

Handling Emergency Management in Object Oriented Modelling Environment

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Abstract. It has been understood that protection of a nation from extreme disasters is a challenging task. Impacts of extreme disasters on a nation's critical infrastructures, economy and society could be devastating. A protection plan itself would not be sufficient when a disaster strikes. Hence, there is a need for a holistic approach to establish more resilient infrastructures to withstand extreme disasters. A resilient infrastructure can be defined as a system or facility that is able to withstand damage, but if affected, can be readily and cost-effectively restored. The key issue to establish resilient infrastructures is to incorporate existing protection plans with comprehensive preparedness actions to respond, recover and restore as quickly as possible, and to minimize extreme disaster impacts. Although national organizations will respond to a disaster, extreme disasters need to be handled mostly by local emergency management departments. Since emergency management departments have to deal with complex systems, they have to have a manageable plan and efficient organizational structures to coordinate all these systems. A strong organizational structure is the key in responding fast before and during disasters, and recovering quickly after disasters. In this study, the entire emergency management is viewed as an enterprise and modelled through enterprise management approach. Managing an enterprise or a large complex system is a very challenging task. It is critical for an enterprise to respond to challenges in a timely manner with quick decision making. This study addresses the problem of handling emergency management at regional level in an object oriented modelling environment developed by use of TopEase® software. Emergency Operation Plan of the City of Hampton, Virginia, has been incorporated into TopEase® for analysis. The methodology used in this study has been supported by a case study on critical infrastructure resiliency in Hampton Roads.

I. INTRODUCTION

Hampton Roads consists of sixteen city and county jurisdictions, and is home to 1.6 million people (the fifth largest metro area in the south eastern U.S. and the second largest metro area between Washington, D.C. and Atlanta). Hampton Roads is very critical for national security both militarily and economically, because it has the largest complex of military bases in the world and the second-largest port on the Atlantic coast, and it is the site of the world's largest shipbuilder of combat vessels. Hampton Roads is low-lying and thus prone to flooding, is vulnerable to the effects of hurricanes and occasionally tornadoes, and is a likely target for terrorist attacks. It is obvious that protection plans are not enough after a disaster strikes to the region. Thus, there is a need for a holistic approach to establish more resilient infrastructures to withstand extreme disasters. A resilient infrastructure can be defined as a component, system or facility that is able to withstand damage or disruption, but if affected, can be readily and cost-effectively restored. The key issue to achieve this is to

incorporate existing protection plans with comprehensive preparedness actions to respond, recover and restore as quickly as possible, and to minimize extreme disaster impacts [1]. Therefore, Critical Infrastructure Resilience of Hampton Roads Region (CIRHRR) project, which was funded by Department of Homeland Security, has been done to analyze the regional resiliency in terms of four critical infrastructures; namely electricity, transportation, communications and water sectors. Service interruption of any one or more of these interdependent infrastructures due to various threats could be catastrophic not only for the region but also for the entire nation.

Extreme disasters, both natural and manmade, must be handled by each city's emergency management departments. It is important to have a manageable plan which is prepared by emergency management departments before disasters. Since emergency management departments have to deal with other complex and large scale systems such as plant managements, public utilities, fire department and police

department, they have to have efficient and effective organizational structures to coordinate all these systems. A strong organizational structure is the key in responding fast before and during disasters, and recovering quickly after disasters. In order to establish strong emergency management and organizational structures for cities, an enterprise management approach can be useful. Managing an enterprise or large complex system is a very challenging task because of rapid technological changes, complex economic dynamics and adaptation to new markets, trends and opportunities. It is critical for enterprises to respond to these challenges in a timely manner with quick decision making. TopEase® is a software tool which provides managers the necessary critical information on an enterprise itself to visualize a holistic picture of a complex system such as an emergency service providing enterprise [2]. TopEase® has been developed by a Swiss Company, Pulinco Engineering AG, to provide a methodology for a holistic view of a system to manage its complexity, to get transparency, and to control the change and/or transformation processes for continuous improvement and success. It is designed to handle “business processes” and provides a desirable end state of an enterprise, business or application while highlighting the gap between the current “as is” and desired “to be” states. Therefore, an approach based on TopEase® has been used in the CIRHRR project. The goal of this application was to show that emergency management operations can be handled as enterprise management processes. In order to achieve this goal, Emergency Operation Plan (EOP) of the City of Hampton, Virginia has been implemented into TopEase®. In this paper, some examples and TopEase® implementation process are presented. TopEase® models emergency management at regional level in an object oriented environment. Hence, Object Oriented Programming (OOP) will be briefly explained in the next section.

II. OBJECT ORIENTED PROGRAMMING

“Objects” are used to design applications and computer programs in OOP. OOP can use several concepts or techniques from previously established paradigms such as inheritance, modularity, polymorphism or encapsulation. These concepts give support to the development of efficient class structures. The aim of OOP is to approximate the behaviour of real world elements within software environment [3]. In OOP, each object

is capable of receiving messages, processing data and sending messages to other objects. Each object can be viewed as an independent unit with a distinct role or responsibility. Some of the key concepts of OOP are described next:

Class defines the abstract characteristics of a thing (its attributes or properties) and the things it can do (its behavior).

Object is a particular instance of a class, and is a software package that includes all the necessary data and procedures to represent a real world object for a specific set of purposes.

Message Passing signifies the objects interacting with each other by sending requests for services known as messages.

Encapsulation is the mechanism by which related data and procedures are bound together within an object. It conceals the exact details of how a particular class works from objects that use its code or send messages to it.

Polymorphism is the behavior that varies depending on the class in which the behavior is invoked, that is, two or more classes can react differently to the same message. The power of polymorphism is that it greatly simplifies the logic of programs by shortening and increasing the execution speed.

Inheritance is the mechanism that allows classes to be defined as special cases, or *subclasses*, of each other [2], [4].

The approach used by TopEase® is explained in the next section.

III. TOPEASE® SOFTWARE AND ITS APPROACH

TopEase®, which has been used for more than 20 years as a *business application* tool, aims to provide solutions to the problems of variety of sectors such as economic, health and law enforcement. TopEase® helps manage the complexity of a system, see the holistic aspects of a system and control its processes at every step to achieve continuous improvements in the system. The idea behind developing this software was to establish balance between principles and pragmatism. TopEase® uses 1-3-5-7 axioms to achieve solutions for businesses (Figure 1).

1 methodology provides a common understanding based on an established terminology. TopEase® uses a single methodology, which pursues principals in a pragmatic and balanced manner to accomplish its targets.

3 layers assist in obtaining a target audience related business structure. 3 layers are named as definition, support and implementation layers.

5 models provide a system to be modelled, documented and elaborated. The system may be validated through value chains and questions, if all artifacts are modelled appropriately. 5 models are named as business, resource, information, delivery and change models.

7 questions help analyze and interpret connections between 3 layers and 5 models. It is important to ask 7 significant questions to determine interrelationships among nodes which are constructed models. These questions are about cost, benefit, risk, quality, feasibility [produce (how)], manageability [people (who)] and impact.

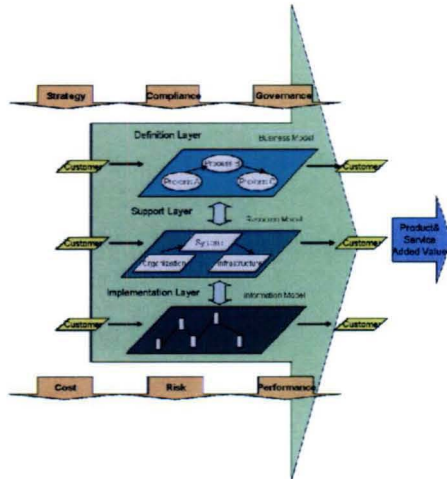


Figure 1: 1-3-5-7 approach used by TopEase® [2]

Problem definition and methodology used in the CIRHRR project are presented in the next section.

IV. PROBLEM DEFINITION AND METHODOLOGY

A. Critical Infrastructure Resilience of Hampton Roads Region Project

In order to enhance regional security and resiliency of Hampton Roads, a complex set of management and policy issues are required to be addressed. Diverse local jurisdictions and the range of federal, commonwealth and private facilities serving the region complicate the analysis and coordination of regional security and reliability. In order to establish a regional disaster mitigation, response and

recovery plan for Hampton Roads, there is a need for an integrated regional model for all branches of jurisdictions and private facilities involved. Facilities in all jurisdictions, relationships among them and their dependencies on private facilities have been analyzed to determine response and recovery capabilities of these jurisdictions during emergency situations.

B. Hampton City Emergency Model

Hampton Roads has unique characteristics as a region. Existence of multiple jurisdictions, privately owned utility companies and military facilities require an analytical solution through the application of the system of system technology. This seems to be adequate for addressing issues of emergency situations. In order to analyze the current state of emergency plan, the EOP of the City of Hampton has been implemented into TopEase® as part of the CIRHRR project. Critical infrastructures have been modelled as layers (Figure 2). Functions of these integrated critical infrastructures and emergency operations against different threats are cross cutting issues as can be seen in Figure 3. The purpose of this study was to put the EOP of the City of Hampton in a single model to see the interdependencies among critical infrastructures.

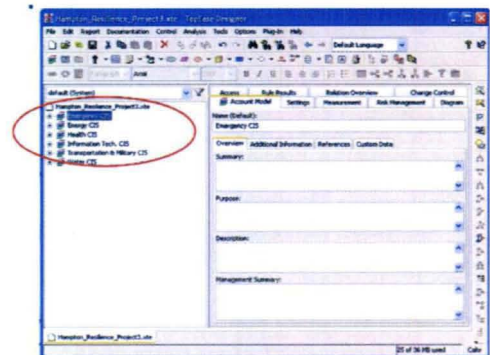


Figure 2: Critical infrastructures as layers

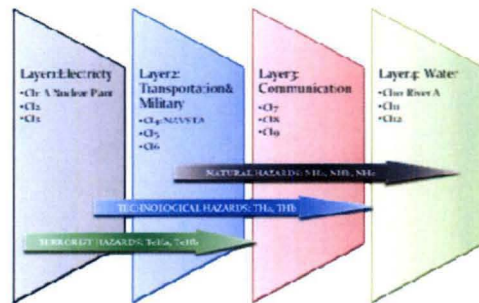


Figure 3: Critical infrastructures and threats associated with them

As the first step, the organizational chart of Hampton City Management has been incorporated into TopEase® RACI (Responsible, Accountable, Concerned and Informed) matrix as detailed as in the EOP of the City of Hampton. The RACI matrix evaluates and maps the characteristics and responsibilities of various positions in the organizational chart. Hence, RACI helps mapping of all artifacts which allow describing and analyzing the entire organizational mapping, influence, and most importantly, interdependencies. Part of the RACI matrix output can be seen in Figure 4.

Figure 4: Example of the RACI matrix output

Processes including detailed activities, lifecycle of emergency operations and their activities from origination to termination have been adapted directly from the EOP of the City of Hampton. Since full representation is impossible, partial representation of processes and activities along with assigned people, jobs and roles are visualized in Figure 5. TopEase® can be used to generate charts and diagrams that show complex and interconnected components of a system.

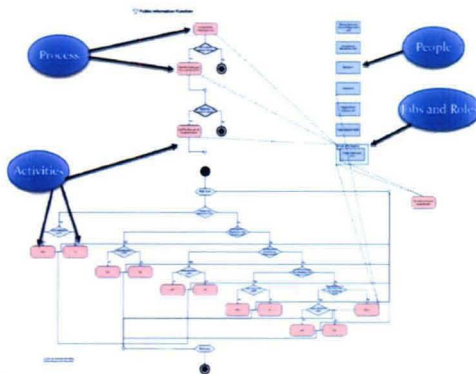


Figure 5: Visualization of processes, activities and roles

Risk catalogue function of TopEase® can handle all kinds of risk to the system. Risk is

defined in TopEase® by two parameters which are impact and likelihood. Categories of impact and likelihood are given in Tables 1 and 2, respectively. In our study, risk of having a disaster can be assigned to any operation or critical infrastructure to calculate the total risk of that disaster. This assigned risk can be represented in different ways such as using a risk matrix or interdependency diagram. For instance, likelihoods of having different types of disasters versus impacts of these disasters on a nuclear power plant are visualized as a risk map in Figure 6.

Table 1: Likelihood ranking categories

General	Frequency of Reoccurring Events	Probability of a One-off Event
Improbable	Once every 10,000 years	1 in 1,000
Remote	Once every 1,000 years	1 in 100
Occasional	Once every 100 years	1 in 10
Probable	Once every 10 years	More likely than not
Frequent	Once every year	Almost certain

Table 2: Impact severity categories

Descriptive	Safety	Security
Minor	Minor injuries	Minor breach regulations
Moderate	Major injuries	Reportable breach of regulations
Significant	Single fatality	Prosecution
Substantial	Multiple fatalities (tens)	
Mega	Multiple fatalities (hundreds)	

V. CONCLUSION

As part of our efforts to obtain a holistic view of the EOP of the City of Hampton, this plan has been incorporated into TopEase® as a single model. TopEase® was developed for "business process" solutions based on OOP paradigm. The main idea behind implementing the EOP into TopEase® was to approach emergency management operations as a "business process" and to define critical

infrastructures as different layers in a single model. Other functions of TopEase® have also been used in the model in order to incorporate every detail of the EOP into a single model. For example, definitions in the EOP have been incorporated into the model via a glossary function. References and laws have also been included in the model. In addition, governmental partners like FEMA that are outside system boundaries have been identified and incorporated into the model as external agents. These functions altogether will provide ways of understanding the effects of interdependencies for determining vulnerable parts of the system.

As a future study, EOPs of other jurisdictions could be modeled to be able to make comparisons among jurisdictions to see their interdependencies. Such an analysis will provide the opportunity to evaluate vulnerable points of jurisdictions and to give decision makers an idea to use limited resources effectively. In addition, TopEase® has “as-is” and “to-be” functions which will be useful for comparative analysis and for coordinating the transition between “as-is” and “to-be” states.

As part of future study, impact analysis feature of TopEase® could be used to identify vulnerable points of critical infrastructures. It is possible to develop different threat scenarios in TopEase® to see how the system reacts under stress. As a powerful feature, any changes in an enterprise such as changes in system parameters, or presence or absence of a process can be tracked by the impact analysis. It is possible to analyze how an unexpected failure in part of a critical infrastructure can affect other infrastructures by using the impact analysis. This type of analysis can help emergency managers see all possible interdependencies among critical infrastructures.

Likelihood \ Impact	Very low	Low	Medium	High	Very High
Very high					
High	A nuclear plant Earthquake	A nuclear plant Cyber attack	A nuclear plant Hurricane		
Medium		A nuclear plant Industrial ac.			
Low					
Very low					

Figure 6: Risk map for a nuclear power plant

VI. REFERENCES

1. Scalingi, P. L., "Moving beyond Critical Infrastructure Protection to Disaster Resilience," *Critical Thinking: Moving from Infrastructure Protection to Infrastructure Resilience, CIP Program Discussion Paper Series*, George Mason University, 2007.
2. Pulfer, R. & Schmid, U. (2006) "Control Your Business: The Balance between Principles and Pragmatism," Pulinco Engineering AG.
3. Agostini M.N., Decker, I.C, & Silveira e Silva, A. (2007) "A new approach for the design of electric power system software using object oriented modeling," *Electrical Power and Energy Systems*, vol. 29, pp. 505–513.
4. Gossain, S. & Anderson, D. B. (1999) "An object oriented approach to VLSI routing," *IEE Colloquium on Applications of OOP*, pp.6/1-6/4.