

A Case-Based Knowledge Management System for Disaster Management: Fundamental Concepts

Samuel Otim

Department of Management
101 Sistine Hall
Clemson University, Clemson SC 29634
sotim@clemson.edu

ABSTRACT

Computer-based knowledge management systems are vital for disaster detection, response planning, and management. These systems aid in early warning, and provide decision support for disaster response and recovery management. Managing past knowledge for reuse can expedite the process of disaster response and recovery management. While early warning systems predict some disasters with remarkable accuracy, there is a paucity of knowledge management systems for disaster response and management. This paper outlines a case-based reasoning (CBR) knowledge management system that in effect, is a model of human reasoning since it is based upon the idea that people frequently rely on previous problem-solving experiences when solving new problems. A CBR knowledge management system results in efficient and effective disaster response and management.

Keywords

Case-base reasoning, knowledge management system, disaster response, disaster management.

INTRODUCTION

Despite sophisticated early warning systems, natural disasters still overwhelm us. A recent case is Hurricane Katrina that caused great havoc when it hit the US Gulf Coast at the end of August 2005. The devastation it left behind will last at least several years as families, communities, and businesses struggle to recover. As Katrina's evil twin, Hurricane Rita also made landfall on the Gulf Coast early October 2005. Both hurricanes were Category 5, causing the most devastating effects unmatched in history.

The 2005 extraordinary hurricane season offers some lessons learned in terms of disaster management. Both the Federal Government and vulnerable communities relied on Katrina's experience in responding to Hurricane Rita. Criticized for their sluggish response to Katrina, officials from the White House, the Department of Homeland Security, and the Federal Emergency Management Agency all went to great lengths to demonstrate their readiness for Rita (Mulrine et al., 2005). Vulnerable communities were also quick to respond. While Rita was still far out in the Gulf, Texans even many miles inland from the coast were streaming north. People had learned from the indelible images of New Orleans, Louisiana, the price of not evacuating early.

Emergencies and disasters do not affect only health and well being; frequently large number of people are displaced, killed or injured or subjected to a greater risk of epidemics. A disaster management strategy and the preparedness to avert any loss of life, human suffering, and economic losses are vital. While there are sophisticated computer-based information systems for natural disaster detection and early warning, computer-based information systems for disaster response and management still lag behind. There have been only scanty attempts to employ computer-based information systems specifically designed for disaster response and management. For example, the Federal Emergency Management Agency (FEMA) in June 1993 tested a new disaster management information system using notebook computers, Lotus Notes-based applications, and microwave and satellite data hookups to provide quick communication between relief workers and support offices (Dostert, 1993). There have been also some efforts to utilize geographic information systems (GISs) for natural disaster management. For example, after Hurricane Andrew destroyed large sections of southern Florida, GISs proved crucial for coordinating relief efforts (Baum,

1992). Even when imminent disasters are detected in time by the early warning systems, disaster response and management has often been slow. This is often due to the knowledge gap about how to coordinate and manage the response to a disaster. Moreover, emergencies and disasters are high stress situations that require organizations to respond in a manner that is different from their normal operating procedures (Jennex, 2004; Turoff, 2002). Speedy response occasioned by leveraging past knowledge can mitigate the devastation of the current disaster. However, utilizing past knowledge requires the use of a sound knowledge management system. Although concepts of knowledge and knowledge management abound in the literature (see von Krogh, Roos and Kleine, 1998, for an overview), knowledge management remains a significant challenge for organizations. This is partly because both the concept of knowledge and how to manage it are fairly elusive.

The objective of this paper is to provide conceptual insights on how case-based reasoning (CBR) knowledge management systems can be applied to achieve agility in disaster response and management. While CBR technique is not new, a further objective is to raise awareness about the intuitive appeal of CBR knowledge management systems for disaster planning and management. A CBR system is akin to template-based emergency information system (EIS) having multiple templates for a variety of actions that can be modified as needed (Turoff, 2002). A CBR knowledge management system is a special type of template-based EIS because the templates represent actual past disaster case occurrences. By drawing upon a prior knowledge base, similarities, as well as fundamental differences between phenomena can be identified, averting the need to approach each new disaster as if it is completely without precedent (Macgill and Siu, 2004). Disaster management knowledge base can facilitate organization and management of what different people know about a given disaster issue and response and management strategies previously used, and in turn the dissemination and sharing of this information amongst interested constituencies. In order to elaborate a CBR knowledge management system, it is necessary to more formally define knowledge, and knowledge management (KM), which then provides a platform to specify what in the CBR approach knowledge is and how it is managed.

BACKGROUND

Knowledge and Knowledge Management

The concept of knowledge refers to a definition of knowledge as well as to relevant dimensions and types of knowledge in organizations. It underpins ideas about relevant knowledge, the identification of knowledge processes and of instruments to manage them. It is no accident that Fahey and Prusak (1998) put 'not developing a working definition of knowledge' at the top of their list of the 11 deadliest sins of knowledge management. Although many authors give different definitions (see Venzin et al., 1998, for an overview), a comprehensive definition is provided by Davenport and Prusak (1998, p. 5): 'knowledge is a fluid mix of framed experience, contextual information, values and expert insight that provides a framework for evaluating and incorporating new experiences and information'. Davenport and Prusak's definition of knowledge highlights the following components of a framework for evaluating and incorporating new experiences and information:

- *Framed experience*: this is situation- or case-specific experience (that is, experience gained from dealing with a particular situation)
- *Contextual information*: data/information that pertains to a particular context.
- *Expert insights*. Specific insights that experts integrate into a particular situation or context based on their intuition and expertise
- *Values*. Organizational culture, procedures, communication systems, and protocol.

Knowledge management is then the practice of selectively applying knowledge from previous experiences of decision making to current and future decision making activities with the express purpose of improving the organization's effectiveness (Jennex, 2005). It involves three core elements: relevant knowledge (situation or context-based), knowledge processes, instruments for managing these processes. Several authors on knowledge management identify a variety of relevant processes. These include: knowledge creation, knowledge transfer, knowledge generation, knowledge sharing, knowledge application, knowledge codification and retention of knowledge (Nonaka and Takeuchi, 1995; Leonard-Barton, 1995; Davenport and Prusak, 1998; Bukowitz and Williams, 1999). These processes can be organized into four main processes:

- *Generation of knowledge*. Generating organizational knowledge can be done by acquiring external knowledge (e.g., buying, renting or even stealing knowledge; Davenport and Prusak, 1998) or by means of knowledge creation in a process of learning (Davenport and Prusak, 1998; Probst, et al., 1998; Nonaka and Takeuchi, 1995).

- *Retention of knowledge.* To keep knowledge available, some kind of 'organizational memory' is needed. Retention of knowledge refers to the process of storing knowledge and making retrieval possible.
- *Knowledge sharing.* The aim of this process is to make sure that (existing) knowledge gets at the right place in an organization. Disseminating or transferring knowledge may be other labels for this process.
- *Application or use of knowledge.* The other three knowledge processes are subsidiary to the application of knowledge.

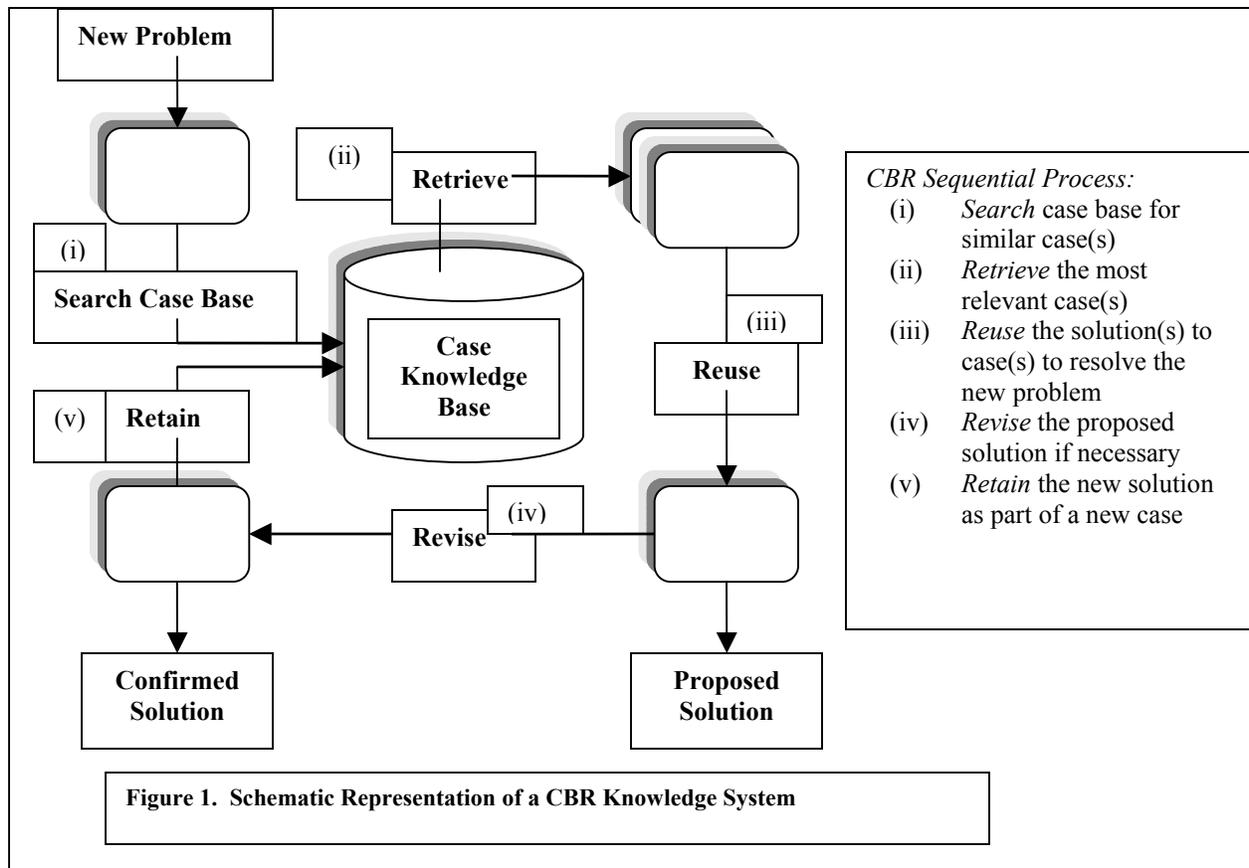
A case-based reasoning knowledge management system is an instrument for the management of knowledge retention and knowledge sharing processes of a knowledge management system. The next section provides a concise discussion of the key concepts of a CBR knowledge system.

Case-Based Reasoning Knowledge Management System

A case-based reasoning knowledge system solves new problems by adapting solutions that were used to solve previous problems (Islam and Chowdhury, 2001; Riesbeck and Schank, 1989; Schank, 1982). The key component of a CBR knowledge management system is the case knowledge base (see Figure 1). The case knowledge base is a repository of cases which consists of the knowledge representation used, the cases themselves, the similarity metric used in identifying cases to be reused, and the mechanism for adapting solutions, if any (Cunningham and Bonzano, 1999). In knowledge container terms, these four components correspond to the vocabulary, case, retrieval and adaptation (Richter, 1995). The knowledge base is generated from past actual cases and their solutions. The knowledge generation process is essentially exogenous to the CBR knowledge management system. The case knowledge base helps in the storing of knowledge and making retrieval possible.

Whenever a new problem is encountered, situation assessment and description of the new problem should be done before proceeding to solve it by using CBR technique (Islam and Chowdhury, 2001). The case base is then searched for similar previous problems. This is a critical step in using a CBR knowledge system because at the heart of the issue is the need to effectively describe the target problem in such a way that it can be matched to problems with similar instances in the case base (Sun et al., 2003). Every case in the case knowledge base is a complete description of a successful solution of a past problem. It must contain unique identification so that it can be retrieved when required. This is achieved by using a unique key or an index (similar to a primary key in database systems) to identify each problem case and link it to its solution. Suitable cases are retrieved from the case knowledge base by using the indexes.

In the retrieval step, if the search process found a matching case in the case knowledge base, then it is retrieved, together with its solution. The selected cases are reused to generate a solution appropriate to the current problem. This solution is revised and adapted if necessary and finally, the new case (i.e. the problem description and its solution) is stored in the case knowledge base for future use. The final step is vital in that if the current case has enough potential to solve future problems, it is stored into the case knowledge base to ensure continuous learning process. All of these actions are self-contained and may be represented by a cyclic sequence of processes, in which human interaction may be needed. The working of a CBR knowledge management system naturally fits into Jennex's (2005) definition of knowledge management (that is, the practice of selectively applying knowledge from previous experiences of decision making to current and future decision making activities with the express purpose of improving the organization's effectiveness). A CBR knowledge management system combines the power of case narrative and codification of knowledge in computers to enable the use of past experience in solving current and future similar case situations. A CBR knowledge management system is grounded in commonsense premises and observations of human cognition and has applicability to a variety of reasoning tasks, providing for each, a means of attaining increased efficiency and better performance (Kolodner, 1993). A CBR knowledge management system also facilitates the processes of knowledge sharing (e.g. through a Web interface) and knowledge use (e.g. through drills and simulations).

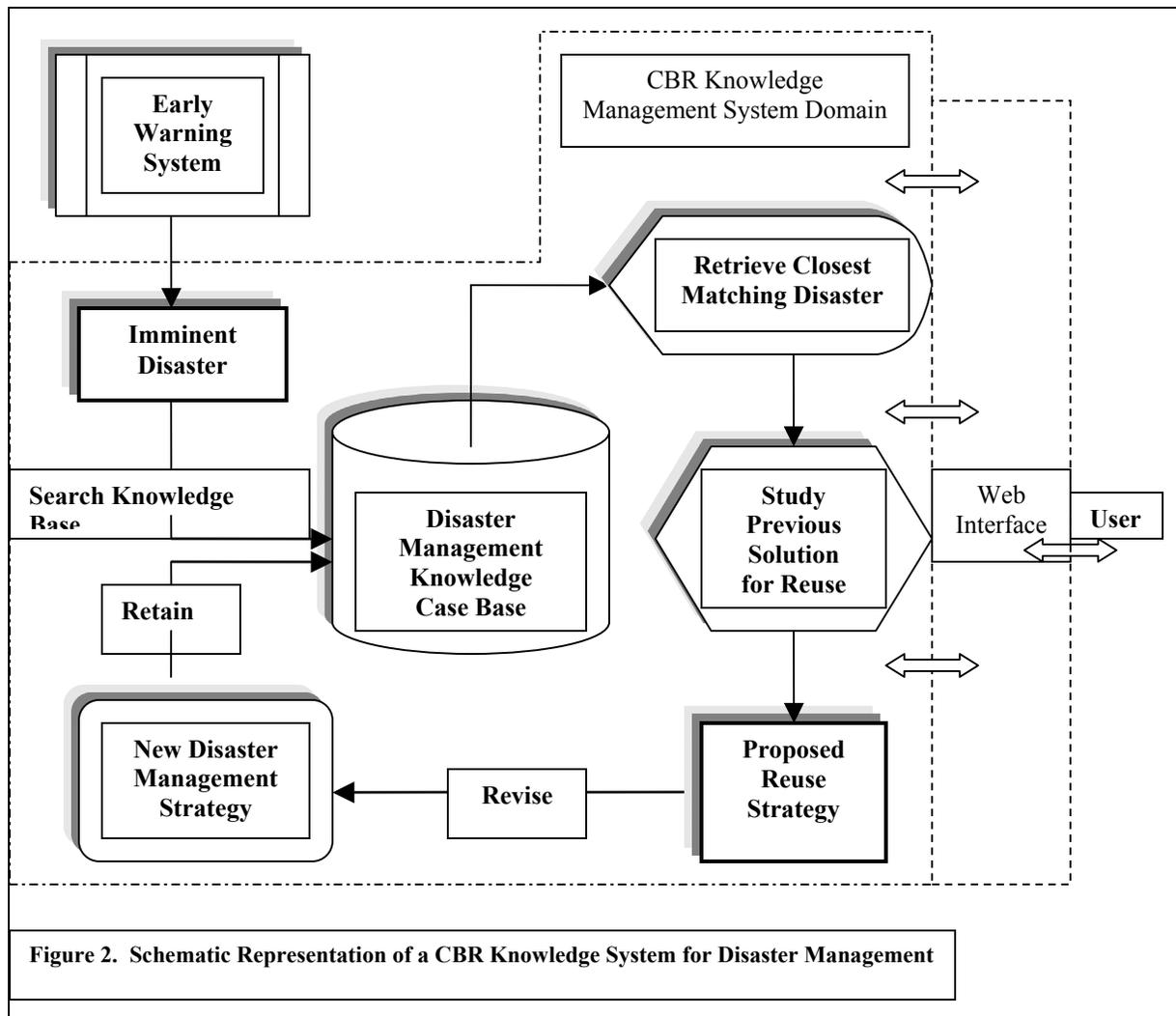


APPLICATION OF CBR KNOWLEDGE MANAGEMENT SYSTEM TO DISASTER MANAGEMENT

The main goal of knowledge management is to make it possible to leverage past experiences (knowledge) to improve organizational effectiveness. A schematic representation of a CBR knowledge management system specifically designed for disaster management is presented in Figure 2. In principle, the early warning system is exogenous to the CBR knowledge system for disaster management. The early warning system falls under the domain of risk detection and assessment. For natural disasters, contemporary computer-based early warning systems are quite sophisticated and often predict impending natural disasters such as hurricanes and earthquakes with reasonable accuracy. However, the problem is still acute in disaster response and management even in cases where sufficient early warning window exists before a natural disaster strikes. This is where a CBR knowledge management system delivers its benefits.

Since situation assessment is a critical requirement for the successful application of a standard CBR knowledge system, an early warning system, though treated as exogenous, is vital in that it provides the necessary information for situation assessment step. For example, in the case of hurricanes, early warning weather systems have often provided the necessary information for situation assessment; such as the category of the hurricane, where and when it is expected to strike, as well as potential damage along its way. That information is useful in devising a plan for disaster response and management using a CBR knowledge management system. Armed with this information, after situation analysis, the respective constituencies can then search the disaster management knowledge base for a possible matching solution (previously used successful disaster response and management strategy).

Once the disaster management knowledge base is searched for matching problems to the new one, the closest matching problem and its solution should be retrieved to expedite the process of disaster response and management. The previous disaster response and management strategy can then be studied for possible reuse or adaptation, if necessary. This can mitigate problems associated with response planning, logistics, and protocols that often hamper



timely response by the respective constituencies. Problems in these areas are often blamed for the slow response to disasters. Such information should be readily available from a previously used strategy. Such information can also be reported instantaneously from the field through an information system that works in concert with a CBR knowledge management system. For example, the city of Glendale, California, uses an automated emergency response system for assessment of damage. The land information system makes it possible for the city to immediately dispatch inspectors throughout Glendale carrying handheld computers for direct assessment of damage. The ability to instantaneously report damage from the field provides a more accurate assessment of the damage and activates response services at the appropriate level more rapidly than traditional manual systems (Penton Media, 2005). Integrating this type of information system with a CBR knowledge management system could lead to better disaster management. For example, city officials would have precise knowledge of where the damage is located and its severity and be able to immediately devise a response and management strategy that could better protect the public and dispatch resources to the areas with the most need. It is worth pointing out that a CBR knowledge management system is as good as the problem cases stored in it. Once in a while, there may be wicked problems without precedent (e.g. 9/11 terrorist attacks on the U.S. east coast). Effective management response to disaster therefore includes using both programmed and non-programmed solutions (March and Simon 1958). In a CBR knowledge framework, programmed solutions are cases of actual previous disasters for which the cause-effect relationships and means-ends solution strategies are explicit and tightly coupled. Based on CBR knowledge management logic, non-programmed solutions are operationalized when the ends are clear but the means are not. This requires the skill of improvisation (an extreme case of adaptation) through discretionary decision making by the respective parties, on-the-spot adjustments and continuous feedback to effectively respond to uncertainty. This is especially important when discretionary activities of multiple actors, such as multidisciplinary members of a disaster

recovery team, exist (Georgopoulos 1986). Nevertheless, even for non-programmed solutions, the importance of disaster planning cannot be underestimated.

Advantages of Using a CBR Knowledge System for Disaster Management

There are several advantages to using a CBR knowledge system for disaster response and management. These advantages particularly accrue in situations where the domain doesn't have an underlying model, cases recur frequently, there are exceptions and novel cases, relevant past cases are obtainable, and there is significant benefit in adapting past solutions (Shiu and Pal, 2004). In general, CBR knowledge management systems make it possible to learn from and leverage past experience in the management of current problems. As there are many situations where we, as humans, use a form of case-based reasoning, we can understand a CBR system's reasoning and explanations, and are able to be convinced of the validity of the solutions we receive from the system. For example, the Federal Emergency Management Agency (FEMA)'s emergency information management system (EIMS) developed by Nautilus Systems facilitates rapid building and maintenance of disaster operations plans, and provides consistent, integrated command (decision support), control (logistics management), and communication (information dissemination) throughout all phases of disaster management. The remote GIS capability provides the ability to support multiple disasters with a central GIS team, conserving scarce resources (nautilus-systems.com). A CBR knowledge management system has the advantage that most of the relevant information for solving a disaster is gathered and stored prior to the disaster using actual cases and lessons learned from previous similar disasters. Lee and Bui (2000) observed that using such a system could have facilitated the Kobe, Japan earthquake disaster response. Learning what actually happened (as made possible by a CBR knowledge management system) is extremely important to improving emergency response performance (Turoff, 2002). Moreover, a CBR knowledge system can minimize stress in disaster response by automating response processes and workflows. A CBR knowledge management system can also aid in the training of disaster response personnel since actual problem cases in the case knowledge base can be used to design realistic training exercises, drills, and simulations (Patton and Flin, 1999; Renaud and Phillips, 2003). A CBR knowledge management system also facilitates information and knowledge sharing since crisis situations require large numbers of individuals to share information without causing information overload (Turoff, 2002). Information sharing is particularly facilitated by using Web/Internet interfaces to CBR knowledge systems as a common infrastructure providing access for disaster response teams distributed across multiple locations (Fischer, 1998).

CONCLUSION

Knowledge management of past disaster case problems using a case-based reasoning knowledge management system can facilitate disaster response and management and enhance the efficiency and effectiveness of constituent agencies and organizations. Catastrophic incidents, such as the terrorist attacks of September 11, 2001, and the recent Hurricane Katrina that struck in October, 2005, have placed new scrutiny on disaster preparedness for public agencies and a host of other organizations. Despite the regularity of natural disasters such as hurricanes, disaster response and management realities still reveal institutional vulnerability and inadequacy of decision models to confront large-scale disasters. Much can be learned from organizations' engagement with disasters because that rare event propels the organization from paper planning, simulation, and drills into actual, real-time responses. Responses to this type of test reveal the overall integrity of disaster management of the various organizational entities. By capturing such experiences in a CBR knowledge management system, respective constituencies can learn lessons about actual challenges to management assumptions about adequate disaster preparedness and response execution and be able to leverage that knowledge for efficient and effective management of future similar disasters. However, it should be borne in mind that knowledge management systems can only provide decision support; people in emergency situations deal with the actual emergency or disaster. As a result, exact actions and responsibilities of individuals cannot be predetermined due to some unforeseen events occurring during the disaster. Roles can be planned but whoever steps into a role at any given moment defies the attempt to prescribe behavior and the crucial problem of the moment drives allocation of resources (Turoff, 2002). Since a knowledge management system that is not used regularly will not be used in an emergency (Turoff, 2002), it is important to train and drill with the CBR knowledge management system on a regular basis to ensure personal can use it and help overcome political and cultural issues in multi-organizational teams (Jennex, 2004).

ACKNOWLEDGEMENTS

I thank Murray Jennex for constructive comments on an earlier version of this paper.

REFERENCES

1. Baum, D. (1992) IS Proves Critical to Hurricane Andrew Relief Effort, *InfoWorld*, 14, 41, 68.
2. Bukowitz, W. R. and Williams, R. L. (1999) *The Knowledge Management Fieldbook*. Pearson: Edinburgh.
3. Cunningham, P. and Bonzano, A. (1999) Knowledge Engineering Issues in Developing a Case-Based Reasoning Application, *Knowledge-Based Systems*, 12, 371-379.
4. Davenport T. H. and Prusak L. (1998) *Working Knowledge*. Harvard Business School Press: Boston, MA.
5. Dostert, M. (1993) FEMA Disaster Recovery System Goes High-Tech, *Computerworld*, 27, 25, 51.
6. Fahey, L. and Prusak, L. (1998) The Eleven Deadliest Sins of Knowledge Management. *California Management Review*, 40 (3), 265-267.
7. Fdez-Riverola, F. and Corchado, J. M. (2004) FSfRT: Forecasting System for Red Tides, *Applied Intelligence*, 21, 251-264.
8. Fischer, H.W. (1998) The Role of New Information Technologies in Emergency Mitigation, Planning, Response, and Recovery. *Disaster Prevention and management*, 7, 1, 28-37.
9. Georgopoulos, B. S. (1986) Organizational Structure, Problem Solving and Effectiveness. San Francisco: Jossey-Bass.
10. Islam, S. and Chowdhury, N. (2001) A Case-Based Windows Graphic Package for the Education and Training of Power System Restoration, *IEEE Transactions on Power Systems*, 16, 2, 181- 187.
11. Jennex, M.E. (2004) Emergency Response Systems: The Utility Y2K Experience. *Journal of Information Technology Theory and Application*, 6 (3), 85-102.
12. Jennex, M.E. (2005) What is Knowledge Management? *International Journal of Knowledge Management*, 1 (4), i-iv.
13. Kolodner, J. (1993) *Case-Based Reasoning*, Morgan Kaufmann: San Mateo, CA.
14. Lee, J. and Bui, T. (2000) A Template-based Methodology for Disaster Management Information System. Proceedings of the 33rd Hawaii International Conference on System Sciences.
15. Leonard-Barton, D. (1995) *Wellsprings of Knowledge*, Harvard Business School Press: Cambridge, MA.
16. Macgill, S. M. and Siu, Y. L. (2004) The Nature of Risk, *Journal of Risk Research*, 7, 3, 315-352.
17. Mulrine, A.; Marek, C.K.; and Querna, B. (2005) Not again (hurricane season, 2005 editorial). *U.S. News & World Report*, 139, 12 (October): 22.
18. March, J. G., and Simon, H. A. (1958) *Organizations*, New York: Wiley and Sons, Inc.
19. Nautilus Systems. Case Study: Emergency Information Management System. (<http://www.nautilus-systems.com/csei.html>).
20. Nonaka, I. and Takeuchi, H. (1995) *The Knowledge Creating Company*. Oxford University Press: New York.
21. Patton, D. and Flin, R. (1999) Disaster Stress: An Emergency Management Perspective. *Disaster Prevention and Management*, 8 (4), 261-267.
22. Penton Media, Inc. (2005) City Protects and Serves Citizens With Emergency Preparedness Solution, *Government Procurement*, 13, 2, 42.
23. Probst, G., Buchel, B. and Raub, S. (1998) Knowledge as A Strategic Resource. In *Knowing in Firms*, von Krogh G, Roos J, Kleine D (eds). Sage: London; 240-252.
24. Renaud, R. and Phillips, S. (2003) Developing an Integrated Emergency Response Programme for Facilities: The Experience of Public Works and Government Services Canada. *Journal of Facilities Management*, 1 (4), 347-363.
25. Riesbeck, C. K. and Schank, R. C. (1989) *Inside Case-Based Reasoning*, Lawrence Erlbaum Ass: Hillsdale.
26. Schank, R. C. (1982) *Dynamic Memory*, Cambridge University Press: Cambridge, UK.
27. Shiu, S. C. K. and Pal, S. K. (2004) Case-Based Reasoning: Concepts, Features and Soft Computing, *Applied Intelligence*, 21, 233-238.
28. Sun, B., Xu, L. D., Pei, X., and Li, H. (2003) Scenario-Based Knowledge Representation in Case-Based Reasoning Systems, *Expert Systems*, 20, 2, 92-99.
29. Turoff, M. (2002) Past and Future Emergency Response Information Systems. *Communications of the ACM*, 45 (4), 29-32.
30. Venzin, M. von Krogh, G. and Roos, J. (1998) Future research into knowledge management. In *Knowing in Firms*, von Krogh G, Roos J, Kleine D (eds). Sage: London; 26-66.
31. von Krogh G, Roos J, Kleine D (eds). 1998. *Knowing in Firms*. Sage: London.