The Pennsylvania State University

The Graduate School

College of Information Sciences and Technology

UNDERSTANDING 911 DISPATCH TEAMS ACROSS CONTEXT: IMPLICATIONS FOR THEORY, INFORMATION TECHNOLOGY, AND PRACTICE

A Thesis in

Information Sciences and Technology

by

Ivanna S. Terrell

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

May 2006

The thesis of Ivanna Terrell was reviewed and approved* by the following:

Michael McNeese
Associate Professor of Information Sciences and Technology
Thesis Adviser
Chair of Committee

David Hall
Associate Dean for Research
Information Sciences and Technology

Carleen Maitland
Assistant Professor of Information Sciences and Technology

Alan MacEachren
Professor of Geography

Joseph Lambert
Senior Associate Dean
Associate Professor of Information Sciences and Technology
Chair, Graduate Programs Advisory Committee
Head of the College of Information Sciences and Technology

* Signatures are on file in the Graduate School

ABSTRACT

The research plan presented in this study sought to assess and evaluate the decision making procedures, communication activities, and human-computer interactions that facilitate teamwork in 911 dispatch teams. Due to the variability in emergency allocation procedures among 911 dispatch teams across differing contexts, dispatch groups located within two diverse geographical and demographical contexts were evaluated. Data from *in situ* observations and cognitive task analyses with 911 dispatchers was analyzed according to the principles and implications of three extant theories of teamwork: distributed cognition, transactive memory, and Recognition-Primed Decision (RPD) making. Each theory was evaluated to determine its applications and shortcomings to the characteristics of 911 dispatch group contexts. Additionally, the current research evaluated the application of information technology to support teamwork, team decision making, and the formation of team mental models in 911 dispatch teams within the various contexts of the dispatch teams. The results suggest that geographical and demographical context can affect the nature of teamwork in regards to team decision making procedures, communications, utilization of information technology, and formation of team mental models. The results also revealed fifteen key characteristics or attributes of 911 dispatch teams concerning team decision making, communication, and utilization of information technology. Application of extant theory to the attributes of 911 dispatch teams suggests that distributed cognition theory is more applicable to the study of 911 dispatch teams than transactive memory theory and RPD. Transactive memory was found to be more applicable to the study of 911 dispatch teams than RPD. While all theories were applicable to some of the key attributes of 911 dispatch teams, none of the theories were applicable to all attributes. Additionally, some attributes of 911 dispatch teams were not applicable to any of the theories. Therefore, a new framework, the Rapid Aysnchronous-Synchronous Distributed Decision (RASDD – pronounced "raised") framework, was proposed to account for all key attributes of 911 dispatch teams.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

First, thank you to the Lord Jesus for getting me through the last four years. Through Him, all things are possible, and I'm excited about His plans for the next phase of my life.

As far as people on the planet Earth are concerned, I want to extend a heartfelt thanks to my adviser, Dr. Michael McNeese. You were an outstanding mentor, instructor, mediator, and kicker-in-the-you-know-what when you saw me procrastinating too much on something. And I never told you this, but I have always wanted to thank you for just giving me a shot at the Ph.D. I am sure that when you were looking through the stack of resumes trying to decide who would be among your next batch of lab groupies, you probably saw a lot of resumes that had higher test scores and GPAs than mine. Thanks for taking a chance on me. You made me an original MIND, and I quickly found out that you have a great original mind of your own. You've described it as a warped one, but nevertheless it soon became one that I admire. I also want to thank Judy for all of the hospitality and good food you've shared with me over the years. I still think about those caramel brownies every now and then…I just had a moment now. God bless to you both.

To all of my committee members: Mike, Dave, Carleen, and Alan – thank you for all of your advice and guidance. I hope I didn't mess up your vacations too bad by having my defense the day after spring break!!

A special thank you to Dave Hall, for always having an open door policy whether it was to listen to me gripe or to pull me out of one of my many writer's blocks. And thanks for all the times when you would check in just to check in. Your support always gave me a sense of much needed reassurance during times when I wasn't sure if I would be able to pull through.

Thanks to all the rest of my IST friends (second year class – we are the one, the only), and faculty. Special thanks to Eileen, Lynette, and Isaac.

And lastly, but only because I like to save the best for last, thanks to my Mom and Dad for giving me the best possible kick start to life that anyone could ask for. You were my secret weapon during the last four years. You never gave up on me even when I felt like throwing in the towel. Aunt Jo – I'm still waiting on the prophecy, but you never made me wait for support. Uncle Bob, I can hear your voice from heaven saying "Go 'head Sammy!" And to Amani and Elon: we survived Bethesda together, then Milliken, Marcus, UT, and car trips with all three of us crammed into the backseat trying to shove each other out of our spaces. My best memories of life so far have the two of you in it. Good times…good times. Thank you for all of them, and thank you for the ones to come.

To anyone I may have missed, charge it to my head and not my heart.

DEDICATION

I dedicate this thesis to my grandparents – Grandpa Emory, Grandma Carrie, Grandpa George, and Grandma Peggy – intelligent people who were never given the chance to use their talents. Despite your setbacks, you instilled the importance of education to those you raised, and your legacy lives on. Everyone has said congratulations to me, and now I offer my sincere thanks and congratulations to you.

CHAPTER I: INTRODUCTION

A witness or victim of an emergency such as a heart attack, auto accident, or collapsed building may instinctively respond by locating a phone, dialing 911, and requesting help from the answering operator or dispatcher. The dispatcher, in turn, may ask the caller what is happening, who is involved or injured, and where they are to determine the most appropriate response to take. The answering dispatcher will, to the best of his or her ability, attempt to gather enough information from the caller to answer questions such as: what emergency resources should be sent; how many resources should be sent; and where is the emergency aid needed? The situation must be carefully considered so that all of the above questions are answered and acted upon to the utmost degree of accuracy. After all, it could very well be that someone's life depends upon the accuracy and efficiency of the dispatcher's final decision.

Established in 1968 (*The Development of 9-1-1*, 2005), individuals have enlisted the aid of the 911 system for emergencies of various degrees of intensity and severity – from local petty theft to large scale disasters such as Hurricane Katrina and the World Trade Center disaster (Connolly, 2005). Emergency dispatchers field these types of calls and help to ensure that the appropriate emergency response arrives to the aid of the individuals and entities in need of assistance. In many cases, 911 dispatchers are the first line of outside contact once an emergency situation has occurred. They are the first outside people who are given a synopsis of what happened and who it happened to. They are often the first to decide what resources to send as emergency aid. Due to the time-critical nature of this dispatch work, mere seconds can mark the difference between life and death (Holzman, 1999). Therefore, it is essential to study how 911 dispatchers release resources to emergencies, the efficiency in which this is done, and to determine how to improve upon the 911 system.

It is important to note, however, that many of the decisions made by any individual 911 dispatcher are augmented by other sources of information. These can include other dispatchers, information technology resources, and first responders such as police, fire,

paramedic, and hazardous material (hazmat) crews (Terrell, McNeese, Jefferson, & Craven, 2004). Thus, it is critical that when discussing the study and analysis of 911 dispatchers' methods of decision making, the study must consider how a 911 dispatcher functions as a part of a team which includes other dispatchers, first responders, information technology, and other available resources.

1.1 Problem Focus

The purpose of this research was to investigate how individuals in 911 dispatch teams communicate and cooperate with each other and with other individuals to make appropriate decisions regarding the dispatch of resources to a given emergency situation. In other words, the focus of the current study is on the collaboration and teamwork of 911 dispatchers and their use of information technology to make decisions.

Generically speaking, teamwork refers to the activities of groups as they work within complementary tasks and resources towards a shared goal (Andersen, 2000; Langan-Fox, Anglim, & Wilson, 2004; Yen et al.). A collaborative group, in turn, can be defined as a contingent of individuals who participate in goal-oriented activities (Gokhale, 1995; Levine & Moreland, 2004). Therefore, in 911 dispatch, the collaborative group refers to the team of dispatchers who receive information about emergency situations (via witness phone calls, news reports, field worker calls) and how they utilize available resources, communicate between each other, and devote themselves to certain complementary tasks in order to achieve their goal of allocating emergency resources to pacify an emergency situation. For the purposes and focus of this study, this collaborative group will be referred to as a 911 dispatch team[1].

Given the stated focus of this study, the overarching goals of this research were:

[1] A 911 dispatch team includes individuals who answer emergency calls, dispatch emergency resources, and manage call-taking and resource allocations.

- to outline the network, relationships, and collaboration between 911 dispatchers, information technology, and other resources when responding to an emergency situation;
- to determine the specific types and functions of information technology used by 911 dispatchers to facilitate teamwork and team and individual decision making;
- to assess and evaluate the applicability of existing theories of cognition and decision making with the decision making activities of 911 dispatch teams; and
- to develop a new framework regarding teamwork that can be used as a foundation for the future measurement of 911 dispatch teamwork and team activities.

The realization of these goals was essential toward the understanding of teamwork, team decision making, and use of information technology as it applies to 911 dispatch activities. The following section, which presents background information concerning teams and team decision making, will help to clarify why this study, and the realization of its subsequent goals, was deemed necessary for practical and theoretical advancement.

1.2 Background Information

A 911 dispatch team is a goal-oriented group. Yet even though members of the group are oriented towards a common goal, which is to pacify an emergency situation, individual perspectives within the dispatch team concerning the situation could yield difficulty in determining how the goal should be achieved. In extreme situations, this could result in goal conflict (Woods & Cook, 1999). However, if the perceptions are more congruent, then there is a greater chance that common ground between group members will be formulated. As suggested by Terrell et. al. (2004), reports heard by individual dispatchers regarding a certain emergency situation may differ. Therefore, a team of dispatchers must achieve a common perspective, or team mental model, of the emergency. Otherwise, the final decision may be based upon inaccurate or incomplete

information possibly causing the inappropriate type and/or number of resources to be sent to the emergency site. Given this, it was imperative to ask the following question that is a prime focus of this research: "*How are team mental models achieved?"*

1.2.1 Team Mental Models

Previous research suggests that communication, or information exchange (Losee, 1999; Pika, Lieval, & Tomasello, 2003), facilitates coordination - i.e. the management of work dependencies to achieve a common goal - (Malone et al., 1999; Ricci, Omicini, & Denti, 2002) by informing group members of their knowledge or perception of a situation, thereby creating a common bond or mental model between individuals (Chwe, 2000; Fuks, Laufer, Choren, & Blois, 1999). The exchange of information between members of a collaborative dispatch group affords individuals in the group the ability to develop an understanding or mental model of a given emergency situation. A mental model can be defined as constructs that allow us to understand, illustrate, foresee, and describe the characteristics of a situation (Davidson, Dove, & Weltz, 1999; Langan-Fox et al., 2004). A mental model can possess cause and effect relations relative to a given situation and can be altered continuously as a situation changes. Since a 911 dispatch workgroup collaborates under a common goal, it is essential that the group acquire a shared or *team mental model* (Espinosa, Kraut, Lerch, & Slaughter, 2001; Wellens & Ergener, 1998) of a situation before effective emergency response measures can be taken. A team mental model is a representation of the shared understanding among individuals in a group about a given problem or situation (Cannon-Bowers, Salas, & Converse, 1993b; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Mohammed, Klimoski, & Rentsch, 2000). It refers to the collective understanding of a situation; i.e. what information, perceptions, and concepts are shared by all members of the group. In this way, team mental models are distinct from and transcend individual mental models (Ford & Sterman, 1997; Langan-Fox et al., 2004; Moore & Rocklin, 1998). In many situations, such as those commonly handled by 911 dispatch teams, it is not always the case that all team members share the same mental model. Individual past experiences often yield variations in mental models between group members. However, as individuals compile

their experiences over time with situations that are more frequent and similar, their individual mental models become more similar to each other and the team members are able to perform better with each other. Therefore, the lower the degree of shared team experiences, the lower the team performance. Conversely, the higher the degree of shared or similar team experiences, the higher the team performance (Espinosa et al., 2002; Rentsch & Klimoski, 2001).

It should be noted, however, that not all mental models are created equal. Mental models can be strong or weak (Fouche, 2005; Norman, 1983; Wells & Fuerst, 2000) or they can be accurate or inaccurate (Fouche, 2005; Leveson, Allen, & Story, 2002; Muramatsu & Pratt, 2001). According to Norman (1983), who studied individuals' mental models of computer systems, a strong mental model has a high degree of similarity to the components and features of a given entity. A weak mental model is one that lacks understanding of key aspects of a given entity. Likewise, an accurate mental model is one that correctly (and in detail) understands the components of a given entity whereas an inaccurate mental model is one that incorrectly understands a certain entity (Gentner, 2002; Kurtz, 2005). For instance, one may understand that at night, the moon appears to give off light and thereby conclude that the moon does indeed generate its own light. While this person's mental model of the moon is highly similar to the moon's physical features, it is nonetheless inaccurate (in that the moon does not generate its own light). In this case, the mental model is strong but nevertheless inaccurate. This is just one example of how strong and weak mental models can be conjoined with accurate or inaccurate mental models.

Continuing with the moon example, imagine a two member team where one member is assigned to study the visual qualities of the moon and the other is assigned to study the basis of moonlight. Both individuals on the team communicate their individual mental models about the moon to the other, and together, a team mental model is formed. The resulting team mental model can be strong and accurate, weak and accurate, strong and inaccurate, or weak and inaccurate. Table 1.1 gives further examples of each of these outcomes.

Table 1.1 Strong/Weak and Accurate/Inaccurate Mental Models

	Strong	**Weak**
Accurate	One member of a team recognizes the image of the moon and is able to show the other person what the moon looks like. The other member of the team is aware that the light the moon appears to emit is actually emitted by the sun. Communication creates a strong, accurate team mental model where both team members can visually recognize the moon and know where moonlight comes from.	One member of a team does not recognize the image of the moon and is unable to show the other person what the moon looks like. The other member of the team is aware that the light the moon appears to emit is actually emitted by the sun. Communication creates a weak yet accurate team mental model where neither team member can visually recognize the moon but both are aware of where moonlight comes from.
Inaccurate	One member of a team recognizes the image of the moon and is able to show the other person what the moon looks like. The other member of the team incorrectly concludes that the moon generates its own light. Communication creates a strong yet inaccurate team mental model where both team members can visually recognize the moon but inaccurately believe that the moon generates its own light.	One member of a team does not recognize the image of the moon and is unable to show the other person what the moon looks like. The other member of the team incorrectly concludes that the moon generates its own light. Communication creates a weak, inaccurate team mental model where neither team member can visually recognize the moon and both inaccurately believe that the moon generates its own light.

As suggested by Table 1.1, a weak, inaccurate team mental model certainly appears to be the worst case scenario. How, then, can such a misunderstanding occur? According to Kurtz (2005), an inaccurate mental model of a given entity may negatively affect an individual's or team's interactions with it because there is a low understanding of the entity in question. If interaction with a given entity is hindered due to the presence of an

inaccurate mental model, then this could yield a weak mental model of the entity since user interaction is what allows individuals and team members to develop a strong mental model (Sasse, 1997). Although not well-founded in literature, it appears that weak mental models can also yield inaccurate mental models given anecdotal evidence that suggests a correlation between these types of mental models (Kurtz, 2005).

1.2.2 Context and Team Cognitive, Communicative, and Collaborative Processes

Team mental models and cognition are influenced by team members' coordination and collaborative processes (Grote & Zala-Mezö, 2004). Research indicates that the work context of a collaborative group affects methods of communication, collaboration (Bishop, 2004; Jones, 2004), and team cognition (Strohschneider & Gerdes, 2004) (see Figure 1).

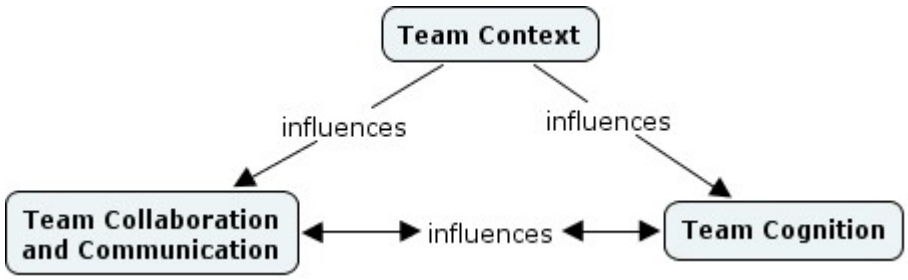

Figure 1.1: Team Context, Cognition, Collaboration and Communication

Evidence provided in literature, suggests that the context of a workgroup has significant impacts upon the cognition, collaboration, and communication processes of workgroups. Therefore, when attempting to execute generalizations about a particular domain relative to cognition and decision making, it is imperative that varying contexts of that domain be considered.

Context can be behavioral (Vingerhoets, van Geleuken, van Tilburg, & van Heck, 1996), cultural (Gergen, Gulerce, Lock, & Misra, 1996), technological (Welsh, 2000), social (Wyer & Srull, 1989), historical (Chalmers, 2004), geographical (Weber & Kwan, 2003),

demographical (Stevens, 1992), physical or environmental (Perkins, Florin, Rich, Wandersman, & Chavi, 1990). Although this is not an exhaustive list, it is apparent that there are several various types of context, each of which can influence team decision making activities. The current study addresses variations in group decision making across diverse geographical and demographical contexts in emergency management. Past research suggests that diverse geographical and demographical contexts can affect the manner in which groups share and process information to arrive at decisions. For instance, Bucknall (2000) observed teams of nurses working in the critical care units of hospitals in varying geographical contexts. His findings suggest that nurses working in urban environments make more decisions than those working in rural environments. However, nurses in rural environments tended to make a greater variety of decisions than urban based nurses. Additionally, differences in the physical structures of the rural and urban critical care units are likely accountable for differences in communication, task-assignment, and decision making between the two geographically and demographically diverse locations (Bucknall, 2000; Jones, 2004).

Although the focus of this study was limited to a single domain, 911 dispatch teams, differences in geographical and demographical surroundings may impact the flow of information within dispatch teams. Prior research suggests that contexts that are perceived to be a part of a “common domain” can have varying communication and collaboration procedures. For instance, Lecocq and Gauvin (2005) describe an ethnographic study in which the knowledge management, information sharing, and collaboration practices were evaluated within different contexts of the Canadian military: the Army, Navy, and Air Force. Analysis of survey data collected from members from each branch of the military suggests that certain processes for knowledge sharing, learning, and collaboration vary between the different contexts of the military. For instance, in the Army, knowledge sharing, learning, and collaboration generally occur via interactions with superiors and colleagues. The Navy, however, employs more of a "teaching" or mentor approach to knowledge sharing, learning, and collaboration while the Air Force encourages creativity and group consensus to accomplish these objectives.

According to Bishop (2004) and Jones (2004), different contexts of characteristically similar organizations may also use technology differently as a means of storing and retrieving knowledge. Bishop maintains that in extreme, complex contexts where cognitive load is high, such as aviation, individuals tend to place a high reliance upon technology. This finding is shared by Jones who evaluated 911 dispatch teams in contexts where the occurrence of complex emergency situations was low and 911 dispatch teams in contexts where the occurrence of complex emergency situations was relatively high. Jones found that, in the lower complexity context, reliance upon technology was minimal; in fact, a large portion of information was recorded by hand. Emergency dispatchers in the higher complexity context also utilized handwritten notes; however, their reliance upon technology was much higher (and the technology itself much more sophisticated) than dispatchers in the lower complexity context.

Context can also vary by the extremity or degree of risk in a certain environment. Geographical and demographical characteristics can influence the degree of risk within a certain location (Brewer, McNeese, Frazier, Fuhrmann, & Terrell, 2005; Jones, 2004). Strochschneider and Gerdes (2004) evaluated conceptual models of emergency practitioners in a low risk emergency environment, which can be defined as an environment where the chance of a grave emergency is low, but could nevertheless still occur. A grave emergency, according to the authors, is one with "…a sizeable number of casualties and material damage." (p. 16). The authors purport that, in low risk environments, conceptual models of extreme emergencies may be somewhat incomplete due to individuals' infrequent interaction with them. However, research with emergency practitioners in a higher risk emergency management environment suggests that, even in the midst of an unexpected grave emergency, emergency management teams are able to effectively communicate and utilize resources to quickly evaluate the situation and determine the correct course of action (Guha-Sapir, 1991; Markus, Fiedrich, Gehbauer, & Hirschberger, 2000).

In addition to grave or high risk emergencies, contexts that vary by work load and cognitive load can have varying degrees of team coordination. According to Grote and

Zala-Mezö (2004), in contexts where work load is relatively low, team coordination is lower than in cognitively complex environments. This may occur since individuals in a lower complexity environment have time to evaluate and manage a situation on their own. Likewise, results from Jones' (2004) research of 911 dispatch centers in varying geographical contexts suggest that, in contexts with lower work loads, the majority of the groups' responsibilities can be effectively managed with a very limited number of persons while the opposite is true in more complex, higher risk environments. Interestingly, however, research implies that in contexts where cognitive load is consistently high, the quality of information shared between teams members is relatively low (Silberstein, 2001).

It was the premise of this study to determine how variations in the geographical and demographical contexts of 911 dispatch teams affect the manner in which information is processes, stored, and shared for effective team decision making. In order to achieve this objective, this study used the principles of select theories of decision making to help evaluate the cognitive activities in 911 dispatch teams.

1.2.3 Research Objectives and Questions

Current theories of cognition have been applied to several domains including (but not limited to) aircrews (Hutchins, 1995; E. Hutchins & Klausen, 1992), paramedics (Jones, 2004; Regehr, Hill, Goldberg, & Hughes, 2003), and hospital staff (Gosbee & Ritchie, 1997; Sullivan, 1993). The intent of this study was to assess three theories of decision making - *Hutchins' distributed cognition theory* (Hutchins, 2000), *transactive memory* (Wegner, 1986), and *recognition primed decision theory* (Klein, 1993; Klein, Calderwood, & Clinton-Cirocco, 1986) - and evaluate their applications and shortcomings to the formation of team mental models and collaborative activities within 911 dispatch groups. This served as a basis for the development of a new framework to which the activities, interactions, and cognitive processes of 911 dispatch groups can be applied.

In light of past research findings and theories regarding teamwork, team decision making, and context, the current research sought to address the following questions:

1. *What characteristics, behaviors, and aspects of 911 dispatch teams can be accounted for[2] by each of the aforementioned theories of decision making?*
2. *How can current theories of cognition be applied to facilitate the study of cognition, communication, and decision making activities of 911 dispatch teams?*
3. *How well do current theories of cognition assist in the understanding of the cognition, communication, and decision making activities of 911 dispatch teams?*
4. *How does information technology facilitate the formation of team mental models among 911 dispatchers?*
    a. *Does information technology help to formulate accurate team mental models?*
    b. *Does information technology help to formulate strong team mental models?*
    c. *How does information technology influence the formation of team mental models with respect to accuracy and strength?*
    d. *Do team mental models among 911 dispatchers vary between different contexts of 911 dispatch teams (e.g. strong vs. weak; accurate vs. inaccurate)?*

1.3 Summary of Current Research

As implied by the above research questions, the primary focus of this research was to understand the behavior, interactions, and decision making activities of 911 dispatch teams. Given this objective, the subjects of this study were 911 dispatch teams who were observed and interviewed in their environmental work contexts as they performed their usual work activities.

[2] "Accounted for," in this instance, refers to the aspects of 911 dispatch teams that can be explained and measured by a given theory

This study included observations and interviews of 911 dispatchers from two contexts varying in demographic, geographic, and work environment characteristics. The dispatchers were interviewed to obtain information about topics such as: the type of communication techniques commonly used in their work activities, how information is exchanged within a dispatch team, 911 dispatch team decision making procedures, and the functions and uses of information technology by 911 dispatch teams.

In addition to the evaluation of 911 dispatch teams in various contexts, analysis was conducted to determine 911 dispatch team communications and decision making activities given a specific emergency scenario as told to the dispatchers during the interviews. Dispatcher responses to the scenario were subsequently evaluated to ascertain the potential formation of team mental models should the stated scenario, or a similar scenario, occur.

Lastly, the data from the interview and observation sessions was coded to identify similarities and differences between team activities within each of the dispatch centers. Additionally, the data was also evaluated to determine which aspects of the aforementioned decision theories (Hutchins' distributed cognition, transactive memory, and recognition primed decision making) could be applied to the decision making and collaborative activities of 911 dispatch teams. This served as a basis for the formation of a new framework that represents the structure of 911 dispatch teams as well as other teams within domains that share similar characteristics.

1.4 Research Contributions

This research offers new insight into popular foci of research in both government and academic domains. Since the events of September 11, 2001, much attention has been placed upon homeland security and emergency management. In light of this, homeland security has also become a primary topic of study by academic researchers who have a vested interest in group collaborations, cognition, and technologies that make up the network of emergency management. In following, the current study focused on the

collaborative and cognitive procedures that occur directly within 911 dispatch centers (the hub of local emergency management). The study of these collaborative groups sheds new insight on the formation of common team perspectives, team cognition, team collaboration, and team decision making. Furthermore, the results of this research establish a foundation for the advancement of theory and models related to group cognition, interaction, and problem solving.

Within the area of Information Sciences and Technology (IST), this research serves to advance the knowledge of technologies used to mediate collaboration, communication, and serve as a platform for the generation of team mental models. By studying the behaviors and activities of 911 collaborative teams in different contexts, the results of this study provide the domain of IST with empirical information regarding the use and role of information technology in decision making procedures within collaborative teams.

Finally, the domain of local emergency management will benefit from the results of this study. By disseminating the results to 911 dispatch team stakeholders, individuals within this domain will be able to note areas where current practices can be improved for the overall more efficient allocation of emergency resources. Additionally, the development of a framework to which the structure of 911 dispatch teams can be applied provides a foundation for the development of information technology that can be utilized not only by 911 teams, but also by members in other domains with similar attributes to 911 groups.

CHAPTER II: LITERATURE REVIEW

When one or more calls are placed to a dispatch center regarding an emergency situation, dispatchers must communicate, collaborate, and analyze available information about the emergency in order to determine the correct number of appropriate resources to send to a given destination. Often, this information is incomplete and ill-defined (*Dispatch Monthly Magazine*, 2005; Gosbee & Ritchie, 1997). Yet despite this, dispatch personnel must evaluate and process all given pieces of information quickly so that emergency relief arrives at the correct destination before the situation further intensifies. The ability to enact effective problem solutions in complex, time-constrained environments requires quality teamwork, collaboration, and the creation of a shared perception of the situation between group members.

2.1 Emergency Management Services

Emergency Management Services (EMS) can be defined as the response and organization of requests for emergency assistance during an incident (Clawson & Dernocoeur, 1998) as well as recovery operations after an incident (Schaafstal, Johnston, & Oser, 2001). Within EMS, resource dispatching is comprised of receiving and prioritizing calls for emergency aid as well as allocating emergency resources (Blandford & Wong, 2004).

When dispatchers receive calls about an emergency, their top priority is to obtain a precise location of the incident from the caller and gather as many other relevant details as possible. This information includes, but is not particularly limited to, the name and contact information of the person reporting the incident, who is involved, where the incident took place, and when it occurred (Terrell et al., 2004). Dispatchers must record and evaluate this information which, in turn, helps them determine what and how many emergency resources should be dispatched. Additionally, it is the responsibility of the dispatcher to share all relevant information with the incident's first responders (McCarthy, Wright, Healey, Dearden, & Harrison, 1997; Wybo & Kowalski, 1998).

Information sharing and generation of problem solutions can be cognitively taxing given the conditions under which dispatchers and field workers (e.g. police, fire, paramedic, and hazardous material crews) must thrive. The environments of both dispatchers and field workers can be tense, noisy, and stressful (Holzman, 1999; Stolk, Alexandrian, Gros, & Paggio, 2001) and decisions must be made under extremely time-constrained circumstances (Xiao & Group, 2001).

Within EMS, individuals make decisions not just as part of one team but rather as a "team of teams." For instance, dispatchers who make decisions concerning a given incident are working as a team. However, they are additionally part of the team of the first responders who are also responding to the incident. Therefore, dispatchers must be trained to develop not only taskwork skills, but also extensive teamwork skills (Crichton & Flin, 2001; Schaafstal et al., 2001). According to Cannon-Bowers et al., (1995), taskwork skills involve the acquisition of the skills necessary to implement or handle a specific situation, whereas teamwork skills refer exclusively to the ability to obtain information from colleagues independent from a given task. EMS, therefore, fosters an environment of intense interdependence between EMS personnel . Individuals within EMS teams have to realize how their actions influence and are influenced by their fellow team members.

The actions of dispatch team members are not only affected by the actions and distribution of information that occur between each other, but by the information that is shared between dispatchers and callers also. Prior research analyzing transcripts between 911 dispatchers and callers suggest that a wealth of information is provided through short interactions that usually include: a) the caller's brief description of an incident and request for a specific form of help or resource and b) probing by the dispatcher to gain more information about the incident including what occurred during the incident and who was involved (Imbens-Bailey & McCabe, 2000; Whalen & Zimmerman, 1987).

Although the scope of the current study is limited to the collaboration, interactions, and mental models of dispatch teams, information from callers and field workers play key

roles in the perception of emergency situations and the formation of individual and team mental models relative to these situations. Therefore, it is essential that the design of information technology systems within 911 dispatch centers allow for the effective presentation and organization of information from both human (e.g. dispatchers, callers, field workers) and non-human resources for the efficient generation of problem solutions to emergency situations. Furthermore, it is necessary that the appropriate framework serve as a foundation and perceptual model for the design of such systems. Failure to do so may result in the design of EMS systems that do not conform to the cognitive, environmental and procedural characteristics of 911 dispatch teams.

2.2 Team Decision Making

Before further mention of EMS environments and domains with similar characteristics to EMS takes place, it is necessary to describe the basic activities of team decision making and review how it differs from individual decision making.

According Paris, Salas, and Cannon-Bowers (2000), a team is more than simply a group of individuals who aggregate tasks. A team is a group of individuals who, within their own roles and responsibilities, work collectively towards a common goal (Depken, 2000; Hoegl & Gemuenden, 2001; Salas, Dickinson, Converse, & Tannenbaum, 1992). Distinguishable factors that define a team include: specific, assigned roles and responsibilities that, collectively, lead towards a common goal; specialized, member knowledge about individual tasks and responsibilities, and the ability of the team to dynamically adapt strategy in response to change (Modrick, 1986).

Cohen and Thompson (2001) suggest that there are notable advantages that team decision making may provide over individual decision making. The advantages, in short, stem from the proverbial adage that "two heads are better than one." When individuals attempt to make a decision as a team, they are able to bring together complementary information and perspectives that help to provide a more complete picture of a given situation. Since there are often a number of diverse perspectives brought to the table, this

also gives team members several alternative problem solutions. Effective team decision making requires that information be shared and evaluated by individual team members so that the team may develop a mental model of a certain situation (Flin, 1997). Team mental models reflect the goals and objectives of the team, team members' individual roles and responsibilities, team member relationships, and team activity patterns (Paris, Salas, & Cannon-Bowers, 2000). The advantage of having a shared mental model within a team is that it helps to determine the relationships between individual tasks, create a deeper understanding of the responsibilities of other team members, detect errors, and provide informational support when needed (Duncan et al., 1996). It should be noted, however, that sharing perspectives and alternative solutions may only be considered an advantage if the team practices a suitable method for choosing among alternative solutions (Kerr, MacCoun, & Kramer, 1996). In consideration of different perspectives that are presented in team decision making, it is noteworthy to consider where these perspectives come from; i.e., the diverse types of individual perspectives that make up a decision team.

Members of decision making teams often hold individual, expert situational perspectives and knowledge gathered from unique job experiences and tasks (Hedlund, Ilgen, & Hollenbeck, 1998; Larsen, Christensen, Franz, & Abbott, 1998; Lehner, Seyed-Solorforough, O'Connor, Sak, & Mullin, 1997). This unique, individual knowledge is referred to as *unshared information* as opposed to *shared information*, which is information known by all team members. It has been suggested that, in team decision making, the ability to disclose unshared information to other team members yields a decision that is more informed than a decision made by an individual team member (Stasser, 1992; Stasser & Titus, 1985). If unshared information is not pooled and disclosed to all team members, the accuracy of a team decision could be drastically decreased (Larsen et al., 1998). This, in turn, is likely to affect the formation of accurate and complete team mental models (Ferzandi, Skattebo, Terrell, & Bains, 2004).

According to Cannon-Bowers, Salas, and Converse (1993a), individual and team mental models affect team situation awareness, i.e., the team's understanding of the situation and

the environment (Endsley, 2001). Although individuals within a team have their own mental model of a given situation, these models must be integrated to develop a common perception of the situation shared by all members of the team. By communicating individual perceptions of a given situation to other members of the team, the situational awareness of the team as a whole is ultimately affected.

2.2.1 Communication and Team Decision Making in Time-Critical Environments

Thus far, several factors that affect team decision making have been identified. These include team situational awareness (Artman & Granlund, 1998; Sonnenwald & Pierce, 2000), the formations of team mental models (Bolstad & Endsley, 1999; Mohammed & Dumville, 2001; Rasker, Post, & Schraagen, 2000), and individual knowledge (Cooke, Salas, Cannon-Bowers, & Stout, 2000; McNeese et al., 2005). Although this is by no means an exhaustive list, there is at least one other element that strongly influences team decision making and is a major premise of the current study: contextual factors (Papadakis, Lioukas, & Chambers, 1998; Paris et al., 2000). The focus context evaluated in this study is that of time-constrained environments where team decisions must be rapidly made.

Time-constrained (Cohen, Freeman, & Wolf, 1996; Ordonez & Benson, 1997), uncertain (Erdem & Keane, 1996; Lipshitz & Strauss, 1997), and frequently changing contexts (Campbell, Cooper, Greenbaum, & Wojcik, 2000; Gunasekaran, Patel, & Tirtiroglu, 2001) affect the character and decision making procedures of a team. In this type of environment, there are certain factors to consider such as: how efficient is communication and could the team members reach a point where they have communicated too much? Communication, by its nature, most often causes a delay in the implementation of a decisive action. Team members, therefore, must determine whether (and if so, how much) communication is worth such a delay. In dynamically changing situations that are met with uncertainty, it is suggested that successful teams have intact and advance plans for coordination and task assignment (Cohen & Thompson, 2001).

Klein (1989) states that, in time-constrained environments, approximately 95% of team decisions are made without taking into consideration substitute solutions. Rather, they may recognize a situation as similar to a past event and decide upon a course of action based upon previous situational experience. Given the factor of response delay that must be considered in regards to communication, some teams in time-critical situations may (either intentionally or unintentionally) decide not to communicate or severely limit communication. In this case, individuals, although working complementary as part of a team, may make decisions and take action autonomously based upon their assumptions of the probable actions of other team members. In instances where team members do decide to communicate with each other, the time-constrained nature of the situation limits the amount of time that can be devoted to information sharing and, ultimately, the amount of information that is eventually shared. Therefore, individuals in the team must consider how reliable their team mental model actually is (Cohen & Thompson, 2001).

Recent studies suggest that time restraints in team decision making may indeed affect the formation of team mental models. For instance, in dynamically changing, time-constrained environments, decision makers rarely follow commonly suggested organizational decision making processes which involve the careful evaluation of all possible solution alternatives and their probable outcomes (Klimoski & Jones, 1995). Rather, in time-stressed contexts, decision makers rapidly implement decisions based upon their recognition of past experiences, even if much of the current situation is fairly ambiguous. In fact, in time-constrained environments, extensive team decision evaluation may be costly in time and circumstance (Freeman & Cohen, 1996).

So perhaps it could be effectively argued that team members in time-constrained environments do not always have to form a team mental model to reach a consensual decision. Hedlund suggests that in time-constrained environments, team consensus may not be possible. If truth be told, consensus may not even be desirable. This is often the case with teams whose individual members have expertise in a specific skill or domain and, therefore, do not possess identical knowledge and understanding of a situation (Hedlund et al., 1998; Jones & Roelofsma, 2000; Lehner et al., 1997). A surgical team,

for example, may consist of a number of individuals with expertise in different skills (e.g. a surgeon, nurse, and anesthesiologist) who, though working towards a common goal, do not need to posses the same knowledge to achieve a given objective.

Realize, though, that the above statements are not meant to discourage or diminish the necessity of communication in team decision making in time-constrained environments. Rather, communication is one of the most important aspects of teamwork and team decision making. Research in team decision making in time-constrained environments purports that effective team decision making in dynamic situations is more influenced by team communication, coordination, and awareness of individual and team member responsibilities than system comprehension (Artman, 1999; Flin, 1997). In short, decision making is more efficient when team members have developed effective listening and response skills (Flin, 1997). Additionally, communication among team members can yield more timely activation of decisions and drastically reduce team decision error even when workload is high (Sexton, Thomas, & Helmreich, 2000).

The primary goal of teams in time-stressed environments seem to be to make accurate, effective decisions in a prompt manner (Zachary, Ryder, & Hicinbothom, 1998). Several factors appear to contribute to this goal. Therefore, in review, factors that impact team decision making include:

- the formation of team mental models,
- communication frequency,
- individual tasks and skill expertise, and
- team members' knowledge of colleagues' individual tasks and skill expertise.

To understand the influences and practices of team decision making in time-stressed environments, the next section will discuss team decision making in specific, time-constrained, dynamically changing domains.

2.2.2 Applications of Team Decision making in Time-Constrained Environments

There are many domains in which teams make decisions in time-constrained environments. Such environments include command and control (Gill et al., 1999), fighter pilots (Young & McNeese, 1995), air traffic control (Findler & Lo, 1993), and medical teams (Young & McNeese, 1995). Although each of these areas has its own body of literature outlining impacts of time-constrained environments, consider three real world situations, each involving different human and technical ensembles, in which critical decisions emerge in a time-constrained environment:

1. *During wartime, a fighter pilot is flying his aircraft within enemy territory in order to locate a certain target. During the mission, the pilot has to consider and be acutely aware of several factors including (but not limited to): other pilots in the area working towards a similar goal, his location, possible enemy threats, weather, time of day, the functioning level of equipment, several types of information provided by the equipment, and cockpit noise. The pilot must efficiently process each of these environmental factors in order to make effective, time-critical decisions (Young & McNeese, 1995).*

In air mission situations, pilots are required to be highly capable of rapid decision making in a complex, dynamically changing, and multi-tasking environment. Furthermore, decision making is a team effort between the pilot, other pilots working to carry out the same objective, and technological resources providing situational information. The team must rapidly access a given situation or threat, quickly modify plans and strategy, as well as rapidly evaluate possible outcomes of a given strategy depending upon current situational status. In this type of domain, information is coming from environmental cues, multiple communication sources and aircraft sensors. The team has to combine all of this information to develop an accurate picture of the current situation on which decisions can be based (Murray et al., 1995). In essence, air combat pilots cope with a

myriad of physical and psychological demands that could influence decision making. These can include stress, anxiety, exhaustion, and workload (McIlroy & Heinze, 1996).

2. *On March 8, 2005, a sudden snow squall near Grand Rapids, Michigan caused a major car pileup of approximately 90 vehicles killing one person and injuring as many as 34 others. According to a fire chief, rescue crews worked for hours to untangle what he described as "'knots' of wreckage." (Wreckage extends half a mile on snowy road, 2005). Response measures to the incident most likely included several individuals including (but perhaps not limited to): fire crews (as implied by the scenario), paramedics to assist the injured, and police to redirect traffic and sanction the roadways.*

According to Smith and Dowell (2000), disaster management in mass injury situations such as the one above often involves inter-agency coordination which in turn yields decision making on a meta-team level (i.e. individuals within agencies form a team; however, inter-agency coordination forms a meta-team). The necessity for meta-teams to form a shared mental model is one of the major difficulties regarding disaster management of large scale emergencies. Once again, the importance of efficient communication channels between agencies is critical for effective team decision making, particularly for a meta-team. Communication difficulties between organizations can result in a weak team mental model, thereby resulting in team decision difficulties (Smith & Dowell, 2000).

3. *In response to the above incident, paramedics rush several people to a local hospital where some are taken immediately into surgery. During surgery, individuals such as doctors, nurses, and anesthesiologists exchange information, monitor patient vital signs, and track information feedback given from various machines and monitors (Young & McNeese, 1995).*

Decisions made in critical care units are most often made in teams. Teams in critical care units can include senior level doctors, junior doctors, and nurses. In this setting, the

majority of decisions made by the team are in regard to the organization of tasks and responsibilities. Due to the life-threatening, high dependency status of patients in critical care units, the critical care team has to quickly make several decisions in a time-stressed environment (Bucknall, 2000; Bucknall & Thomas, 1997). Furthermore, in contexts such as this, environmental stressors may be augmented due to conflicting opinions such as the appropriate courses of action and ethical considerations regarding patient care (Bucknall & Thomas, 1997).

Although inspired by relatively different domains – piloting, local emergency management, and medical operation – the above problem situations have several underlying common characteristics such as:

- They have multiple possible solutions.
- They take place in information-rich environments.
- They involve rich social contexts.
- They involve decision made on the fly.
- They are ill-structured.
- They have information distributed among several people.
- They likely contain both relevant and irrelevant information for solving the problem.
- They are goal-oriented.

According to Young and McNeese (1995), each of the above factors are characteristic of problem solving in complex situations. Therefore, each of the aforementioned domains have attributes that are relatively similar to those found within 911 dispatch centers (Terrell et al., 2004). The results of this research will advance not only the study of 911 dispatch teams, but also domains such as pilot, local emergency management, and hospital services.

Although there are similar characteristics between 911 dispatch teams and teams within other domains, there are unique features in each also. The current study explored these unique characteristics as they relate to 911 dispatch teams.

2.3 Theories in Decision making

The following sections evaluate three theories of decision making - *Hutchins' view of distributed cognition* (Hollan, Hutchins, & Kirsch, 2000), *transactive memory* (Wegner, 1995), *and Klein's Recognition Primed Decision making* (Klein, 1993; Klein et al., 1986) - and their inferences on the formation of team mental models and team behavior. An introduction of each theory, along with a definition of the theory, is provided. Next, the applications in research for the theory are discussed followed by the implications or principles associated with the theory as it applies to decision making activities.

2.3.1 Hutchins' Distributed Cognition Theory Defined

According to Hollan, Hutchins, and Kirsch , cognition and sources of information are not limited to an individual mind nor are they limited to a collection or group of minds. Rather, information pertaining to a given situation can come from both computer and non-computer resources, the environment, and interactions between resources, people (Barab & Plucker, 2002; Hutchins & Palen, 1997), and the environment. Essentially, Hutchins' theory of distributed cognition seeks to understand how cognition is organized among these various entities in order to arrive at problem solutions (Hutchins & Hazelhurst, 1995).

According to Hollan et al., the organization and fragmentation of cognitive systems distinguishes distributed cognition from other cognitive theories. Within the principles of distributed cognition theory[3], a cognitive process is composed of cognitive subsystems (within individuals, resources, the environment) and the relationships between these subsystems (Rogers, 2005).

[3] Unless otherwise stated, all references to distributed cognition refer to Hutchins' view.

2.3.1.1 Distributed Cognition and Research Applications

The foundations of Hutchins' theory of distributed cognition are rooted from his research with ship crews (Rogers, 1997, 2005) and airline crews (Hutchins, 1995; Hutchins & Klausen, 1996). Over the course of Hutchins' research career, his view of distributed cognition has evolved. Therefore, this current research focused primarily on Hutchins' research and discussions of distributed cognition with airline crews since that body of work is more recent than his research with ship crews. Bear in mind that aviation, as previously stated, holds many of the attributes as the unit of analysis in the current study: 911 dispatch groups.

Hutchins and Klausen (1996) note the relationships and interactions between people, technology, and environment in their study of the cognitive processes of airline crews. According to Hutchins (2000), the completion of a successful flight is not due to merely the cognitive processes that occur within individual minds . Rather, it is a collection of human cognition, environmental structure, and the functioning of the technology. For instance, pilots often extend memory to external resources and devices in the cockpit (e.g., the recording of the speed of the plane relative to its weight is displayed in an external resource) (Hutchins, 1995). Therefore, the unit of study for cognitive analysis should include more than just the pilot; it should also include the relationships and interactions between the pilot, other human characters (e.g. the entire airline crew), the environment, resources, and information technology. This suggests that, within teams working in time-constrained environments, information, tasks, and cognition may be highly distributed (Hollan et al., 2000).

Although the findings from these studies are from ethnographic investigations of airline crews, it is likely that results from these research efforts can be generalized towards the study of cognition in other domains with similar characteristics.

2.3.1.2 Principles of Hutchins' Distributed Cognition Theory

Findings from the aforementioned research studies describe various principles of distributed cognition that could potentially be generalized to understand the cognitive systems within domains other than airline crews. They are:

1. Cognitive tasks are distributed (i.e. while one person is working on one task, another person is working on a different yet objectively related task) (Hollan et al., 2000).
2. Access to information is distributed in that all group members are usually able to observe the same type of information; this allows group members to form and share their interpretations of the information (Hutchins, 1995).
3. Information is shared via interaction (Rogers, 2005).
4. Information is distributively stored (the same information is stored in different facets by the team and is therefore available if someone's access to the information becomes unavailable) (Hutchins, 1995).
5. Memory is stored in artifacts (Hutchins & Hazelhurst, 1995).
6. Cognition can be distributed temporally so that subsequent events are affected by earlier events (Barab & Plucker, 2002).
7. Cognition can be distributed within a group (i.e. it surpasses the boundaries of the individual) (Hutchins & Palen, 1997).
8. Cognition involves relationships and collaboration between resources and the environment (context) (Hutchins & Palen, 1997).

The intent of the current study was to determine how, or if, these characteristics are applicable to the cognitive and work processes found within 911 dispatch teams.

2.3.2 Transactive Memory Theory Defined

A transactive memory system can be defined as a memory system in which individuals in a group supplement their own memories by relying upon other group members to

remember certain information (Argote & Moreland, 2005; Wegner, 1986, 1987, 1995; Wegner, Erber, & Raymond, 1991; Wegner, Giuliano, & Hertel, 1985). Therefore, a transactive memory system is not only about what individuals in a group know, but knowing that other individual members in a group know certain types of information and knowing who knows what (Lambert, Kunz, & Levitt, 2005). According to Wegner (1986), this occurs when individuals in a group take responsibility for learning and knowing certain pieces of information and expect others in their group to do the same.

Transactive memory systems are developed when individuals who communicate with each other come to know the cognitive strengths, or expertise, of others. From there, certain people become assigned or are held responsible to know certain pieces of information. The rest of the group members may not necessarily know this (or all of this) information, but they are aware of who in the group knows. Individuals in a group know who to consult to retrieve certain pieces of information. Strong transactive memory systems make sure that all necessary pieces of information are accounted for by someone in the group. If it is found that an essential informational element is not accounted for, then people are brought into the group to be held responsible for the information (Wegner, 1987).

The development of a transactive memory system in groups gives group members a sense of assurance in that if individuals believe their memories of certain information are incomplete or unreliable, they can rely upon information known by others to supplement it. Benefits of transactive memory systems are that group members are able to assign tasks more efficiently (due to the fact that they know who knows what type of information) (Argote, Gruenfeld, & Naquin, 2000; Liang, Moreland, & Argote, 1995), solve problems quickly (Blickensderfer, 2000) (again since they know the information strengths and weakness of each other) and coordinate actions rather than simply respond to the actions of others (Argote & Moreland, 2005).

2.3.2.1 Transactive Memory Theory and Research Applications

Wegner et al., (1991) stipulates that individuals who know each other better are more likely to anticipate the responses and actions of each other (i.e., they are more likely to know the strengths and weaknesses of the other as far as knowledge about certain information is concerned). Results from their evaluation with memory performance in paired individuals imply that when close couples, or non-strangers, were given a memory assignment and were each assigned specific memory tasks by the experimenters, their performance was significantly worse than pairs that were not close (strangers). However, in instances where the participants were not assigned tasks by the experimenters, close couples performed significantly better at memorization tasks than couples who were not close.

It could be argued, however, that individuals with a strong social connection or who work in a common group are able to anticipate the actions and responses of each other because their mental processes are similar - not necessarily because they have knowledge of what the other(s) knows. However, Wegner and colleagues (1985) reject this notion. The researchers argue that group members are able to coordinate and solve problems efficiently due to the communication processes that occur within the group. Communication processes are central to the "group mind." In short, transactive memory can be referred to as a collections of individuals and their communicative processes (Wegner et al., 1985).

2.3.2.2 Principles of Transactive Memory Theory

Based on literature evaluating transactive memory theory, it could be concluded that transactive memory theory adheres to the following generalizations:

1. Members in a group may be considered "experts" of certain skills or activities (Wegner, 1987, 1995).

2. The cognitive system is one in which information is stored within and retrieved from individuals in a group (Ren, Carley, & Argote, 2001; Wegner et al., 1991; Wegner et al., 1985).
3. Communication is necessary for information to be effectively stored and retrieved by individuals in a group (Ren et al., 2001; Wegner et al., 1991; Wegner et al., 1985).

The intention of the current study was to determine how, or if, these characteristics are applicable to the cognitive and work processes found within 911 dispatch groups.

2.3.3 Recognition Primed Decision Theory Defined

Recognition Primed Decision (RPD) making is a theory commonly used to evaluate how experts generate alternative problem solutions in complex, dynamically changing real-world environments (Klein, 1993; Klein et al., 1986; Meso, Troutt, & Rudnicka, 2002) that are characterized by ill-defined, risky, time-sensitive, situations (Ball, Lambell, Reed, & Reid, 2001; Klein, 1998; Lipshitz, Klein, Orasanu, & Salas, 2001). It explores how experts evaluate the situation, environment, and affordances to quickly arrive at decision points. An expert can be defined as one who recognizes what the goals and objectives of a given situation are, and one who knows how to achieve those goals based on knowledge acquired from prior experiences (Meso et al., 2002).

Specifically, RPD posits that when faced with a time-critical problem situation, experts do not compare and contrast multiple solution alternatives before implementing a course of action. Rather, experts use their prior domain experience to assess a problem situation, mentally "play out" a solution to determine its feasibility, and implement the first reasonable solution that comes to mind (Klein, 1993; Klein et al., 1986). Therefore, RDP is a fusion of two mental processes: 1) situational assessment in which experts use their prior experiences to categorize or recognize the attributes of a situation and 2) mental simulation in which experts mentally simulate a problem solution before implementing it (Klein, 1993).

It should be noted, however, that although expert decision makers are able to utilize their expertise and prior experience to quickly arrive at effective problem solutions, the solution that is ultimately implemented may not necessarily be the best one (Klein, 1993; Klein et al., 1986). In time critical situations, the goal of expert decision makers is to find a satisfactory solution. While it may be that there are other solutions that are better than the one implemented, the time-critical nature of the situation does not allow them to compare and contrast several alternatives before acting on the situation.

RPD stipulates that expert decision makers are: 1) flexible; they are able to shift to an alternative problem solution if a change in a situation deems it necessary, 2) quick; they are able to go through the decision cycle and arrive at decision points quickly, 3) resilient; they can make decisions during moments of intense stress, 4) risk taking; they can effectively assess the level of risk in a given situation, and 5) accurate; they are able to deliver effective, working solutions (Cannon-Bowers & Bell, 1997) as cited by (Meso et al., 2002).

2.3.3.1 RPD and Research Applications

The development of RPD stems from Klein's ethnographic research involving the decision strategies of fire fighter commanders (1986). In this landmark study, fire commanders were observed as they carried out emergency action plans; additionally, the commanders were questioned after an incident to learn how each commander arrived at a given solution. Klein's observations imply that, given the time-critical nature of fire emergencies, the commanders did not choose a given strategy based on a mental list of alternative solutions. Rather, the commanders insisted that they reacted to a given situation based on prior experience with other similar situations. They noted that if they were to compare and contrast several solutions before taking action, they would possibly lose control of the situation. The commanders were not concerned with finding the best solution, but rather sought to implement a workable solution as quickly as possible.

2.3.3.2 Principles of RPD

RPD specifies some key characteristics that set it apart from other views of cognition and decision making:

1. Experts in time-critical situations seek to employ a workable solution - not necessarily the best one (Orasanu & Connolly, 1993).
2. Experts use prior experience to assess a situation and arrive at a decision (Orasanu & Connolly, 1993).
3. The first solution that an expert decision maker considers is usually satisfactory.
4. When more than one solution is considered before action is taken, solutions are considered sequentially (usually from typical to least typical); they are not compared to each other (Orasanu & Connolly, 1993).
5. Flaws of a possible solution are identified via mental simulation or "run through" (Klein, 1993).

The intent of the current study was to determine how, or if, these characteristics are applicable to the cognitive and work processes found within 911 dispatch groups.

2.3.4 Theories Summarized

Table 2.1 depicts a matrix summarizing the three aforementioned theories and their implications concerning mental models. An objective of the current study was to compare and evaluate the characteristics of 911 dispatch teams in light of the principles and implications of the theories. This, in essence, provided a foundation for the development of a framework that can be used to describe the collaborations, decision making activities, and human-computer interactions of dispatch teams.

Table 2.1: Theory Matrix

Theory	Cognitive Unit of Analysis	Research Foundations	Flow of Information	Implications for Mental Models
Distributed Cognition Theory	Workgroups, artifacts, environment	Anthropology, History - Ship and Airline crews	Information is stored in and retrieved from internal (individual cognition) and external (artifacts) sources	Groups with strong mental models have complete and accurate conceptions of the environment, artifacts, the situation and it is shared between team members
Transactive Memory	Workgroups	Organizations	Information is stored in and retrieved from internal (individual or self cognition) and external (other group members' cognition) sources	Groups with strong mental models share a complete and accurate conception of the situation
RPD	Individuals (who may or may not be part of a workgroup)	Cognitive Psychology - fire commanders	Information is stored over time by individual experience and retrieved via individual situational assessment and cognitive simulation	Individuals with satisfactory mental models have an accurate, but not always complete, conception of the situation

There are several theories of team decision making (Barab & Plucker, 2002; Kerr & Tindale, 2004; Wright, Fields, & Harrison, 2000) that provide a conceptualization on the formation of mental models (both team and individual) and how these mental models dictate response to certain situations and environmental cues. However, out of the several theories that could have been chosen as a basis for this study, the current research explored the applicability of 911 dispatch team decision making and communication activities to the three aforementioned theories. The rationale for selecting these three specific theories largely stemmed from the disciplinary and research foundations from which they were derived. For instance, distributed cognition is one of the primary theories used in research concerning how group cognition is affected by environmental factors, tools, and individual perceptions (Hutchins, 1995). Transactive memory theory

was one of the first theories to acknowledge that individuals in working groups use external agents and individuals to supplement limited memory capacity (Wegner, 1987). Lastly, RPD is from the theory of naturalistic decision making which was developed to study the manner in which individuals react in time-constrained, ambiguous, and dynamically changing situations (Zsambok & Klein, 1997) which are attributes that are characteristic of emergency management domains .

As suggested from the above sections, each of these theories have been applied towards the ecological study of the cognitive aspects of small groups outside of the business setting. Additionally, each theory lends credence to the role of context and group interactions. Given that the primary objective of the current study was to enhance theory, the theories of distributed cognition, transactive memory, and RPD were chosen primarily because, in many respects, each theory accounts for key attributes that previous research has identified as characteristics of emergency management. (Bui, Cho, Sankaran, & Sovereign, 2000; Cutter, 2003). However, none of these theories have been specifically applied to the study of 911 dispatch teams. This study sought to evaluate theory by completing this very task.

The following section lends insight into the realm of human-computer interaction via the evaluation of computer-supported cooperative work in order to determine its implications regarding team communication, collaboration, and decision making.

2.4 Computer Supported Cooperative Work

Computer Supported Cooperative Work (CSCW) can be defined as a computer system that mediates group work and provides a shared interface for group members to reach a common goal (Eseryel, Ganesan, & Edmonds, 2002). CSCW applications are technologies that help support group workflow (McDermott & Mulvihill, 1996) and cooperative work between group members (Karagiannis, Radermacher, Teufel, & Wynne, 1994). CSCW applications help support group members “in their communication….cooperation, and in the coordination of their activities" (Karagiannis et

al., 1994, p. 374) for the generation of alternative solutions (Jessup, Tansik, & Laase, 1988).

CSCW applications were developed from the rising need for applications to support communication between group members independent of geographic location and time. However, there are also CSCW applications that foster communication between members who are meeting at the same time and place in order to better distribute information, knowledge, and ideas to group members (McCarthy, 1994).

Perhaps due to the differing types of knowledge and ideas shared between group members, the number of alternative solutions put forth by groups surpasses the number of alternative decisions made by a solitary working individual (DeSanctis & Gallupe, 1987). Therefore, it is essential that CSCW systems serve as an efficient medium for the presentation of the many individual mental models represented in the workgroup in order to help facilitate the generation of a strong and accurate team mental model.

Boland, Tankasi, and Te'eni (1994) support the design of CSCW applications that encourage individuals within workgroups to share their own mental model or interpretation of a situation. By sharing their own perceptions of the problem, team members will develop a greater understanding of the situation, thereby enabling the group to form a cohesive team mental model leading to the generation of problem solutions.

The authors further purport that three criteria must be met in order for CSCW applications to best support distributed cognition for the formation of team mental models: 1) CSCW systems should not focus on the individual as a decision maker, but rather on the individual as one who shares and evaluates his or her interpretation of the problem with others, 2) the system should not remove individual interpretations of the problem, but rather broaden individuals' understanding of the problem, and finally 3) CSCW systems should allow for the equal exchange of cognitive interpretations via a shared communication space.

By meeting these criteria, the authors profess that CSCW systems will not merely be a shared repository for information and a shared communication space, but will facilitate the exchange of understandings and perceptions relative to the problem. This, in turn, will aid in the generation of a team mental model and the production of problem solutions. These criteria, especially within certain contexts of emergency management services (Farand et al., 1995; Jones, 2004), are essential for productive group work and realization of a shared team goal.

2.5 Literature Review Summarization

The above sections have discussed the basics and foundations of teamwork: teamwork in time-constrained environments, teamwork in specific time-constrained domains and their theoretical foundations, and the influence of technology on teamwork. This section synthesizes the above information to determine how each of the above topics apply to 911 dispatch teams and why they justify further study in regards to teamwork in 911 centers.

It appears that each of the three aforementioned theories defined above – distributed cognition, transactive memory, and RPD – can help in understanding 911 dispatch teams. Each of these theories is concerned with cognitive decision making. Further, prior research suggests that they have real world applicability in regards to team decision making. Although none of the theories have been applied specifically to 911 dispatch teams, parallels in characteristics between 911 dispatch teams and domains that the theories have been applied to suggest that they each, in some way, are applicable to the study of 911 dispatch teams. Furthermore, each theory has been used to study domains where individuals work together as a team towards a common goal. This research, therefore, allows some insight into the question *"How can current theories of cognition be applied to facilitate the study of cognition, communication, and decision making activities of 911 dispatch teams?"*

To answer this question, it is necessary to recall some aspects of 911 dispatch teams. Note that this is not an exhaustive list, but is one based upon preliminary data (Terrell et al., 2004). In fact, one goal of this study is to generate a more complete and revised list. Currently, the list of 911 dispatch team characteristics includes:

- Involvement of rich social contexts between team members.
- Distribution of information among several people and artifacts.
- Ill-structured information among team members.
- Team members are goal-oriented.
- Team members are under time-constraints.
- Decisions are based upon past experiences.
- Decisions are often made in teams.

In comparison, characteristics of real world domains in which the three aforementioned theories have been applied can be summarized as follows:

- *Distributed Cognition:* information-rich environment, information is distributed among several people and artifacts (e.g. CSCW systems).
- *Transactive Memory:* information is distributed among people, team members are aware of colleagues' areas of expertise.
- *RPD:* decisions are based upon past experiences, decisions are made on the fly, and the environment is time-constrained.

Furthermore, the domains to which each of the theories have been applied share the characteristic that team decision making is goal-oriented. This shared factor, in conjunction with the 911 team characteristics listed above, provided a basis for understanding and interpreting the dynamics of 911 team decision making procedures for this study.

This is not to suggest, however, that all of the principles of each theory are fully applicable to 911 dispatch teams. Rather, this suggests that each theory holds some

principles that provided assistance with the study and further understanding of certain aspects of 911 dispatch teams. This consideration, in turn, is a lead-in to another key question: *"How well do current theories of cognition assist in the understanding of the cognition, communication, and decision making activities of 911 dispatch teams?"* This was a critical question that the current study sought to answer. However, given the characteristics of the domains to which the theories have already been applied and the known characteristics of 911 dispatch teams, preliminary data (Terrell et al., 2004) suggest the following as an initial answer, as outlined in Table 2.2.

Table 2.2: Dispatch Team and Theoretical Domain Context Factors

911 Dispatch Team Characteristics	Distributed Cognition	Transactive Memory	RPD
Involve rich social contexts	Yes	Yes	Yes
Have information distributed among several people	Yes	Yes	No
Have information distributed among artifacts (e.g. information technology)	Yes	No	No
Ill-structured information	No	No	No
Goal-oriented	Yes	Yes	Yes
Time-constrained	No	No	Yes
Decisions are based upon past experiences	No	No	Yes
Decisions are often made in teams	Yes	Yes	No

The information provided in Table 2.2 implies that all of the factors known thus far regarding the decision making procedures of 911 dispatch teams are accounted for by at least one of the three theories. However, none of the three theories can account for all of the factors by itself. This suggests, therefore, that there is a gap in theory and literature concerning team decision making as it applies to 911 dispatch teams and decision teams within similar domains. The intent of this study was to address this gap in literature and theory by researching the decision making practices of 911 dispatch teams. This study, in

turn, proposed a framework which can be used as a tool for further understanding and study of 911 dispatch teams and teams with similar characteristics.

CHAPTER III: RESEARCH DESIGN

This section describes how the current study was conducted as well as the logistics for the chosen methods. The research philosophy and focus of the study is stated followed by the objectives of the research method. Finally, there is a detailed description of how the study was conducted including where and how the data was collected and how it was analyzed.

3.1 Research Philosophy and Focus

This study represents an a priori qualitative study. The conduct of a priori research is in the tradition of applying current theories or beliefs towards research. There are traditionally two primary reasons why researchers apply current theory to a given research topic: to strengthen a given theory via the generalization of the theory to diverse areas of research or to seek gaps in current theory when it is applied to a given topic or entity. The goal of the current research is more within the sphere of the latter objective: to advance the evolution of science and theory by challenging the generalization and applicability of extant theory. In order to accomplish this objective, this study required the richness of data collection provided by a mixed methods qualitative study. Employing qualitative methods allows researchers to understand participants' logistics and reasoning for certain behaviors. This type of information could be largely overlooked if it was limited to quantitative methods (Trauth & Jessup, 2000).

This research assessed and evaluated the communication, coordination, decision making procedures, and human-computer interactions that facilitate teamwork in 911 dispatch teams. In order to do this, it was necessary to observe dispatch teams working in their own environment while performing their work tasks. Because emergency situations and appropriate responses may vary depending upon geographical location (Jones, 2004), it was necessary to study dispatch teams of varying contexts in order to obtain a comprehensive picture of what dispatch teams do. Also, the study of dispatch teams in diverse contexts facilitated data generalization across contexts.

3.1.1 Participants

The participants in this study included members of 911 dispatch teams from two different geographical contexts that varied by population density and geographic characteristics. Participants included 911 dispatch team members from the Centre County Office of Emergency Communications and the Allegheny County 911 Center.

The participants from the Centre County Office included two managers and the observations of three shifts of dispatch teams. There were four members in each dispatch team at the Centre County Office. The four members of each dispatch team included: a shift manager whose job was to oversee the activities of the other dispatchers on duty, a 911 call taker whose primary task was to answer emergency calls that came into the dispatch center, a dispatcher whose primary task was to dispatch police units, a dispatcher whose primary task was to dispatch fire units, and a dispatcher whose primary task was to dispatch paramedic units. The participants from the Allegheny County Center included one senior manager, one middle manager, one trainer, and three shifts of dispatch teams. There were forty-three members in each dispatch team at the Allegheny Center. Some members of the dispatch team are exclusively responsible for receiving 911 calls (call takers) while the remaining members are exclusively responsible for dispatching emergency resources to the site of an emergency.

3.1.2 Demographic Characteristics of Research Sites

The following presents a brief overview of the demographical characteristics of both Centre and Allegheny County. Although the locations differ by several characteristics, only a few will be discussed in order to draw attention to the vast differences between the two areas.

The Centre County Office of Emergency Communications is located in the town of Bellefonte, Pennsylvania. The Centre County Office dispatches emergency resources for six townships and boroughs. Centre Country lies in central Pennsylvania; it is 1,107

square miles, has a population of approximately 136,000[4], and has a population density of 126.8 persons per square mile (*Population Overview*, 2006). Centre County is a largely rural, agricultural area interspersed with residential and old town communities. The ethnic composition of Centre County is listed in Table 3.1.

Table 3.1: Ethnic Composition of Centre County, PA

RACE AND ETHNICITY		
	Number	**Percent**
White	124,134	91.4
Black or African-American	3,544	2.6
American Indian	184	0.1
Asian	5,373	4.0
Hawaiian/Pacific Islander	94	0.1
Other	1,003	0.7
Two or more races	1,426	1.1
Hispanic or Latino	2,243	1.7

(from *Population Overview*, 2006)

Centre County is also the location of The Pennsylvania State University (Penn State) at University Park which is located within the borough of State College, Pennsylvania. Penn State is host to approximately 41,000 students and 2,500 faculty members (*2005-2006 Common Data Set Penn State University Park*, 2006). Therefore, with an estimated population of roughly 40,000 in the year 2003, the borough of State College has a high population density average of 8,459 persons for each of its 2,000 square miles (*U.S. Census Bureau State & County QuickFacts*, 2006). Therefore, this populous town is in sharp contrast with its surrounding rural, Amish populated farmland, thereby making Centre County unique with its diverse geographical and demographical characteristics.

The Allegheny County 911 Center is located in the city of Pittsburgh, Pennsylvania and dispatches emergency resources for 68 townships and boroughs. Allegheny County lies

[4] Unless otherwise stated, all population and demographic counts reflect the count of the most recent census in 2000.

in southwest Pennsylvania, is 730.2 square miles, has a population of approximately 1.25 million, and a population density of 1,173.0 persons per square mile (*Allegheny County County Profile*, 2006). Allegheny County is a highly urban area with high rise buildings, venues of performing arts, museums and other historical sites, seven colleges and universities, and four major professional sports teams. The ethnic demographics of Allegheny County are listed in Table 3.2.

Table 3.2: Ethnic Composition of Allegheny County, PA

RACE AND ETHNICITY		
	Number	**Percent**
White	1,080,800	84.3
Black or African-American	159,058	12.4
American Indian	1,593	0.1
Asian	21,716	1.7
Hawaiian/Pacific Islander	335	0.0
Other	4,399	0.3
Two or more races	13,765	1.1
Hispanic or Latino	11,166	0.9

from (*Allegheny County County Profile*, 2006)

3.2 Research Procedure Overview

Given the focus of this study, it was imperative that the research methods allow for effective data elicitation, analysis, and evaluation of 911 dispatch teams and their use of information technology systems. Therefore, the objectives of the research methods were:

a.) *To outline and define the activities of 911 dispatch teams and determine how these activities differ between dispatch teams in various contexts.*

b.). *To describe the cognitive processes of 911 dispatch teams and determine if (and if so, how) cognitive processes vary between dispatch teams in various contexts, and*

c.) *To determine how 911 dispatch teams analyze and evaluate an emergency situation to decide what and how many resources to deploy to a given site.*

These objectives were developed in order to achieve a comprehensive understanding of cognitive and collaborative work activities that transpire for a given context. Through documentation of data to fulfill these objectives, an assessment and evaluation of actual work content and process was juxtaposed to the selected theoretical positions outlined in the introduction to determine the best fit of theory to practice across both contexts studied. In order to achieve these objectives, the selected research method needed to be one that would elicit active and frequent participant dialog and information sharing with the researcher throughout the methods process; facilitate the researcher's recording of accurate, participant-centered information; and allow the development of a comprehensive understanding of the perceptions and cognitive procedures of the actual 911 dispatch workers.

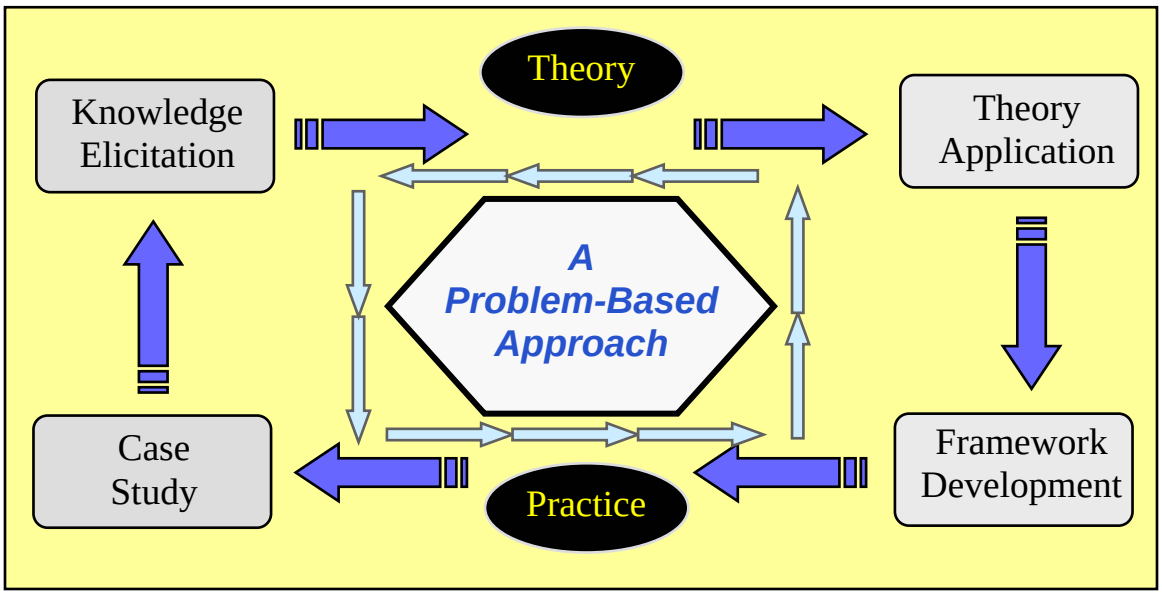

Figure 3.1: The Living Lab Framework (adapted from McNeese, 1996)

In consideration of the objectives, needs, and requirements of the research method, the methodology for the current study followed the modified principles and structure of a comprehensive research approach termed the Living Lab Framework (McNeese, 1996;

McNeese et al., 2004) (see Figure 3.1). The figure outlines four components to data collection, analysis, and theoretical application and framework development in a manner in which domain experts are key players. The current study followed the principles of the Living Lab Framework (LLF) in order to: a) elicit knowledge concerning work activities, information flow, cognitive processes, human-to-human interactions, and human-computer interactions of 911 dispatch teams and b) determine similarities and differences in the aforementioned factors between different contexts of dispatch teams.

In essence, the LLF presents a chronological approach to methods that guides the researcher from preliminary data collection to final data analysis. For the purposes of the current study, the methodology began with a case study that included document analysis and introductory interviews with key 911 dispatch center employees from both research sites. Referred to as *bootstrapping*, this initial case study activity is performed to familiarize the researcher with the activities and work environment of the participants (Potter, Roth, Woods, & Elm, 2000b). Additionally, bootstrapping gives the participants an idea about the type of information the knowledge elicitor seeks to gain. The next phase of the LLF, knowledge elicitation, was carried out via extensive interviews with key personnel at both dispatch centers. Data from the case study and knowledge elicitation phases were analyzed to determine key attributes of 911 dispatch teams and their applicability to extant theory. This, in turn led to the development of a new framework of team decision making. It should be noted that, for the case study and knowledge elicitation phases of data collection, data was first collected at the Centre County Office of Communications. Next, the case study and knowledge elicitation activities were repeated at the Allegheny County 911 Center. Data collected from both sites was used for the theory application and framework development phases.

The following sub-sections will explain, in greater detail, each phase of the LLF in the current study.

3.3 Case Study Phase

Initial data collection for this study employed a case study approach in which information regarding the cooperation, communications, and human-computer interactions of 911 dispatch teams was gathered from 911 dispatch centers in two different environments. According to Creswell (1994), a case study is a qualitative research method wherein the research explores a single type of entity (in this instance, 911 dispatch teams). A case study is completed within a sustained time frame and employs data collection techniques to gather comprehensive data. The case study phase of the research involved two separate components: bootstrapping and *in situ* observation.

3.3.1 Bootstrapping

Research suggests that knowledge elicitation can be enhanced if the researcher conducts an informal interview with key members of the focus group to gather basic information about the study group's skills, environment, domain, work experience, and technical skills before conducting a formal, goal-specific interview (Potter, Roth, Woods, & Elm, 2000a). Often referred to as bootstrapping, this procedure allows researchers to learn about the focus group's tasks, cognitive challenges, and environmental affordances (Hutchins, 2004). This helps researchers to obtain a better understanding of the participants' environment prior to formal information acquisitions. Additionally, bootstrapping can include the gathering and evaluation of documentation (e.g. white papers) about the participants' procedures, environment, and policies.

In an ethnographic study investigating the impact of information technology in Ireland, Trauth (2000) conducted initial, open-ended interviews to develop a conceptual model of the focus group under investigation. This allowed for a preliminary understanding of the participants and their environment. Additionally, the preliminary interviews provided a foundation for the generation of questions to be asked in future interviews. According to Olswang (2005), the interviewing process should begin with broad, "grand tour" questions that will give the interviewer an understanding of what the participant feels is

most important towards understanding a certain issue. This, in turn, will help the interviewer derive more specific, focus-driven questions for incorporation into subsequent interviews.

In this study, bootstrapping provided an initial conceptual understanding of the activities and environment of 911 dispatch teams before eliciting knowledge via formal interviews. An initial conceptualization of the participant's job helped to facilitate the generation of open-ended questions prior to the formal interview process which resulted in the acquisition of more comprehensive data during the formal interview process. Additionally, by establishing this initial introduction to the domain experts before the subsequent phases of the study, the bootstrapping phase served to secure primary points of contact. Establishing a point of contact at each research site was essential to the data collection phases of this study in that it provided a) someone to contact to set up visits to a given dispatch center, b) a person who would assist in providing access to other people, facilities, and resources for richer and more comprehensive data collection, and c) a person to coordinate future contacts and follow-ups after initial data collection.

3.3.1.1 Bootstrapping at the Dispatch Sites

In preparation for the knowledge elicitation phase of this study, the bootstrapping procedures for both contexts were as follows. Document analysis regarding general information on 911 dispatch teams was performed. Specifically, this included documents related to training 911 dispatchers, extant models of 911 dispatch team workflow, as well as the types of technology used by 911 dispatch teams. Bootstrapping at the dispatch sites also included unstructured introductory interviews with the managers from each center.

In addition, the bootstrapping phase also involved extensive one hour tours of each center. During these tours, elements of each center such as the dispatching room, the storage room of computer servers and other information technology systems, and various team meeting rooms were observed. Their functions were described in detail by each

center's corresponding manager(s).

In further preparation for the knowledge elicitation phase of the study, a series of *in situ* observation visits were completed at each dispatch center. During this phase, the researcher sat in the control room (i.e., the room where dispatch teams receive 911 calls and dispatch emergency resources) and observed a 911 dispatch team performing their daily activities (namely receiving information concerning emergency situations and performing the steps necessary to eventually respond - or allocate resources - to the emergency situations). *In situ* observation was completed three times at each center for approximately one hour per visit.

The purpose of the bootstrapping phase was to further develop a richer understanding of the context, domain, and activities (i.e. witnessing these factors in person) of 911 dispatch teams before instigating the knowledge elicitation phase. Information gathered from the *in situ* phase was documented by researcher's notes (Trauth, 2000). Additionally, for reliability and validity purposes, these notes were compiled, reviewed, and edited to insure quality management and control of data. This was accomplished via the researcher's review of the data as well as follow up phone conversations with the aforementioned managers at each of the dispatch centers to ensure data accuracy (Trauth, 2000).

3.4 Knowledge Elicitation Phase

Although *in situ* observation helps researchers to become more familiar with the participants' tasks and working domain, observation alone is not sufficient to arrive at a thorough understanding of the participants' and their activities. In order to collect accurate results via qualitative methods, it is necessary that the researcher actively seek out the perceptions and viewpoints of the participants (Genzuk, 2005). This can be derived through the knowledge elicitation approach outlined by McNeese and his colleagues (McNeese et al., 2004; McNeese, Zaff, Citera, Brown, & Whitaker, 1995; Zaff, McNeese, & Snyder, 1993). When conducting a case study, it is important that the

knowledge elicitation method facilitate mutual cooperation, understanding, and communication between the user population and the researcher (McNeese et al., 1995; Zaff et al., 1993). To achieve this objective, this study incorporated participatory knowledge elicitation utilizing a knowledge representation/documentation process known as concept mapping.

Concept mapping is a form of knowledge documentation in which knowledge is graphically represented as a network of interrelated concepts and actions (*Concept Map*, 2005; Crandell, Klein, & Soderston, 1996; Komis, Avouris, & Fidas, 2002; Novak, 2005). Due to its non-linear structure, a concept map gives the participants and the knowledge elicitors the ability to view all the relationships between domain related concepts, tasks, and decision points. Additionally, concept mapping allows the domain experts to participate in the framing and construction of the data during the knowledge elicitation process since the concept map is generated and can be viewed (as well as modified) by the participants during the actual interview session (*The Use of Concept Maps in the Teaching-Learning Process*, 2005). Therefore, concept maps provide a basis for mutual understanding, cooperation, and communication of a given entity during knowledge elicitation.

It should be noted that concept mapping, a graphical-based form of knowledge elicitation, represents only one method of knowledge elicitation. Other types of knowledge elicitation methods include (but are not limited to):

- Critical decision method: a method in which experts are presented with a non-routine scenario and are instructed to describe what actions, precautions, and considerations they would make in response to the situation (Klein, Calderwood, & Macgregor, 1989);
- Protocol analysis: a method in which transcripts of interviews are evaluated to identify certain relationships, events, and characteristics that are relevant to the topic under study (*Knowledge Acquisition*, 2003);

- Laddering technique: a method that categorizes the flow of knowledge and information in a hierarchical manner (*Knowledge Acquisition*, 2003);
- Limited-information and constrained processing tasks: a method in which experts are asked to perform a task within a constrained amount of time; this helps the knowledge elicitor extract the key activities and information required to perform the task (*Knowledge Acquisition*, 2003);
- Verbal protocol analysis: a method in which experts verbally state their thoughts as they perform a certain activity (*Knowledge elicitation methods and their advantages and disadvantages*, 2006); and
- Group tasks analysis: a method where a group of individuals discuss activities and procedures related to a given topic (*Knowledge elicitation methods and their advantages and disadvantages*, 2006).

The success of a certain knowledge elicitation technique as a data collection tool highly depends upon the domain and work activities of the participants (McNeese et al., 1995). Past research with experts in emergency management suggests that concept mapping provides a rich set of data that proficiently represents the numerous decision points, hierarchical relationships, constraints, and actions of individuals who work in this domain (Connors et al., 2004). Therefore, despite the availability of other knowledge elicitation methods, concept mapping was the chosen method for the current study.

3.4.1 Knowledge Elicitation at the Dispatch Sites

This study utilized both scenario-based (i.e. stories or situation descriptions that describe an event that could feasibly occur on the experts' job - see Hoffman, Shadbolt, Burton, & Klein, 1995; Rosson & Carroll, 2002) and non-scenario based knowledge acquisition in order to generate the concept maps. Research in knowledge elicitation techniques suggests that the use of scenarios in knowledge elicitation can yield different types of information. For instance, the use of scenarios in knowledge elicitation can provide the researcher with an in-depth understanding of the participants' domain, cognitive processes (Rosson & Carroll, 2002), and human-computer interactions (Jarke, 1999).

Preliminary data from interviews with 911 dispatch teams suggest that the use of a scenario-based question will result in the acquisition of information concerning the social network of humans, information technology systems, and other resources in emergency dispatch (Terrell et al., 2004). However, the use of a non-scenario based question will result in the acquisition of general information such as: standard procedures, rules, and the functions of information technology systems in emergency dispatch.

Therefore, data collected in the non-scenario based concept mapping session was documented via a concept map referred to as a *concept definition map* (see Figure 3.2). A concept definition map is a concept map where the documentation of relationships between various entities define the concepts noted in the representation (Connors et al., 2004). Data collected from the scenario-based concept mapping session was documented via a concept map referred to as a *procedural concept map* (see Figure 3.3). This type of concept map displays concepts, actions, and decision points as they occur temporally as a situation progresses (Brewer, 2005; Brewer et al., 2005; Connors et al., 2004)[5]. However, it should be noted that a concept procedural map is not necessarily linear since multiple events can occur at a given time.

Therefore, two types of concept maps, a definition map and a procedural map, were produced at each dispatch center. At both centers, the first concept mapping session was prompted with the following non-scenario based question:

> *Walk me through the procedures that you follow after receiving a 911 call. How are resources dispatched?*

The second concept mapping session was prompted with the following scenario-based question:

[5] Although the example displayed in Figure 3.3 depicts a time bar, the concept procedural maps in the current study do not display this feature due to the rapid assessment and actions of 911 dispatcher activities.

A sudden snow squall reduces visibility on a major highway to almost zero percent. A head on collision between two vehicles escalates into a 50 car pile up including trucks carrying hazardous material. Calls begin to come into the center concerning this accident. The reports include sights of flames, smoke and individuals trapped in their cars. Walk me through the procedures that you would follow from these reports.[6]

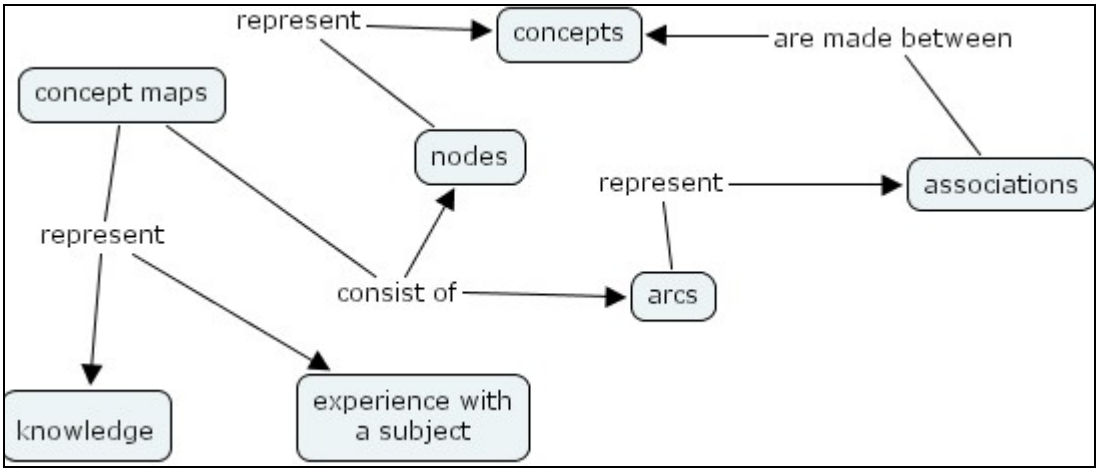

Figure 3.2: Concept Definition Map

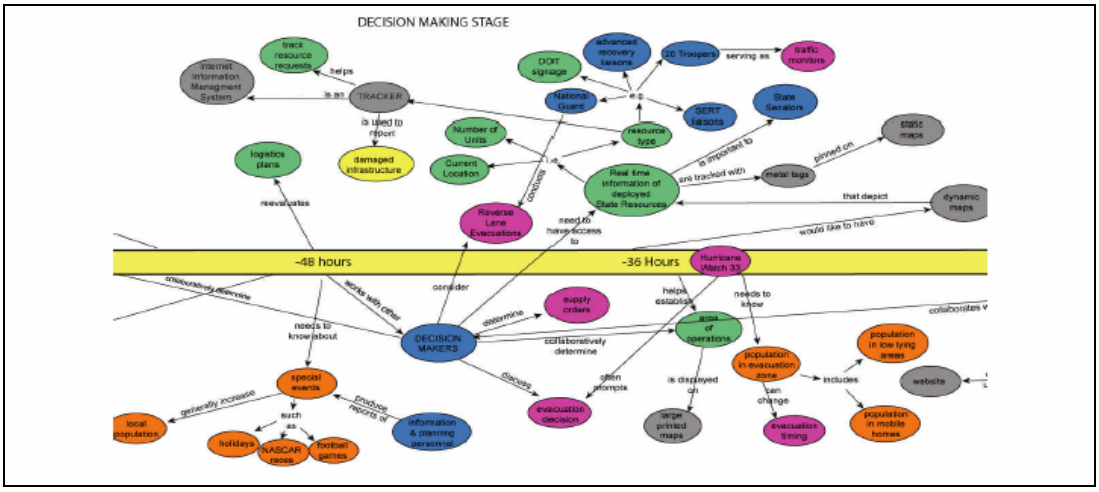

Figure 3.3: Procedural Concept Map (see Brewer, 2005)

[6] This scenario was derived from an actual event that occurred in Centre Country, Pennsylvania in 2004

For each session, additional probe questions were asked as the concept map was generated (Zaff et al., 1993). These probe questions were dynamically generated during the concept mapping sessions for information clarification or information enhancement purposes (i.e. additional probe questions depended upon the flow of the conversation).

At the Centre County Office, the participants for concept mapping sessions included (in addition to the researcher) one shift manager, a 911 call taker, a police unit dispatcher, a fire unit dispatcher, and a paramedic/hazardous materials dispatcher. Since all of the participants' viewpoints were represented on each of the two concept maps generated at the dispatch center, these concept mapping sessions were group concept mapping exercises (Brewer et al., 2005). Due to time and space restrictions, two individuals at the Allegheny Center participated in individual concept mapping sessions. Therefore, the concept mapping sessions at the Allegheny Center were individual concept mapping exercises. One participant was an individual referred to as the Shift Commander, i.e. an individual who oversees all of the 911 call taking and dispatching activities for a given shift. The other participant was a 911 resource dispatcher and trainer. Each participant participated in a non-scenario based concept mapping exercise and a scenario based concept mapping exercise. The respective concept maps were consolidated to form one concept definition map and one procedural concept map to represent the activities of the Allegheny County Center.

3.4.2 Knowledge Elicitation Data Analysis

In order to analyze the concept maps generated during the knowledge elicitation phase, the concept maps were first entered into a concept mapping software program known as *Cmap* developed by the Institute for Human Machine Cognition (IHMC), an affiliate of the University of West Florida (see http://cmap.ihmc.us for more information). Although this program does not perform analysis functions, it nevertheless aids in data analysis by allowing for the organized arrangement of nodes and links in a concept map. Furthermore, this software program allowed for the use of color to highlight and separate common concepts, actions, and themes found in the concept map. For instance, Figure

3.4 depicts a concept definition map based on preliminary data from knowledge elicitation sessions with 911 dispatchers in the Centre County Office (Terrell et al., 2004). The concepts in the map shown in Figure 3.4 were reviewed and color-coded according to themes and key topics (*Concept Mapping*, 2005; Crandell et al., 1996; *Improving Note Taking with Concept Maps*, 2005). In this instance, the blue-color nodes represent concepts that refer to people, purple nodes represent concepts that refer to information technology, yellow nodes represent concepts related to decision actions, and white nodes represent miscellaneous information. A similar schema (further described in the subsequent Results section) was used to evaluate the concept maps in the current study.

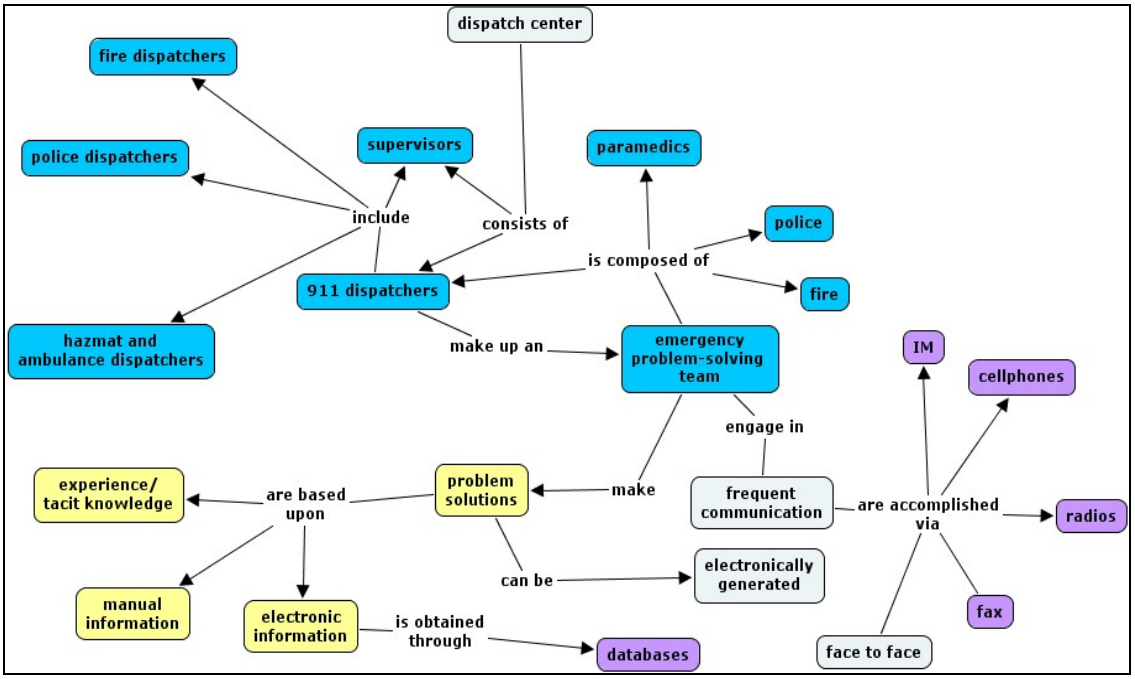

Figure 3.4: Concept Definition Map of 911 Dispatch Activities

3.5 Theory Application Phase

The application of theory to 911 dispatch teams was accomplished by determining the attributes of dispatch teams based upon the data collected from the case study and knowledge elicitation phases of the research. The applicability of these attributes to the aforementioned theories was determined by comparing these attributes with the principles

of each of the theories. This evaluation allowed the researcher to determine the degree to which each of the theories can be applied towards 911 dispatch teams; additionally, this also allowed the researcher to identify gaps or shortcomings in current theories of cognition and their applications towards team decision making. This led to the subsequent generation of a new framework that represents the structure of 911 dispatch teams.

A similar approach towards the generation of theory development was performed by business researchers (2005; O'Connell & Irurita, 2000) who sought to develop theories related to e-waste (i.e. environmental damage caused by technology) (2005). Data was collected (via qualitative research techniques) from various stakeholders and evaluated according to the principles of extant frameworks regarding e-waste. From this analysis came the development of theory to further access the causes, effects, and solutions to e-waste.

Within the domain of emergency management, O'Connell and Irurita (2000) stipulate that research and data analysis by qualitative techniques is a viable means towards theory development. Furthermore, Siepman (2004) acknowledges that, in order for science to progress, theories must be used as a "basis for experimentation" for the generation of new theories. This, similarly, is precisely what the current research seeks to accomplish: to use current theories of decision making for the basis of research in order to develop a new framework which may be applied to 911 dispatch team cognition and decision making.

Figure 3.5 displays the flow of the research methods for the current study and the transitions between the phases of the LLF.

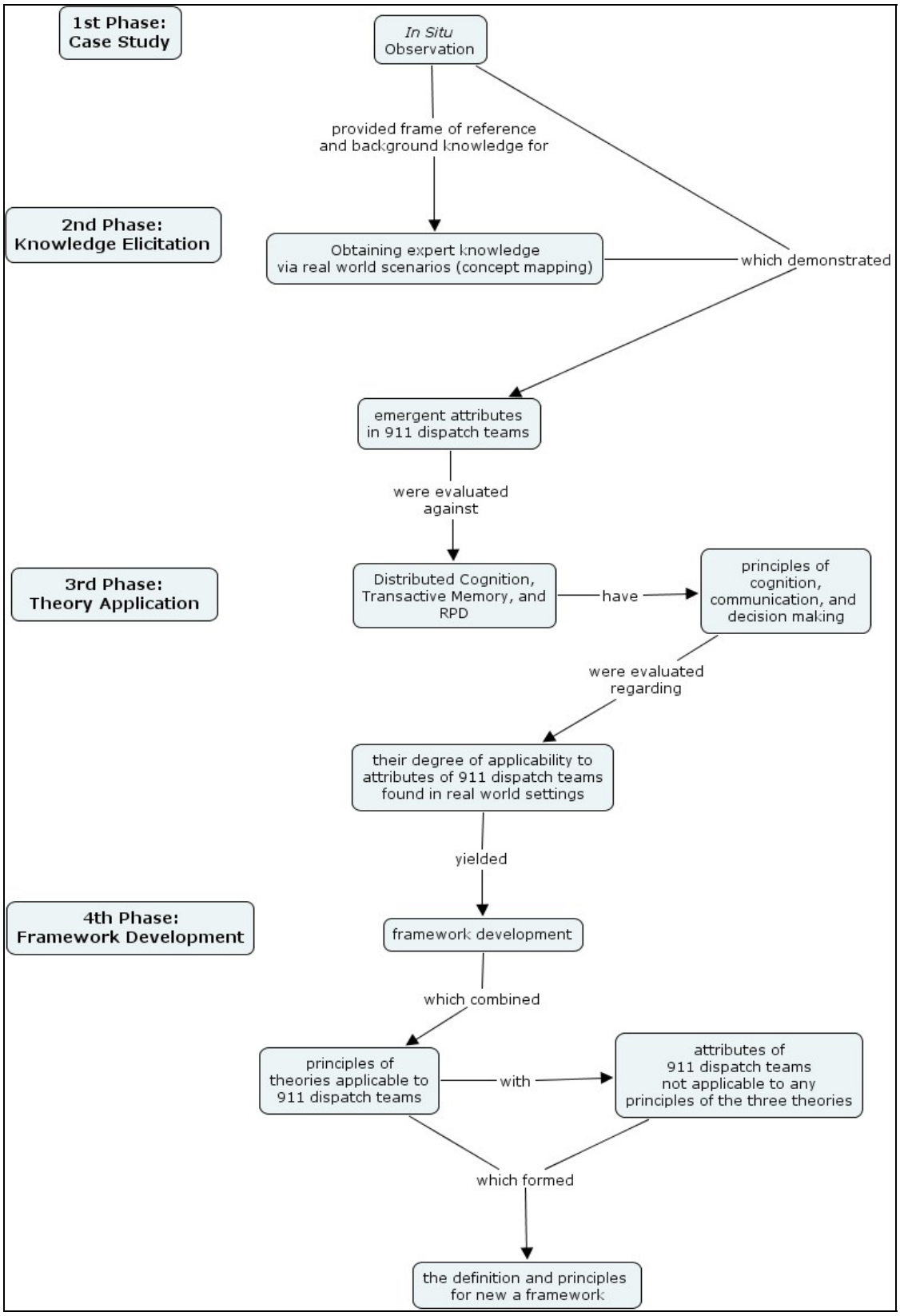

Figure 3.5: Flowchart of Research Methods

CHAPTER IV: RESULTS

Each phase of the LLF resulted in various outputs. The output from each phase helped foster the transition into the next phase. The data collected from the case study phase, which involved *in situ* observation within the dispatch centers, allowed the researcher to gather in depth information regarding general activities and procedures within the dispatch centers. This, in turn, gave the researcher a frame of reference for understanding the more specific, real-world applications of the communicative, procedural, and technical aspects of 911 dispatch teams that were revealed during the knowledge elicitation phase. The analytical review of data from the case study and knowledge elicitation phases revealed attributes of 911 dispatch teams that consistently emerged throughout the data collection process. Each attribute was reviewed to determine whether it could be applied to any of the three foundational theories. For instance, if a certain attribute was a real-world example of a principle within a certain theory, then this was suggestive of the given theory's application to 911 dispatch teams. The number of attributes that could be applied to each theory determined each theory's degree of applicabilty to 911 dispatch teams. Finally, the principles of each theory that were found to be applicable to 911 dispatch teams, in conjunction with attributes of 911 dispatch teams that could not be applied to any of the theories, were conjoined to develop a framework that is representative of the key characteristics of 911 dispatch teams.

The following sections state the results from each phase of the LLF in this study. The first sections, which present the results from the case study phase, will state the similarities and differences between the structure, utilizations and types of technology, common procedures, decision making activities, and communications of 911 dispatch teams between the two centers. This will be followed by a description of the results from the concept mapping sessions in the knowledge elicitation phase. The final section will present the application of data collected from the case study and knowledge elicitation phases to current theories of cognition.

4.1 Case Study Results: In Situ Observation

This section states the research notes that were observed during *in situ* observation at the Centre County and Allegheny County dispatch centers.

4.1.1 Demographics and Characteristics of the Dispatch Centers

Number of Call Takers and/or Dispatchers during each shift:

- *Centre County*: 4-6 (all dispatch team members receive calls and dispatch resources). The dispatchers are in a very small room and are in close proximity to each other (see Figures 4.1 and 4.3)[7].

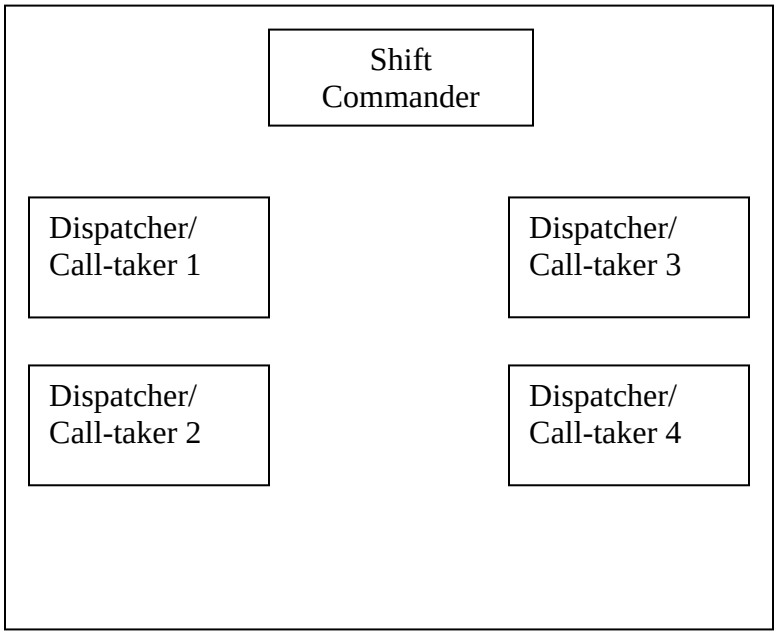

Figure 4.1: Centre County Dispatch Room Layout

- *Allegheny County*: 43 dispatchers and approximately 20 call takers. The dispatchers and call takers work in a very large room (see Figures 4.2 and 4.4) [8]; however, this is primarily due to the number of dispatchers and call takers on duty at one time. Individuals on duty work in fairly close proximity to each other.

[7] Figure 4.1 is not drawn to scale.
[8] As reflected in Figure 4.4, the dispatch room at the Allegheny center is a darkened area.

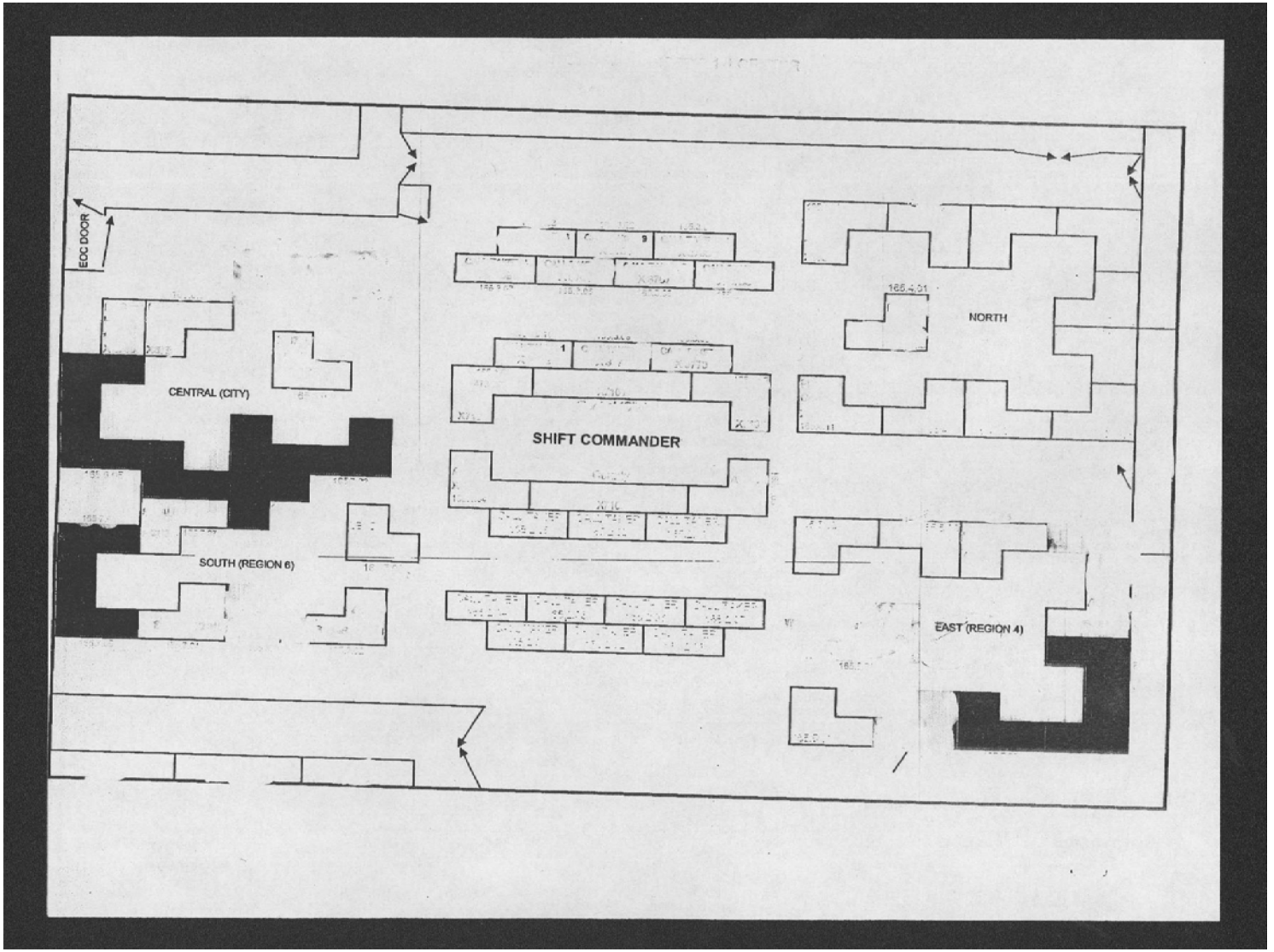

Figure 4.2: Allegheny County Dispatch Center Layout

Roles and Tasks of the dispatch team members:

- *Centre County*: This location is a consolidated communication center in which the same people take the 911 calls, take the information, and directly dispatch the units. However, during each shift, one individual serves as the primary call taker. If that person's line is busy, then incoming emergency calls will be received by other members of the team. Each of the other members is assigned primary responsibility over dispatching a single type of emergency resource: police, fire, or ambulance. Nevertheless, all team members, including the primary call taker, may dispatch any type of resource if the individual primarily responsible for a given resource is occupied when it is needed. Therefore, a dispatch team will typically consist of:
    - A primary call taker
    - A dispatcher who is primarily responsible for dispatching police units
    - A dispatcher who is primarily responsible for dispatching fire units
    - A dispatcher who is primarily responsible for dispatching paramedic units
    - A supervisor who assigns roles for the day and manages activities; the supervisor sits on a heightened platform directly behind the call taker and dispatchers on duty. The supervisor role may not be filled for every shift.

Individuals do not perform the same role each time they are on shift. A person who was a call taker during one shift may return as a police dispatcher for the next shift. With the exception of the supervisor role, all dispatchers are trained and able to perform each of the above roles.

- *Allegheny County*: Team members are divided into call takers and dispatchers. In contrast to the Centre County dispatch system, dispatchers are not primarily responsible for dispatching one type of resource per shift. All dispatchers dispatch all types of resources.
    - Also on call is a Shift Commander who is seated on a heightened platform in the middle of the room. This person sees all team members on shift and supervises all activities that occur within the dispatch room.

The dispatch center is divided into four sections. Call takers and dispatchers working in a given section are responsible for a certain county zone: North, South, East, and Central (see Figure 4.2). Therefore, the group of call takers and dispatchers who respond to a call depends solely upon what area of the county the call comes from. Additionally, each zone has multiple call takers and dispatchers.

Figure 4.3: Centre County 911 Dispatch Room

Figure 4.4: Allegheny County 911 Dispatch Room

4.1.2 CSCW Technology used to Aid Team Decision Making:

Both dispatch centers use a CSCW technology referred to as the *Computer Aided Dispatch (CAD) system* (see Figures 4.5 and 4.6)[9] to share information and make team decisions. The CAD is an interactive, visual based technology used by members of dispatch teams to enter information regarding an emergency situation, receive recommendations for appropriate emergency response, and to share information about a given emergency with fellow colleagues. At both dispatch centers, the CAD is accessed via a network of desktop computers. All dispatchers and/or call takers perform their tasks at their individual workstations.

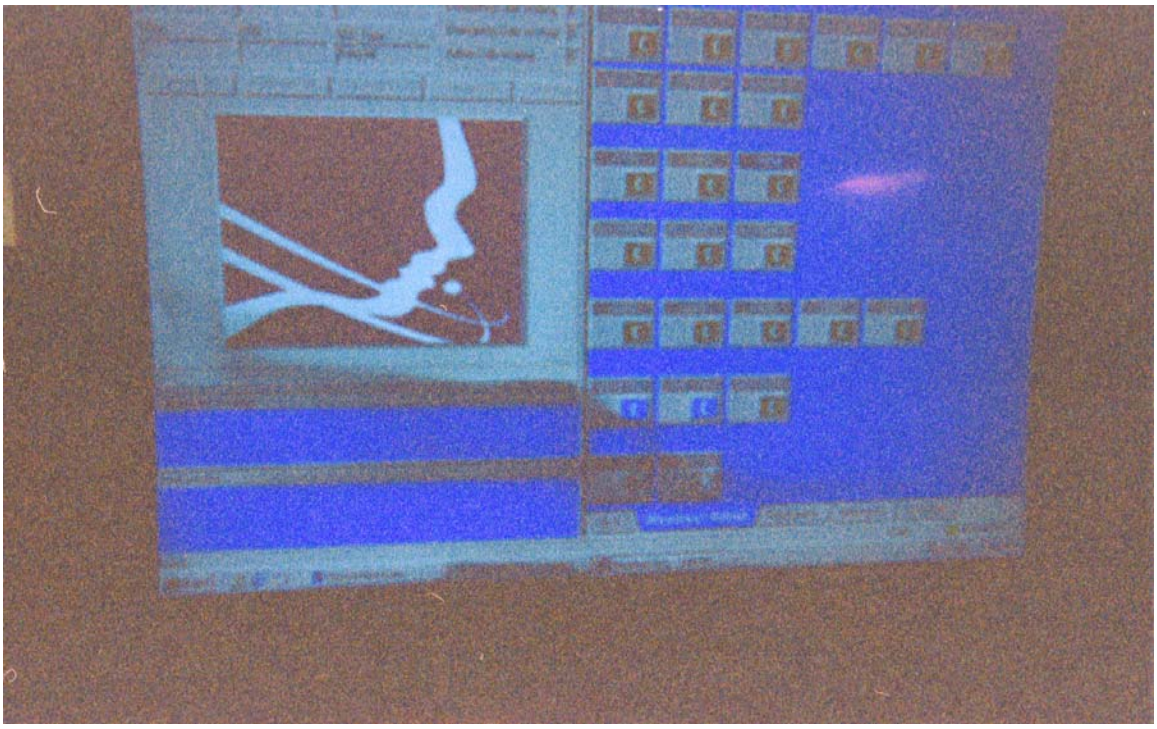

Figure 4.5: Allegheny Center CAD (this screen appears when a call taker receives a call)

[9] Due to confidentiality restrictions at the Centre County Office, both figures display images of the CAD system used at the Allegheny County Center.

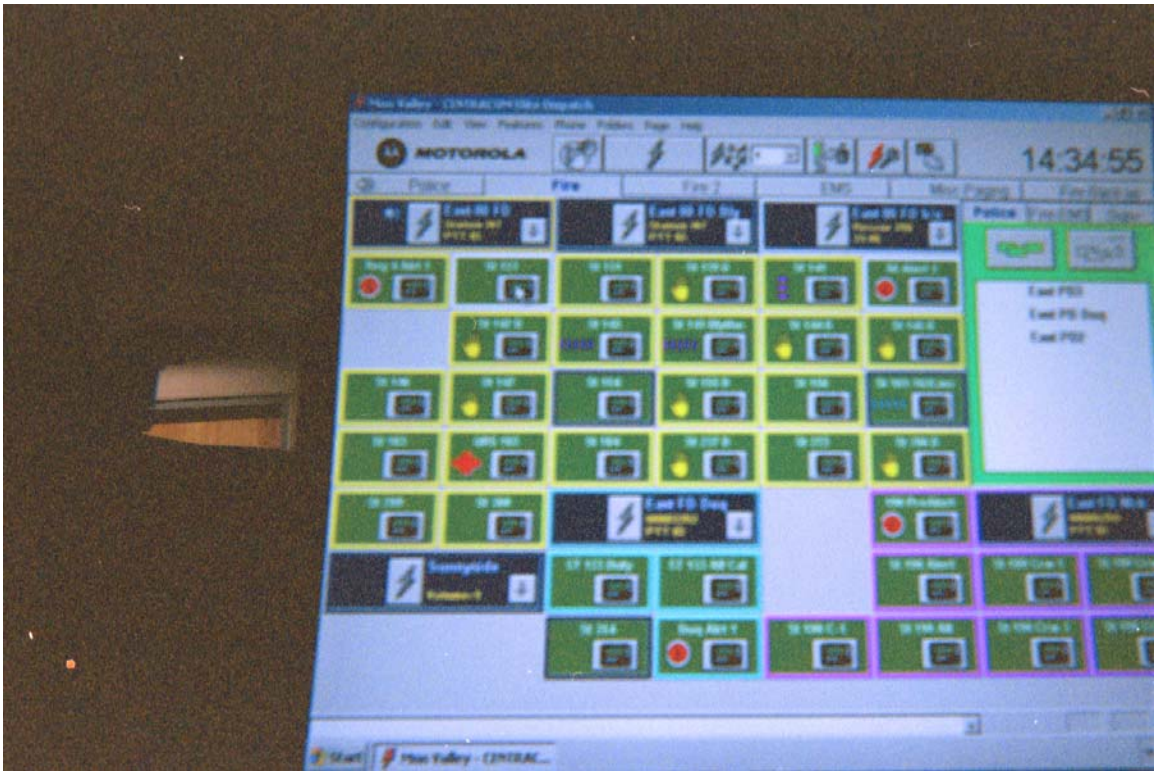

Figure 4.6: Allegheny County CAD Screen (one of the screens used to contact first responder units)

There are common features of the CAD system between both dispatch centers. Such features include:

- The retrieval and display of caller information such as the caller's name and phone number and address that the person is calling from.
- The display and storage of the location of an emergency situation.
- The display and storage of the type of incident; e.g. a fire, domestic dispute, medical emergency.
- The CAD recommends the type and number of resources that should be dispatched to a given emergency situation.
- The CAD prioritizes emergency situations based upon the severity of the incident.
- The CAD records information for an incident from its initial report to its completion.

In both dispatch centers, all of the above information is entered onto one screen, referred to as the *Event Entry Screen*. At both centers, this screen appears each time a call taker at a dispatch center answers a call. Additionally, information such as the caller's phone number and calling address automatically appear on this screen when the call is answered (i.e., the call taker does not have to manually input this information into the system). The remaining information such as the type of incident, who is involved, and other relevant information entered by the call taker and/or dispatcher is entered by the call taker given the caller's description of the incident.

Additionally, the CAD is also used as a tool for the formation of team mental models. At each center, all of the dispatchers and call takers are able to access and view all reported incidents at their individual workstations.

It should be noted that although the CAD system makes recommendations regarding the type and number of resources that should respond to a certain emergency, sometimes dispatchers will refer to prior experience to notify resources that differ from the recommendations made by the CAD.

Although both dispatch centers use a CAD system, there are notable differences in its design between the centers.

4.1.3 Unique Features of the CAD System used in the Centre County Office

The CAD system in Centre County manages the availability of emergency units and equipment in multiple counties.

The following is a description of other interactive features in the CAD system used to aid in team decision making at the Centre County Office:

- *Clean Commonwealth Law Enforcement Agency Screen* – This screen allows dispatchers to check into a person's background history. Sometimes the police will radio into the dispatch center and will have a dispatcher perform a background search if the officer is not in his or her car at the time.

- *Center Roads Screen* – This screen displays a graphical map application that allows the dispatchers to view actual pictures of a certain location. The dispatchers can type in an address and view a photograph of the location. In so doing, the dispatcher is able to give an inquiring first responder a description of what a particular building or structure looks like.
- *Citation History Search* – This application gives dispatchers the ability to view an individual's previous citations for a certain offense. For example, if the police are called to a person's home due to excessive noise (i.e. disturbing the peace), the officer can radio to a dispatcher to request information on how many times this person has been previously cited for similar incidents.
- *Warrant Search* – This application allows dispatchers to find out if there is a warrant for a certain individual. Police can radio in to the dispatch center to request this information. The police do not have immediate access to this information from their cruisers.
- *Instant Messaging (IM)* – Dispatchers will use IM to communicate with each other, provide more information about a particular incident, and update the CAD. Dispatchers also communicate with the police through IM since police have access to this application in their cars. The police may IM dispatchers to have a document copied, printed, and/or faxed to the police station.

The dispatchers also use a paging system via the CAD in order to contact emergency units for the services. Dispatchers can page:

1. Fire stations
2. Ambulance units, and
3. Police (individual squad cars) units.

4.1.4 Features of the CAD System used in the Allegheny County Center

The CAD system in the Allegheny Center has five primary screens:

- *Resource Screen* – This screen has information not related to typical emergency management resources such as tow trucks and animal control.

- *Phone screen* – This screen provides information about how a certain call was phoned into the center (e.g. wireless, home) and displays the phone number that the caller phoned from.
- *Screens 3 & 4* – These screens are the actual CAD screens; they display what and how many resources to dispatch to a given emergency.
- *Radio Screen* – This screen allows dispatchers to communicate with emergency units via radio.

The following is a description of other interactive features in the CAD system used to aid in team decision making at the Allegheny County Center:

- *Fire1 Screen* - Dispatchers can activate the sirens of fire units as well as the fire unit pagers. The sirens are activated for fire, rescues, and boat emergencies. From this screen, dispatchers can also send alarms referred to as *pre-alert tones* to the fire units. The number of pre-alert tones that they send depends on whether the fire is a structural or non-structural fire. One pre-alert tone is for a non-structural fire (e.g. brush, dumpster, vehicle). Two pre-alert tones are for structural fires (e.g. house, business, etc.).
- *Fire2 Screen* – Despite the name of this screen, this screen is used by dispatchers to send out an alert tone to police units. Upon activating the alert tone from this screen, the dispatchers immediately begin communicating to all police units via radio (on all other channels, however, the dispatchers must wait for a police unit to acknowledge them). Dispatchers will send out alert tones for situations such as domestic disturbances in progress, gun shots, burglaries, fights, and other disturbances. Alert tones essentially instruct police units to stop what they are currently doing and listen to what the dispatcher is saying. It should be noted, however, that the alert tones are only used for two of the municipalities (Wilkinsburg and Homestead) for which the Allegheny County Office is responsible for dispatching resources.
- *Fire Backup Screen* - This screen is used when the towers that carry communication signals to the fire units are not functioning and the backup towers must be activated. From this screen, dispatchers will always activate pagers but not always the siren.

- *EMS Screen* – From this screen, dispatchers are able to access a pager button which activates the pagers for all ambulance units. The dispatchers will activate the pagers for every situation in which a paramedic is needed. This is the only way paramedic units are alerted to the need for their assistance. However, there are different pager alerts depending on the priority and severity of the situation. They are:
    - E1 - high priority; i.e. get there as fast as you can; examples of E1 priority include chest pain, uncontrolled bleeding, breathing problems, diabetic emergency
    - E2 - moderate priority; examples of E2 priority include a fall with abdominal pain, upper leg, shoulder, or head pain
    - E3 - low priority; i.e. not a big emergency; examples of E1 priority include a hand, wrist, foot, or ankle injury

In addition to the above functions, the CAD system is also used to store records. All emergency calls that are received by the dispatch center are stored in the CAD system for three months.

4.1.5 Other Technology used by Dispatch Teams for Decision Making

Dispatch teams at both centers all watch television in the dispatch room to refer to weather conditions that may affect the number of traffic incidents reported to the centers. There are several television sets in the Allegheny Center dispatch room and one in the Centre County dispatch room. Dispatchers at the Centre County Office may tune into the news to watch a video of a certain incident that recently occurred in the area so they can physically see it. If a call comes in regarding a certain incident, the dispatchers might be able to see, among other things, the building, the people involved, and the setting of the incident.

4.1.6 Responding to a 911 call

The basic flow of emergency response procedures is similar between both dispatch centers. Both Centre and Allegheny County Centers follow the subsequent basic protocol for emergency response:

1. Classify the incident (fire, police, chemical, etc.).
2. Verify the caller's description and information given about the incident in question; the dispatcher attempts to collect information from the caller by asking:
    a. Where is the exact location of incident/ coordinates?
    b. What are the details of the accident?
    c. Who is involved and what is the status of the person(s) involved?
3. Verify caller information such as: name, address, type of address (e.g. business or residential, city, county, company, primary phone number).
4. Dispatch units.
5. The first responders occupying the dispatched units tell the dispatch center when and to what they are responding to.
6. The dispatchers update the CAD to indicate that emergency units are on transit to the scene.
7. Emergency units arrive at the scene and the dispatch team drops to a supporting role.

There is a preplanned protocol for each particular situation. For instance, when a call comes in, the dispatcher types the information into the CAD which then returns a list of the type and number of emergency resources to dispatch. For instance, if a report of a domestic dispute is called into the Allegheny Country dispatch center, the CAD will rank the situation as a high priority emergency and suggest that one squad car be sent to the scene. However, dispatch centers cannot realistically preplan for every situation that may arise. Therefore, unique situations are handled depending upon its similarity to another situation that may have arisen in the past. For instance, a dispatcher, based on prior

individual or team experiences, may conclude that what worked for a past fire situation may also work for a current situation involving hazardous materials.

Although the basic structure of 911 call and response is similar between both dispatch centers, there are notable differences in the flow of information and communication.

Centre County 911 Response Protocol: At the Centre County Office, the standard procedure for call response is as follows:

1. The call taker receives a call.
2. The call taker makes an assessment of the situation given information provided by the caller. For instance, the call taker will determine if the incident is a situation that should be primarily handled by a police, fire, or paramedic unit(s).
3. The call taker verifies key information provided by the caller such as the caller's address, name, and phone number.
4. The call taker will electronically save all relevant information to the CAD; the information can be immediately viewed by all members of the dispatch team. In so doing, the dispatch team is provided with a common operational picture of the situation.
    a. The CAD will make recommendations for the types and number of emergency resources to send to the emergency site.
5. Depending upon the type of situation, the appropriate dispatcher(s) will dispatch or contact the necessary resources for the emergency. For instance, if an emergency situation requires a police unit, the dispatcher primarily responsible for dispatching police units during that shift will perform the task. Additionally, if a situation calls for more than one type of emergency resource, such as police and fire, the primary police dispatcher will dispatch police units to the scene and the primary fire dispatcher will be responsible for sending fire crews to the same incident.

In response to a 911 call in which an individual clearly requires immediate action, the dispatchers have a hardcopy medical guide that they have to recite to the caller word for

word. The guide gives directions for medical emergency aid that can be administered before a field worker arrives. The guide includes, but is not limited to, instructions for emergency procedures or situations such as:

1. CPR
2. births/deliveries
3. burns
4. choking
5. breathing problems
6. treatment for diabetics

All of this information is provided in the ambulance medical guide and the dispatchers cannot deviate from what is written in the guide.

Allegheny County 911 Response Protocol: At the Allegheny County Center, the standard procedure for call response is as follows:

1. A call taker, receiving calls for a given zone of the county, answers a 911 call.
2. The call taker makes an assessment of the situation given information provided by the caller. For instance, the call taker will determine if the incident is a situation that should be primarily handled by a police, fire, or paramedic unit(s).
3. The call taker verifies key information provided by the caller such as the caller's address, name, and phone number.
4. The call taker saves all relevant information to the CAD.
5. The CAD will make recommendations for the type of units (and number of each type of resource) to send to the emergency site.
6. The information received by the call taker will appear in the queue of one of the dispatchers dispatching resources for that particular zone. The dispatcher will respond by dispatching or contacting the necessary emergency units.

4.1.7 Resource Dispatching and Tracking

There are similarities and differences between the two dispatch centers in regards to resource dispatching and tracking.

At the Centre County Office, the dispatchers page fire and ambulance stations to alert them to an emergency that needs their attention. From there, it is up to each station to decide what units to send out. In fact, some members of the ambulance and fire crews may be at home when they are needed. The station may page them to come in. In addition, the dispatchers may page administration if a coroner or a deputy is needed.

For police dispatch in Centre County, the dispatchers will send out a page that will go out to all of the police in the county. It is then up to the police to decide which unit, depending upon availability and proximity to the incident, will respond to that emergency. The dispatchers have no way of knowing what squad car is closest. Usually, a police unit will use the radio to respond "That's close to where I am – I'll go." However, the dispatchers are limited in regards to where they can send certain police units. The police in Centre County are not allowed to leave their jurisdictional boundaries. If someone calls from outside the Centre County area, the dispatcher cannot send a police to that person's location. However, the dispatcher will notify the police station in the caller's area that they should send a unit to the area of complaint.

Other resources that can be dispatched include:

a. Street crews + the Pennsylvania Department of Transportation
b. Red cross
c. Salvation army
d. Commercial vendors
e. Forestry/ gaming commission. These resources are often dispatched in response to forest fires.

All information pertaining to these resources can be accessed in the CAD system.

Akin to procedures at the Centre County Office, dispatchers at the Allegheny County Center alert ambulance and fire crews to the need for their assistance through paging systems. This is the only way that they receive their assignments. Again, it is up to the discretion of the stations to decide what unit to send out. Each fire and ambulance station in Allegheny County specifies exactly what units to send out in certain situations via *run cards*. For instance, if an incident is classified as a level 2 alarm structural fire, each fire station's run card will specify exactly which unit(s) should be sent to the scene. Furthermore, both fire and ambulance stations specify backup units on their run cards in case the first units that are indicated on the run cards are not available. Fire stations fill out their run cards depending upon the nature of the call. Ambulance stations fill out their run cards according to the zone the incident is located in. All run cards are stored in the CAD system and are displayed when fire and/or paramedic units are needed. In response to circumstances where fire or ambulance crews are needed, dispatchers refer to the run cards and dispatch the appropriate units to the scene depending upon which units are available. However, the dispatchers must follow what is stated on the run cards.

In circumstances requiring police assistance, the CAD system at the Allegheny Center recommends a specific unit also. The unit recommended by the CAD is usually the one that has been idle (i.e., has not responded to any emergency situations) the longest. Since this is usually the supervisor unit for the day, the dispatcher rarely sends out the CAD recommendation and instead notifies another unit.

It should be noted that neither dispatch center is equipped with geographical positioning systems that monitor the exact location of resources units. Technically, dispatchers have no way of knowing exactly where a unit is; this is especially true if a certain unit is in route to a given location. Tracking and availability of response units is done primarily through first responder to dispatcher communication. First responders radio the dispatch center to alert them to when they are responding to an emergency situation and when they are en route to a certain location. The dispatchers can then indicate in the CAD that a

unit is unavailable or on assignment. Finally, first responders of resource units that have responded to a given emergency situation will radio to the dispatch center that they have completed their task at the scene and are once again available for another assignment. The availability status of that unit is altered in the CAD. Resource availability is recorded by the dispatchers in the CAD systems throughout the day.

4.1.8 Determining Priority of an Emergency Situation via the CAD System

At each center, the priority of an emergency situation is displayed on the Event Entry Screen. Although this is a common feature between the CAD systems at both dispatch centers, the priority of an emergency situation is determined differently between the systems.

Incident Prioritization at the Centre County Office: At the Centre County Office, dispatchers assess an emergency situation with the given caller information. The dispatcher enters an *incident classification* from among 300 given classification types (see Table 4.1 for examples). Initial priority rank of a situation is assigned by the CAD depending upon its incident classification. However, first responders at the scene have the right and responsibility to change the status and priority level of a situation if necessary. This can be an increase or decrease in priority. In order for a priority level to be changed, field workers must identify themselves by an identification number. Changes in status and priority level are only taken from command or line officers.

Assignment of priority rank for threat, such as a bomb threat, is somewhat different. Threats are placed on priority according to the viability and perceived accuracy of the source. Assigning a priority level to threats has a lot to do with the human judgment of the dispatchers.

Table 4.1: Centre County Incident Classifications

Incident	Classifications
Burglary	• In Progress • Just Occur • One week (or more) later
Mass Casualty	• Approximately 1 to 6 patients • Approximately 6 to 10 patients • Over 10 patients
Fire	• Type ▪ Structural or Building • Alarm Level ▪ 1, 2, or 3

Incident Prioritization at the Allegheny County Center - Priority rank is assigned by the CAD depending on the incident classification. The highest priority number possible is 1 and 9 is the lowest. Dispatchers can override a priority number initially assigned by the CAD system. For instance, at the Allegheny Center, an incident classified as a non-physical dispute will be assigned a priority rank of "1" by the CAD. The dispatcher responsible for that incident can assign it a lower priority number.

After an emergency situation is entered into the CAD system, subsequent information reported by field workers may change the nature of the situation. If the situation changes, it may be assigned a higher priority number to indicate that the situation is now of higher priority, but it will never be assigned a lower priority number. Furthermore, dispatchers do not manually alter the priority number of a situation depending upon other incidents that are in their queue because a situation is what it is. Rather, the dispatchers have to decide what emergency situation in their queue should be handled first.

There are several instances, at both dispatch centers, in which the CAD system assigns two or more separate incidents the same priority level. In such cases, the dispatcher who is primarily responsible for those incidents must decide which situation to attend to first. These decisions are usually based upon the dispatcher's prior knowledge to responding to

emergency situations. Additionally, the dispatcher may consult with the supervisor or shift commander on duty before making a final decision.

4.1.9 Communications between Dispatchers

In addition to sharing information via the CAD system, other forms of communication between the dispatchers were noted also.

Centre County: In the Centre County dispatch room, dispatchers communicate with each other via hand signals and by raising their voices while on the phone with a caller to communicate to the other dispatch team members to listen to what they are saying. Additionally, dispatchers at Centre County will often roll their chairs over to talk directly to another dispatcher and/or to view what is on another person's screen to obtain information regarding a certain incident.

Dispatchers at both centers utilize instant messaging and email to communicate with other dispatchers.

4.1.10 Communicating Information Concerning a Single Incident

Dispatchers will often field several calls concerning one incident. Because the information contained in these calls is often arbitrary and lacks complete information, the dispatch team must pool information in order to determine the appropriate type and number of resources to send to the site.

At the Centre County Office, the dispatch team will share information and make a decision by listening to each other and discussing addresses, phone numbers, and other information given from their respective callers. As previously stated, dispatchers at the Centre County Office also use hand gestures to communicate information. During *in situ* observation at this office, there was a noted incident in which a dispatcher was on the line with a caller and asked the other dispatchers if anyone received a call about a certain

emergency. Another dispatcher snapped his fingers in response and gave the OK sign to signal that he had received and was handling such a call; he was on his phone line while responding to the call at the time.

At the Allegheny County Center, resources are dispatched to a given emergency upon the initial call. Other calls that are reported to the dispatch center regarding that incident are entered into the CAD as a duplicate. The call taker(s) will use the "Append as Dup" button which allows them to add more information to a pending situation stored in the CAD without creating a record of a new emergency situation. Upon entering the information into the CAD, they will activate a button on the screen labeled “More to Follow.” Activating the functions of this button will send the information to other call takers and dispatchers. The addition of new information to a reported incident may change the incident classification of the situation. The incident classification is manually altered by the call taker. The alteration of the incident classification may prompt the CAD to change the priority number of a situation to a number that indicates higher priority. After the addition and possible alteration of information, the dispatcher hits the “Recommendation” button on their screen to determine if the CAD recommends that additional resources be sent to the scene. Finally, the dispatcher contacts the field workers at the scene to give them the updated information and to ask if they request additional units to the scene as recommended by the CAD. Once first responders have arrived to the scene of the incident, a dispatcher will not dispatch additional units to the incident regardless of a change in the situation and a subsequent increase in priority. Additional units are always and only sent out on verbal order from field workers.

4.1.11 Dispatch Team Communications with First Responders

Communications between the dispatch team and first responders are similar at both dispatch centers. At both centers, dispatch workers use radio systems that allow them to communicate with first responders and listen to police frequencies. At each center, the dispatchers wear headsets to speak to first responders.

At the Centre County Office, the dispatchers can press a lever under the desk that activates a radio which allows them to talk to a specific police, fire, and ambulance unit. A screen in the CAD system displays icons that represent individual units. The icon that is highlighted on the CAD screen represents the unit that they can talk to after they have pressed the lever. At the Allegheny Center, the dispatchers can use a mouse or a push button worn on their clothing to access the radio system.

The Allegheny Center has several different radio channels used to communicate to various field workers. For instance, there is a separate channel used to communicate to first responders in areas that they do not dispatch for. This is used in extreme emergencies where several first responders from surrounding areas are needed. Additionally, the Allegheny Center uses a *regional channel* which is used to speak to the fire marshal and hazardous material crews. This channel is used for large emergency situations that are still in progress. The dispatchers can also access and speak through multiple radio channels simultaneously. Dispatchers at the Allegheny Center can also communicate to all field workers synchronously by sending alert tones through the radio. There are different alert tones depending upon the type of information that the dispatcher is trying to communicate (e.g. weather tone, weather watch or warning, amber alerts). Although these alert tones are intended to provide information to emergency units, other individuals such as tow truck drivers and private persons may hear the alert if they are tapped into the appropriate radio frequency.

Dispatchers at both centers also communicate information stored in the CAD to first responders to aid them while on an emergency site. For instance, the Centre County dispatchers can access satellite photographs of several locations in the county (from the Center Roads Screen) in order to help provide first responders with information about a certain area while on site. Likewise, the CAD system at the Allegheny County Center can record hazards about a certain location. For example, if a home has three vicious dogs, that information will be displayed on the screen whenever that location is entered into the CAD as the location of an emergency situation. The dispatchers can give warnings of possible location hazards to units that are in transit to that location. Other

location hazard warnings relayed by the dispatchers may include: weapon storage, hazardous material, and structural damage. Hazards are updated by dispatchers as information reveals itself over time.

Field Worker to Dispatch Center Communications: It is important to note that communication can also flow from first responders on scene to the dispatch team. Field workers contacting the Centre County Office often use cell phones and radios to speak to dispatch team workers to relay or verify certain information. For instance, if a call comes in about a domestic violence situation and the police arrive on scene but are told by one of the parties involved that no violence occurred, the police may call in to the dispatch center and have them play back the call to verify if the reports are consistent or indeed contradictory. The dispatchers at Centre County have a system that allows them to play back the last 10-15 minutes of calls they have taken to allow them or a field worker to verify what the caller said.

Contradictory information can be given to dispatch workers from different field workers who are in charge of a certain emergency situation (or who have declared themselves in charge). In such instances, the dispatchers will talk to the incident commander and say, "so and so said this or that." There may be a delay by a few seconds as the dispatchers get information back from the incident commander. The incident commander has the final say as to what resources are sent to the scene.

4.1.12 Dispatcher Communications in Large Scale Emergencies

In response to large scale emergencies, measures of communication differ between the two dispatch centers. The Centre County Office, for example, will send what is referred to as a *tactical dispatch team* to the scene of the incident. The task of the tactical dispatch team is to coordinate activities and relay information between first responders on the scene and the dispatch team at the dispatch center. Such communications often include requests from field workers for additional resources. Since tactical dispatchers cannot dispatch resources, they relay this information to the dispatchers at the control

room who, in turn, perform the requested tasks. The dispatchers on call will be convened, primarily, in the dispatch room. In the event of large scale emergencies, there can be up to eight individuals (as opposed to the usual four) working on the dispatch team and performing separate tasks such as: police dispatch, fire dispatch, ambulance dispatch, call taker, and a supervisor. If the supervisor anticipates that, for some reason, there may be an increase in emergency incidents that day (due to bad weather, for example) the supervisor may arrange for more dispatchers to be on call at the center. Usually, however, operations proceed as normal until calls indicating large scale emergencies or higher incident rates are reported to the center.

Figure 4.7: EOC Room

Figure 4.8: EOC Room

During large scale emergencies, dispatchers at the Allegheny County Center will gather with individuals from other organizations equipped to handle large scale emergencies in an area referred to as the *EOC Room* (see Figures 4.7 and 4.8). This room is directly next to the dispatch room and in fact shares a connecting door (refer to Figure 4.2). During disasters that require use of this room, dispatchers and individuals from other organizations are in close proximity to each other and can communicate, share information (either electronic or hand written), and dispatch resources. In cases where the EOC room is in use, the shift commander will put pages out to first responders through the CAD. The pages will indicate to the first responders whether the EOC Room is partially or fully activated. If it is fully activated, they will respond directly to the emergency. Partial or full activation of the EOC Room depends upon the breadth of the emergency.

4.1.13 Other Communication Activities

There are a number of other communication activities that occur at the dispatch centers to share and receive certain information. For instance, some citizens in Allegheny County have a police scanner and will call the dispatch center to communicate certain information that they hear over the radio. In addition, the Allegheny County Center uses regular fax machines to communicate with municipalities. Some municipalities, such as the Municipal Borough Building, do not have a computer, making fax the most efficient method of communication with them. Also, if there is a situation in which the regularly used desktop systems cannot be used, or if there is a location outside of the dispatch center where emergency units need to be dispatched from, dispatchers at the Allegheny County Center employ "*911 in a Box*". These boxes are portable units that can be taken to any location and used to receive and respond to 911 calls. The Center has 14 of these units on hand.

Both the Centre and Allegheny County offices utilize email and IM as a communication tool between dispatchers. Furthermore, dispatchers at the Allegheny County Center can use email to communicate with almost anyone who works in the county. Email is used to

communicate information related to issues such as: scheduling, training, changes in policy, changes in administration, and human resources. However, the dispatchers at the Allegheny Center mainly use email for internal communications and to store information.

4.1.14 Workload Fluctuations

Throughout the day, both dispatch centers experience fluctuations in call frequency. At the Centre County Office, the lowest call frequency is usually between 4am and 5:30am. The highest call frequency often occurs between 10pm and 4am.

During the daylight and evening hours, the dispatchers at the Centre County Office respond to several calls concerning issues such as local business problems (e.g. people who have not returned videos to a video rental store, store theft, bounced checks), keys locked in vehicles, and parking permissions.

Common emergencies reported between the hours of 4pm to 6pm at the Centre County Office often concern car accidents. Before a dispatcher dispatches emergency resources to the incident, the dispatcher will attempt to determine whether there are any injuries, the extent of the injuries (if any), and whether the car is on or off the road. Car accidents are usually reported by people who have passed the incident. Calls received in the early morning hours, such as 12:00 am, often involve issues relating to drunken persons, disorderly conduct, and criminal activity.

At the Allegheny County Center, about 30 call takers and dispatchers are on their phone lines at the same time. However, average workload fluctuations account for variations of dispatch team size throughout the day. There are three primary shifts at the Allegheny Center: 11pm – 7am, 7am – 3pm, and 3pm – 11pm. Variations in team size throughout the day are as follows:

- Between 3-11pm, there are a total of 45 dispatchers and call takers on duty.

- All other times (11pm – 3pm the following day) there are a total of 42 to 43 dispatchers and call takers on duty.

About 40% of the calls that come into the Allegheny Center are from Pittsburgh; the remaining 60% are from surrounding communities.

Workload and Group Dynamics: Group dynamics and interactions are different between the daylight and midnight shifts at the Centre County Office. During the night shift, more joking occurs between the dispatchers. This may have to do with the nature of the calls that come in at night as opposed to the daytime.

Other Contextual Factors: Because Penn State is located within Centre County, the dispatch center places more people on shift during home game days to prepare for the possibility of higher than average emergency situations. During football Fridays, there may be up to six dispatchers on duty. During these times, there are a number of calls concerning intoxication, fighting, and vandalism. There may also be yelling in the dispatch center as the dispatchers attempt to relay information to each other.

4.2 Case Study Results: Open Coding

The following is the results of analysis of the above data by means of open coding (Boufoy-Bastick, 2004; Trauth, 2000). Open coding is a method of data evaluation routinely used in qualitative studies in which researcher notes are reviewed and organized in groups or topics (and, if appropriate, sub-groups) that represent common themes found throughout the interview process. Open coding allows the researcher to determine what concepts were of most relevance to the topic in question and the issues, actions, and sentiments that the participants relate to these concepts. There are several open coding software packages (such as NUDIST, Ethnograph, and NVivo) available that will automatically arrange researcher notes into categorical themes. However, these software packages may not arrange the data into proper hierarchical structure (Kaczynski, 2004) or recognize grammatical variations used by participants to reference the same concept (Trauth, 2000). Additionally, since the category themes were pre-determined prior to

open coding, it was not necessary to use software to identify and suggest common themes within the data. For these reasons, no software was used during the open coding process.

The principles of distributed cognition as elaborated by Hutchins (Hutchins, 1995), transactive memory, and RPD served as the principle code headings. Strips (written in italics) of data that support a given principle are stated below the principle. As stated in section 2.3, the principles for each theory are as follows:

Distributed Cognition:

1. Cognitive tasks are distributed (i.e. while one person is working on one task, another person is working on a different yet objectively related task).
2. Access to information is distributed in that all crew members are usually able to observe the same type of information; this allows crew members to form and share their interpretations of the information.
3. Information is shared via interaction.
4. Information is distributively stored (the same information is stored in different facets by the crew and is therefore available if someone's access to the information becomes unavailable).
5. Memory is stored in artifacts.
6. Cognition can be distributed temporally so that subsequent events are affected by earlier events.
7. Cognition can be distributed within a group (i.e. it surpasses the boundaries of the individual).
8. Cognition involves relationships and collaboration between resources and the environment (context).

Transactive Memory:

1. Members in a group may be considered "experts" of certain skills or activities.
2. The cognitive system is one in which information is stored within and retrieved from individuals in a group.

3. Communication is necessary for information to be effectively stored and retrieved by individuals in a group.

RPD:

1. Experts in time-critical situations seek to employ a workable solution - not necessarily the best one.
2. Experts use prior experience to assess a situation and arrive at a decision.
3. The first solution that an expert decision maker considers is usually satisfactory.
4. When more than one solution is considered before action is taken, solutions are considered sequentially (usually from typical to least typical); they are not compared to each other.
5. Flaws of a possible solution are identified via mental simulation or "run through".

Open coding analysis of *in situ* observation of dispatch teams from the two centers reflected principles of the three theories of cognition in both similar and different manners. The similarities in open coding between the dispatch centers will first be presented. Next, unique aspects of open coding analysis with the data collected from Centre County will be featured, followed by analysis of data from Allegheny County.[10]

4.2.1 Open Coding Similarities between the Dispatch Centers

Distributed Cognition

1. Cognitive tasks are distributed (i.e. while one person is working on one task, another person is working on a different yet objectively related task).

Dispatchers at both centers also communicate information stored in the CAD to first responders to aid them while on an emergency site.

[10] Theories or theory principles not listed under a given section indicates that there was no data that was attributable to the theory or principle

2. Access to information is distributed in that all crew members are usually able to observe the same type of information; this allows crew members to form and share their interpretations of the information.

Both dispatch centers use a CSCW technology referred to as the Computer Aided Dispatch (CAD) system to share information and make team decisions.

Additionally, the CAD is also used as a tool for the formation of team mental models. At each center, all of the dispatchers and call takers are able to access and view all reported incidents at their individual workstations.

Dispatch teams at both centers can watch television in the dispatch room (there are several television sets in the Allegheny Center dispatch room and one in the Centre County dispatch room) to refer to weather conditions that may affect the number of traffic incidents reported to the centers. In addition, dispatchers at the Centre County Office may tune into the news to watch a video of a certain incident so that recently occurred in the area so they can physically see it. If a call comes in regarding a certain incident, the dispatchers might be able to see the building, the people involved, the setting, etc.

3. Information is shared via interaction.

…communication can also flow from first responders on scene to the dispatch team [in addition to communicative flow from dispatch team members to first responders].

At both dispatch centers, first responders of resource units that have responded to a given emergency situation will radio to the dispatch center that they have completed their task at the scene and are once again available for another assignment.

4. Information is distributively stored (the same information is stored in different facets by the crew and is therefore available if someone's access to the information becomes unavailable).

At both dispatch centers, the CAD is accessed via a network of desktop computers. Each dispatcher and/or call taker performs their tasks at his or her individual workstation.

5. Memory is stored in artifacts.

Resource availability is recorded by the dispatchers in the CAD systems throughout the day.

There are common features of the CAD between both dispatch centers. Such features include:

- *Caller information such as the name, phone number, and address that the person is calling from.*
- *The location of an emergency situation.*
- *The type of incident; e.g. a fire, domestic dispute, medical emergency.*
- *The CAD recommends the dispatching of one or a combination of emergency units to the emergency scene depending upon the priority of the emergency situation compared to other emergency situations that are currently in the CAD system (and still in need of emergency response action.)*
- *The CAD records information for an incident from first phone call to completion.*

6. Cognition can be distributed temporally so that subsequent events are affected by earlier events.

…sometimes dispatchers will refer to prior experience to notify resources that differ from the recommendations made by the CAD.

Transactive Memory

1. Communication is necessary for information to be effectively stored and retrieved by individuals in a group.

Instant Messaging (IM) – dispatchers will use IM to talk to each other, provide more information about a particular incident, and update the CAD.

- *Dispatchers also communicate with the police through IM (police have access in their cars). The police may IM dispatchers to have something run, printed out, and faxed to the police station.*

The dispatchers also use a paging system via the CAD in order to contact emergency units. Dispatchers can page:

4. *Fire stations*
5. *Ambulance units*
6. *Police (individual squad cars) units*

Recognition Primed Decision (RPD)

1. Experts use prior experience to assess a situation and arrive at a decision.

…dispatch centers cannot realistically preplan for every situation that may arise. Therefore, unique situations are handled through its similarity to another situation that may have arisen in the past. For instance, a dispatcher may conclude that what worked for a past fire situation may also work for a current situation involving hazardous materials.

4.2.1.1 Summaries of Open Coding Similarities between the Dispatch Centers

Distributed Cognition: Distributed cognition was demonstrated at each center due to the dispatch team members' sharing and retrieval of related information via the CAD. Additionally, the CAD also allows the dispatch team members to observe the same type of information in regards to an emergency situation, thereby allowing them to form their own interpretations of the information. The same information is also shared when the dispatch team tunes into the television to gain information about certain emergencies. Data suggests that at each center, information is distributively stored between call takers and certain dispatchers. Additionally, at both dispatch centers, the CAD, an artifact, stores the same basic information about an emergency situation (e.g., caller information, incident identification, call recordings). Finally, dispatch team members at each center rely upon prior experience in responding to emergency situations to make what they feel are the most appropriate decisions in response to an incident.

Transactive Memory: Members of dispatch teams at the centers use similar methods of communication to share information that is known by one person but is not known by another. However, members of the dispatch teams know what resource to obtain the information from. The means by which they communicate and obtain this information includes instant messaging and fax machines.

RPD: Dispatch team members at both centers rely upon prior experience and judgment calls when confronted with situations that do not have a specific, pre-planned response protocol.

4.2.2 Open Coding of Centre County Data[11]

Distributed Cognition

1. Cognitive tasks are distributed (i.e. while one person is working on one task, another person is working on a different yet objectively related task).

Centre County: 4-6 (all dispatch team members receive calls and dispatch resources).

Centre County: This location is a consolidated communication center in which the same people take the 911 calls, take the information, and directly dispatch the units. However, during each shift, one individual serves as the primary call taker. If that person's line is busy, then incoming emergency calls will be received by the other members of the team. Each of the other members is assigned responsibility over dispatching a single type of emergency resource: police, fire, and ambulance. Nevertheless, all team members may dispatch any type of resource if the individual primarily responsible for a given resource is occupied when it is needed.

…if a situation calls for more than one type of emergency resource, such as police and fire, the police dispatcher will dispatch police units to the scene and the fire dispatcher is responsible for sending fire crews to the same incident.

2. Information is shared via interaction.

At the Centre County Office, the dispatch team will share information and make a decision by listening to each other, discussing addresses, phone numbers, and other information given from their respective callers.

The task of the tactical dispatch team is to coordinate activities and relay information between first responders on the scene and the dispatch team at the dispatch center.

[11] Data recorded in Section 4.2.1 will not be restated in Section 4.2.2

If the county has depleted all of its resources to handle a certain situation, the dispatchers will contact dispatch centers in other counties for further assistance.

3. Memory is stored in artifacts.

The CAD system in Centre County manages the availability of emergency units and equipment in multiple counties.

The dispatchers at Centre County have a system that allows them to play back the last 10-15 minutes of calls they have taken to allow them, or a field worker, to verify what the caller said.

4. Cognition can be distributed temporally so that subsequent events are affected by earlier events.

When an emergency situation arises, the dispatch center will usually field several calls concerning one incident [these calls may be received by the dispatch center throughout a certain period of time]. Because the information contained in these calls are often arbitrary and lack complete information, the dispatchers must communicate amongst each other to get a handle of the situation and decided what and how many of certain units to send out. They must put together pieces of a puzzle, so to speak, in order to see the whole.

Transactive Memory

1. Communication is necessary for information to be effectively stored and retrieved by individuals in a group.

Radio screen – allows dispatchers to communicate with emergency units via radio.

In the Centre County dispatch room, dispatchers communicate with each other via hand signals and by raising their voices while on the phone with a caller to communicate to the other dispatch team members to listen to what they are saying. Additionally, dispatchers at Centre County will often roll their chairs over to talk directly to another dispatcher and/or to view what is on another person's screen to obtain information regarding a certain incident.

4.2.2.1 Summaries of Open Coding from Centre County Data

Distributed Cognition: The data collected from the dispatch center of Centre County suggests that cognitive tasks are distributed albeit related. This is due to a dispatch team's separation of primary tasks regarding call taker, police dispatcher, fire dispatcher, and ambulance unit dispatcher. Additionally, a dispatch team is highly interactive in their sharing of information given the members' use of the CAD system to interact with each other and other field workers. Lastly, the data suggests that subsequent events are affected by earlier events given dispatch teams' tendency to use information given about a certain incident over time to make decisions.

Transactive Memory: Dispatch team members store and retrieve data via various forms of communication. Communication methods include use of radio and coming into close proximity of another dispatcher to communicate.

4.2.3 Open Coding of Allegheny County Data[12]

Distributed Cognition

1. Cognitive tasks are distributed (i.e. while one person is working on one task, another person is working on a different yet objectively related task).

[12] Data recorded in Section 4.2.1 will not be restated in Section 4.2.3

The information received by the call taker will appear in the queue of one of the dispatchers dispatching resources for that particular zone. The dispatcher will respond by dispatching or contacting the necessary emergency units.

Allegheny County: 43 dispatchers and approximately 20 call takers.

All zones have individuals who work specifically on calls and people who work specifically on dispatch.

2. Information is shared via interaction.

In cases where the EOC room is in use, the shift commander will put pages out through the CAD.

3. Memory is stored in artifacts.

It should also be noted that the CAD system is also used to store records. All emergency calls that are received by the dispatch center are stored in the CAD system for three months.

Run Cards – specify exactly what units to send out to an incident:

- *Fire and EMS have run cards while police do not (the dispatchers are obligated to follow these run cards)*
- *Both fire and EMS have backups on their run cards in case the first units that are indicated on the run cards are not available*

Fire fills out their run cards according to or dependent upon the nature of the call while EMS fills out their run cards according to zone.

4. Cognition can be distributed within a group (i.e. it surpasses the boundaries of the individual).

Other calls that are reported to the dispatch center regarding that incident are entered into the CAD as a duplicate. The call taker(s) will use the "Append as Dup" button which allows them to add more information to a pending situation stored in the CAD but does not create a new call. Upon entering the information into the CAD, they will activate a button on the screen labeled "More to Follow."

Transactive Memory

1. Members in a group may be considered "experts" of knowledge in certain information.

…the group of call takers and dispatchers who respond to a call depends solely upon what area of the county the call comes from.

2. Communication is necessary for information to be effectively stored and retrieved by individuals in a group.

Fire1 Screen - Dispatchers can activate the sirens of fire units as well as the fire unit pagers. The sirens are activated for fire, rescues, and boat emergencies. From this screen, dispatchers can also send alarms referred to as pre-alert tones to the fire units.

4.2.3.1 Summaries of Open Coding from Allegheny County Data

Distributed Cognition: Data collected from the Allegheny County dispatch center suggests that cognitive tasks are distributed yet related towards a common task. This is due to a dispatch team's separation of call takers and resource dispatchers; individuals working on either task work to respond to the same, given situation. Dispatch teams are highly interactive when responding to large scale emergencies and the EOC Room is either partially or fully activated. Critical emergency response information, such as directives stated on run cards, is stored in the CAD system (i.e., memory is stored in an artifact). Finally, the data suggests that cognition is distributed within the dispatch team.

When multiple calls are received about a certain incident, cognition regarding that incident is distributed within individuals of the dispatch team. However, the information is reconciled by sharing information through the CAD system.

Transactive Memory: Because groups of call takers and dispatchers respond exclusively to 911 calls from a given county zone, the data suggests that the members of the dispatch team are "experts" about emergency information and patterns within their assigned zones. Additionally, the dispatchers utilize various methods of communication to store and retrieve information such as pagers and alert tones.

4.3 Knowledge Elicitation Phase

This section describes the results of the concept mapping sessions at the Centre County and Allegheny County Dispatch Centers. Analysis of concept maps included color-coding to identify different types of concepts that were classified as a result of the concept mapping sessions (see Table 4.2).

Centre County Non-Scenario Concept Map (see Figure 4.9): A dispatcher receives a 911 call that describes an emergency situation. The dispatcher assesses the call and assigns it a certain classification. For example, the dispatcher may classify the situation as a fire and assign the fire as a level 1, 2, or 3 depending on the description of the fire's smoke and flames. The CAD lists the appropriate resources to send to the emergency situation depending upon the dispatcher's classification of the incident. The dispatcher sends first responders to the emergency situation. The responders can include one or any combination fire, police, or paramedic units. Once the first responders arrive at the emergency situation, they are supported by the dispatch center; i.e., the dispatch center is no longer in charge of making the primary decisions. First responders at the scene of an emergency may change the classification of the incident.

Allegheny County Non-Scenario Concept Map (see Figure 4.10): A dispatcher asks the caller for information such as what borough, township, or city they are calling from. The dispatcher also determines the nature of the call. For instance, the nature of the call could

be one that requires an ambulance, fire, or police unit. Each of these units are examples of an Emergency Management Service (EMS). The dispatcher dispatches appropriate EMS units. The dispatched EMS units will give their status to the dispatcher while they are on assignment. Examples of status that each type of emergency unit may report to the dispatch center include: en route, on scene, or clear (i.e., the scene of the emergency situation is clear). In addition, a fire unit may also report that a situation is under control; an ambulance unit may report that it is at the hospital.

Centre County Scenario Concept Map (see Figure 4.11): A dispatcher receives a single call that reports an accident but the number of injuries, if any, is unknown. The dispatcher dispatches first responders to the accident site. The first responders include police, fire, and ambulance units. The first responders arrive on scene. At the same time, the other dispatchers receive additional phone calls from citizens and eyewitnesses regarding the accident. The phone calls provide additional information about the accident to the dispatchers. Such additional information may include fire reports, the number of trailers involved in the accident, and other on-scene signals. The accident is identified as a mass casualty situation. The dispatchers pass the additional information to the on-scene first responders. First responders request the assistance of additional emergency resources. Additional resources are alerted and dispatched by the dispatchers.

Allegheny County Scenario Concept Map (see Figure 4.12): The dispatcher will dispatch for a head-on collision between two cars. The dispatcher enters information into the CAD. The dispatcher determines what kind of assistance is needed and how many resource units are needed (e.g. 1 or 2). The dispatcher notifies paramedic and fire units. The dispatcher cannot call a hazardous materials (hazmat) unit. The hazmat unit is notified by page via the CAD. The paramedic and fire units arrive on scene. The fire units need tankers. The locations of the tankers are reported in the CAD. Therefore, the fire units contact the dispatch center for tanker information. In addition, the dispatch center may also get requests from first responders for tow trucks and buses. The incident manager may also make requests for the assistance of additional resource units. The dispatchers notify the assisting resource units which later arrive on scene.

Table 4.2: Concept Map Color Key

Color	Category
Brown	*Technology* used to store, retrieve, and evaluate information (e.g. CSCW systems, other IT systems)
Red	Any *person-based entity* that provides, receives, and/or uses information related to an emergency situation (e.g. dispatchers, first responders, callers providing information)
Purple	A *problem* related to an emergency situation that needs to be solved (e.g. an accident, how many resources to send)
Yellow	A *decision* made by a dispatcher, first responder, or technology system
Green	The *status* of any given entity (e.g. status of a first responder unit, the emergency situation)
Blue	*Information* that is given or received by a dispatcher, call taker, or first responder to make decisions
White	A *query* for further information

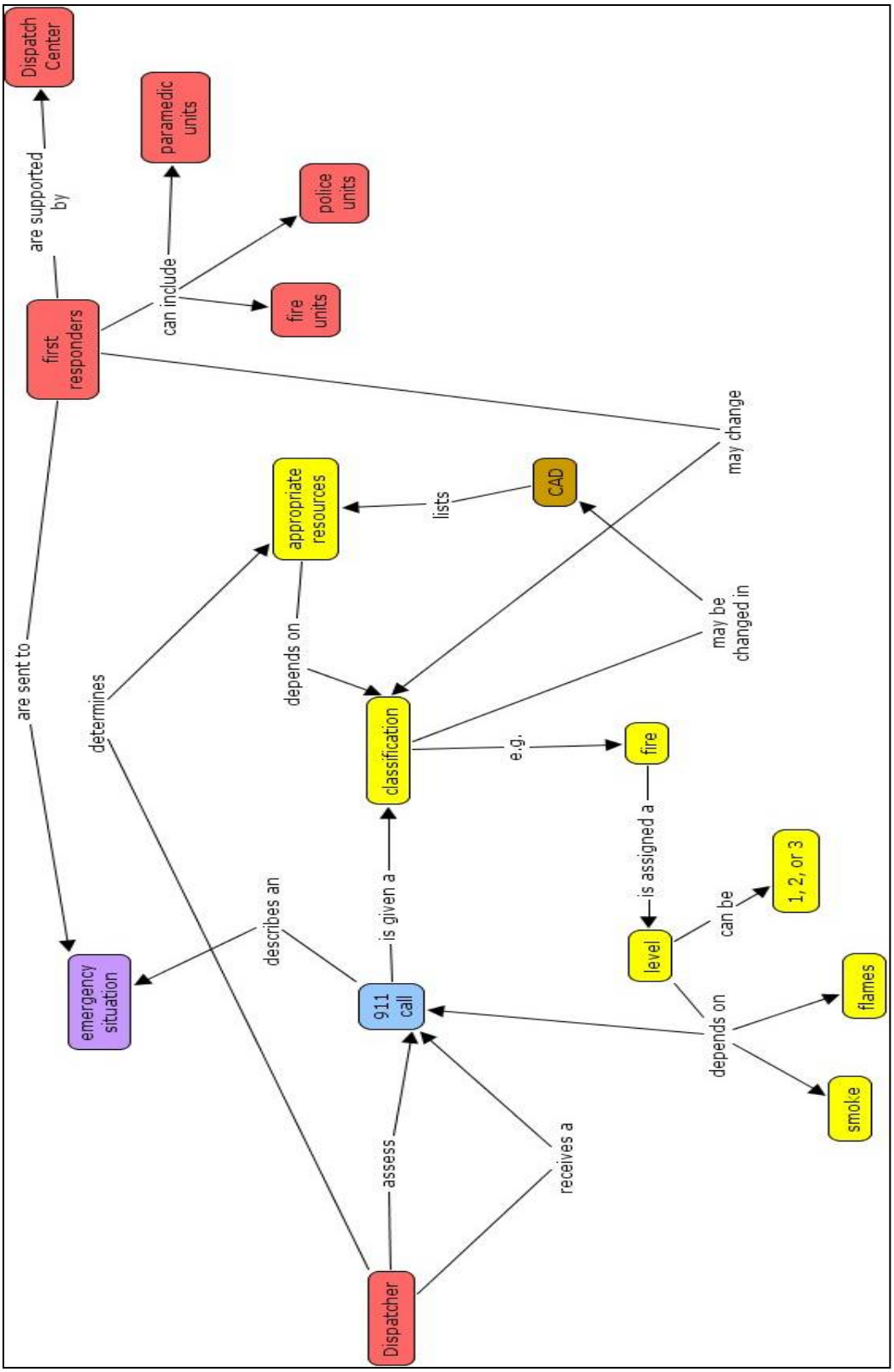

Figure 4.9: Centre County Non-scenario Concept Map

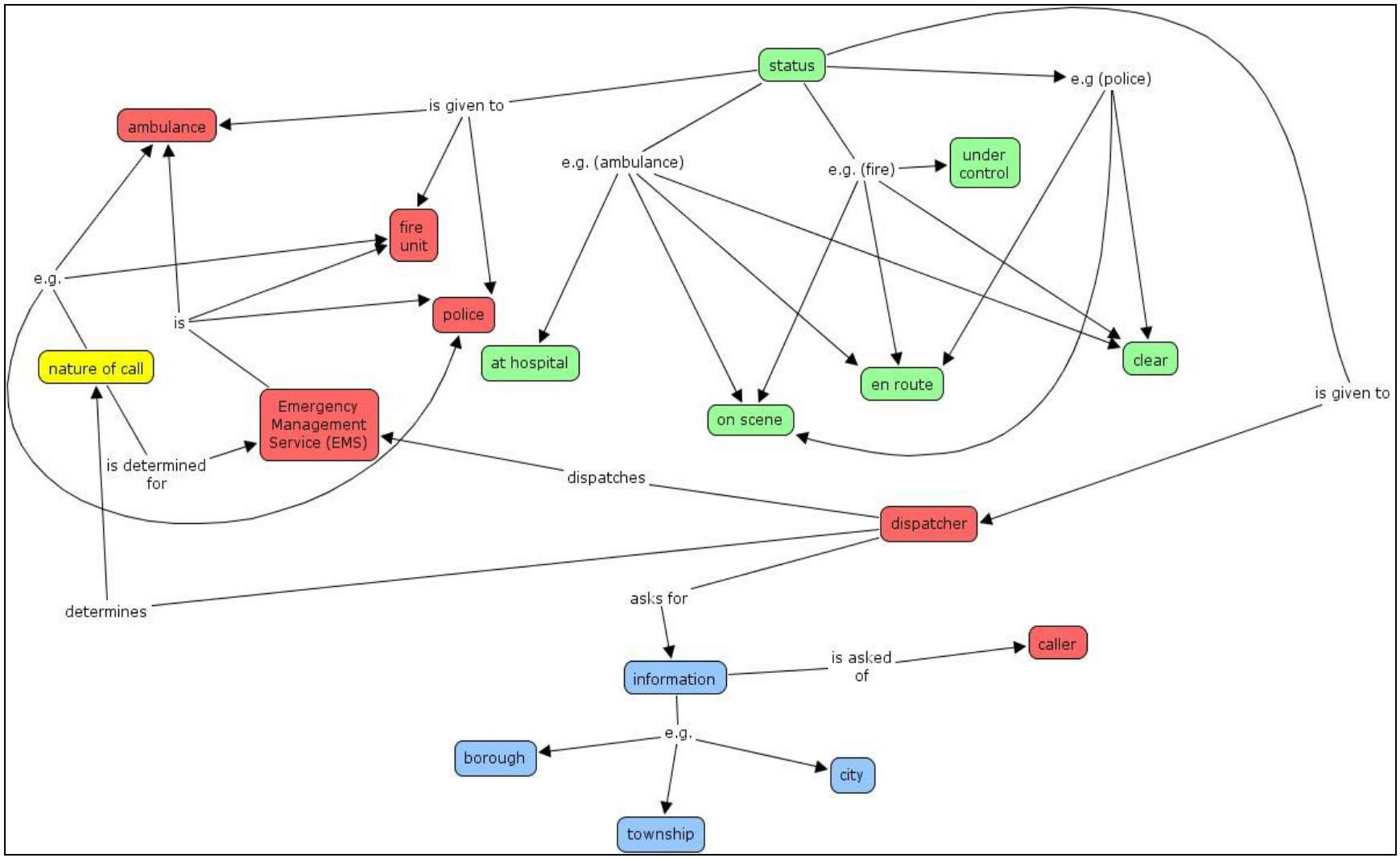

Figure 4.10: Allegheny County Non-scenario Concept Map

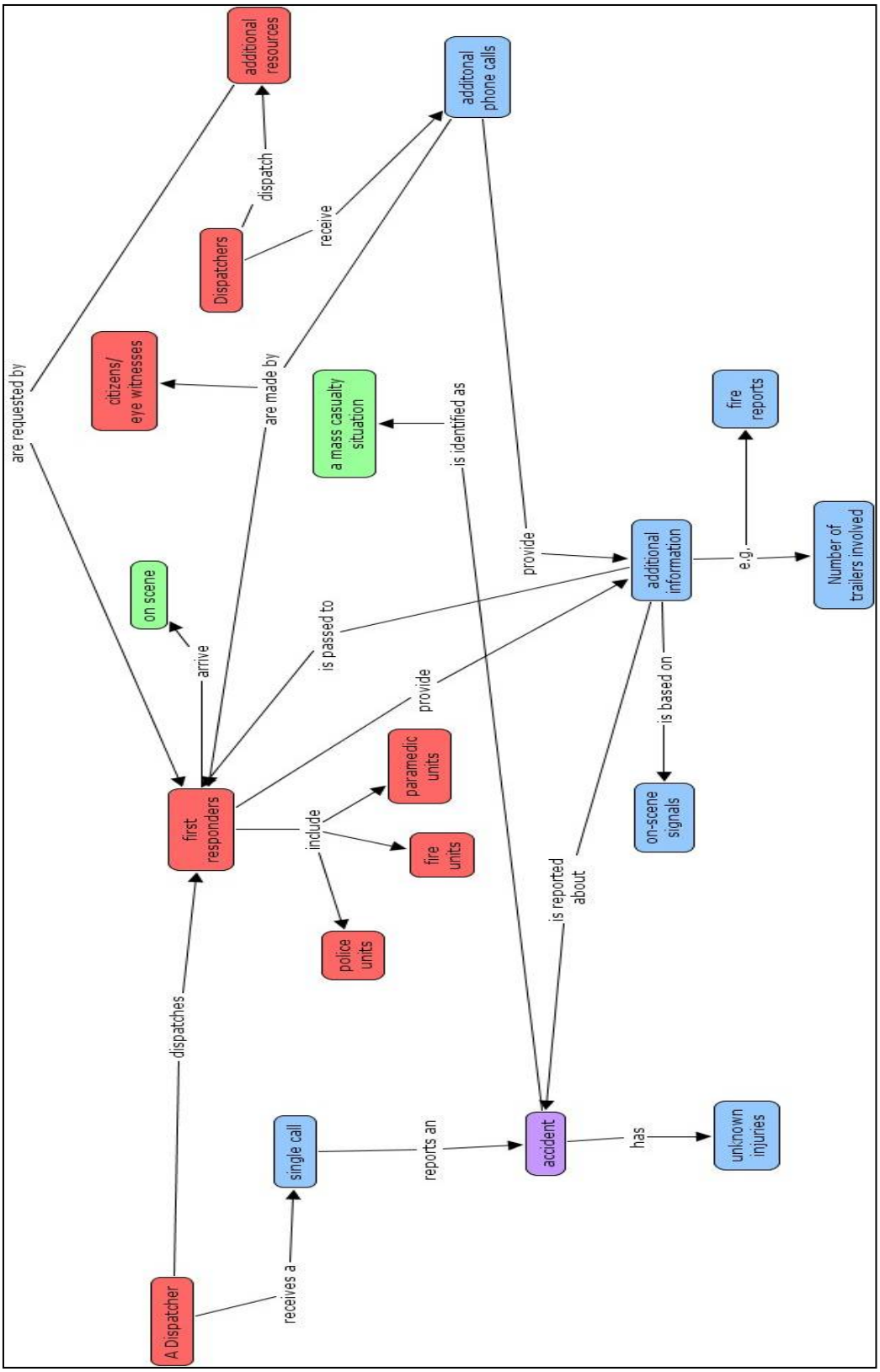

Figure 4.11: Centre County Scenario Concept Map

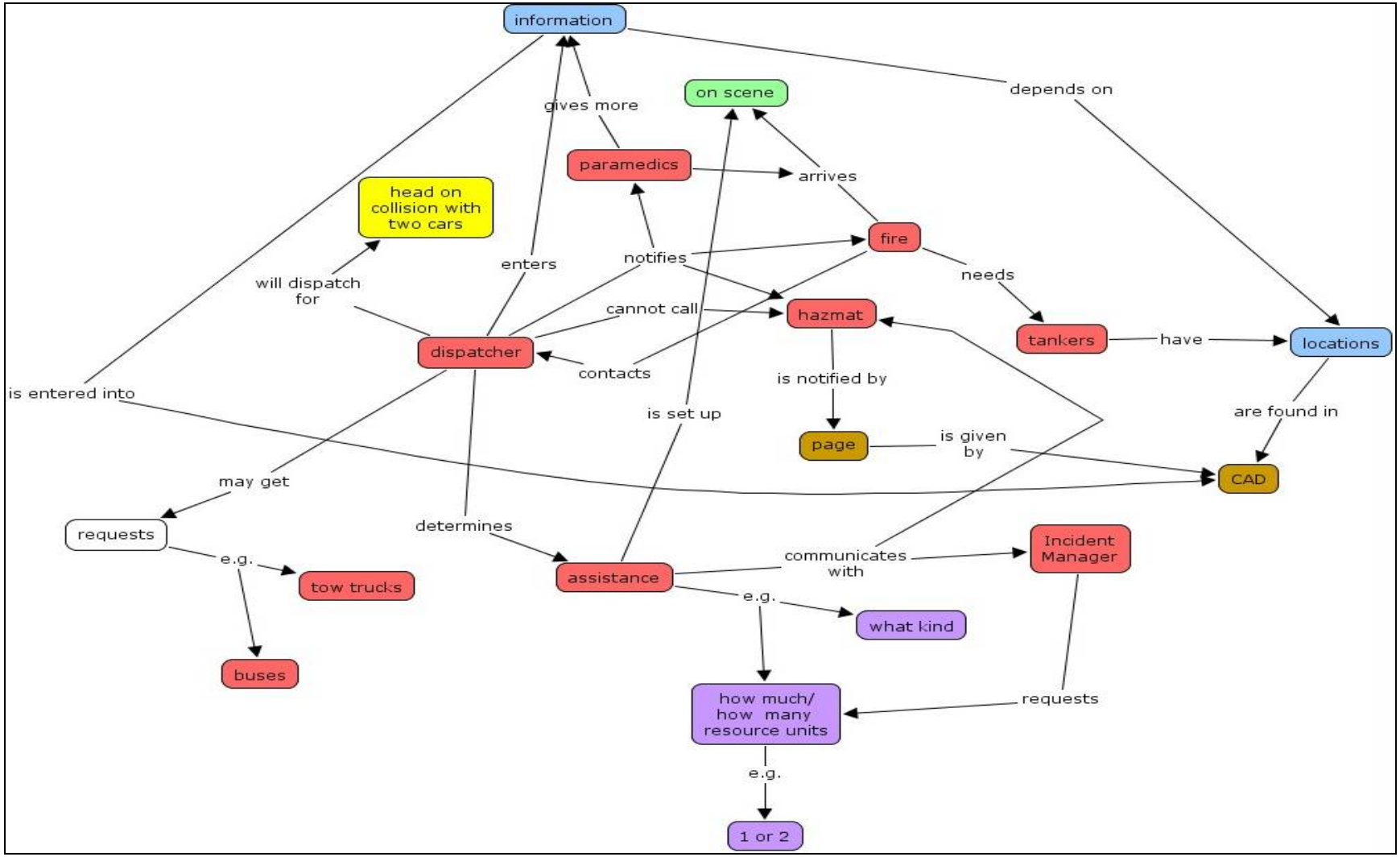

Figure 4.12: Allegheny County Scenario Concept Map

4.4 Theory Application Phase

Data collected from the case study phase of the study served as a means to help the researcher develop a firm understanding of the activities of 911 dispatch teams. This in turn, helped the researcher understand references to certain entities and resources mentioned by the participants during the knowledge elicitation phase of the study. Data from the case study phase, in conjunction with data collected from the knowledge elicitation phases of the study, suggests that there are certain characteristics or attributes that are prevalent within 911 dispatch teams. In other words, certain key attributes were consistently noted throughout the case study and knowledge elicitation phases of this research. The following list describes each of these attributes:

- Distributed Tasks: multiple individuals working on different tasks to achieve a common goal
- Distributed Information: information related to a common goal can be distributed between multiple individuals and entities
- Hidden Knowledge Profiles: individual knowledge or information about a given situation that is not known to, but can be accessed by, other team members
- Dynamic Decision Making: decisions that must be dynamically made and altered depending upon rapidly evolving situations or environments
- Rapid decision making
- Experienced Decision Making: use of prior experience to make decisions
- Individual-to-Individual Teamwork and Communication: teamwork and communication that occurs between two or more individuals
- Team-to-Team Teamwork and Communication: teamwork and communication that occurs between two or more teams to form a meta-team
- Synchronous Communication: synchronous communication between individuals on a team
- Asynchronous Communication: asynchronous communication between individuals on a team

- Individual-to-Agent Teamwork: teamwork that occurs between one or more individuals *and* one or more agents thereby influencing the nature of team mental models generated within the team
- Rapid Team Mental Model Development: rapid consolidation of information, given over a period of time, to generate and alter mental models
- Information Technology as a Decision Maker: technology that is used not only as a transactive memory system to hold information but is also used to evaluate user information and output decisions
- Asynchronous and Synchronous Communication: both synchronous and asynchronous communication occur between team members simultaneously; information is subsequently consolidated
- Individual Multi-tasking: an individual performing different yet related tasks to achieve a certain objective

Table 4.3 shows which theory or theories, if any, are applicable to each of the above attributes of 911 dispatch teams. Results show that the principles of distributed cognition theory can be used to measure the decision making and communication activities of 911 dispatch teams to a relatively greater extent than transactive memory and RPD theory. Of the three theories under evaluation in this study, transactive memory is the second most applicable theory towards the evaluation of 911 dispatch teams, while RPD is the least applicable theory. Distributed cognition is applicable to 60% of the attributes of 911 dispatch teams, transactive memory theory is applicable to 40% of the attributes, and RPD is applicable to approximately 20% of the attributes (see Figure 4.13)[13]. Furthermore, the majority of the attributes that are applicable to the transactive memory theory are also applicable to the theory of distributed cognition.

[13] Figure drawn to approximate scale

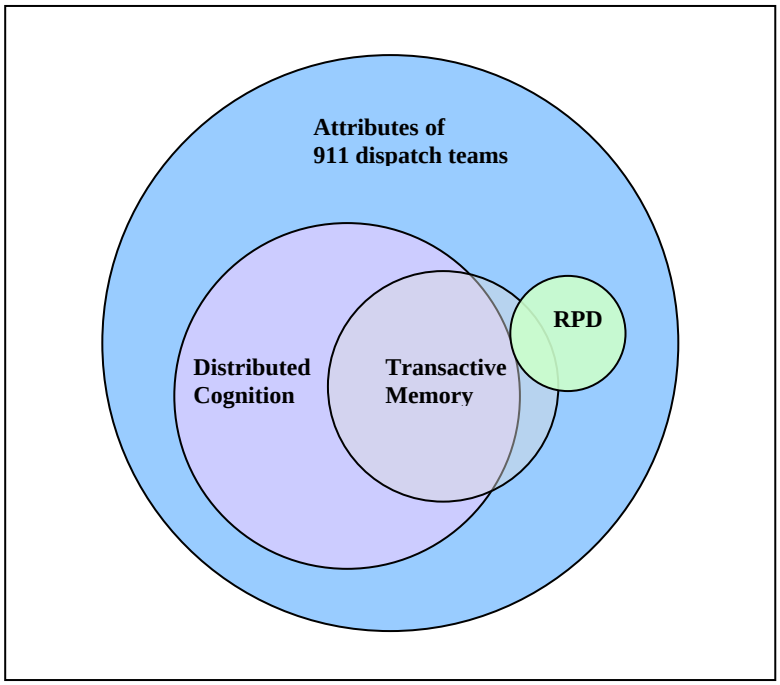

Figure 4.13: Overlap of Theory to 911 Dispatch Attributes

Although each of the theories are, to some extent, applicable to the study of 911 dispatch teams, none of the theories can account for all of the attributes accredited to 911 dispatch teams. Additionally, there are some attributes to which none of the theories can be applied. Therefore, this suggests the need for the proposal of an alternative framework of team decision making.

Table 4.3: Dispatcher Attributes and Theory Comparison

	Distributed Cognition	Transactive Memory	RPD
Distributed Tasks	✓		
Distributed Information	✓	✓	
Hidden Knowledge Profiles	✓		
Dynamic Decision Making			✓
Rapid Decision Making			✓
Experienced Decision Making		✓	✓
Individual-to-Individual Teamwork and Communication	✓	✓	
Team-to-Team Teamwork and Communication	✓		
Synchronous Communication	✓	✓	
Asynchronous Communication	✓	✓	
Individual-to-Agent Teamwork	✓	✓	
Rapid Team Mental Model Development			
Information Technology as a Decision Maker			
Synchronous/Asynchronous Communication			
Individual Multitasking			

CHAPTER V: DISCUSSION - FINAL THEORY DEVELOPMENT PHASE

5.1 Theory Application and 911 Dispatch Teams

As displayed in Table 4.3, fifteen common attributes regarding communication, use of information technology, and decision making were found within 911 dispatch groups. It appears that, upon consolidation of data from both the Centre County and Allegheny County dispatch centers, each of the theories of decision making and cognition that were used as a basis of measurement in this study – distributed cognition, transactive memory, and RPD – justifies some aspects of the decision making, communication, and CSCW activities practiced within 911 dispatch groups. In addition, some attributes can be applied to more than one theory. The following sections describe theory application to the decisions, communications, and use of information technology to 911 dispatch team attributes in more detail.

5.1.1 Theory Application and 911 Dispatch Team Decision Making

There are several attributes of decision making activities within 911 dispatch teams that are applicable to one or more of the three aforementioned theories. Results of data collected from observations and interviews with members of 911 dispatch teams suggest that such attributes include: the distribution of tasks and information, consolidation of hidden knowledge, and rapid decision making by experienced individuals. The following discusses each of these attributes and their application to theory in more detail.

Distributed Tasks – This attribute can be applied to the theory of distributed cognition. The theory of distributed cognition states that related tasks, or tasks that are related towards the realization of a common goal, are distributed or shared within a group (Hutchins & Hazelhurst, 1995). Several instances of distributed tasking were observed at both dispatch centers. For instance, at both centers, the CAD is used to distribute tasks related to a single emergency incident. At the Centre County Office, dispatcher tasks are separated into call taking, police

dispatch, fire dispatch, and paramedic dispatch. All members of a dispatch team use the CAD to share common information regarding a single incident and to attend to their individual, primary tasks. At the Allegheny County Center, tasks regarding a common incident are divided into call taker and resource dispatcher. Again, through the CAD, information is shared between call takers and dispatchers about a single incident that requires emergency attention.

Distributed Information – This attribute of 911 dispatch teams can be applied to the theories of distributed cognition and transactive memory. The theory of distributed cognition states that access to information is distributed so that all group members are able to share and observe common information (Hutchins & Klausen, 1996). Likewise, the theory of transactive memory purports that individuals in a group rely upon other members to know and store certain information so other group members can retrieve the information from them when it is needed (Ren et al., 2001; Wegner et al., 1991; Wegner et al., 1985). As implied above, in addition to tasks, information among members of a dispatch team is distributed. For instance, at the Centre County Office, all members of dispatch teams are able to share and observe common information related to a given task via the CAD. At the Allegheny Office, common information is shared between a call taker and a dispatcher. However, separation of tasks will lead some individuals to know certain unique information that other team members do not. As justified by the theory of transactive memory, it may not be necessary for all team members to know all pieces of information so long as someone on the team knows information that another does not know. In this way, dispatchers will know who to consult if a certain piece of information is needed.

Hidden Knowledge Profiles – This attribute can be applied to distributed cognition theory. Although not explicitly stated among the principles of the theory, prior research has linked hidden knowledge profiles to distributed cognition. Past research purports that when cognition is distributed, it is likely that some essential information regarding a certain solution is known only by

certain members of the group (Jefferson, Ferzandi, & McNeese, 2004). In other words, some essential knowledge is hidden from other members of the group. This phenomenon occurs within dispatch teams also. For instance, when multiple calls are placed to the dispatch center about a single incident and multiple call takers are gathering information about the incident, it is unlikely that each dispatcher is gathering the exact same information. Rather, there may be varying details that are told to and known by one or more dispatch team members but not all of them. This occurrence, therefore, creates temporary hidden knowledge profiles within the dispatch team. It is the goal of the dispatch team members, therefore, to share, consolidate, and analyze this information as rapidly as possible to make an effective decision.

Dynamic Decision Making – This attribute can be applied to the RPD theory given that the primary focus of RPD is the means of decision making in time-constrained, dynamically changing environments (Klein, 1993). Upon receiving and consolidating available information about a given situation (from callers, other dispatchers, the CAD), the problem may change within a short period of time. Dispatch teams must be quickly evaluate the current situational status and invoke an appropriate response.

Rapid Decision Making – This attribute can be applied to the RPD theory. The key premise of rapid decision making states that workable, although not necessarily ideal, solutions are employed based upon recognition of prior experiences (Orasanu & Connolly, 1993). Dispatch teams at both centers devised problem solutions in a time-constrained environment. For instance, when dispatch teams evaluate an emergency situation, they do not consider multiple solutions before acting upon the emergency situation. Rather, rapid decisions are made based upon prior experiences of the dispatchers, first responders, and CAD recommendations which were, indirectly, also based upon the prior experiences of others.

Experienced Decision Making – This attribute can be applied to the transactive memory and RPD theories. Transactive memory acknowledges that, in a working group domain, there are "experts" regarding certain areas of knowledge (Wegner, 1987, 1995). An individual who is an expert in a certain domain is so due to experience. Likewise, RPD theory states that experts use prior experience to assess a situation and arrive at a decision (Orasanu & Connolly, 1993). The separation of tasks in both dispatch centers creates areas of expertise among various individuals regarding certain tasks and situations. At the Allegheny Center, for instance, call takers are more experienced and have greater expertise in taking calls than resource dispatchers. Conversely, individuals who are dispatchers have greater expertise in dispatching resources than call takers. However, both groups of individuals use their experiences and skills to assess incidents and make decisions. Although members of dispatch teams at the Centre County Office are divided into primary tasks also, their roles are not specific given that someone who is working primarily on police dispatch, for example, can and does function as a call taker when necessary. Furthermore, an individual who works as a fire dispatcher during one shift may work as a call taker or other unit dispatcher during another shift. This may, at first, dim the notion of expertise in this center. However, consider that a person who works primarily as a fire dispatcher during one shift is an expert concerning incidents and other factors concerning fire units during a certain period of time. This person may use experience gained during a shift period to make decisions about what fire unit to contact about an incident, or to predict how a certain incident may affect future circumstances.

5.1.2 Theory Application and 911 Dispatch Team Communications

Several aspects of communication activities in 911 dispatch teams can also be applied to the three foundational theories. Data results imply that individuals must continuously interact and communicate with each other in order to share information, consolidate distributed information, and evaluate available information concerning a certain

emergency incident. For instance, individual-to-individual teamwork occurs particularly between dispatchers and first responders who often communicate with each other to share information such as incident status, availability of resources, and resource location. In addition, 911 dispatchers and call takers, as a team, must also communicate with teams of first responders. Data analysis suggests, however, that communications between individual dispatchers and between the dispatch team and first responders may occur either synchronously or asynchronously. The following explains these aspects of communication and their application to theory in more detail.

Individual-to-Individual Teamwork and Communication – This attribute can be applied to the theories of both distributed cognition and transactive memory. Distributed cognition theory holds that tasks and cognition are distributed between multiple individuals and implies that communication between these individuals is necessary for effective teamwork (Hollan et al., 2000). Furthermore, transactive memory theory states that certain information is cognitively stored within and retrieved by members in a group (Argote & Moreland, 2005). Also, as previously stated, transactive memory theory acknowledges the necessity of communication between individuals in a group for effective information retrieval (Ren et al., 2001). Several instances of teamwork between individuals within a dispatch team were noted at each dispatch center during both the case study and knowledge elicitation phases. Face to face communication, radio interaction, and information relayed directly between individuals via the CAD are each examples of teamwork occurring between individuals.

Team-to-Team Teamwork and Communication – This attribute can be applied to the theories of distributed cognition and transactive memory (Barab & Plucker, 2002; Wegner et al., 1991; Wegner et al., 1985). Cognition between a 911 dispatch team and a first responder team is distributed. For instance, call takers and dispatchers may have more details about information given by a caller to describe an incident than do first responders. In addition, the dispatchers will

have detailed access to feedback about the accident that was provided by the CAD. However, upon arriving at the scene of an incident, first responders will have more information about current incident status than do dispatchers. As implied in the section detailing decision making, it is not necessary that the team of first responders know all information initially provided to the dispatch team. Conversely, it is not necessary for the dispatch team to know all information about an incident's status. However, as explained by transactive memory, team members, be they dispatch or first responders, are aware of who to contact in order to obtain the information that they do not yet know.

Synchronous Communication and *Asynchronous Communication* – These attributes of 911 dispatch teams can be applied to the theories of both distributed cognition and transactive memory. Both theories acknowledge the necessity of interaction and communication for the effective sharing, storage, and retrieval of information (Hutchins & Palen, 1997; Wegner, 1995; Wegner et al., 1991). At the Centre County Office, synchronous communication is noted in face to face interactions between dispatchers sharing information about a particular incident. Additionally, at both dispatch centers, synchronous communication is practiced via instant messaging and communications with first responders via radio. Asynchronous communications are similar at both dispatch centers. Dispatchers at both centers use the CAD to relay common information between their colleagues. This was noted at the Centre County Office when it was displayed that information about a particular incident can be accessed at will by all members of the dispatch team through the CAD. Similarly, asynchronous communication at the Allegheny Center is practiced when information about a particular incident is sent to the queue of a resource dispatcher who accesses and responds to the information when appropriate.

5.1.3 Theory Application and 911 Dispatch Team CSCW Utilizations

Results of data analysis also imply that CSCW systems are a fundamental part of 911 dispatch teams. In fact, such agents may even be considered a part of the dispatch team. In dispatch teams, CSCW systems receive information from dispatch team members, evaluate facts, and contribute alternative problem solutions to the team. Therefore, CSCW agents are more than simply a tool for the storage and retrieval of information. They are essentially core members of the dispatch team. The following describes this issue in further detail.

> *Individual-to-Agent Teamwork* – This attribute is justified by the theories of distributed cognition and transactive memory, both of which acknowledge that memory is stored in artifacts (Hutchins & Klausen, 1996; *Transactive Memories*, 2003). This implies, therefore, that some form of interaction between individuals and artifacts is possible and perhaps even necessary for effective teamwork. It is not necessary for individuals to know how the artifact system functions; rather, they must know how and what kind of information can be retrieved from the artifact when required. At each dispatch center, there are defined moments of teamwork between individuals and agents when the dispatcher consults and follows the directions of the CAD when determining what resources to send to a given scene. Although the information regarding emergency response did, initially and indirectly, come from an individual, the direct correspondence and teamwork in these instances are between an individual and an agent.

5.1.4 Overall Theory Assessment

Each of the above attributes of 911 dispatch teams is applicable to one or more of the theories. Additionally, analysis of the results found that the majority of the attributes that are applicable towards transactive memory theory are also applicable towards distributed cognition theory, suggesting a correlation between these two theories. This relationship may be due to the common assertion of both theories that information is distributed

between individuals and artifacts. However, the additional acknowledgements of distributed tasks, the affects of hidden individual knowledge, and team-to-team communications within the theory of distributed cognition set it apart from transactive memory theory, as does the acknowledgement of expertise within transactive memory theory. Although there are principles within transactive memory theory that are not found within the principles of distributed cognition, the majority of these principles do not appear to be applicable towards the key attributes of 911 dispatch teams. Furthermore, between the two theories, distributed cognition appears to be a better fit towards the study of 911 dispatch teams than does transactive memory and RPD.

A reference back to Table 4.3 will show the suggestion that there are some attributes of dispatch teams that are not accounted for by any of the theories. Therefore, there is a need for the exploration of another framework that can be used as a foundation for the study and measurement of 911 dispatch teams and other contexts with similar attributes.

5.2 Framework Development for 911 Dispatch Teams

Due to the lack of a complete theoretical foundation for 911 dispatch teams and teams with similar attributes, the proposition of a new framework for the study of such workgroups seems needed. The application of extant theory to attributes of 911 dispatchers, in conjunction with the evaluation of attributes are not represented by any theory, led the researcher of the current study to propose a framework that generalizes all key attributes of 911 dispatch teams. The proposed framework is referred to as the Rapid Asynchronous-Synchronous Distributed Decision (RASDD – pronounced “raised”) framework. *The RASDD framework states that: distributed information between individuals, teams, agents, and technology is rapidly consolidated via simultaneous synchronous and asynchronous communication for the generation of an effective problem solution.* The following states the terms and practical logistics of the RASDD framework in further detail:

Rapid – Results indicate that 911 dispatch teams form mental models, consolidate information, and make decisions rapidly.

Asynchronous – Results indicate that 911 dispatch teams communicate and share information asynchronously; this is indicated in their use of the CAD to collect and evaluate information which is stored in the CAD system to be referenced at a later (albeit short) period of time by other dispatchers or callers.

Synchronous – Results indicate that 911 dispatch teams communicate and share information synchronously via face to face interaction and radio frequencies that can be heard by all team members. Additionally, results also suggest that synchronous and asynchronous communications can occur simultaneously.

Distributed – Results indicate that tasks and cognition is distributed among members of dispatch teams. Utilization of the CAD system allows team members to consolidate information and hidden knowledge between each other and between themselves and first responders (team-to-team teamwork).

Decision – Results indicate that the aforementioned characteristics are attributes of 911 dispatch team decision making.

Given the attributes of 911 dispatch teams (as defined in Section 4.4 and listed in Table 4.3) and their applications, and lack thereof, to current theory, the principles of the RASDD framework are as follows:

1. Cognition, tasks, and information are distributed and shared between individuals, teams, and artifacts or agents.
2. Decisions are made rapidly and dynamically depending on current circumstances.
3. Individual mental models can be incomplete; the communication of individual mental models yields the rapid development of a team mental model that is sufficient for effective problem solving.

4. A team mental model may only be known to certain members of the team depending on their tasks and responsibilities.
5. Interaction between individuals, teams, and artifacts is both synchronous and asynchronous.
6. Both synchronous and asynchronous interaction can occur simultaneously.
7. Teamwork can occur between individual-to-individual, individual-to-agents, individual-to-team, or team-to-team.
8. Individuals and agents or artifacts are used for information storage and retrieval.
9. Individual tasks are performed synchronously (i.e. individual multitasking).

The above principles of the RASDD framework represents a consolidation of the theories of distributed cognition, transactive memory, and RPD. The RASDD framework accounts for some attributes of 911 dispatch teams in a similar yet more succinct manner than the three foundational theories. In addition to these attributes, the RASDD framework also acknowledges aspects of team decision making, communications, and utilization of agents that the foundational theories do not account for. For instance, the RASDD framework specifically accounts for distributed information, simultaneous synchronous and asynchronous communication, rapid mental model formation, and subsequent rapid decision making between individuals, teams, and agents or artifacts. The following describes, in further detail, the manner in which the RASDD framework accounts for attributes of 911 dispatch teams identified in this study.

5.2.1 Application of the RASDD Theory to 911 Dispatch Teams

Similar to the theories of distributed cognition and transactive memory theory, the RASDD framework succinctly emphasizes that tasks and information are distributed between individuals within teams, between teams (i.e. for the formation of a meta-team), and between individuals and agents. As a result of the distribution of tasks and cognition, the existence of hidden knowledge profiles between individuals and teams necessitates the consolidation of this information. Yet the RASDD framework, in addition, stresses

the importance of rapid consolidation of distributed information for the quick generation of team mental models and decision making.

Rapid Team Mental Model Development: The rapid formation of mental models based upon prior experience is certainly the basis of the RPD theory (Ball et al., 2001; Lipshitz et al., 2001). However, the cognitive unit of analysis in the foundational research to which this theory was applied was highly concentrated upon the individual; i.e. the rapid development of an individual mental model. Although this theory has more recently been applied towards the study of emergency management teams (Klein, 1998), this research does not fully acknowledge instances where individuals in a team share their own perceptions of a situation in order to make effective decisions. This may be due to the time-constrained domains to which RPD is most commonly applied; for instance, it may be that in some time-constrained domains, group members do not have the time and/or protocol to share information with each other. However, despite the time-constrained nature of the 911 dispatch domain, members of 911 dispatcher teams must rapidly consolidate information received from callers (and often multiple callers about the same incident), other dispatchers, and the CAD system in order to develop the most accurate team mental model possible. Yet due to the often incomplete information given by callers, as well as the possible status change of an emergency situation, the team mental model formed may be inaccurate and incomplete. However, the resulting mental model is evaluated by the dispatchers and the CAD in order to rapidly generate a problem solution. Additionally, the RASDD framework emphasizes that the action decisions occurring from the resulting team mental model is not always known by all members of the dispatch team who dealt with the situation. For instance, it may be that although information about a particular incident is shared among all members of a dispatch team, as is the case with the Centre County dispatchers, it may not be evaluated and acted upon by all members of the dispatch team. Rather, the final resulting team model may be one that is shared only between the first responders and the dispatcher relaying information to them.

The formation of team mental models in this study warrants further discussion. As previously stated, a team mental model is defined as a common body of knowledge shared by members of a team to form a common bond between group members (Mohammed & Dumville, 2001). Therefore, it could perhaps be effectively argued that, in 911 dispatch teams, a team mental model is not formed at all if the resulting consolidation of information is not always known by all members of the team. However, to come to such a conclusion is fairly extreme and current literature disputes this argument (Espinosa et al., 2002). It seems to be that the team mental model is only shared by some members of the team, i.e. the members who are ultimately responsible for consolidating the information, dispatching the resources, and relaying the consolidated information to the first responders who are also members of the meta-level emergency response team. For that reason, the existence of team mental models within 911 dispatch teams seems apparent.

Information Technology as a Decision Maker: Although the theories of distributed cognition and transactive memory acknowledge that memory is stored in artifacts, these theories do not validate the strong suggestion that information technology can function as a respected decision maker within the team as does the RASDD framework. The function of the CAD system in dispatch teams, for instance, is more than a vehicle for the storage and retrieval of information. Rather, it processes information and provides problem solutions depending upon the circumstance; this occurs even in cases where the circumstance changes and a modification of an initial decision should be made. Of course it must be recognized that, similar to other technologies, the output of the decision came originally from human knowledge. However, the direct output of a decision is from the CAD itself and is frequently consulted by the dispatch team for its ability to provide efficient solutions to a given situation. Recent research, in fact, suggests that human decision making can be supplemented by the "recognition" of certain situations by information technology which, in turn, uses this information to suggest problem solutions based upon past situations (Xiacong, Sun, McNeese, & Yen, 2005). While this is clearly an application of RPD to

information technology, the foundational principles of RPD do not account for the decision making capabilities of information technology as a supplement to the human workgroup. Therefore, this suggests another theoretical gap that can be filled by the RASDD framework.

Since information technology stores, process, and evaluates information to generate problem solutions, it can be strongly suggested that the use of information technology by dispatch team members influences the nature of the team mental model that is generated after information related to a given problem is consolidated. As previously stated, team, as well as individual, mental models can be strong and accurate, weak and accurate, strong and inaccurate, or weak and inaccurate. In order to determine the nature of team mental models within 911 dispatch teams, it must be made clear what constitutes each type of mental model. Results suggest that the type of mental model that is formed by the team is dependent upon the team's understanding of the situation given certain information. Therefore, in regards to 911 dispatch teams, strong, weak, accurate, and inaccurate models can be defined as the following:

- A strong accurate mental model is one in which the dispatch team understands a given situation and has relevant, factual information about the situation in order to analyze the circumstance. For example, the dispatch team knows that a reported situation is a domestic dispute. In addition, they are aware of the attributes regarding the situation such as physical injury or loud disturbance noise. They are also aware about which type and number of emergency resources need to be dispatched to the scene.
- A strong inaccurate mental model is one in which the dispatch team understands a given situation but has false information about the situation that hinders accurate analysis. For instance, the dispatch team knows that a reported situation is a domestic dispute. However, they do not know or be they may be mistaken about certain attributes regarding the situation such as physical injury or loud disturbance noises. In addition, they may not also know or be mistaken about

which type and number of emergency resources need to be dispatched to the scene.

- A weak accurate mental model is one in which the dispatch team does not understand or has little understanding of a given situation; however, the team has relevant, factual information about a given situation in order to analyze the circumstance. For example, the dispatch team does not know that a reported situation is a domestic dispute. However, they are aware that the reported situation is one that involves physical injury and loud disturbance noises.
- A weak inaccurate mental model is one in which the dispatch team does not understand or has little understanding of a given situation and has false information about the situation that hinders accurate analysis. For instance, the dispatch team does not know that a reported situation is a domestic dispute nor are they aware that the reported situation is one that involves physical injury and loud disturbance noises.

Given the results of the data, there is little evidence to conclude that, at either dispatch center, the CAD facilitates any other type of team mental model than one that is strong and accurate. At both dispatch centers, the function of the CAD is to consolidate all information about a single incident, process what is given, report a problem solution, and share this information with other members of the team. This is not to suggest, however, that weak and/or inaccurate team mental models do not exist within dispatch teams. On the contrary, given the manner in which emergency situations dynamically change and considering the fact that individual callers often report inaccurate or insufficient information, resulting team mental models may, quite often, be weak, inaccurate, or both. However, the generation of these types of mental models is due primarily to information sources external to the CAD. Since the CAD cannot differentiate the difference between accurate and inaccurate information that is inputted into the system about a certain situation, it could be argued that the CAD is capable of yielding an inaccurate team mental model if it is given inaccurate information to process. This again, however, would be primarily the fault of an entity external to the CAD rather than faulty processing by the CAD.

It should also be noted that the while the CAD facilitates strong and accurate team mental models, it simultaneously allows for the generation of weak, accurate individual mental models. Since one of the primary functions of the CAD is to process and consolidate individual information to yield problem solutions, it is not necessary for all members of the dispatch team at either center to fully understand the entirety of an emergency situation in order to accurately respond to an emergency. At the Centre County Office, for example, if an emergency situation requiring a police and a paramedic unit is reported to the center, the CAD will recommend the type and number of each unit required for effective response to all dispatchers. However, the dispatcher who is primarily responsible for dispatching police units may have a weak mental model in that he or she relates more to the situation as it involves the police. While this perspective of the situation is accurate, it is somewhat limited in that there is more to the emergency situation than the requirement of a police unit. The same is true for the individual primarily responsible for the paramedic unit. The CAD consolidates all of this information into a team mental model that can be accessed by any member of the dispatch team if they wish. However, face to face interaction at the Centre County Office is high, so the weakness of the individual mental models may not be as extreme in every situation as suggested by this example. Yet given that the CAD system at the Centre County office allows for the division of responsibilities in the manner practiced by the dispatch team, this seems to imply that in some instances, individual mental models among the dispatchers can be somewhat weak.

At the Allegheny Center, the CAD simultaneously facilitates strong, accurate team mental models and weak, accurate individual mental models also. For instance, if a call is placed to the dispatch center regarding an incident that has already been reported, the call taker will store the information in the CAD and indicate that this information is in addition to the information that has already been reported about the incident. It is not necessary for the call taker to know all of the information related to that incident. The call taker's primary concern is to collect as much additional information as possible for more efficient emergency response. Therefore, the call taker's individual mental model about the situation may be weak; however, similar to the CAD system at the Centre

County Office, the CAD consolidates the information to form a strong team mental model that is shared with the dispatcher responsible for the situation and the first responder units that are contacted.

Simultaneous Synchronous/Asynchronous Communication: It has already been acknowledged that communications, both synchronous and asynchronous, are applicable to the theories of both distributed cognition and transactive memory. What is not made clear by either theory, however, is the manner in which both types of communication can occur. It is this ambiguity that the RASDD framework specifically clarifies. The results of the data suggest that, in 911 dispatch teams, there are several moments of problem solving where communication regarding a single incident is simultaneously synchronous and asynchronous. At the Centre County Office, for example, if multiple calls (by either a citizen caller or a first responder), are received about a given incident, this information is quickly processed and can be accessed in the queue by other dispatchers. This is a form of asynchronous communication given that the dispatchers can either view details about the incident immediately or at a later time. Often, however, other dispatchers may be taking a call about the same incident and communicating face to face with each other – i.e., synchronous communication. Another dispatcher(s) may refer to information that was communicated asynchronously about that incident for further clarification. In this instance, simultaneous synchronous and asynchronous communication can be observed. At the Allegheny Center, a similar phenomenon can occur. There are several moments where a call taker may take information about an emergency situation and relay it to a dispatcher where it appears in his or her queue to be accessed at will, albeit rapidly. This again is asynchronous communication. However, simultaneously, another call taker may be receiving a call about the same incident from a caller. Although this communication is not between two or more members of the actual dispatch team, it is still synchronous information about the same incident regardless. Therefore, the simultaneous occurrence of both synchronous and asynchronous information can be observed in this instance

also. Due to the frequent occurrence of this phenomenon at both dispatch centers, it seems important that the RASDD framework specifically acknowledge that this trend can and does happen within teams.

Individual tasks are performed synchronously: While it may appear out of context for a theory focused upon team decision making and interaction to specifically list individual multitasking among its properties, it is the very presence of the team that accounts for the prevalence of individual multitasking by group members. At both dispatch centers, members of dispatch teams must interact with several individuals and entities simultaneously. Members of dispatch teams simultaneously interact with callers, communicate with each other, communicate with first responders, listen to the calls of other dispatchers, enter in caller information, and dispatch resources. The RASDD framework, therefore, fills a theoretical gap by acknowledging that although a group setting allows for the distribution of multiple tasks and responsibilities, the presence of other individuals can create a co-dependent environment where an individual has to simultaneously interact with multiple individuals and perform several tasks in order to accomplish his or her own primary, individual tasks.

5.2.2 Application of the RASDD Framework to Other Contexts

Although this study and its subsequent report was specifically focused upon the procedures and activities of 911 dispatch teams, it was also the premise of this study to further the knowledge of extant information concerning work groups within other domains. Previous discussion of other research from other work environments would suggest that, given the attributes of 911 dispatch teams, the current research can be generalized to other contexts. In reflection, contexts that were specifically mentioned as having characteristics similar to 911 dispatch teams were: fighter pilots, local first responders, and hospital service members. Furthermore, the specific environmental characteristics that, based on previous research, were attributable to teams from these contexts as well as to 911 dispatch teams were:

- It involves rich social contexts
- It involves decisions made “on the fly”
- Information is ill-structured
- Information is distributed among several people
- It is goal-oriented

While specific principles of the RASDD framework have been defined according to the data generated from observations and interviews with 911 dispatch team members, similarities in attributes between 911 dispatch teams and teams within other domains suggest that the RASDD framework can be applied towards other contexts. The following discusses the generalization of the RASDD framework to the aforementioned domain attributes in further detail.

Information Rich Environment and Distributed Information: Data collected from the case study and knowledge elicitation phases of this research strongly suggests that relevant information about a single incident can be obtained from multiple sources including other dispatchers or call takers, citizen callers, first responders, and agents such as the CAD. Similarly, information within the environments of fighter pilots, first response teams, and medical practitioners is also abundant yet highly distributed. In regards to fighter pilots, information comes from and is distributed between the environment, aircraft agents, ground crews, and other pilots in the area. Similarly, first responders must gather an abundance of information that is distributed between other first responders, 911 dispatchers, the environment, witnesses and victim information. In addition, information within medical teams is dispersed between agents, team members, patient feedback, and perhaps first responder information. The principles of the RASDD framework, in turn, acknowledge the existence of distributed information as well as the fact that information can be gathered from multiple sources. This can be noted in the principle stating that teamwork can occur between individual-to-individual, individual-to-agents, individual-to-team, or team-to-team.

Ill-Structured: The reference to information as "ill-structured" by Young and McNeese (1995) is, in essence, a factor of the reality that information in domains with similar attributes to fighter pilots and emergency related domains is often distributed. It is true that all of these domains maintain pre-planned protocols and action strategies depending upon current circumstances. However, since information in such domains stems from multiple resources and is highly dependent upon a dynamically changing environment, information is somewhat ill-structured. Because the RASDD framework specifically acknowledges the evidence that information in 911 dispatch teams and teams with similar attributes is distributed and dynamically affected by changing events, it is therefore highly applicable towards the study of teams that must deal with ill-structured information in a time-constrained environment.

Decisions made on the fly: Due to progressions and changes in emergency situations, 911 dispatch teams, in support of first responders, must make rapid decisions based upon current situational status. Therefore, it is necessary for the RASDD framework to specifically acknowledge the occurrence of dynamic decision making. Evidence from the current study does suggest that this is a common event within 911 dispatch teams. However, prior research also suggests that this is indeed an attribute of the other aforementioned teams (Findler & Lo, 1993; Young & McNeese, 1995). When fighter pilots are on a mission, the status of that mission may change and decisions must be made based on such changes. Furthermore and as previously stated, a change in emergency status may alter the types of decisions that first responders make on scene. Finally, in medical environments, patient status or patient health may change with or without a great deal of warning, thereby causing the medical team to take immediate decisive action.

Goal-oriented: Although the statement "goal-oriented" is not listed specifically among the principles of the RASDD framework, this does not suggest that this framework does not apply to teams that are goal-oriented. Rather, this framework

is highly applicable to such teams. For instance, the very definition of teamwork refers to the activities of groups whose members work towards a common goal (Andersen, 2000; Langan-Fox et al., 2004; Yen et al., 2001). Principles of the RASDD framework referring to teamwork and team mental models highly suggest that, as implied by the data results, 911 dispatch teams are extremely goal-oriented. Therefore, when considering a theoretical foundation for the study of goal-oriented teams with attributes similar to that of 911 dispatch teams, the RASDD framework would be applicable in such circumstances.

CHAPTER VI: CONCLUSION

Theory concerning teamwork, team collaborations, and team communications is quite abundant in academic literature. The current study used three such notable theories – distributed cognition, transactive memory, and Recognition Primed Decision (RPD) – as a foundation to study a specific type of team unit: 911 dispatchers. The intent of this study was to determine the communications, decision making activities, and use of information technology to find and fill gaps in current theory regarding team relations. In order to advance theory, however, it was necessary to collect data that could be generalized to varying contexts and environments. Just as organizations that are in the same practice of business can have varying team interactions, so do 911 dispatch teams located in different environments. Therefore, for the sake of data generalization, data was collected from dispatch teams in two different geographical and demographical contexts.

The results of consolidated data from both dispatch centers revealed prominent attributes of 911 dispatch teams. Some characteristics of the decision making activities of 911 dispatch teams include: the distribution of tasks and information between team members that may yield hidden knowledge profiles, dynamic decision making, rapid team mental model development and decision making, and decision making based upon previous experiences. Attributes concerning the communication activities of 911 dispatch teams include: synchronous and asynchronous communication, simultaneous synchronous and asynchronous communication, as well as interactions between individuals, between teams, and between individuals and agents. Lastly, data analysis implied that another attribute of 911 dispatch teams is the use of information technology agents as a functional decision maker within the group.

The majority of the attributes identified in the study could be justified by at least one, and sometimes two, of the three aforementioned foundational theories. However, the results suggest that none of the theories could validate all of the attributes of 911 dispatch teams. Furthermore, some attributes of 911 dispatch teams such as simultaneous

synchronous/asynchronous communication, rapid team mental model development, and the use of information technology as a decision maker, were not accounted for by any of the principles of the three theories. Therefore, in order to fill these gaps in cognitive theory, a new framework of cognition was proposed. This framework, termed the Rapid Asynchronous Synchronous Distributed Decision (RASDD) framework, acknowledges that in certain time-constrained environments, information distributed between various team entities is rapidly consolidated via simultaneous synchronous and asynchronous communication to make effective team decisions. The principles of the RASDD framework serve to account for each of the primary attributes of 911 dispatch teams noted in this study. Therefore, the RASDD framework serves as a basis for the theoretical consolidation of the three foundational theories and a means for filling gaps left by extant theories of cognition.

6.1 Research Limitations

There were some limitations of this research that may have affected the results presented in the current study. One limitation of this study stems from the fact that 911 dispatch teams handle sensitive information regarding local emergency management. Non-access to classified information concerning first responder units and emergency caller or witness identifications limited the amount of data that could be collected in this study. The data presented in this study reflect only what the managers of the dispatchers centers allowed to be reported. Whether access to private, sensitive information would have significantly altered the results of the data is unknown.

Another limitation of this study concerns the relative lack of contextual diversity represented in the study. Although data was collected from dispatch teams from two different contexts, these contexts do not exhaust all geographical and demographical locations in which 911 dispatch teams can be found. Collection of data from dispatch teams in other counties, states, and possibly even countries could lead to the identification of attributes that were not found in this study. Study of dispatch teams in

other contexts could lead to better generalization of data than what is presented in the current study.

A third limitation in this study concerns some aspects of the methods used to collect data. Although concept mapping provided a strong addition to the dataset, the manner in which the concept mapping sessions were accomplished may have affected the richness of the data that was obtained. For instance, prior research using concept mapping as a knowledge elicitation technique has involved the generation of the concept maps on large sheets of paper or whiteboards (Brewer et al., 2005; Connors et al., 2004; McNeese et al., 2004; McNeese et al., 1995). This practice allows the participant(s) to view the concept map as it is generated and become an active participant in the formation of the concept map if the participant desires. This practice also helps to foster dynamic, active feedback between the researcher and the participant as the concept map is generated which could result in a more precise dataset. Due to space and participant time constraints, the concept maps generated in the current study were produced on standard sized notebook paper by the researcher. Although the researcher allowed the participants to view the concept maps as they were being generated thereby fostering participatory knowledge elicitation sessions, the use larger sheets of paper or whiteboards may have enhanced the degree to which the participants contributed to the generation of the concept maps.

Finally, researcher time constraints limited the total amount of time that was spent at each dispatch center. Although the current study incorporated case study and knowledge elicitation methods to collect data, a more in depth ethnographic study at each dispatch center may have yielded a richer dataset than what is presented in this study. An ethnographic study, specifically, is commonly defined as a study in which the researcher immerses him or herself into the context or culture of the group of persons under study (Trauth, 2000). This type of undertaking often requires the researcher to repeatedly visit a site for several weeks in order to become fully engrossed in the activities and domain of the participants. Given the numerous activities of 911 dispatch teams, the inability to conduct an ethnographic investigation may have limited the amount of relevant data that could have been collected.

6.2 Future Research and Final Thoughts

Each of the limitations of this study presents an avenue of research that should be explored in future studies. For instance, the study of 911 dispatch teams in other geographical locations may lead to an even broader knowledge of 911 dispatch teams and teams in time-constrained environments. Another prospect for advancement of this research would be the opportunity to explore information that was not allowed to be viewed or reported for the purposes of the current study. While it may be difficult to locate a 911 dispatch center that allows outside researchers to evaluate sensitive information, the opportunity to explore such a body of knowledge in a future study could be a valuable addition to this research effort. Furthermore, the replication of this study with considerably less restrictions in regards to participant and researcher time-constraints may certainly lead to the enhancement of the data presented in the current study.

The advancement and evaluation of the RASDD framework is an appropriate direction for the future of this research given that this is the basis of the methodology, the Living Lab Framework, used in this study. This same methodology can subsequently be used in future studies involving team decision making. Consider, one last time, the Living Lab Framework depicted in Figure 3.1. Notice that the Framework is in fact a continuous cycle of study and research. This study represents only one cycle of the Framework: one case study phase, one knowledge elicitation phase, one phase of theory application, and one phase of framework development. However, there is another arrow between the final stage, framework development, and the first stage, the case study. Future research in this area should continue the cycle of the Living Lab into other domains. It has been previously implied that the results of this study can be applied towards other domains or teams similar to that of 911 dispatchers. Therefore, this research should be continued via the application of the RASDD framework to other like domains in a manner similar to the way the three foundational theories were applied to the study of 911 dispatch teams. Future studies such as these can lead to the further development, modification or generalization of the RASDD framework to extend the understanding and advancement

of 911 dispatch teams and other similar workgroups. And this, philosophically, is the hallmark of the evolution of science: to take an implication, be it new or old, and challenge its applicability towards other avenues and to use the results for the betterment of society.

REFERENCES

2005-2006 Common Data Set Penn State University Park. (2006). Retrieved January 20, 2006, from http://www.budget.psu.edu/CDS/FacultyClassSize.asp?Location=UP&AY=20052006

Allegheny County County Profile. (2006). Retrieved January 19, 2006, from http://www.epodunk.com/cgi-bin/genInfo.php?locIndex=13489

Andersen, A. (2000). Implementation of engineering product design using international student teamwork. In J. Michel (Ed.), *The Many Facets of International Education of Engineers*. Balkema, Rotterdam.

Argote, L., Gruenfeld, D., & Naquin, C. (2000). Group learning in organizations. In M. Turner (Ed.), *Groups at work: Advances in theory and research*. New York: Erlbaum.

Argote, L., & Moreland, R. (2005). *Transactive Memory and Work Group Performance*. Retrieved March 30, 2005, from http://www.casos.ece.cmu.edu/conference2000/pdf/Argote&Moreland.pdf

Artman, H. (1999). Situation awareness and co-operation within and between hierarchical units in dynamic decision making. *Ergonomics, 42*(11), 1404-1417.

Artman, H., & Granlund, R. (1998). *Team situation awareness using graphical or textual databases in dynamic decision making.* Paper presented at the Proceedings of the 9th Conference on Cognitive Ergonomics, University of Limerick, Ireland.

Ball, L. J., Lambell, N. J., Reed, S. E., & Reid, F. J. M. (2001). *The exploration of solution options in design: A 'Naturalistic Decision Making' perspective.* Paper presented at the Designing in Context: Proceedings of the Fifth Design Thinking Research Symposium—DTRS-5, Delft, The Netherlands.

Barab, S. A., & Plucker, J. A. (2002). Smart people or smart contexts? Cognition, ability, and talent development in an age of situated approaches to knowing and learning. *Educational Psychologist, 37*(3), 165-182.

Bishop, S. L. (2004). Evaluating teams in extreme environments: From issues to answers. *Aviation, Space, and Environmental Medicine, 75*(Supplement 1), C14-C21(11).

Blandford, A., & Wong, B. L. W. (2004). Situation awareness in emergency medical dispatch. *International Journal of Human-Computer Studies, 61*, 421-452.

Blickensderfer, E. L. (2000). Role of experience and team knowledge in team process and performance. *Dissertation Abstracts International: Section B: The Sciences & Engineering, 61*(2-B), 1116.

Boland, R. J. J., Tankasi, R. V., & Te'eni, D. (1994). Designing information technology to support distributed cognition. *Organization Science, 5*(3), 456-475.

Bolstad, C. A., & Endsley, M. R. (1999, September 27 - October 1). *Shared mental models and shared displays: An empirical evaluation of team performance.* Paper presented at the 43rd Meeting of the Human Factors & Ergonomics Society, Houston, TX.

Boufoy-Bastick, B. (2004). Auto-interviewing, auto-ethnography and critical incident methodology for eliciting a self-conceptualised worldview. *Qualitative Social Research, 5*(1).

Brewer, I. (2005). Understanding work with geospatial information in emergency management: A cognitive engineering approach in giscience, *Adobe Acrobat*. University Park.

Brewer, I., McNeese, M. D., Frazier, T., Fuhrmann, S., & Terrell, I. S. (2005). *Expanding team knowledge elicitation through procedural, temporal, and strategic elements*. University Park, PA: The Pennsylvania State University.

Bucknall, T. K. (2000). Critical care nurses' decision-making activities in the natural clinical setting. *Journal of Clinical Nursing, 9*(1), 25-36.

Bucknall, T. K., & Thomas, S. (1997). Nurses' reflections on problems associated with decison-making in critical care settings. *Journal of Advanced Nursing, 25*, 229-237.

Bui, T., Cho, S., Sankaran, S., & Sovereign, M. (2000). A framework for designing a global information network for multinational humanitarian assistance/disaster relief. *Information Systems Frontiers, 1*(4), 427-442.

Campbell, K. C., Cooper, W. W. J., Greenbaum, D. P., & Wojcik, L. A. (2000, June 13-16). *Modelling distributed human decision making in traffic flow management operations.* Paper presented at the 3 USA/Europe Air traffic Management R&D Seminar, Napoli.

Cannon-Bowers, J. A., & Bell, H. H. (1997). Training decision makers for complex environments: Implications of the naturalistic decision making perspective. In C. E. Zsambok & G. Klein (Eds.), *Naturalistic Decision Making*. Mahwah, NJ: Laurence Erlbaum Associates.

Cannon-Bowers, J. A., Salas, E., & Converse, S. A. (1993a). Shared mental models in expert team decision-making. In J. N. J. Castellan (Ed.), *Individual and Group Decision Making* (pp. 221-246). Hillsdale: Lawrence Erlbaum.

Cannon-Bowers, J. A., Salas, E., & Converse, S. A. (1993b). Shared mental models in team decision making. In N. J. C. Jr. (Ed.), *Individual and Group Decision Making* (pp. 221-246). Hillsdale, NJ: Erlbaum.

Cannon-Bowers, J. A., Tannenbaum, S. I., Salas, E., & Volpe, C. E. (1995). Defining competencies and establishing team training requirements. In R. A. Guzzo & E. Salas (Eds.), *Team Effectiveness and Decision Making in Organizations* (pp. 333). San Francisco, CA: Jossey-Bass.

Chalmers, M. (2004). A historical view of context. *Computer Supported Cooperative Work, 13*(3-4), 223-247.

Chwe, M. S.-Y. (2000). Communication and coordination in social networks. *The Review of Economic Studies, 67*(1), 1-16.

Clawson, J. J., & Dernocoeur, K. B. (1998). Principles of Emergency Medical Dispatch. In *The National Academy of Emergency Medical Dispatch* (2nd ed.). Salt Lake City, Utah: Priority Press.

Cohen, M. S., Freeman, J. T., & Wolf, S. (1996). Metarecognition in time-stressed decision making: recognizing, critiquing, and correcting. *Human Factors, 38*(2), 206-219.

Cohen, M. S., & Thompson, B. B. (2001). Training teams to take initiative: Critical thinking in novel situations. In E. Salas (Ed.), *Advances in Cognitive Engineering and Human Performance Research* (Vol. 1, pp. 251-291). Amsterdam: JAI.

Concept Map. (2005). Retrieved March 26, 2005, from http://www.graphic.org/concept.html

Concept Mapping. (2005). Retrieved March 26, 2005, from http://istudy.psu.edu/FirstYearModules/ConceptMap/ConceptInfo.htm

Connolly, C. (2005). *Thousands of Katrina 911 Calls Went Astray*. Retrieved December 5, 2005, from http://www.washingtonpost.com/wp-dyn/content/article/2005/11/07/AR2005110701334.html

Connors, E. S., Craven, P., McNeese, M. D., Jefferson, J., T., Bains, P., & Hall, D. L. (2004). *An application of the akadam approach to intelligence analyst work.* Paper presented at the Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting, New Orleans, LA.

Cooke, N., Stout, R., & Salas, E. (2005). *A Knowledge Elicitation Approach to the Measurement of Team Situation Awareness*. Retrieved April 5, 2005, from http://www.certt.com/publications/Team%20SA.pdf

Cooke, N. J., Salas, E., Cannon-Bowers, J. A., & Stout, R. (2000). Measuring team knowledge. *Human Factors, 42*(1), 151-173.

Crandell, T. L., Klein, N. A., & Soderston, C. (1996). Empirical evaluation of concept mapping: A job performance aid for writers. *Technical Communication, 43*(2), 157-158.

Creswell, J. W. (1994). *Research Design: Qualitative & Quantitative Approaches*. Thousand Oaks, CA: Sage Publications, Inc.

Crichton, M., & Flin, R. (2001). Training for emergency management: tactical decision games. *Journal of Hazardous Materials, 88*(2-3), 255-266.

Cutter, S. L. (2003). Gi science, disasters, and emergency management. *Transactions in GIS, 7*(4), 439-445.

Davidson, M. J., Dove, L., & Weltz, J. (1999, November 15). *Mental models and usability*. Retrieved March 20, 2005, from http://www.lauradove.info/reports/mental%20models.htm

Depken, C. A. I. (2000). Wage disparity and team productivity: Evidence from major league baseball. *Economic Letters, 67*, 87-92.

DeSanctis, G., & Gallupe, R. B. (1987). A foundation for the study of group decision support systems. *Management Science, 33*(5), 589-609.

The Development of 9-1-1. (2005). Retrieved December 5, 2005, from http://www.nena.org/PR_Pubs/Devel_of_911.htm

Dispatch Monthly Magazine. (2005, March 16, 2005). Retrieved March 17, 2005, from http://www.911dispatch.com/information/QandA2.html

Duncan, P. C., Rouse, W. B., Johnston, J. H., Cannon-Bowers, J. A., Salas, E., & Burns, J. (1996). Training teams working in complex systems: A mental model-based approach. In W. B. Rouse (Ed.), *Human/Technology Interaction in Complex Systems* (Vol. 8, pp. 173-231). Greenwhich: JAI Press.

Endsley, M. R. (2001). *Designing for situation awareness in complex systems.* Paper presented at the Proceedings of the Second International Workshop on Symbiosis of Humans, Artifacts, and environment, Kyoto, Japan.

Erdem, T., & Keane, M. P. (1996). Decision-making under uncertainty: Capturing dynamic brand Choice processes in turbulent consumer goods markets. *Marketing Science, 15*(1), 1-20.

Eseryel, D., Ganesan, R., & Edmonds, G. S. (2002). Review of computer-supported collaborative work systems. *Educational Technology & Society, 5*(2), 130-136.

Espinosa, J. A., Kraut, R. E., Lerch, J. F., & Slaughter, S. A. (2001, December 16th-19th). *Shared mental models and coordination in large scale, distributed software development.* Paper presented at the Twenty-Second International Conference on Information Systems, New Orleans, LA.

Espinosa, J. A., Kraut, R. E., Slaughter, S. A., Lerch, J. F., Herbsleb, J. D., & Mockus, A. (2002). *Shared mental models, familiarity, and coordination: A multi-method study of distributed software teams.* Paper presented at the Twenty-Third International Conference on Information Systems, Barcelona.

Farand, L., Leprohon, J., Kalina, M., Champagne, F., Contandriopoulos, A. P., & Preker, A. (1995). The role of protocols and professional judgement in emergency medical dispatching. *European Journal of Emergency Medicine, 2*(3), 136-148.

Ferzandi, L. A., Skattebo, A. S., Terrell, I. S., & Bains, P. (2004, April 2-4). *Will they share? Team problem-solving in computer-mediated environments.* Paper presented at the 19th Annual SIOP Conference, Chicago, Il.

Findler, N. V., & Lo, R. (1993). Distributed air traffic control - part 1: Theoretical studies. *Journal of Transportation Engineering, 119*, 681-692.

Flin, R. H. (1997). Crew resource management for teams in the offshore oil industry. *Team Performance Management, 3*(2), 121-129.

Ford, D. N., & Sterman, J. D. (1997). *Expert knowledge elicitation to improve mental and formal models*. Retrieved March 21, 2005, from http://web.mit.edu/jsterman/www/ford_sterman_elicit_1.pdf

Fouche, J. (2005). *Using Mental Models as an Evaluation Tool in the Beta Testing of a Multimedia Tutorial*. Retrieved April 4, 2005, from http://hagar.up.ac.za/jf/mentmod/mentmod.htm

Freeman, J. T., & Cohen, M. S. (1996). *Training for complex decision-making: A test of instruction based on the recognition / metacognition model.* Paper presented at the Proceedings of the 1996 Command and Control Research and Technology Symposium, Monterey, California.

Fuks, H., Laufer, C., Choren, R., & Blois, M. (1999). *Communication, coordination and cooperation in distance education.* Paper presented at the Proceedings of V AMCIS '99 - 1999 Amercian Conference on Information Systems, Milwaukee, USA, Agosto 1999.

Gentner, D. (2002). Psychology of Mental Models. In N. J. Smelser & P. B. Bates (Eds.), *International Encyclopedia of the Social and Behavioral Sciences* (pp. 9683-9687). Amsterday:: Elsevier Science.

Genzuk, M. (2005). *A Synthesis of Ethnographic Research*. Retrieved April 11, 2005, from www-rcf.usc.edu/~genzuk/Ethnographic_Research.pdf

Gergen, K. J., Gulerce, A., Lock, A., & Misra, G. (1996). Psychological Science in Cultural Context. *American Psychologist, 51*, 496-503.

Gill, C. D., Kuhns, F., Levine, D. L., Schmidt, D. C., Doerr, B. S., Schantz, R. E., et al. (1999). *Applying adaptive real-time middleware to address grand chanllenges of cots-based mission-critical real-time systems.* Paper presented at the Proceedings of the 1st IEEE International Workshop on Real-Time Mission-Critical Systems: Grand Challenge

Problems.
Gokhale, A. A. (1995). Collaborative learning enhances critical thinking. *Journal of Technology Education, 7*(1), 22-30.
Gosbee, J., & Ritchie, E. (1997). Human-computer interaction and medical software development. *Interactions, July + August*, 13-18.
Grote, G., & Zala-Mezö, E. (2004). *GHRE-Kolleg (Group Interaction in High Risk Environments) of the Dailmer-Benz-Foundation*. Retrieved April 10, 2005, from http://e-collection.ethbib.ethz.ch/show?type=bericht&nr=379&part=text
Guha-Sapir, D. (1991). Rapid assessment of health needs in mass emergencies: review of current concepts and methods. *World Health Statistics Quarterly, 44*(3), 171-181.
Gunasekaran, A., Patel, C., & Tirtiroglu, E. (2001). Performance measures and metrics in a supply chain environment. *International Journal of Operations & Production Management, 21*(1/2), 71-87.
Hedlund, J., Ilgen, D. R., & Hollenbeck, J. R. (1998). Decision accuracy in computer-mediated versus face-to-face decision-making teams. *Organizational Behavior and Human Decision Processes, 76*(1), 30-47.
Hoegl, M., & Gemuenden, H. G. (2001). Teamwork quality and the success of innovative projects: A theoretical concept and empirical evidence. *Organization Science, 12*(4), 435-449.
Hoffman, R. R., Shadbolt, N. R., Burton, A. M., & Klein, G. (1995). Eliciting knowledge from experts: A methodological analysis. *Organizational Behavior and Humand Decision Processes, 62*(2), 129-158.
Hollan, J. D., Hutchins, E., & Kirsch, D. (2000). Distributed Cognition: A new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction, 7*(2), 174-196.
Holzman, T. G. (1999). Computer-human interface solutions for emergency medical care. *Interactions, May/June*, 13-24.
Hutchins, E. (1995). How a cockpit remembers its speed. *Cognitive Science, 19*(3), 265-288.
Hutchins, E. (2000, May 18). *Distributed Cognition.* Retrieved April 5, 2005, from http://eclectic.ss.uci.edu/~drwhite/Anthro179a/DistributedCognition.pdf
Hutchins, E., & Hazelhurst, B. (1995). How to invent a lexicon: the development of shared symbols in interaction. In N. Gilbert & R. Conte (Eds.), *Artificial Societies: The Computer Simulation of Social Life* (pp. 157-189). London: UCL Press.
Hutchins, E., & Klausen, T. (1992). Distributed cognition in an airline cockpit. In D. Middleton & Y. Engestrom (Eds.), *Communication and Cognition at Work.* Cambridge: Cambridge University Press.
Hutchins, E., & Klausen, T. (1996). Distributed cognition in an airline cockpit. In Y. Engeström & D. Middleton (Eds.), *Cognition and communication at work* (pp. 15-34). New York: Cambridge University Press.
Hutchins, E., & Palen, L. (1997). Constructing Meaning from Space, Gesture, and Speech. In L. B. Resnick, R. Saljo, C. Pontecorvo & B. Burge (Eds.), *Discourse, tools, and reasoning: Essays on situated cognition* (pp. 23-40). Heidelberg, Germany: Springer-Verlag.

Hutchins, S. G. (2004). *A new perspective on use of the critical decision method with intelligence analysts*. Retrieved August 12, 2004, from www.dodccrp.org/events/2004/CCRTS_San_Diego/CD/papers/245.pdf

Imbens-Bailey, A., & McCabe, A. (2000). The discourse of distress: a narrative analysis of emergency calls to 911. *Language & Communication, 20*(3), 275-296.

Improving Note Taking with Concept Maps. (2005). Retrieved March 27, 2005, from http://www.psychwww.com/mtsite/mindmaps.html

Jarke, M. (1999). Scenarios for modeling. *Communications of the ACM, 42*(1), 47-48.

Jefferson, T. J., Ferzandi, L., & McNeese, M. D. (2004). *Impact of hidden profiles on distributed cognition in spatially distributed decision-making teams.* Paper presented at the Proceedings of the 48th Annual Meeting of the Human Factors and Ergonomics Society, New Orleans.

Jessup, L. M., Tansik, D. A., & Laase, T. D. (1988). Group problem solving in an anonymity and proximity on group process and outcome with a group decision support system. *Academy of Management Proceedings*, 237-241.

Jones, A. C. (2004). *The Information-Technology-People Abstraction Hierarchy: A Tool for Complex Information Systems Design.* The Pennsylvania State University, University Park, PA.

Kaczynski, D. (2004, December 1). *Examining the impact of qualitative data analysis software upon the analysis process.* Paper presented at the Annual Conference of the Australian Association for Research in Education, Melbourne, Australia.

Karagiannis, D., Radermacher, F. J., Teufel, B., & Wynne, B. E. (1994). Towards cscw: Metalevel environments for enhanced group and organization effectiveness. *Journal of Organizational Computing and Electronic Commerce, 4*(4), 367-392.

Kerr, N. L., MacCoun, R. J., & Kramer, G. P. (1996). When are N heads better (or worse) than one? Biased judgment in individuals versus groups. In E. Witte & J. H. Davis (Eds.), *Understanding group behavior: Consensual action by small groups* (Vol. 1). Mahwah, NJ: Lawrence Erlbaum Associates.

Kerr, N. L., & Tindale, R. S. (2004). Group performance and decision making. *Annu. Rev. Psychol., 55*, 623-655.

Klein, G. (1993). A Recognition-Primed Decision (RPD) Model of Rapid Decision Making. In G. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok (Eds.), *Decision Making in Action: Models and Methods* (pp. 138-147). Norwood, NJ: Ablex Publishing Corporation.

Klein, G. (1998). The power to read minds. In *Sources of Power*. Cambridge: MIT Press.

Klein, G., Calderwood, R., & Clinton-Cirocco, A. (1986). *Rapid decison making on the fire ground.* Paper presented at the Proceedings of the Human Factors Society 30th Annual Meeting, Santa Monica, CA.

Klein, G. A. (1989). Recognition-primed decisions. In W. Rouse (Ed.), *Advances in Man-Machine Systems Research* (Vol. 5, pp. 47-92). Greenwhich: JAI Press.

Klein, G. A. (1998). *Sources of Power: How People Make Decisions*. Cambridge, MA: The MIT Press.

Klein, G. A., Calderwood, R., & Macgregor, D. (1989). Critical decision method for eliciting knowledge. *IEEE Transactions on Systems, Man, and Cybernetics, 19*(3), 462-472.

Klimoski, R., & Jones, R. G. (1995). Staffing for effective group decision making: Key issues in matching people and teams. In R. A. Guzzo & E. Salas (Eds.), *Team Effectiveness and Decision Making in Organizations* (pp. 291-332). San Francisco: Jossey-Bass.

Knowledge Acquisition. (2003). Retrieved February 23, 2006, from http://www.epistemics.co.uk/Notes/63-0-0.htm

Knowledge elicitation methods and their advantages and disadvantages. (2006). Retrieved February 23, 2006, from http://www2.psych.purdue.edu/~proctor/ACM_tables.pdf

Komis, V., Avouris, N., & Fidas, C. (2002). Computer-supported collaborative concept mapping: Study of synchronous peer interaction. *Education and Information Technologies, 7*(2), 169-188.

Kurtz, A. (2005). *Mental models - a theory critique*. Retrieved April 4, 2005, from http://www.slis.indiana.edu/faculty/yrogers/ment_mod/

Lambert, M. H., Kunz, J., & Levitt, R. E. (2005). *Hierarchies and Transactive Memory Systems: Crafting a Model of Flexible Exception Handling*. Retrieved March 30, 2005

Langan-Fox, J., Anglim, J., & Wilson, J. R. (2004). Mental models, team mental models, and performance: Process, development, and future directions. *Human Factors and Ergonomics in Manufacturing, 14*(4), 331-352.

Larsen, J. R. J., Christensen, C., Franz, T. M., & Abbott, A. S. (1998). Diagnosing groups: The pooling, management, and impact of shared and unshared case information in team-based medical decision making. *Journal of Personality and Social Psychology, 75*(1), 93-108.

Lecocq, R., & Gauvin, M. (2005). *Cross-Analysis of Data Collected on Knowledge Management Practices in Canadian Forces Environments*. Val-Bélair, Quebec: Defence R&D Canada – Valcartier.

Lehner, P., Seyed-Solorforough, M.-M., O'Connor, M. F., Sak, S., & Mullin, T. (1997). Cognitive biases and time stress in team decision making. *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans, 27*(5), 698-703.

Leveson, N. G., Allen, P., & Story, M.-A. (2002). *The analysis of a friendly fire accident using a systems model of accidents.* Paper presented at the International Conference of the Systems Safety Society, Denver.

Levine, J. M., & Moreland, R. L. (2004). Collaboration: The social context of theory development. *Personality and Social Psychology Review, 8*(2), 164-172.

Liang, D., Moreland, R., & Argote, L. (1995). Group versus individual training and group performance: The mediating role of transactive memory. *Personality and Social Psychology Bulletin, 21*, 384-393.

Lindell, M. K. (2000). An overview of protective action decision-making for a nuclear power plant emergency. *Journal of Hazardous Materials, 75*, 113-129.

Lipshitz, R., Klein, G., Orasanu, J., & Salas, E. (2001). Taking stock of naturalistic decision making. *Journal of Behavioral Decision Making, 14*(5), 331-352.

Lipshitz, R., & Strauss, O. (1997). Coping with uncertainty: A naturalistic decision-making analysis. *Organizational Behavior and Human Decision Processes, 69*(2), 149-163.

Losee, R. M. (1999). Communication defined as complementary informative processes. *Journal of Information, 5*(3), 1-15.

Malone, T. W., Crowston, K., Lee, J., Pentland, B., Dellarocas, C., Wyner, G., et al. (1999). Tools for inventing organizations: Toward a handbook of organizational processes. *Management Science, 43*(3).

Markus, M., Fiedrich, F., Gehbauer, F., & Hirschberger, S. (2000, May 1999). *Strong earthquakes, rapid damage assessment and rescue planning.* Paper presented at the Proceedings of the 7th Annual Conference of the International Emergency Management Society: "Contingency, Emergency, Crisis, and Disaster Management: Emergency Management in the Third Millennium", Orlando.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. *The Journal of Applied Psychology, 85*(2), 273-283.

McCarthy, J. (1994). The state-of-the-art of cscw: CSCW systems, cooperative work and organization. *Journal of Information Technology, 9*(2), 73-83.

McCarthy, J. C., Wright, P. C., Healey, P., Dearden, A., & Harrison, M. D. (1997, November 16-19). *Locating the scene: the particular and the general in contexts for ambulance control.* Paper presented at the Proceedings of the international ACM SIGGROUP conference on Supporting group work : the integration challenge: the integration challenge, Phoenix, Arizona.

McDermott, G., & Mulvihill, C. (1996). Dynamic workflow analysis in a multiuser task context. *International Journal of Human-Computer Interaction, 8*(4), 433-455.

McIlroy, D., & Heinze, C. (1996). *Air combat tactics implementation in the smart whole air mission model.* Paper presented at the Proceedings of the 1st International SIMTECT Conference, Melbourne, Australia.

McNeese, M. D. (1996). An ecological perspective applied to multi-operator systems. In O. Brown & H. L. Hendrick (Eds.), *Human factors in organizational design and management - VI* (pp. 365-370). The Netherlands: Elsevier.

McNeese, M. D., Connors, E. S., Jefferson, J., T., Bains, P., Jones, R. E. T., Terrell, I. S., et al. (2004). *An Assessment of Image Analyst Work Using the Living Laboratory Framework (Tech. Rep. No. 0017)*: University Park, Pennsylvania: Pennsylvania State University, School of Information Sciences and Technology. Report to the National Geospatial-intelligence Agency (NGA). Washington DC.

McNeese, M. D., Jefferson, T., Bains, P., Brewer, I., Brown, C., Connors, E. S., et al. (2005, July 22-25). *Assessing the impact of hidden knowledge profiles on distributed cognition and team decision making: Recounting the development of the NeoCITIES Simulation.* Paper presented at the 11th International Conference of Human-Computer Interaction, LasVegas, NV.

McNeese, M. D., Zaff, B. S., Citera, M., Brown, C. E., & Whitaker, R. (1995). AKADAM: Eliciting user knowledge to support participatory ergonomics. *International Journal of Industrial Ergonomics, 15*, 345-363.

Meso, P., Troutt, M. D., & Rudnicka, J. (2002). A review of naturalistic decision making research with some implications for knowledge management. *Journal of Knowledge Management, 6*(1), 63-73.

Modrick, J. A. (1986). Team performance and training. In J. Zeidner (Ed.), *Human Productivity Enhancement: Training and Human Factors in Systems Design* (Vol. 1, pp. 130-166). New York: Praeger.

Mohammed, S., & Dumville, B. C. (2001). Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries. *Journal of Organizational Behavior, 22*(2), 89-106.

Mohammed, S., Klimoski, R., & Rentsch, J. R. (2000). The measurement of team mental models: We have no shared schema. *Organizational Research Methods, 3*(2), 123-165.

Moore, J. L., & Rocklin, T. R. (1998). The distribution of distributed cognitions: Multiple interpretations and uses. *Educational Psychology Review, 10*(1), 97-113.

Muramatsu, J., & Pratt, W. (2001). *Investigating users' mental models of search engines.* Paper presented at the Proceedings of the 24th Annual International ACM SIGIR Conference on Research and Development in

Information Retrieval, New York.

Murray, G., Steuart, S., Appla, D., McIlroy, D., Heinze, C., Cross, M., et al. (1995). *The challenge of whole air mission modelling.* Paper presented at the Proceedings of the Australian Joint Conference on Artificial Intelligence, Melbourne, Australia.

Norman, D. A. (1983). Some Observations on Mental Models. In D. Gentner & A. L. Stevens (Eds.), *Mental Models*. Hillsdale, NJ: Lawrence Erlbaum.

Novak, J. D. (2005). *The Theory Underlying Concept Maps and How to Construct Them*. Retrieved March 26, 2005, from http://cmap.coginst.uwf.edu/info/

O'Connell, B., & Irurita, V. (2000). Facilitating the process of theory development by creating a visual data analysis trail. *Research for Nursing Practice, 2*(1).

Olswang, L. B. (2005). *Ethnography and Phenomenology: Approaches for Studying Communication in Context*. Retrieved March 25, 2005, from http://faculty.washington.edu/lolswang/html/308/pdf/308observationguidelines.pdf

One killed, dozens hurt in Michigan car pileup. (2005, March 8). Retrieved March 16, 2005, from http://www.msnbc.msn.com/id/7132894/

Orasanu, J., & Connolly, T. (1993). The Reinvention of Decision Making. In G. A. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok (Eds.), *Decision Making in Action: Models and Methods* (pp. 3-20). Ablex, Norwood, New Jersey.

Ordonez, L., & Benson, L. (1997). Decisions under time pressure: How time constraint affects risky decision making. *Organizational Behavior and Human Decision Processes, 71*(2), 121-140.

Papadakis, V. M., Lioukas, S., & Chambers, D. (1998). Strategic decision-making processes: the role of management and context. *Strategic Management Journal, 19*(2), 115-147.

Paris, C. R., Salas, E., & Cannon-Bowers, J. A. (2000). Teamwork in multi-person systems: A review and analysis. *Ergonomics, 43*(8), 1052-1075.

Perkins, D. D., Florin, P., Rich, R. C., Wandersman, A., & Chavi, D. M. (1990). Participation and the social and physical environment of residential blocks: Crime and community context. *American Journal of Community Psychology, 18*(1), 83-115.

Pika, S., Lieval, K., & Tomasello, M. (2003). Gestural communication in young gorillas (Gorilla gorilla): Gestural repertoire, learning, and use. *American Journal of Primatology, 60*(3), 95-111.

Population Overview. (2006). Retrieved January 19, 2006, from http://www.epodunk.com/cgi-bin/popInfo.php?locIndex=13710

Potter, S. S., Roth, E. M., Woods, D. D., & Elm, W. C. (2000a). *Bootstrapping Multiple Converging Cognitive Task Analysis Techniques for System Design*.

Potter, S. S., Roth, E. M., Woods, D. D., & Elm, W. C. (2000b). Bootstrapping Multiple Converging Cognitive Task Analysis Techniques for System Design. In Chipman, Shalin & Schraagen (Eds.), *Cognitive Task Analysis* (pp. 317-340). New Jersey: Lawrence Erlbaum.

Rasker, P. C., Post, W. M., & Schraagen, J. M. C. (2000). Effects of two types of intra-team feedback on developing a shared mental model in command & control teams. *Ergonomics, 43*(8), 1167-1189.

Regehr, C., Hill, J., Goldberg, G., & Hughes, J. (2003). Postmortem inquiries and trauma responses in paramedics and firefighters. *Journal of Interpersonal Violence, 18*(6), 607-622.

Ren, Y., Carley, K. M., & Argote, L. (2001). *Simulating the role of transactive memory in group training and performance*. Pittsburgh, PA: Carnegie Mellon University.

Rentsch, J. R., & Klimoski, R. J. (2001). Why do great minds think alike? Antecedents of team member schema agreement. *Journal of Organizational Behavior, 22*(2), 107-120.

Ricci, A., Omicini, A., & Denti, E. (2002). Virtual enterprises and workflow management as agent coordination issues. *11, 11*(3&4), 355-379.

Rogers, Y. (1997). *A Brief Introduction to Distributed Cognition*. Retrieved April 10, 2005, from http://www.cogs.susx.ac.uk/users/yvonner/papers/dcog/dcog-brief-intro.pdf

Rogers, Y. (2005). *Distributed Cognition and Communication*. Retrieved April 5, 2005, from http://www.slis.indiana.edu/faculty/yrogers/papers/Rogers_DCog04.pdf

Rosson, M. B., & Carroll, J. M. (2002). *Usability engineering: Scenario-based development of human-computer interaction*. San Francisco, CA: Morgan-Kaufmann Publishers.

Salas, E., Dickinson, T. L., Converse, S. A., & Tannenbaum, S. L. (1992). Towards and understanding of team performance and training. In R. W. Swezey & E. Salas (Eds.), *Teams: Their Training and Performance* (pp. 3-29). Norwood, NJ: Albex.

Sasse, M. A. (1997). *Eliciting and Describing Users' Models of Computer Systems.* Unpublished Ph.D., University of Birmingham.

Schaafstal, A. M., Johnston, J. H., & Oser, R. L. (2001). Training teams for emergency management. *Computers in Human Behavior, 17*(5-6), 615-626.

Sexton, J. B., Thomas, E. J., & Helmreich, R. L. (2000). Error, stress, and teamwork in medicine and aviation: Cross sectional surveys. *BMJ, 320*, 745-749.

Siepman, J. P. (2004). *Theorietics: The Future of Theory Development*. Retrieved March 27, 2005, from http://www.journaloftheoretics.com/Editorials/Vol-6/e6-6.htm

Silberstein, D. (2001). *Group Interaction in High Risk Environments*. Retrieved April 10, 2005, from http://www2.hu-berlin.de/GIHRE/Download/Publications/InitiatingCrewResources.pdf

Smith, W., & Dowell, J. (2000). A case study of co-ordinative decision-making in disaster management. *Ergonomics, 43*(8), 1153-1166.
Sonnenwald, D. H., & Pierce, L. G. (2000). Information behavior in dynamic group work contexts: Interwoven situational awareness, dense social networks
and contested collaboration in command and control. *Information Processing and Management, 36*(3), 461-479.
Stasser, G. (1992). Pooling of unshared information in group discussions. In S. Worchel, W. Wood & J. Simpson (Eds.), *Group process and productivity*. Newbury Park: Sage.
Stasser, G., & Titus, W. (1985). Pooling of unshared information in group decision making. *Journal of Personality and Social Psychology, 48*, 1467-1478.
Stevens, G. (1992). The social and demographic context of language use in the United States. *American Sociological Review, 57*(2), 171-185.
Stolk, D., Alexandrian, D., Gros, B., & Paggio, R. (2001). Gaming and multimedia applications for environmental crisis management training. *Computers in Human Behavior, 17*, 627-642.
Strohschneider, S., & Gerdes, J. (2004). Ms antwerpen: Emergency management training for low-risk environments. *Simulation & Gaming, 34*(X), 1-20.
Sullivan, P. J. (1993). Occupational stress in psychiatric nursing. *Journal of Advanced Nursing, 18*(4), 591-601.
Terrell, I. S., McNeese, M. D., Jefferson, T. J., & Craven, P. (2004). *Exploring Cognitive Work Within a 911 Dispatch Center: Using Complementary Knowledge Elicitation Techniques.* Paper presented at the Proceedings of the 48th Annual Meeting of the Human Factors Ergonomic Society, Santa Monica, CA.
Transactive Memories. (2003, September 6, 2003). Retrieved March 30, 2005, from http://sati.weblogs.us/archives/003274.html
Trauth, E. M. (2000). *The Culture of an Information Economy: Influences and Impacts in the Republic of Ireland*. Dordrecht, The Netherlands: Kluwer Academic Publishers.
Trauth, E. M., & Jessup, L. (2000). Understanding computer-mediated Discussions: Positivist and Interpretive Analyses of Group Support System Use. *MIS Quarterly, Special Issue on Intensive Research, 24*(1), 43-79.
U.S. Census Bureau State & County QuickFacts. (2006). Retrieved January 20, 2006, from http://quickfacts.census.gov/qfd/states/42/4273808.html
The Use of Concept Maps in the Teaching-Learning Process. (2005). Retrieved March 26, 2005, from http://www.fed.cuhk.edu.hk~johnson/misconceptions/concept_map/cmapguid.html
Vingerhoets, A. J. J. M., van Geleuken, A. J. M. L., van Tilburg, M. A. L., & van Heck, G. L. (1996). The psychological context of crying: Towards a model of adult crying. *Psychological Medicine, 58*, 323-336.
Weber, J., & Kwan, M. P. (2003). Evaluating the effects of geographic contexts on individual accessbility: A multilevel approach. *Urban Geography, 24*(8), 647-671.

Wegner, D. M. (1986). Transactive memory: A contemporary analysis of the group mind. In B. Mullen & G. R. Goethals (Eds.), *Theories of Group Behavior* (pp. 185-208). New York: Springer-Verlag.
Wegner, D. M. (1987). Transactive Memory: A Contemporary Analysis of the Group Mind. In B. Mullen & G. R. Goethals (Eds.), *Theories of Group Behavior* (pp. 185-208). New York, NY: Springer-Verlag.
Wegner, D. M. (1995). A computer network model of human transactive memory. *Social Cognition, 13*(3), 319-339.
Wegner, D. M., Erber, R., & Raymond, P. (1991). Transactive memory in close relationships. *Journal of Personality and Social Psychology, 61*(6), 923-929.
Wegner, D. M., Giuliano, T., & Hertel, P. (1985). Cognitive interdependence in close relationships. In W. J. Ickes (Ed.), *Compatible and incompatible relationships* (pp. 253-276). New York: Springer-Verlag.
Wellens, A. R., & Ergener, D. (1998). The c.i.t.i.e.s. game: A computer-based situation assessment task for studying distributed decision making. *Simulation & Games, 19*(3), 304-327.
Wells, J. D., & Fuerst, W. L. (2000). *Domain-oriented interphace metaphors: Designing web interfaces for effective customer interaction.* Paper presented at the Proceedings of the 33rd Hawaii International Conference on System Sciences: HICSS '2000.
Welsh, J. F. (2000). Course ownership in a new technological context: the dynamics of problem definition. *Journal of Higher Education, 71*(6), 668-699.
Whalen, M. R., & Zimmerman, D. H. (1987). Sequential and institutional contexs in calls for help. *Social Psychology Quarterly, 50*(2), 172-185.
Woods, D. D., & Cook, R. I. (1999). Perspectives on Human Error: Hindsight Bias and Local Rationality. In F. Durso (Ed.), *Handbook of Applied Cognition* (pp. 141-171). Chichester: Wiley.
Wright, P. C., Fields, R. E., & Harrison, M. D. (2000). Analyzing human-computer interaction as distributed cognition: The resources model. *Human-Computer Interaction, 15*(1), 1-41.
Wybo, J. L., & Kowalski, K. M. (1998). Command centers and emergency management support. *Safety Science, 30*, 131-138.
Wyer, R. S. J., & Srull, T. K. (1989). *Memory and cognition in its social context*. Hillsdale, NJ: Erlbaum.
Xiacong, F., Sun, S., McNeese, M., & Yen, J. (2005). *Extending the recognition-primed decision model to support human-agent collaboration.* Paper presented at the Proceedings of the Fourth International Joint Conference on Autonomous Agents and Multi Agent Systems (AAMAS).
Xiao, Y., & Group, t. L. (2001). Understanding coordination in a dynamic medical environment: Methods and results. In M. D. McNeese, E. Salas & M. Endsley (Eds.), *New trends in cooperative activities: System dynamics in complex environments* (pp. 1-8). Santa Monica, CA: Human Factors in Ergonomics Society Press.
Yen, J., Yin, J., Ioerger, T. R., Miller, M. S., Xu, D., & Volz, R. A. (2001). *CAST: Collaborative Agents for Simulating Teamwork.* Paper presented at the International Joint Conference on Artificial Intelligence (IJCAI), Seattle.

Young, M. F., & McNeese, M. D. (1995). A Situated Cognition Approach to Problem Solving. In P. Hancock, J. Flach, J. Caird & K. Vincente (Eds.), *Local Applications of the Ecological Approach to Human Machine Systems* (pp. 359-391). Hillsdale, New Jersey: Erlbaum.

Zachary, W. W., Ryder, J. M., & Hicinbothom, J. H. (1998). Cognitive task analysis and modeling of decision making in complex environments. In J. Cannon-Bowers & E. Salas (Eds.), *Decision Making Under Stress: Implications for Training and Simulation*. Washington, DC: American Psychological Association.

Zaff, B. S., McNeese, M. D., & Snyder, D. E. (1993). Capturing multiple perspectives: A user-centered approach to knowledge and design acquisition. *Knowledge Acquisition, 5*, 79-116.

Zsambok, C. E., & Klein, G. (1997). *Naturalistic Decision Making*. New York: LEA.

Curriculum Vitae
Ivanna S. Terrell

313D IST Building
The Pennsylvania State University
University Park, PA 16802
email: iterrell@ist.psu.edu

Education

Ph.D. Information Sciences and Technology, The Pennsylvania State University 8/02-5/06
Dissertation: *Understanding 911 dispatch teams across context: Implications for theory, information technology, and practice*

M. S. Information Technology, University of North Texas 4/00-8/02

B. A. Psychology, The University of Texas at Austin 8/95-8/99

Peer-Reviewed Publications

McNeese, M. D., Jones, R. E. T., Brewer, I., Connors, E., Bains, P., Terrell, I. S., and Jefferson, T. Jr. (submitted). Understanding work in the intelligence community: Acquiring knowledge from expert image analysts. Submitted to the *International Journal of Cognition, Technology, and Work.*

Jones, R. E. T., Terrell, I. S., and Connors, E. S. (in press). Addressing the gender gap in IT via women's preferences in video games. To be published in *Gender and IT Encyclopedia*.

Brewer, I., McNeese, M. D., Frazier, T., Fuhrmann, S., and Terrell, I. (2005, Sept. 26-30). Expanding team knowledge elicitation through procedural, temporal, and strategic elements. Paper presented at the Human Factors and Ergonomics Society 49th Annual Meeting, Orlando, Fl.

McNeese, M. D., Connors, E. S., Jones, R. E. T., Terrell, I. S., Jefferson, T. Jr., Brewer, I., and Bains, P. (2005, July 22-25). Encountering computer-supported cooperative work via the living lab: Application to emergency crisis management. Paper presented at the 11th International Conference of Human-Computer Interaction, Las Vegas, NV.

Terrell, I. S., McNeese, M. D., Huang, H., Fuhrmann, S., and McNeese, M. D. (2005, July 22-25). The use of mobile technologies by west nile virus field workers. Paper presented at the 11th International Conference of Human-Computer Interaction, Las Vegas, NV.

McNeese, M. D., Jefferson, T., Bains, P., Brewer, I., Brown, C., Connors, E. S., Jones, R. E., and Terrell, I. S. (2005, July 22-25). Assessing the impact of hidden knowledge profiles on distributed cognition and team decision making: Recounting the development of the NeoCITIES Simulation. Paper presented at the 11th International Conference of Human-Computer Interaction, Las Vegas, NV.

Terrell, I. S., McNeese, M. D., & Jefferson, Jr., T. (2004). Exploring cognitive work within a 911 dispatch center.: Using complementary knowledge elicitation techniques. *Proceedings of the 48th Annual Meeting of the HumanFactors and Ergonomics Society* (pp. 605-609). Santa Monica CA: Human Factors and Ergonomics Society.

Ferzandi, L. A., Skattebo, A. S., Terrell, I. S., & Bains, P. (2004, April 2-4). *Will they share? Team problem-solving in computer-mediated environments.* Paper presented at the 19th Annual SIOP Conference, Chicago, Il.

Terrell, F.; Terrell, I. S.; & Von Drashek, S. R. (2001). Loneliness and fear of intimacy among adolescents who were taught not to trust strangers during childhood. *Adolescence, 35*, 611-617.