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ABSTRACT

Disasters have the potential to cripple a country and those countries that are particularly susceptible to disasters must have adequate disaster recovery plans in place to ensure that the country can return to normalcy as soon as possible after the disaster. These plans will involve a number of autonomous entities that need to be able to communicate and coordinate their activities effectively. This paper describes how ontologies can be used to support this effective communication and coordination between entities and how they can help to ensure that the disaster recovery plan (DRP) is effective. The applicability of ontologies to DRPs will be demonstrated using a case study of an electric utility company in Jamaica, a country in the hurricane region.

Keywords

Disaster recovery plans, ontology, case study.

INTRODUCTION

Disasters have the potential to inflict extensive damage on a country's society and infrastructure and the longer it takes to return to normalcy following the disaster, the more costly it will be for the country. Hurricanes are one such disaster and a recent National Science Foundation (NSF) press release stated that the number of category 4 and 5 hurricanes has doubled over the past 35 years (NSF, 2005). These categories of hurricanes are the most intense and they have the potential to cause devastation to a country.

The scale of recent disasters highlights the need for a holistic approach to address and plan for them (Joshi, Seker, Bayrak, Ramaswamy and Connelly, 2007), thus, the need for disaster recovery plans (DRPs). The aim of a DRP is to ensure that entities (e.g. organisations, countries) function effectively during and following a disaster (Bryson, Millar, Joseph and Mobolurin, 2002). A well thought out DRP can play a major role in an organization's/country's survival/success (Fallara, 2003). Operationalizing a plan requires the communication and coordination of a number of authorities (e.g. public services, government agencies). In many cases, the poor response to disasters has been blamed on the lack of communication and coordination among these relevant authorities. If these authorities and the communication and coordination that needs to take place between them can be captured in a formal representation (i.e. ontology), it will help with the response time as there is a common point of reference, readily accessible to all. The ontology will also facilitate the use of a common vocabulary, an important consideration when a number of independent entities need to come together to achieve a common goal. Additionally, having a formal representation of a DRP will allow for its automated evaluation (e.g. ensuring consistency) before it is deployed.

Entities have realized the importance of these DRPs and do have them in place. However, few have recognized the role that ontologies can play in improving the effectiveness of the plan. This study will demonstrate how an organizational ontology and a disaster domain ontology can be used in the DRP by examining the existing DRP of an electric utility company in Jamaica, a country in the Caribbean that is faced with the annual threat of hurricanes.

The following section describes the disaster planning and ontology literature and the limited research on applying ontologies to DRP. A description of the case study of the electric utility company in Jamaica will follow. The applicability of ontologies for DRP in this domain will then be described and finally there will be some concluding remarks and suggestions for future directions for this research.

LITERATURE REVIEW

Disaster Recovery Planning

A disaster recovery plan (DRP) focuses on ensuring the speedy restoration of services for critical organizational processes in the event that there are operational failures due to natural or man-made disasters. A DRP aims to minimize potential loss by identifying, prioritizing and safeguarding those organizational assets that are most valuable and that need the most protection (Bryson et al., 2002). The plan must be a comprehensive statement of consistent actions to be taken before, during and after a disaster. The contents of the plan should follow a logical sequence and be written in a standard and understandable format (Wold, 2002). Bryson et al. (2002) identified four properties that could be used to evaluate the DRP namely feasibility, consistency, completeness and reliability. Feasibility refers to the availability of the resources required for the DRP. Completeness addresses the issue of whether or not the DRP covers all the important organizational resources that need to be protected in the event of a disaster. The consistency property ensures that the plan, as a whole, is consistent. Because the plan involves a number of stakeholders each with their own set of requirements in terms of what the plan must cover care must be taken to ensure that the same set of resources are not being allocated to different activities at the same time. Reliability measures the likelihood of the plan achieving its objectives. Developing an ontology for DRP will allow existing techniques for measuring the consistency and completeness of ontologies to be applied to the evaluation of the DRP.

Disaster operations management is multi-organizational and the fact that these organizations are only loosely connected increases the possibility of managerial confusions and ambiguity of authority (Altay and Green, 2006). Altay and Green (2006) identify the need for the OR/MS research community to focus on disaster management. They contend that most of the research in this area is related to social sciences and that operations research has significant application to the management of disaster preparedness programs.

Ontologies

Ontologies provide a formal description of a domain which can be shared among different applications and expressed in a language that can be used for reasoning (Noy, 2004). This formal representation facilitates the automation of the process of checking the consistency of the disaster recovery plan. In order to formally describe the domain of discourse and provide some mechanism for reasoning, an appropriate knowledge representation language must be selected to formally represent the ontology. Two such languages that have been proposed are first order logic (Fox and Gruninger, 1998) and sorted logic (Kaneiwa and Mizoguchi, 2004).

Ontologies have been identified as important components of a number of information systems (Guarino, 1998; Pinto and Martins, 2004) such as knowledge management systems (KMS) (Rao and Osei-Bryson, 2007; Sicilia, Lytras, Rodriguez and Garcia-Barriocanal, 2006). As ontologies become more prevalent in information systems, ensuring their quality is an important consideration in the development of the systems of which they are a part. Quality is a multi-dimensional concept, and, in order to assess the quality of the ontology, a set of quality dimensions must be defined. Two such quality dimensions are coverage/completeness and consistency (Jarke, Jeusfeld, Quix and Vassiliadis, 1999). Consistency has been defined as the consistency of the meaning of concepts, relationships and business rules used in the ontology while coverage has been defined as the extent to which the ontology covers the domain of interest (Rao and Osei-Bryson, 2007). Techniques for ontology development should seek to ensure that the ontology has a high level of coverage (Rao, Reichgelt and Osei-Bryson, forthcoming) and consistency.

An enterprise (organizational) model is a computational representation of the structure, activities, processes, information, resources, people, behaviour, goals, and constraints of a business, government, or other enterprise (Fox, Barbuceanu, Gruninger and Lin, 1998). These enterprise models are the core of the information infrastructure of the organization. Sharma & Osei-Bryson (2008) extended the organizational ontology proposed by Fox et al. (1998) to include additional concepts and relationships such as business processes and various types of resources (Sharma and Osei-Bryson, 2008).

Rao et al. (forthcoming) describe an approach to the development, representation and evaluation of formal ontologies with the explicit aim of developing a set of techniques that will improve the coverage of the ontology, and thus its overall quality. The initial ontological structure to identify the terminology of the ontology is developed using a hybrid approach that combines the information from existing literature on organizational ontologies with the information obtained by using the laddering knowledge elicitation technique (Rao et al., forthcoming).

Ontologies for DRP

The use of an ontology would help to address the ambiguity and communication problems that may arise when loosely connected organizations are required to work together. Ontologies are typically viewed as presenting a shared understanding of some domain of interest, which is often conceived as a set of classes (concepts), relations, functions, axioms and instances (Noy and McGuinness, 2001). Noy and McGuinness (2001) argue that developing an ontology to make domain assumptions explicit offers several benefits, these include permitting the sharing of a common understanding of the structure of information among stakeholders in a discipline, facilitating more effective communication and idea-sharing and generally supporting the analysis of domain knowledge. These benefits are extremely relevant to DRP as they can help to reduce the possibility of confusion and ambiguity caused when different groups of stakeholders have to come together and share information to make decisions (Altay and Green, 2006).

Some research has addressed the development of systems for DRP and the application of ontologies to DRP (Joshi et al., 2007; Little, 2003; Mecella, Angelaccio, Krek, Catarci, Buttarazzi and Dustdar, 2006). Joshi et al. (2007) propose an ontology-based approach for disaster mitigation. They argue that their approach allows for the seamless integration and management of heterogeneous, multi-lateral data from different local, state as well as federal agencies. They demonstrate the integration of various sub-ontologies, using an overly simplified example in which the ontologies are primarily hierarchical. To detect inconsistencies, a hierarchical representation for a DRP will be inadequate. Little (2003) proposes a general methodology for ontology construction and demonstrates its applicability using the Disaster-Response Ontology (Dis-ReO) Research Project which is aimed at constructing an ontology for earthquake disaster response.

Mecella et al. (2006) describe the main results of a research project (WORKPAD) aimed at building and developing an innovative software infrastructure (software, models, services, etc.) to support the collaborative work of human operators in emergency/disaster scenarios. They stress that in such scenarios different teams, belonging to different organizations, need to collaborate with each other to reach a common goal.

CASE STUDY

Jamaica is faced with the annual threat of hurricanes and the activity during the hurricane season has been increasing, especially in the more dangerous 3, 4 and 5 categories (see Figure 1) (http://stormcarib.com). The damage that a category 3-5 hurricane can cause on a small island is colossal. Therefore, it is imperative that there are DRPs in place at all levels (i.e. organizational and national).

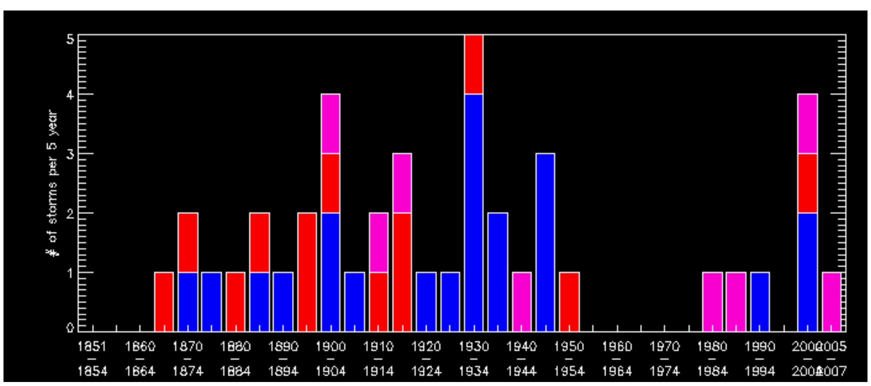

Figure 1. Hurricane Activity for the Period 1851- 2007
category 3-5 hurricanes: purple; category 1-2: red; tropical storms: blue

An electric utility company is one of those organizations most integral to the restoration of normalcy after a disaster. Therefore, the recovery of the country is highly dependent on the ability of these organizations to recover from the disaster as quickly as possible. Additionally, there is the potential for an increase in criminal activity while the power is out and this can cause havoc in a country that is already feeling the effects of a natural disaster. Having an effective DRP in place will help the electric utility companies to recover as quickly as possible.

In 2004 a deadly category 4 hurricane named Ivan with winds packing 140 mph threatened to hit Jamaica but at the last moment passed just south of it. Nevertheless its effects on the country were still substantial. After the passing of the hurricane, the electric utility company did a damage assessment on the transmission and distribution of power. In terms of restoration, the company performed creditably (see Figure 2) and in January 2005 it received the "Emergency Response Award" from the US-based Edison Electric Institute (EEI) in recognition of its outstanding work in restoring electricity to customers in the wake of Hurricane Ivan.

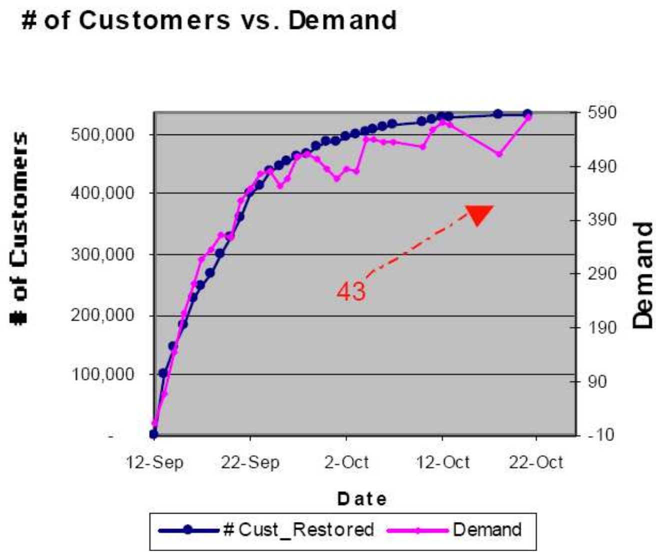

Figure 2. Performance of Electric Utility Company after Ivan

Based on the experience of Hurricane Ivan, the utility company identified the areas in which they performed credibility as well as those in which there were improvement opportunities. From this they defined some key supporting activities that needed to be performed for recovery management. They grouped these activities based on the time at which they should take (i.e. those activities that should be performed at the start of the hurricane season, 12 hours prior to the passage of the hurricane, during the passage, 48 hours after the passing, during the restoration phase and during the post mortem phase) (see figure 3).

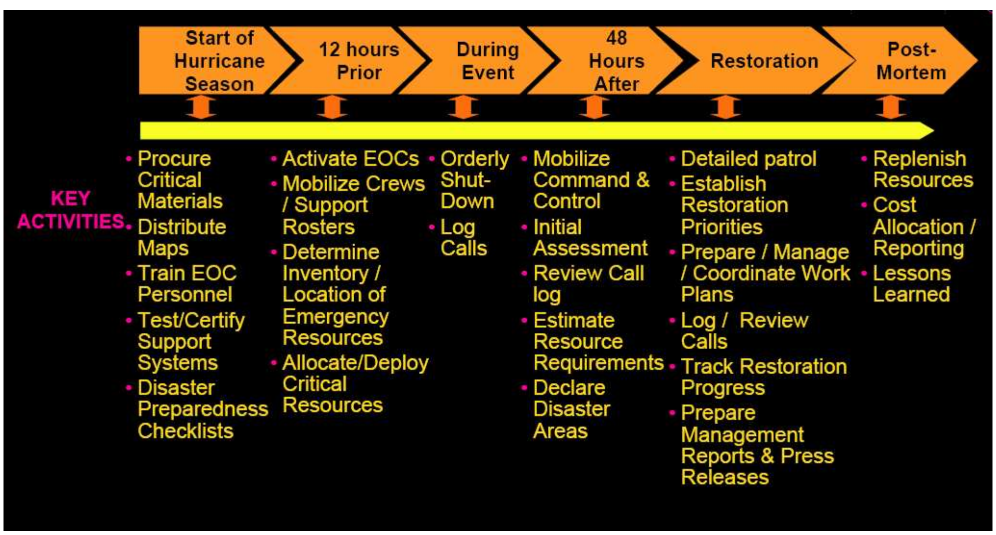

Figure 3. Key Supporting Activities of Recovery Management for the Electric Utility Company

The utility company found that these activities were heavily dependent on the availability and accessibility of information and therefore it faced an extreme information processing challenge. Most of the key activities required information gathering, information processing and decision-making and dissemination. There was a need for (i) intensive vertical and horizontal coordination of many organizational units and resources (e.g. finance, materials management, transmission and distributions operations, customer service/call centre, public relations and generation) and (ii) asset management (i.e. the management of customers, systems, materials, vehicles and people) both of which are highly information intensive. Thus the company identified the information requirements for these various activities (e.g. at the start of the hurricane season material and inventory locations need to be determined while 12 hours prior to the estimated passage of the hurricane the availability and location of emergency vehicles need to be determined) (see figure 4).

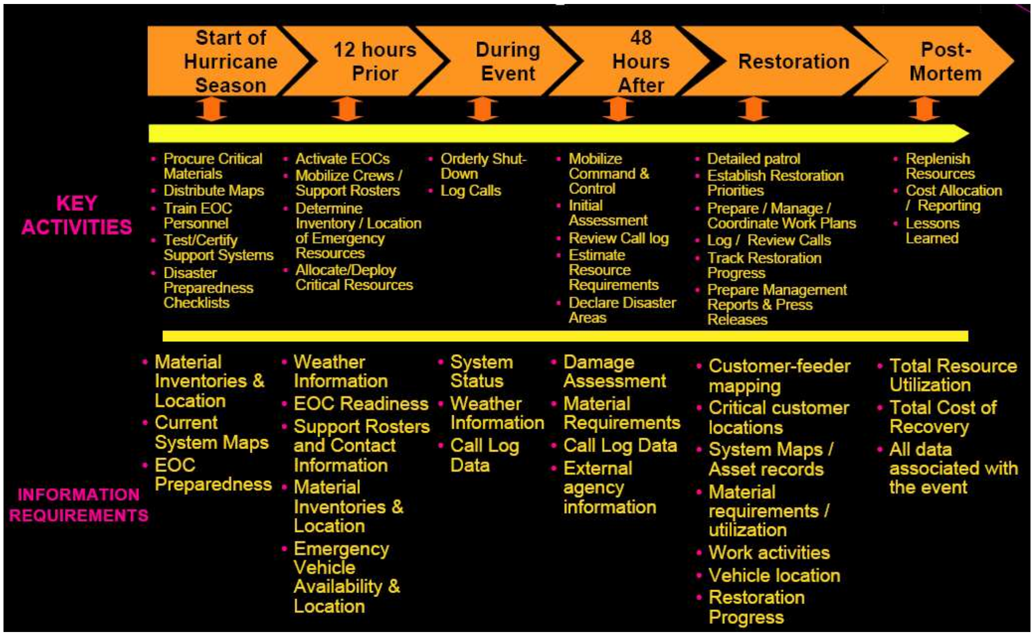

Figure 4. Information Requirements for Recovery Management

A recovery management decision support system (DSS) was proposed to provide support for the information needed to support the key activities of the utility company. The functional requirements of this system included:

- Material requirements, availability and logistics
- Emergency vehicle availability, location and utilization
- Status and response to critical loads
- Restoration planning and prioritization
- Local execution and central aggregation of disaster assessment
- Information support for internal and external reporting

Finally, the utility company also identified other possible relevant components of a decision support system. These included: GIS layers to the data, a knowledge base, a model base, and collaborative and analytic support for national planning agencies (e.g. security forces, National Works Agency (NWA), Office of Disaster Preparedness and Emergency Planning (ODPEM), utilities). The knowledge base would facilitate, for example, best practices while the model base would facilitate, for example, constrained optimization models for vehicle and materials logistics.

From these requirements a possible architecture for this DSS system was proposed (see figure 5).

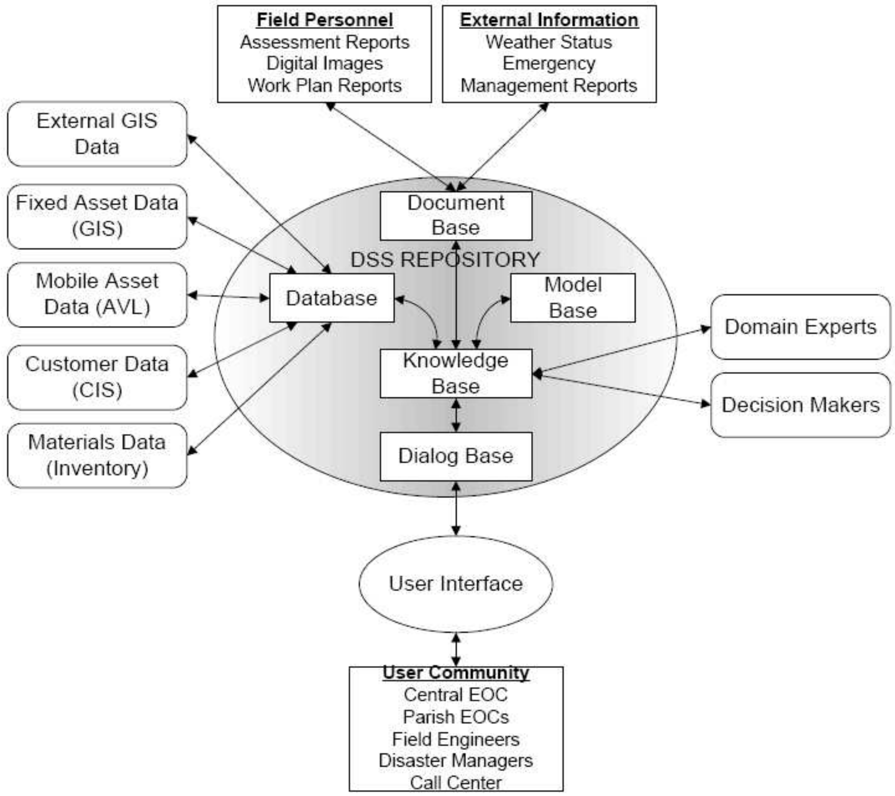

Figure 5. DSS Architecture for Electric Utility Company

ASSESSMENT OF CASE STUDY – THE ROLE OF AN ONTOLOGY FOR DRP

The proposed DSS architecture for the electric utility company (see Figure 5) was derived based on the modelers' understanding of the functional requirements of a DSS for Disaster Recovery. It could benefit from the use of formal ontologies. The proposed DSS architecture could be extended to include both an organizational ontology (see Figure 6) and disaster domain ontology (see Figure 7). These ontologies can be used to ensure that the set of functional requirements is as complete as possible. They describe the important concepts and relations of the organization and the disaster domain, therefore it is more likely that the functional requirements of the system are complete if they are derived from these ontologies. For example, if the disaster recovery plan represents that it is important to know the location of resources then the DSS must have a component to support this.

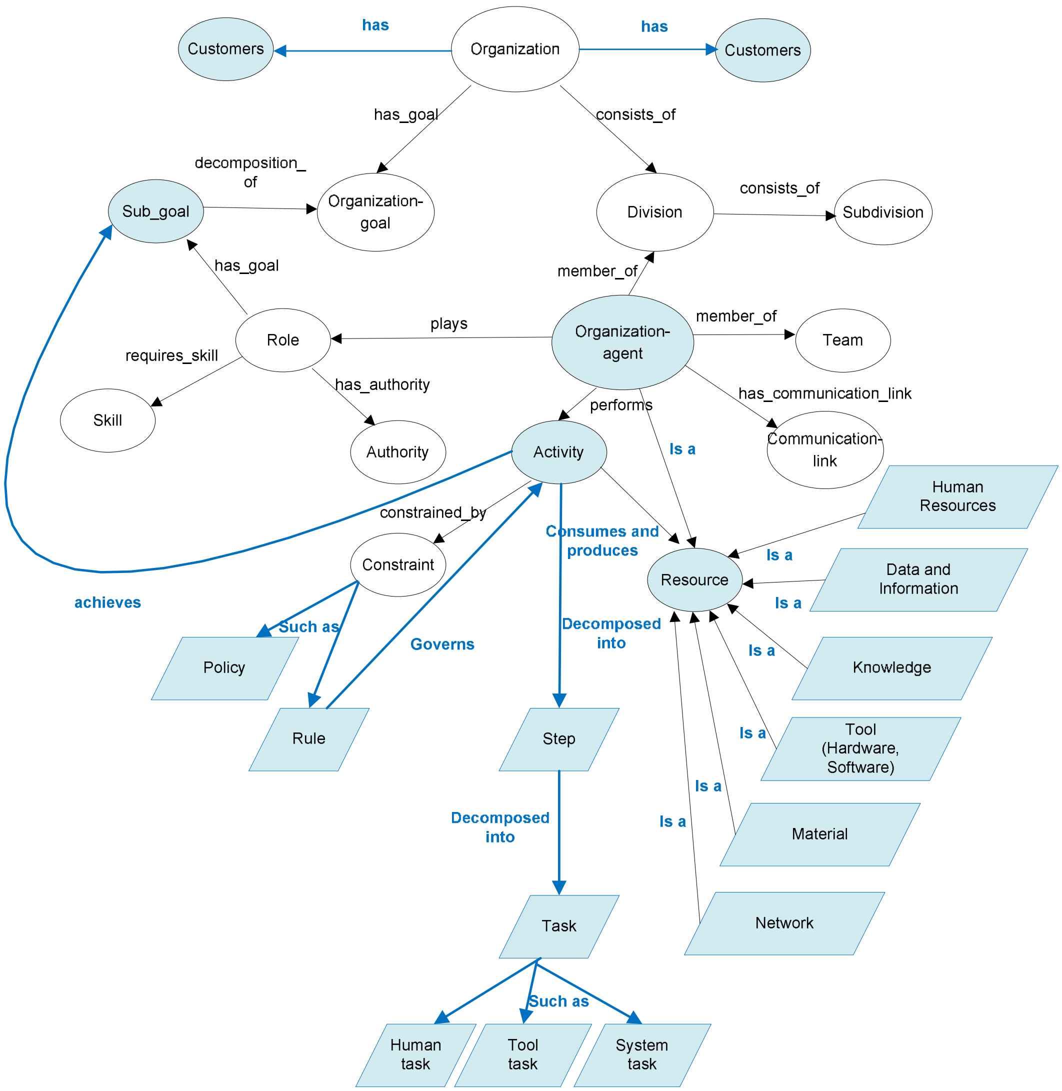

Figure 6. An Organizational Ontology

The disaster domain ontology can be used to formally define the DRP, to develop models for testing the quality of the DRP (using techniques that exist for testing the quality of ontologies) (Rao et al., forthcoming) and can also be used to share DRP between organizations. This ontology facilitates the sharing of DRP between organizations as it provides a reference point for a common vocabulary for all organizations to use in the development and understanding of plans. Thus, if it is accepted that the ontology represents a common language for disaster recovery, then everyone should conform to this language. This sharing of disaster domain ontologies is important, especially for smaller organizations that do not have the resources to develop the DRP on their own.

The organizational ontology provides the means to understand the connection between organizational goals and activities, resources and actors (e.g. domain experts, decision makers). It could be used to support the development of the disaster domain ontology and the DRP as it facilitates the identification of activities and resources that are to be the target of the DRP. It also helps the developers of the plans to identify the agents who should be involved in the plans' development based on their roles and the activities they are carrying out and thus will help to identify those resources and activities that are critical to the organization and which must be protected at all costs. For example, the organizational ontology shows the various resources of the organization and this information can be used to identify the target and solution resources that should be accommodated in the disaster domain ontology (see Figure 7). Additionally, the organizational ontology represents those activities for which the resources are being used and the sub-goals and organizational goals achieved by these activities. Thus the relative importance of each resource can be ascertained which is important to the DRP when the protection of resources must be prioritized.

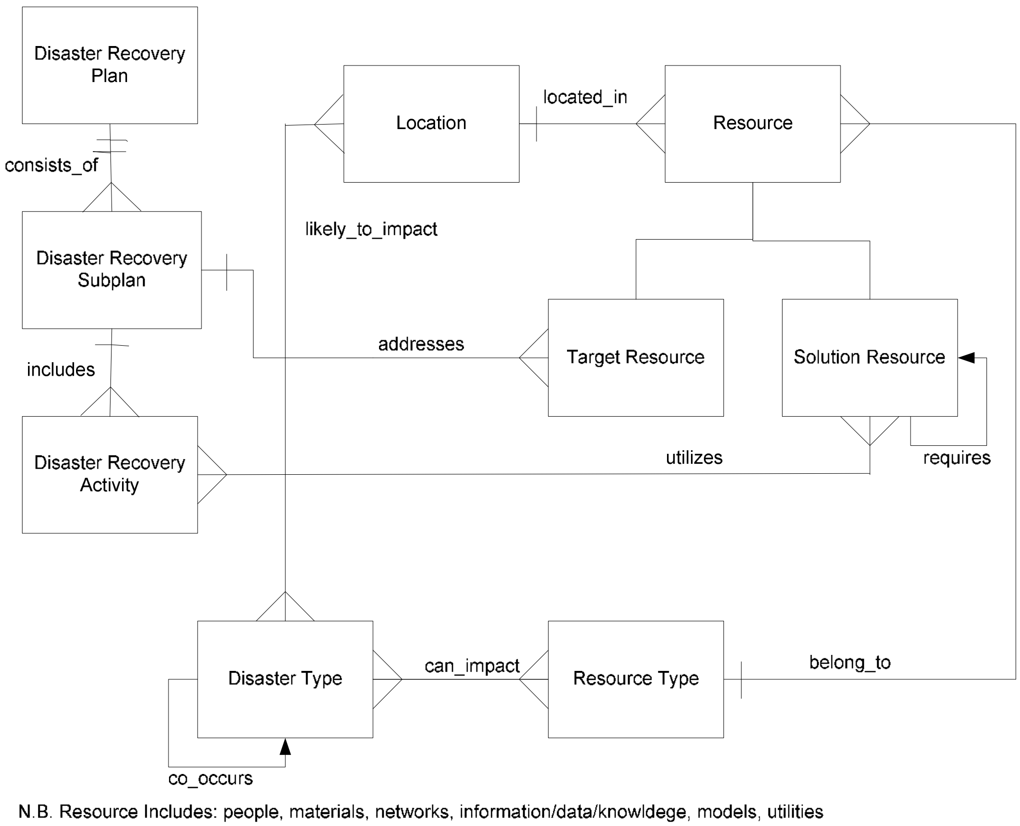

Figure 7. A Disaster Domain Ontology

Another important benefit provided by the ontologies is the reduction of communication and ambiguity problems that can arise when multiple groups of stakeholders came together to develop holistic solutions to problems. The organizational and disaster domain ontologies can facilitate the identification of relevant stakeholders. From the proposed architecture in Figure 5 it is clear that the electric utility company requires a number of user communities to come together to share information (e.g. disaster managers, field engineers, emergency operations centers). Even within the company there is a need for intense vertical and horizontal co-ordination of many organizational units and resources (e.g. finance, materials management, transmission and distributions operations, customer service/call centre, public relations and generation). Additionally, the data for the system is being taken from a number of sources (e.g. external sources, field personnel) and therefore are likely to be heterogeneous. Both the holistic approach and the integration of disparate data require a consistent vocabulary. The ontology will answer this need for a common language as it provides a formal description of a domain which will permit the sharing of a common understanding of the structure of information among the stakeholders and so facilitate more effective communication and idea-sharing and generally supporting the analysis of domain knowledge.

The benefits that the ontologies can provide will only be realized if these ontologies are of a high quality. Therefore, when developing the organizational and disaster domain ontologies, techniques that will improve the quality of the ontology will be used (Rao et al., forthcoming).

One of the issues that did not arise in the case study discussion is the evaluation of the DRP. If an organization does not adequately evaluate its DRP before the occurrence of a disaster, the consequences could be catastrophic as was the case in New Orleans following the passage of Hurricane Katrina. Therefore the plan must be evaluated before deployment and using a high quality, disaster domain ontology can be beneficial in this process. As illustrated in Figure 3, as part of the plan the organization needs to create disaster preparedness checklists and it needs to ensure that these checklists cover all aspects of the domain. If the level of coverage of the disaster domain ontology is high and the DRP is based on this ontology, it is probable that the completeness of the DRP will in turn be high (Bryson et al., 2002).

Another activity that the DSS needs to support is the allocation of resources and preparation, management and coordination of work plans. The disaster domain ontology can be used to ensure that these plans are consistent. For example, if, based on the severity of damage after a hurricane, it would appear that a particular area should be given priority and that vehicles should be allocated to those areas but the routes to those areas are impassible then the plan would be inconsistent. If this information is represented in a formal ontology, these inconsistencies can be automatically detected. Thus, if the consistency of the disaster domain ontology is high (Rao and Osei-Bryson, 2007) then, again, it is probable that the consistency of the DRP will be high (Bryson et al., 2002).

CONCLUSION

This paper has demonstrated the importance of an ontology for DRP and for any system architecture that supports DRP, in particular for electric utility company in Jamaica, an island facing the annual threat of hurricanes. These plans specify the tasks that are to be performed in the event of a threat of a hurricane. These tasks require certain resources but at the same time the disaster can also affect the availability of these resources. Having information readily available in a formal ontology and being able to automate the process of reasoning with this information will make it possible to identify inconsistencies in these plans. If, for example, the disaster recovery plan specifies that a task be performed that requires a resource and that resource is affected by the disaster, the plan would be inconsistent and would need to be modified. Thus, the ontology facilitates the evaluation of plans.

Although, through the case study, the usefulness of an ontology for DRP in a particular domain in a particular region has been clearly demonstrated, it would be beneficial to test the applicability of this research to other domains and countries. In the future, the formal ontology for this domain will be developed so that it can be integrated into a disaster management system.

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