The Role of GIS in Modeling
Critical Infrastructure Interdependencies:
A Case Study at UBC

Cervantes-Larios Alejandro[1], Klinkenberg Brian[2]

1 MSc Student, Geography, University of British Columbia, larios@geog.ubc.ca
2 Associate Professor, Geography, University of British Columbia, brian@geog.ubc.ca

Abstract

In this presentation we will report on research conducted as part of the Joint Infrastructure Interdependencies Research Programme (JIIRP) at the University of British Columbia. The JIIRP at UBC is an interdisciplinary project that aims at studying the complex relationships between infrastructure networks and the way these behave before and during situations of large scale emergencies. In this presentation we explore the nature of the different types of relationships that exist between infrastructure networks. Particularly, we focus on the physical and geographical dependencies. We identify the different methodologies used to classify infrastructure dependencies, and the tools that can be used to analyse these. Focusing on the effect that an earthquake scenario would have on UBC's infrastructure, we illustrate the geographical, physical and human dependencies that can be modeled by constructing an Infrastructure Geographic Information System.

Background and Relevance

The study of critical infrastructures and the interdependencies among them in the context of an emergency situation has become a priority for many countries, including Canada, in the past few years. Governments, universities, and private companies all over the world are spending huge amounts of money and effort trying to better understand how infrastructures and humans react in the time stages before, during, and after a disruptive event. Analyzing complex systems such as those formed by infrastructure networks and decision makers is not a simple task and requires a multidisciplinary holistic approach. The field of research in infrastructure interdependencies is fairly new, and lies in the intersection of areas of knowledge such as emergency management, geography, simulation modeling, planning & safety engineering.

Interdependencies are not static elements of a system, they are dynamic relationships between objects or between objects and humans (Rinaldi, 2001 ;Robinson, 1998). They can change depending on the status of the whole system, in other words, they can change depending on the phase of the emergency cycle in which the system is (Rinaldi, 2004). As the behaviour of infrastructures and the roles of the decision makers change according to the stage in the emergency management cycle, it is not until the moment of a crisis that most of the organizational (human) interdependencies emerge. It would therefore seem contradictory to try to model emergent behaviour if its defining characteristic is that it is unexpected or unpredictable.

We believe, however, that a great number of these emergent behaviours are a consequence of the relationships between the different infrastructures and the people in charge of making decisions during an event that perturbs the natural state of things. By studying the nature of the relationships between interconnected infrastructures and the way these operate at different stress moments, we can come closer to picture what could fail or what should be the subject of attention given a specific disruptive event.

Methods and Data

To demonstrate the types of infrastructure interdependencies that can be modeled with a Geographic Information System, we constructed an Infrastructure GIS (I-GIS) of the UBC campus. Putting together, updating, and standardizing the data was a long and laborious process that we will not address here. The construction of the I-GIS and its interaction with other systems developed within the JIIRP-UBC group allowed us to illustrate the different types of infrastructure dependencies. In this presentation we explain the different approaches to the construction of an I-GIS and describe their observed consequences.

Results

There are two approaches that can be taken when studying the interdependencies between infrastructure networks:
- A top down or integrated approach in which various infrastructure networks are modeled in the same system.
- A bottom-up or coupled approach in which the internal structure of an individual infrastructure system is studied, a failure is then simulated within it, and the results of that simulation are extended to other individual infrastructure systems in order to study the cascading effects (Abdalah, 2006; Pederson et al. 2006).

Choosing one approach over the other has consequences in terms of the level of abstraction, the data needed, and the complexity of the model. We will touch upon these issues in our presentation. We followed the second approach when developing the I-GIS, allowing us to illustrate the physical and geographical dependencies given an outage in an infrastructure network at the UBC campus.

Conclusions

In our research we analyzed the different types of relationships that exist between infrastructure networks, and considered the methods in which these relationships can be modeled, and finally we illustrated, through a practical example, the kind of interdependencies that can be modeled using an infrastructure GIS. Although the process of construction of this I-GIS is not the purpose of this paper, we consider important to state that several issues worthy of study were encountered: Data quality issues, data sharing policies, the definition of the minimum or maximum common level of detail between infrastructure models, a definition of an ontology.

References

Abdallah, R. 2006, An Infrastructure Interdependency-Based Framework for Utilizing Network-Centric GIS as a Core Technology in Disaster Management. Doctoral dissertation, York University.

Pederson et al. 2006, Critical Infrastructure Interdependency Modeling: A Survey of U.S. and International Research, Report prepared for The U.S. Department of Energy National Laboratory

Rinaldi, S., Peerenboom, J. and Kelly, T. 2001. Identifying, Understanding, and Analyzing Critical Infrastructure Interdependencies, IEEE Control Systems Magazine, IEEE, December 2001, pp. 11-25.

Rinaldi, S. 2004, Modeling and Simulating Critical Infrastructures and Their Interdependencies, Proceedings of the 37th Hawaii International Conference on System Sciences

Robinson et al. 1998, Critical Infrastructure: Interlinked and Vulnerable, Issues in Science and Technology, Fall 1998. http://issues.org/15.1/robins.htm