Knowledge Management Task Complexity In Emergency Management: An Instrument Development

Weidong Xia
Florida International University
xiaw@fiu.edu

Irma Becerra-Fernandez
Florida International University
becferi@fiu.edu

Jose Rocha
Florida International University
jose.rocha@business.fiu.edu

Arvind Gudi
Drexel University
arvind.gudi@drexel.edu

ABSTRACT

While there has been a rich body of literature on knowledge management, little research has been reported that defines the dimensions and operationalization of the complexity of knowledge management tasks. Based on literature reviews and field study observations, we conceptualize knowledge management task complexity as consisting of six dimensions: component complexity, interactive complexity, task novelty, task non-routineness, task difficulty, and lack of task information. Using a systematic instrument development process with interviews, observations and survey data obtained at Miami-Dade County Emergency Operations Center (MD-EOC) in Florida, we developed measures of the six dimensions for knowledge management tasks in the context of emergency management. The final instrument demonstrated sufficient reliability and construct validity. Implications of our conceptualization and measures of knowledge management tasks to research and practice as well as directions for future research are discussed.

Keywords: Knowledge management, task complexity, emergency management, instrument development

Acknowledgement

The authors wish to dedicate this paper to the memory of Frank J. Reddish who was the Miami-Dade Office of Emergency Management Coordinator during the time this research was conducted and who selflessly educated and mentored our research team. We also acknowledge the support of (1) the National Science Foundation under grant CNS0452180 and (2) Robert Palestrant, Division Chief, Miami Dade Fire Rescue, David Perez, Government Affairs Coordinator, Soheila Ajabshir, GIS Manager / Senior Systems Analyst, Troy Johnson, Emergency Management Coordinator, and Raymond Misomali, Emergency Management Coordinator.

INTRODUCTION

There is a long tradition and rich body of research literature on knowledge management (Alavi and Leidner, 2001). In general, the knowledge management research literature has studied key concepts of knowledge management such as knowledge acquisition, knowledge sharing, knowledge dissemination, and technologies and organizational processes for knowledge management (Kakabadse, Kakabadse, and Kouzmin, 2003). However, most of the research has not focused on the characteristics and measures of the tasks involved in knowledge management. Without understanding the nature and complexity of the specific tasks involved, our understanding of the knowledge management process may be limited and to some extend biased. Effective strategies for successful knowledge management cannot be developed without adequately understanding the underlying characteristics of task complexity involved.

This research represents a first step towards conceptualizing the key dimensions of knowledge management task complexity and further developing measures of these dimensions in the context of emergency management. The research was conducted using a systematic instrument development process involving a research methodology utilizing multiple data sources. Initially, the research concepts, dimensions and their proposed measures were developed through literature reviews, field interviews, meetings with emergency personnel, and observations of emergency activations and training drills. The measures were further refined through qualitative sorting procedures and pilot tests with emergency personnel. The research design and measurement items were tested using survey data provided by 110 emergency personnel. The measurement demonstrates adequate reliability, unidimensionality, convergent validity, discriminant validity, and nomological validity.

The remainder of this paper is organized as follows. We present the literature review and theoretical background in the next section. Then we explain the conceptual development, measurement dimensions and describe the methodology and results. Finally we conclude with our theoretical contributions, practical implications and suggestions for future research.

CONCEPTUALIZATION OF EMERGENCY MANAGEMENT TASK COMPLEXITY

Based on the literature related to complex systems (Bar-Yam, 2003; Fryer 2003; Perrow 1984), complex tasks (Campbell, 1988; Wood, 1986) and information processing (Galbraith, 1973; Daft and Lengel, 1986) and our field observations, we conceptualize two major dimensions of emergency management tasks: structural complexity and dynamic complexity (Campbell 1988; Wood 1986; Xia and Lee 2005). Structural complexity captures the snap shot of the configuration components and procedures of the tasks whereas dynamic complexity captures the ad hoc unpredictable nature of the tasks.

Task Structural Complexity is composed of two dimensions: *Component Complexity* and *Interactive Complexity* (Campbell 1988; Cooke and Rohleder. 2006; Haeckel and Nolan. 1993; Marais, Dulac, and Levenson, 2004; Shenhar and Divir. 1996; Simon 1996; Thompson 1967; Wood 1986). *Component Complexity* represents the multiplicity of the task components, e.g., number of people assigned, variety of organizations being represented, computer systems being accessed and used, machines required, and variety of resources required to complete the task. *Interactive Complexity* represents the degree of interactions and interdependencies among the components of the task, e.g., the inter-connectedness of the people and different organizations involved in a given task.

Task Dynamic Complexity is composed of four dimensions: *Task Novelty*, *Task Non-routineness*, *Task Difficulty*, and *Lack of Task Information*. *Task Novelty* captures the newness aspects or unexpected and novel events that occur in performing the task (Daft and Macintosh. 1981; Dean and Snell. 1991; Fields 2002; Karimi, Somers, and Gupta, 2004). *Task Non-routineness* refers to task aspects that do not regularly and consistently occur or frequently encountering exceptional circumstances requiring flexibility (Fields, 2002; Dean and Snell, 1991). *Task Difficulty* represents the extent to which there is a lack of understanding about the cause-effect relationships in performing the task (Daft and Lengel. 1986; Daft and Macintosh. 1981). *Lack of Task Information* captures the degree to which the information required to perform the task is missing or not completely available (Daft and Lengel. 1986; Daft and Macintosh. 1981).

RESEARCH METHODS

We used a systematic five-stage approach to develop the measures of the six dimensions of task complexity for emergency management. The research site for this work is the Miami-Dade County Emergency Operations Center (MD-EOC) in Florida. Given the number of disaster events faced every year (mainly tropical depressions, storms, and hurricanes); the MD-EOC is viewed as one of the most active, well trained, and prepared emergency management centers in the world. The MD-EOC endorsed our research project and managers from the MD-EOC actively participated in all stages of our research. We first conducted an extensive review of the literature related to knowledge management, emergency management, and decision making processes in the context of emergencies. We participated in a number of trainings, drills and actual activation sessions of the MD-EOC for a number of emergency management events, in order to obtain first-hand understanding about the practical challenges and decision-making processes involved in managing the highly complex knowledge tasks involved in those emergency management situations. We also conducted a number of interviews with various MD-EOC managers in the development and pre-test of our questionnaires. Using the survey instruments developed, we conducted a survey using both online and paper versions of the instrument.

Constructs, Measurement Items and Literature Sources

In the first stage, we developed our initial conceptualization of the dimensions of knowledge management task complexity based on extensive review of the literature, as well as through field observations and interviews with emergency managers. Second, an initial list of measurement items was generated through review of the literature, interviews with emergency mangers, and pre-test of the instrument with emergency managers. Q-sorting procedures (Moore and Benbasat 1991; Xia and Lee, 2005) were used to refine the measures and to ensure the construct validity of the measures. A pre-test of the instrument with nine MD-EOC managers was conducted to ensure the appropriateness and understandability of the questions. Third, using both online and paper-based questionnaires, we collected 110 usable responses from MD-EOC managers who have been involved in recent MD-EOC activities. Lastly, the measures were refined and validated using exploratory factor analysis and reliability analysis. To test nomological validity, we measured task performance by assessing *Task Efficiency* and *Task Effectiveness*. *Task Efficiency* refers to the extent to which the task was completed within the required time frame and within the allocated budget and resources. *Task Effectiveness* refers to the extent to which the emergency incident requirements were met and completed satisfactorily for all participants and stakeholders. Table 1 below presents the constructs, measurement items and key literature sources.

Table 1. Constructs, Measurement Items and Literature Sources.

Component Complexity (Wood 1986, Campbell 1988, Perrow 1984, Haeckel and Nolan 1993, Shenhar and Dvir 1996, EOC observations and interviews)	
Component Complexity-1	How many people were assigned to this task?
Component Complexity-2	How many machines were used to execute this task?
Component Complexity-3	How many computer systems were used to execute this task?
Interactive Complexity (Wood 1986, Campbell 1988, Perrow 1984, Haeckel and Nolan 1993, Shenhar and Dvir 1996, EOC observations and interviews)	
Interactive Complexity-1	The different activities in the task interacted with each other in unpredictable ways during the execution of the task
Interactive Complexity-2	There were uncertain relationships between the activities and the task outcome
Interactive Complexity-3	A change in one activity had significant impacts on other activities during execution of the task
Task Novelty (Fields, 2002, Dean and Snell, 1991, Snell and Dean, 1994, Daft and Macintosh, 1981 in Karimi et al., 2004)	
Novelty-1	Coordinating/performing the activities of this new task required answering questions that have not been asked before
Novelty-2	Setting the objectives for this new task required adopting new procedures
Novelty-3	Coordinating/performing the activities of this new task required adopting new ways of doing things
Task Non-Routineness (Daft and Macintosh, 1981 in Karimi et al., 2004)	
Nonroutineness-1	This predefined task is not always required when the EOC is activated
Nonroutineness-2	The objectives for this predefined task are not the same every time the EOC is activated
Nonroutineness-3	The activities involved in this predefined task are not the same for every EOC activation
Task Difficulty (Van de Ven and Delbecq, 1974, Daft and Macintosh, 1981, Daft and Lengel, 1986)	
Difficulty-1	It is difficult to see clearly the sequence of steps that can be followed to coordinate/perform the activities of this task
Difficulty-2	You came across specific difficult problems that you were not sure how to solve immediately
Difficulty-3	Coordinating/performing the task required you to spend additional time to think and solve specific problems
Difficulty-4	While coordinating/performing the task, it was difficult to know whether the results of your efforts would be correct
Difficulty-5	The objectives set for this task were not clearly defined according to existing standard operating procedures

Lack of Task Information (Daft and Macintosh, 1981, and Daft and Lengel, 1986)	
Information-1	You waited until all relevant information was examined before deciding a course of action to execute the activities for this task
Information-2	You kept gathering data until an excellent solution emerged before deciding a course of action to execute the activities for this task
Information-3	You went over all the available information until an excellent solution appeared before deciding a course of action to execute the activities for this task
Task Efficiency Performance	
Efficiency-1	The task was completed within the planned time schedule
Efficiency-2	The task was completed within the allocated budget
Efficiency-3	The task was completed within the planned number of person-hours
Efficiency-4	The task was completed with efficient use of all available resources
Task Effectiveness Performance	
Effectiveness-1	The task was completed satisfactorily for all participants
Effectiveness-2	All incident requirements were met when the task was completed
Effectiveness-3	The task was completed successfully without negatively impacting other tasks
Effectiveness-4	The task was effectively completed despite any conflicting task requirements

Data collection and sample characteristics

The target respondents of the survey questionnaire were personnel from various organizations (e.g., utility companies, healthcare facilities, telecommunications companies) and government agencies (public safety, FBI, human services, and infrastructure) who are participants of the MD-EOC activities in responding to an emergency event (such as a hurricane or a wildfire). All personnel are familiar with the tasks involved in coordinating and managing the different aspects of MD-EOC activities during an emergency situation. The MD-EOC activities are organized into three functional groups: human services, infrastructure, and public safety. In addition, there are several support groups (e.g., 311 information center, geographic information systems, logistics section, planning and information section, and special needs support center), information communication systems, and other related agencies. Overall, the target respondent population was composed of 734 individuals who are participants of the MD-EOC emergency management response events.

Before respondents answered the questions related to knowledge management task complexity measures, they were asked to identify a specific emergency task that they recently worked on and were asked to refer to that specific task when answering all questions. To make the interpretations of tasks consistent, a list of typical emergency management tasks were indentified from the MD-EOC Standard Operations Procedures and Incident Action Plan documents and were provided as examples in the survey. Respondents also provided background information such as job title, education, the specific emergency functional group they belong to, number of years working in their current organization, and number of years working in the emergency management field. To reduce common-source biases, we conducted two evaluations of the survey. Out of 734 surveys sent out to the MD-EOC personnel, 110 usable responses were received and used in our data analysis, representing an overall response rate of 14.98%. Table 2 presents the characteristics of the respondents in the sample.

Table 2. Sample Characteristics

Years worked in the emergency management field	13.04 Years
Years worked at current organization	10.07 Years
Years worked at the MD-EOC	5.84 Years
Organizational Level	
Senior Management	43.20%
Middle Management	31.07%
Operations Management	25.73%
Distribution of respondents by MD-EOC functional groups and other organizations:	
· Infrastructure Group	26.4%
· Human Services Group	14.5%
· Public Safety Group	35.5%
Other:	
· Hospitals/Health Care	10.3%
· Planning and Logistics	5.1%
· Staff and Support Organizations	3.4%
· Operations	3.1%
· City/Municipal	1.0%
· Other	.7%

DATA ANALYSES AND RESULTS

Measurement Validation

The measures were refined and validated using exploratory factor analysis methods. More specifically the measures were examined for reliability as indicated by Cronbach's alphas and for construct validity as indicated by convergent and discriminant validity (Straub, Boudreau and Gefen 2004). In addition to the measures for the six dimensions of task complexity, to test nomological validity, we also included task performance measures of *Task Efficiency* and *Task Effectiveness*. As shown in Table 3, the reliability estimates for all constructs are above .60 suggesting satisfactory levels of reliability (Hair, Anderson, Tatham and Black, 1998).

Table 3. Reliability estimates (Cronbach's alphas) for the constructs

Constructs	Number of Items	Cronbach's Alpha
Task Component Complexity Component Complexity-1, Component Complexity-2, Component Complexity-3	3	.80
Task Interactive Complexity Interactive Complexity-1, Interactive Complexity-2, Interactive Complexity-3	3	.60
Task Novelty Novelty-1, Novelty-2, Novelty-3	3	.82
Task Nonroutineness Nonroutineness-1, Nonroutineness-2, Nonroutineness-3	3	.82
Task Difficulty Difficulty-1, Difficulty-2, Difficulty-3, Difficulty-4, Difficulty-5	5	.78
Lack of Task Information Information-1, Information-2, Information-3	3	.80
Task Effectiveness Effectiveness-1, Effectiveness-2, Effectiveness-3, Effectiveness-4	4	.85
Task Efficiency Efficiency-1, Efficiency-2, Efficiency-3, Efficiency-4	4	.81

The convergent and discriminant validity of the measures were validated using exploratory factor analysis. All the 20 items of the task complexity were subject to a factor analysis. Six factors emerged from the factor analysis. The factor structure is consistent with our six dimensions of task complexity. All items that belong to the same construct loaded onto the same factor, indicating satisfactory convergent validity (Straub, Boudreau and Gefen 2004). No items were crossed loaded to other constructs with greater than 0.3 factor loadings, indicating satisfactory discriminant validity. In addition, we generated a correlation matrix among all 20 items and examined the patterns of correlations. In general, items that belong to a particular construct had high correlations among themselves than with items that belong to other constructs. The correlation matrix analysis further suggests satisfactory levels of convergent and discriminant validity.

Table 4. Factor Analysis Results of Knowledge Management Task Complexity Measures

	Component					
	1	2	3	4	5	6
Component Complexity-1		.950				
Component Complexity-2		.976				
Component Complexity-3		.978				
Interactive Complexity-1						.752
Interactive Complexity-2						.680
Interactive Complexity-3						.705
Novelty-1					-.698	
Novelty-2					-.911	
Novelty-3					-.841	
Nonroutineness-1				-.868		
Nonroutineness-2				-.870		
Nonroutineness-3				-.763		
Difficulty-1	.744					
Difficulty-2	.781					
Difficulty-3	.549					
Difficulty-4	.784					
Difficulty-5	.604					
Information-1			.776			
Information-2			.872			
Information-3			.864			

We also examined the nomological validity of the measures for task complexity. Nomological validity assesses whether a construct measured by the new measure is associated with other established constructs as the theory or common practice would predict. In this study, we predict that higher levels of task complexity should be associated with low levels of task performance. In other words, there should be negative associations among the measures of task complexity and the measures of task performance. As shown in Table 5, all dimensions of task complexity are negatively correlated to both task efficiency and task effectiveness. Therefore, the relationships among the task complexity measures and the task performance measures demonstrated by our study sample are consistent with what we have predicted, as such indicating satisfactory nomological validity. In addition, Table 5 suggests an interesting pattern of relationships among the different dimensions of task complexity and the task performance dimensions. For example, task efficiency was significantly and negatively associated with task interactive complexity, task difficulty, and lack of task information, while it was not significantly associated with task component complexity, task novelty, and task non-routineness. In contrast, task effectiveness was significantly and negatively associated only with task difficulty but not with the other dimensions of task complexity. These interesting results point to potential opportunities for future research.

Table 5. Correlations among the Constructs.

	1	2	3	4	5	6	7	8
1. Task Component Complexity	1							
2. Task Interactive Complexity	-.231*	1						
3. Task Novelty	.057	.178	1					
4. Task Non-Routineness	.028	.158	.336**	1				
5. Task Difficulty	.099	.314**	.421**	.279**	1			
6. Lack of Task Information	-.019	-.072	-.012	-.052	-.017	1		
7. Task Efficiency	-.065	-.256**	-.172	-.138	-.269**	-.215*	1	
8. Task Effectiveness	-.180	-.126	-.042	-.050	-.279**	-.136	.544**	1

DISCUSSION AND CONCLUSIONS

In this paper, we conceptualized knowledge management task complexity in terms of structural complexity and dynamic complexity. Structural complexity is further composed of two dimensions: task component complexity and task interactive complexity. Dynamic complexity is further composed of four dimensions: task novelty, task non-routineness, task difficulty, and lack of task information. Based on extensive literature review, observations from participating in the training, drill and actual activation sessions of the MD-EOC emergency management events, interviews with MD-EOC managers and coordinators, we developed a 20-item instrument to measure knowledge management task complexity. The test results using the survey responses from 110 MD-EOC emergency management personnel suggest that the measures for assessing task complexity possess satisfactory levels of reliability, construct validity, and nomological validity.

Our results have significant implications for research. While it has been widely recognized that emergency management tasks are difficult to perform because they are inherently complex, there has been little research that focuses on conceptualizing and operationalizing the dimensions that constitute task complexity. Most research has treated task complexity as a single dimension construct. Our field observations and survey data results suggest that task complexity is a multi-dimensional construct. The six dimensions and the corresponding measures that we developed and empirically validated provide a starting point for theory development and testing. Second, our testing results indicate that there is an interesting set of relationships among the various dimensions of task complexity and the two task performance dimensions of task efficiency and task effectiveness. This preliminary result suggests that these task complexity dimensions can have differing impact on task performance. Furthermore, our data results and field observations have convinced us that researchers studying knowledge management processes and systems need to take into consideration the dimensions and measures of task complexity.

Our research also has important implications for practice. While practitioners often attribute the challenges they face in successfully managing emergency tasks to the high levels of complexity embedded in the tasks, they often cannot effectively articulate and assess the specific types of complexity that they encounter during the disposition of a specific task. The conceptualization of the six dimensions of task complexity that we propose can be used by managers as a framework to describe and distinguish different types of task complexity. Further, the measures that we developed and validated in this research can be used by managers during the planning stages of standard operating procedures before an emergency event occurs to assess the potential levels of complexity they might encounter when responding to a particular task. They can also be used to assess and evaluate the "after action" report procedures conducted after an emergency event.

The findings of our study should be interpreted with the appropriate awareness of the limitations of the study. First, given that task complexity is a complex construct we may have omitted some complexity dimensions in our conceptualization and measures of the construct. Future research is needed to address this limitation by considering other aspects of task complexity. Second, our study results may be limited in terms of generalizability because of the emergency management context from which we developed the measures and collected the survey data. Future research should examine the extent to which our research findings are generalizable to other types of knowledge management tasks.

The focus of this paper was to conceptualize and measure the complexity of knowledge management tasks in emergency management. Some important research issues still remain to be explored. First, the measures developed in our study are exploratory in nature; as such, further research is needed to validate and improve the measures using confirmatory research methods. Second, future research needs to examine the relationships among the different dimensions of the task complexity construct. Third, our survey results suggested an initial set of interesting relationships among the task complexity dimensions and the task performance dimensions. Future research is needed to investigate those relationships using more focused study design. Fourth, to understand and recommend to practitioners about what organizational policies and mechanisms they can use to address the complexity of knowledge management tasks they encounter and to improve the ultimate task performance, it is important to identify and examine organizational factors that may mediate and/or moderate the relationships between task complexity and task performance. Lastly, while researchers have made important progress in both knowledge management and emergency management areas, there has been a general lack of synergistic effort and approach to integrate these two complementary research areas. We hope this research serves as a stepping stone for developing a stream of research that will facilitate the development and testing of theories by utilizing the literatures in both knowledge management and emergency management areas.

REFERENCES

Alavi, M., and Leidner, D.E. "Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues", *MIS Quarterly* (25:1), Mar 2001, Pp 107-136.

Bar-Yam, Y. "Dynamics of complex systems". 2003. Oxford: Westview Press.

Campbell, D.J. "Task Complexity - A review and analysis", *Academy Of Management Review* (13:1), Jan 1988, Pp 40-52.

Cooke, D.L., and Rohleder, T.R. "Learning from incidents: from normal accidents to high reliability", *System Dynamics Review* (22:3), Fal 2006, Pp 213-239.

Daft, R.L., and Lengel, R.H. "Organizational information requirements, media richness and structural design", *Management Science* (32:5), May 1986, Pp 554-571.

Daft, R.L., and Macintosh, N.B. "A tentative exploration into the amount and equivocality of information-processing in organizational work units", *Administrative Science Quarterly* (26:2) 1981, Pp 207-224.

Dean, J.W., and Snell, S.A. "Integrated manufacturing and job design - moderating effects of organizational inertia", *Academy Of Management Journal* (34:4), Dec 1991, Pp 776-804.

Fields, D.L. "Taking the measure of work : A guide to validated scales for organizational research and diagnosis". 2003. Sage, Thousand Oaks, CA.

Fryer P. "What are complex adaptive systems? A brief description of complex adaptive systems and complexity theory". 2003. Available at http://www.trojanmice.com/articles/complexadaptivesystems.htm.

Galbraith, J. "Designing complex organizations". 1973. Reading, MA: Addison-Wesley.

Haeckel, S.H., and Nolan, R.L. "Managing by wire", *Harvard Business Review* (71:5), Sep-Oct 1993, Pp 122-132.

Hair, Joseph F., Jr; Anderson, Rolph E.; Tatham, Ronald L.; and Black, William C. (1998). "Multivariate data analysis". Fifth Edition. Englewood Cliffs, Prentice Hall, NJ.

Kakabadse, N.K., Kakabadse, A., and Kouzmin, A. "Reviewing the knowledge management literature: towards a taxonomy", *Journal Of Knowledge Management* (7:4) 2003, Pp 75-91.

Karimi, J., Somers, T.M., and Gupta, Y.P. "Impact of environmental uncertainty and task characteristics on user satisfaction with data", *Information Systems Research* (15:2), Jun 2004, Pp 175-193.

Marais, K., Dulac, N., and Leveson, N. "Beyond normal accidents and high reliability organizations: The need for an alternate approach to safety in complex systems". 2004. Paper Presented At The Engineering Systems Division Symposium, MIT Cambridge, MA.

Moore, G.C. and Benbasat, I. "Development of an instrument to measure the perceptions of adopting an information technolgy innovation", *Information Systems Research*, (2:3) 1991, Pp 192-222.

Perrow, C. "Normal accidents: Living with high-risk technologies". 1984. Princeton University Press, Princeton, NJ.

Straub D., Boudreau M-C. and Gefen D. "Validation guidelines for IS positivist research", *The Communications of the Association for Information Systems*. (13:24) 2004, Pp.378-427.

Shenhar, A.J., and Dvir, D. "Toward a typological theory of project management", *Research Policy* (25:4), Jun 1996, Pp 607-632.

Simon, H.A. "The sciences of the artificial". 1996. 3rd Ed. MIT Press, Cambridge, MA.

Snell, S. A. and James W. Dean, Jr. "Strategic compensation for integrated manufacturing: the moderating effects of jobs and organizational inertia", *Academy of Management Journal*, (37:5), 1994, Pp1109-1140.

Thompson, D. "Organizations in action". 1967. McGraw-Hill., NY.

Van de Ven, A.H. and André L. Delbecq. "A task contingent model of work unit structure", *Administrative Science Quarterly*, (19:2), 1974, Pp 183-197.

Van de Ven, A.H. and D.L. Ferry. "Measuring and assessing organizations". 1980. Wiley, Inter-Science, NY..

Wood, R.E. "Task complexity - Definition of the construct", *Organizational Behavior and Human Decision Processes* (37:1), Feb 1986, Pp 60-82.

Xia, W., and Lee, G. "Complexity of information systems development projects: Conceptualization and measurement development", *Journal of Management Information Systems*, (22:1), 2005, Pp 45-83.