municipal broadband initiatives offer valuable lessons for future deployments. First, cities need to understand that the project approval process may take longer than expected. During the process, project champions need to be prepared to find evidence to defend against concerns raised by various stakeholders. Hermosa Beach city manager agreed: "Our network was all about politics, beginning to end. It was started by a guy on the council who was a true believer and who influenced others on the council to support his ideas. It ended when council members were convinced by the phone and cable companies that this was not a good idea. It was all politics." Second, it is important to emphasize that there is a great deal of uncertainty in municipal politics. In some cases, individuals who oppose a project may feel that the project is not their idea but a champion's initiative as in the case of San Francisco (Hudson, 2010). As a result, early "on-boarding" engagement of stakeholders and decision makers can be critical to the success of the project.

Table 6 summarizes guidelines and action plans for future municipal broadband projects.

**Table 6**
Practical guidelines for future municipal broadband projects.

| Factors, guidelines, and action plans |
|---|
| **Factor: Dynamic of technology development** |
| *Guideline 1*: A city needs to have a good understanding of users' application needs and stakeholder expectations to develop an appropriate network design. |
| *Action plan*: |
| • Hire knowledgeable consultants to help with network design and customization of the technology to a city's conditions. |
| • Participate in industry conferences to learn about recent technology trends. |
| • Share information with other cities to learn technology implementation details. |
| • Set up task forces to study current broadband availability, pricing, broadband needs, and feasible business models. These task forces should provide recommendations on technical and business solutions for the project. |
| *Guideline 2*: An RFP should not commit a city to a specific technology platform. |
| *Action plan*: |
| • Emphasize desirable performance metrics such as access and backhaul performance, coverage, security, reliability, redundancy, and scalability in an RFP. |
| • Require vendors to provide their plans on technology upgrade to meet with increased bandwidth demand. |
| • Require vendors to provide their roadmap of product development and a plan for a technology refresh if newer technologies become available. |
| *Guideline 3*: A city should manage user expectation of broadband service performances before introducing the service. |
| *Action plan*: |
| • Use public forums and committees to engage various user groups and set up the correct expectation about network performance in the areas of speed, connection reliability, and factors that may impact network performance. |
| *Guideline 4*: A city should develop a systematic performance evaluation of broadband services. |
| *Action plan*: |
| • Hire a third party company to evaluate network performance. |
| • Follow industry trend and share information with other cities to learn useful evaluation plans and ways to address performance issues. |
| **Factor: Partnership commitment** |
| *Guideline 1*: A city needs to have a careful partner selection process. |
| *Action plan*: |
| • Perform comprehensive background checks that cover financial stability and technical capabilities. |
| • Check vendors' experience and their success with other municipal broadband projects. |
| • Use information from vendors' response to an RFP to evaluate their technical capabilities. Some of the useful pieces of information are a vendor's network architecture plan, a plan to mitigate interference issues, system capabilities to support voice, data, and video applications. |
| *Guideline 2*: A city should use service level agreement (SLAs) to characterize the quality of service received from private partners. |
| *Action plan*: |
| • Focus on network performance metrics around key applications under a normal condition and under a high subscriber load for different types of voice, video, and data traffic. |
| • Include customer service support, technical support, and performance management if possible. |
| **Factor: Limitation of external knowledge and roles of learning-by-doing** |
| *Guideline 1*: A city needs to understand that broadband is not a plug-and-play technology. Considerable customization and fine-tuning are needed in the implementation and maintenance process. |
| *Action plan*: |
| • Have dedicated city personnel work closely with private partners to gain necessary knowledge and skills to maintain a network. |
| • Use a pilot project to test network equipment in a small city area. |
| • Have a reasonable number of users to test a system before a large-scale rollout. Use the feedback from the test to adjust a network and prepare necessary resources to address usage problems. |
| **Factor: Political dynamics** |
| *Guideline 1*: A city needs to understand that the project approval process can be a highly political process and may take longer than expected. |
| *Action plan*: |
| • Be prepared to provide necessary evidence to defend against concerns raised by other stakeholders. |
| • Should have early "on-boarding" engagement of stakeholders and decision makers. |

## 7. Conclusion

This research extends the absorptive capacity theory to examine the dynamic of knowledge activities concerning infrastructure development processes in the context of municipal wireless networks. The infrastructure development process is framed as a dynamically emergent social process and knowledge as embedded in social actions. The absorptive capacity model for the infrastructure development process is conceptualized and used to empirically examine the role of prior knowledge, 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 contributes to theory and practice. The study makes at least two contributions to theory. First, this research extends the absorptive capacity theory to examine the infrastructure development by using a sequence of events to explain the outcome of the infrastructure development process. By doing so, rich detailed information about actions and how they unfold over time that lead to different outcomes are preserved (Sabherwal & Robey, 1995). Consequently, this research answers the call for process research by many ISD researchers to offer richer insights to understand such complex social phenomenon (Sabherwal & Robey, 1995; Sambamurthy & Kirsch, 2000).

A second contribution is that the research results suggest four factors that influence the dynamic of knowledge activities: dynamic of technology development, partnership commitments, limitation of external knowledge and the role of learning-by-doing, and political dynamics. Although these four constructs are discovered in the context of municipal wireless networks, they may be generalizable to other contexts beyond infrastructure development such as new product development, new technology adoption, and new technology development.

From a practice perspective, the study provides policy insights for cities that are in the process of planning and deploying municipal wireless networks. For any project, planning, user expectation management, systematic performance evaluation, a careful partner selection process, and the use of service level agreements are important for project success. Cities also need to have realistic expectations about Wi-Fi deployment by 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.

This research has two limitations. First, the retrospective research method limits it to high-level events. As a result, this study is unable to capture micro-level events and the detailed breakdown of knowledge activities (i.e., acquisition, assimilation, integration, and exploitation). The data collected illustrates a smaller number of events and a summary of knowledge activities in the findings. This offers an opportunity for future research to use longitudinal data collection while projects are in progress to capture richer development process and associated knowledge activities. Richer event data would enable researchers to apply other analysis methods (e.g., Phasic case studies, Markov analysis, and Time Series analysis) to develop deeper insights into new knowledge creation in the infrastructure development process. Second, although this research offers a greater understanding of the dynamics of knowledge activities in an infrastructure development process, the collected data would not allow the researchers to evaluate a relationship between knowledge activities and outcomes of the development process. Another useful question to explore in future research is how municipal broadband projects and learning events change the way cities operate. Such extension from this research would contribute significantly to the ISD and knowledge management literatures concerning the importance of knowledge creation and exploitation in the development process.

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## Appendix

For the infrastructure development events and knowledge activities, see Tables 7–9.

**Table 7**
Infrastructure development events and knowledge activities: Chaska, MN.

| Events | Description | Time line | Knowledge activities |
|---|---|---|---|
| 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." |

**Table 7** (*continued*)

| Events | Description | Time line | Knowledge activities |
|---|---|---|---|
| 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>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." |
| 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 1200 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>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 basis." | | The city used what they learned from the complaints and addressed them within the limit of city's resources<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 various conditions in the environment | 2004–2005 | The city discovered several issues related to the technology through various connection problems and most of the problems are related to conditions in the environment (e.g., building materials, trees)<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: unreliable connections | Customers complained about unreliable connections and reduced speeds<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 | 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 |

**Table 7** (*continued* )

| Events | Description | Time line | Knowledge activities |
|---|---|---|---|
| | web. I'd say I can actually use the Internet about 10% of the time." | | |
| Selection of a specific vendor: 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: 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: quality of service downgraded | The city found out that a small number 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>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." | 2005 | The city had to identify an appropriate solution to 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 8**
Infrastructure development events and knowledge activities: Hermosa Beach, CA.

| Events | Description | Time line | Knowledge activities |
|---|---|---|---|
| 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 Wi-Fi Hermosa 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>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 installed the network. The system has 9 access points/nodes placed in the commercial area along the Pier Avenue | May–Aug. 2004 | |

**Table 8** (*continued*)

| Events | Description | Time line | Knowledge activities |
|---|---|---|---|
| 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 interested in learning about the system | 2004 | |
| 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 300–500 residential users and 20–50 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: 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>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>The revenue through advertising was estimated at $2500 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 |
| 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 members who opposed to the project earlier |
| External event: 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 9**
Infrastructure development events and knowledge activities: Fredericton, Canada.

| Events | Description | Time line | Knowledge activities |
|---|---|---|---|
| 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 | 2003 | |

**Table 9** (*continued* )

| Events | Description | Time line | Knowledge activities |
|---|---|---|---|
| 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." | | 2004 | |
| 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>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>One IT staff stated "Proven, reliable, vendor. Cost is not the determining factor. Local presence, local support is important. Someone who can be down 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." | 2005 | |

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