Integrated Infrastructure Management

Week 8: Civil Infrastructure Security and Operational Safety

Week 8: Introduction

This week's discussion will focus on topics related to civil infrastructure security and operational safety including the following:

- Security threat identification
- Safety issues identification
- Security and safety management in infrastructure projects

These particular topics conclude this module of instruction.

Security Threat Identification

Required Resources

- Pradhan A., Laefer D. and Rasdorf W. (2007) "Infrastructure management information system framework requirements for disasters", *Journal of Computing in Civil Engineering* 21 (2) pp. 90-101.
- Arboleda, C., Abraham, D.M., Richard, P.P., and Lubitz, R. (2009) "Vulnerability assessment of health care facilities during disaster events", *Journal of Infrastructure Systems*, 15 (3), September, pp. 149-161.
- Thomas, M. (2010) "Models for managing contingency construction operations", *Journal of Construction Engineering and Management*, 136 (3), pp. 391-398.

The assigned articles address information system frameworks and assessment frameworks for how public authorities should identify security threats and plan for recovery following disaster events. Models for managing contingency construction operations for military threats, natural disasters, or civil disorders are discussed.

Pradhan, Laefer & Rasdorf (2007) describe an information system architecture that offers a robust, efficient, and secure platform to potentially revolutionize disaster management by enabling support of all of the phases of governmental activity that must occur before, during, and after a disaster (Pradhan et al., 2007, p. 90). The authors indicate that publicly and privately initiated computer-based systems designed for disaster management cannot meet the real-time data access and analysis needs at crucial stages, especially those occurring during an actual disaster. Typically the systems are proprietary, stand alone, and segregated (2007, p. 90).

In this paper, the authors propose an integrated, infrastructure management information system as a reliable and effective alternative. The authors address issues related to sharing data, customizing applications, supporting multiple data formats, querying visually, facilitating ubiquitous computing, and upgrading. Achieving maximum flexibility and capacity in a disaster management system relies upon recent advances in the following areas (Pradhan, Laefer & Rasdorf, 2007, p. 90):

(1) Standardized data specifications
(2) Middleware services
(3) Web-enabled, distributed computing

The authors prototype a system that captures the key resources in designing and implementing an arrangement that was initially designed for addressing disaster management of urban explosions. The authors discuss the critical details of that system in this article.

The September 11, 2001 attacks on the World Trade Center acutely demonstrated the need for an integrated management information system to assist in simultaneously assigning governmental services and resources for regular programs and emergency response (Pradhan, Laefer & Rasdorf, 2007, p. 90). Although the majority of cities in the U.S. now have electronic based maps to facilitate urban planning, few of these base maps have disaster management capabilities. The authors report that even among those that do, there are significant functional limitations with respect to (1) accessing data collected by non-disaster management branches of government and (2) supporting data analysis capabilities. Information sharing across multiple users, particularly during disaster response, continues as a major technical challenge (2007, p. 90).

Pradhan, Laefer & Rasdorf propose that the success of any disaster management system is dependent upon capabilities in six disaster-related phases that are generally defined as follows (2007, pp. 91-92):

(1) Identification involves ascertaining and inventorying community assets, which are dominated by the physical infrastructure (e.g., roads, buildings, and bridges) but also include transportable resources such as fire trucks and hospital beds.
(2) Prediction entails conceiving dangers and affiliated impact levels, which may include casualties, property losses, and utility service interruptions.

(3) Mitigation concerns active reductions of the disaster's impact.
(4) Preparation includes needed actions to contend with the portion of the disaster's impact that cannot be mitigated (i.e., there will always be some property damage and some injuries)..
(5) Response addresses real-time actions as the disaster evolves.
(6) Recovery encompasses restoring services and rebuilding disaster-stricken areas.

The authors argue that current disaster management systems are presently focused on an overly restrictive definition of disaster management and, thus, do not adequately address the multiphase nature that is fully reflective of a community's disaster management needs. As such, the architecture of existing systems heavily impedes full applicability and further expansion of these systems (Pradhan, Laefer & Rasdorf, 2007, pp. 91-92).

By adopting an alternative architecture based on an enterprise geographic information system (GIS) framework, the authors propose that the six disaster management phases (Identification, Prediction, Preparation, Mitigation, Response, and Recovery) can be realized in terms of customization, computing resource distribution, data sharing, and upgrading. The authors suggest that an integrated disaster management system based on an enterprise system that supports GIS, a relational database, and multiple data formats offers substantial advantages over existing standalone systems in terms of data collection, administration, retrieval, distribution, and usage (Pradhan, Laefer & Rasdorf, 2007, p. 91).

Arboleda et al. (2009) reinforce the interdependency theme discussed by Pradhan, Laefer & Rasdorf by emphasizing that during disaster events, infrastructure systems are essential to the operation of health care facilities and do not exist in isolation of one another. Telecommunications networks require electricity, transportation networks require systems information to operate, emergency systems require transportation network. Arboleda et al. indicate that during a disaster event, health care facilities are expected to operate efficiently in order to provide sufficient care to injured patients. However, medical care for injured patients can be affected if health care facilities do not have a sufficient supply of electricity, water, access to road transportation networks, etc. (2009, p. 149).

Arboleda et al. present a methodology to assist in the analysis of the operational vulnerability of a health care facility during disaster events, considering the

impact of disruption of a selected number of critical infrastructure systems in the flow of patients. The methodology integrates the analysis of external infrastructure systems and the internal capabilities of the facility (2009, p. 149). The authors designed a system dynamics simulation model to represent the internal operation of the health care facility, including the interaction between the different service areas, the flow of patients within the facility, and the condition of the external infrastructure systems that supply its resources (Arboleda et al, 2009, p. 149).

Physical damage to critical facilities or disruption of their operations or supply chain could prevent a full, effective response and aggravate the consequences of an emergency. Because of these contingencies, the authors argue that an essential component in the vulnerability assessment of critical facilities (i.e., hospitals, government buildings) should be the analysis of interdependencies between the different infrastructure systems that supply resources for the operation of the facility. Arboleda et al. report that traditionally, such a vulnerability assessment is performed using checklists and qualitative evaluation of the effects of a disaster event on the operation of the facility. This type of analysis is restricted because it assumes that the infrastructure systems will support their operations after the disaster events, and does not estimate the effects of disruption of the infrastructure systems.

The authors (Arboleda et al, 2009, p.160) selected a hospital as a case study. Their methodology required the analysis of the facility's normal operations, where there is equilibrium between the supply and the demand in the infrastructure systems where there is equilibrium in the flow of patients. When a disaster event occurs, there is a disruption in the supply of commodities, resulting in demands being unsatisfied at some nodes, including the hospital nodes. This deficiency is analyzed using a disruption model. Finally, the model evaluates restoration strategies whereby new components are added to the infrastructure systems to restore the operation of these systems, especially those linked to the hospital.

The authors (Arboleda et al, 2009, p.160) concluded that the research framework described in this paper can be used to represent different disaster scenarios, to estimate their consequences in the operation of the infrastructure systems, and to assess the impact of these events on patient flows within the hospital. The authors argue that the methodology presented in this study overcomes the limitations of the existing approaches and can be used in conjunction with current qualitative checklists to reduce the vulnerability of these critical facilities.

Thomas (2010) defines a contingency as a crisis such as a national disaster, civil disorder, or military invasion that creates a major threat to the safety and security of a population. He argues that essentially all contingencies require construction support that is generally mission critical and inherently challenging due to the dynamics and uncertainty with the availability of resources and the demands for the projects (Thomas, 2010, p. 391). The author considers a military contingency for which the military must complete all construction projects within a fixed time to achieve mission success.

Thomas notes that there are very few reported studies that deal specifically with managing logistics under contingency conditions (2010, p. 391). Having the right materials at the right place and at the right time is essential for contingency operations. Inventories have to be managed strategically during contingency operations, particularly during the sustainment phase where the demand and duration can both be uncertain. The author points out that construction supporting military contingency operations is generally mission critical and inherently challenging due to the dynamics and uncertainties with the availability of resources and demands for the projects. This makes it very difficult for force commanders to make resource allocation decisions for limited resources to ensure mission accomplishment.

The author (Thomas, 2010, p. 392) points out that all contingency operations include some level of construction that is critical to the success of the overall mission. The amount and type of support will depend upon the particular mission, e.g., military engagement with a hostile force, rescue and recovery operation, or humanitarian relief operations. The author defines contingencies as having three distinct phases: (1) mobilization and deployment; (2) sustained operations; and (3) reconfiguration. Thomas describes two models to assist in managing the allocation of resources for the construction operations: one based on conditions of moderate risk with randomly occurring repetitive loads, and the other a Markov chain model for high-risk conditions whereby the forthcoming state of daily progress depends only on the current state (Thomas, 2010, p. 393).

The author (Thomas, 2010, pp. 392-393) points out the challenges in managing contingency construction operations is in dealing with the risk and dynamics of the prevailing environment throughout the period of the operations. The conventional critical path methods and tools used in planning, scheduling, and tracking workload performance are difficult to apply. The most significant issue in contingency construction is tracking performance and the effectiveness in supporting the overall mission requirements. A given contingency can have several construction projects, each being critical to the overall mission, but the

level of criticality can vary both within and among projects due to the dynamics and conditions of the contingency.

The models described in this paper assess and track the effectiveness in carrying out critical missions during contingencies. Although the models and examples in this paper apply to military contingency construction, Thomas discusses how the approach and results can be applied to nonmilitary organizations as well.

Safety Issues Identification

Required resources

- Sorvari, J. and Seppala, J. (2010) "A decision support tool to prioritize risk management options for contaminated sites", *Science of the Total Environment*, 408 (8) March, pp. 1786-1799.
- Sun, Y., Fang, D., Wang, S., Dai, M., and Lv, X. (2008) "Safety risk identification and assessment for Beijing Olympic venues construction", *Journal of Management in Engineering*, 24 (1), pp.40-47.

This section considers both work safety risks and environmental safety risks and complements the risk identification analysis material included earlier in the module. The first article describes the development of a decision support tool to prioritize environmental safety risks at contaminated sites. The second examines a method to prioritize worker safety risks at construction sites (in this case, Beijing Olympics construction sites).

Sorvari & Seppala (2010) indicate that practical factors such as time and money have typically driven decisions on risk management of contaminated sites in Finland. However, as the authors indicate, risk management is a multifaceted task that generally involves several additional determinants (e.g., performance and environmental effects of remediation methods, psychological and social factors) (Sorvari & Seppala, 2010, p. 1786). Therefore, the authors adopted a multi-criteria decision analysis approach and developed a decision support tool that is viable in decision-making in such a complex situation. Although the authors base the components of the decision support tool on the Dutch REC system (Risk reduction (R), Environmental merit (E), and Cost (C)), their decision support tool is more case-specific. Their decision support tool allows the consideration of the type, magnitude, and scale of contamination, land use, environmental conditions, and socio-cultural aspects (e.g. loss of cultural heritage, image aspects) (Sorvari & Seppala, 2010, p. 1786).

Sorvari & Seppala started the construction of the decision support tool by structuring the decision problem using a value tree. Based on this work, the authors adopted the Multi-Attribute Value Theory (MAVT) for data aggregation. The authors demonstrated the final decision support tool for two model sites for which the risk management alternatives and site-specific data were created based on factual remediation projects and by interviewing experts. The authors carried out the demonstration of the decision support tool in a workshop where representatives of different stakeholders were requested to rank and weight the decision criteria involved (2010, p. 1786).

To get information on the consistency of the ranking of the risk management alternatives, the authors (Sorvari and Seppala, 2010, p. 1786) used different weighting techniques (ratio estimation and pair-wise weighting) and alternative ways to treat individual respondents' weights in calculating the preference scores for each risk management alternative. These dissimilar approaches resulted in some differences in the preference order of the risk management alternatives. The demonstration showed that attention has to be paid to the proper description of the site, the principles of the procedure and the decision criteria. Nevertheless, the procedure proved to enable efficient communication between different stakeholders and the identification of the preferred risk management option.

The decision support tool is particularly useful if none of the optional risk management actions can be clearly prioritized. Furthermore, the framework used in the decision support tool makes it possible to identify and consider the preferences and subjective views of different stakeholders (e.g. risk managers and authorities) in decision-making. The decision support tool facilitates communication and information exchange between the stakeholders, and provides means for public participation. Thus, conflicts that could delay risk management actions may be avoided. The implications of this study for environmental safety are discussed in the next section.

Sun et al. (2008) examined the safety issues associated with the extensive construction that occurred prior to the Beijing Olympics in 2008. Construction for the Beijing Olympic venues adopted new technologies, new materials, and innovative designs (Sun et al., 2008, p. 40). There was a lack of systematic management for safety risks in China’s construction industry, especially for large projects such as the Beijing Olympic venues construction. As a result, the authors were concerned that these risks would potentially bring negative impacts on the site safety performance.

Sun et al. (2008) investigated safety risk factors inherent in Beijing Olympic venues construction venues by identifying 27 experienced and highly respected experts from government agencies, the construction industry, and academe. These experts participated in brainstorming exercises, workshop discussions, and completed questionnaire surveys. Through these procedures and further analysis, the authors were able to identify and rank the key safety risk factors that follows (Sun et al, 2008, p. 43):

(1) Lack of emergency response plan and measures of authority in charge of Beijing Olympic venues construction
(2) Lack of emergency response plan and measures of contractor
(3) Workers' unsafe operation
(4) Contractor' ignoring safety under schedule pressure
(5) Contractor's inadequate implementation of measures on site safety
(6) Contractor's lacking experience on safety management when new technologies, new materials, and innovative structure is adopted in design scheme
(7) Insufficient money input on safety by client, contractor, or subcontractor
(8) Schedule pressure from client
(9) Unqualified personal protection equipment provided by subcontractor
(10) Bad safety and reliability performance of equipment and facilities on site
(11) Foreign designer being unfamiliar with local standard and construction technique level
(12) Difficulty in safety management resulting from the large scale of project
(13) Contractor's poor safety management system
(14) Lack of contractors safety managerial personnel
(15) Subcontractor's ignoring safety when receiving schedule pressure from contractor
(16) Contractor's insufficient supervision toward subcontractor
(17) Project manager's ignoring safety
(18) Subcontractor's poor safety management
(19) Unforeseeable underground condition
(20) Hidden safety troubles resulting from design scheme inconvenient for execution of construction
(21) Problem in contractors plan of safety management
(22) Inexperienced safety managerial personnel of contractors
(23) Designer's ignoring safety when applying new technologies, new materials, and innovative structure in design scheme

(24) Problem in client's organization such as improper decision making
(25) Insufficient communication between contractor and other stakeholders in the project

Based on these critical safety risks, the authors created a risk register and developed a model in application of the analytic hierarchy process to assess the status of risks on site safety. The authors applied the model in two Olympic venue projects (the Beijing Shooting Range Hall and National Swimming Center) to test the assessment model under construction, proving the validity of the approach.

Because of the authors' efforts, Chinese officials integrated the risk checklist, register, and assessment model developed in the paper into the risk management system for Beijing Olympic venues construction.

Security and Safety Management in Infrastructure Projects

Required Resources

- El-Anwar, O., El-Rayes, K. and Elnashai, A. (2010) "Maximizing temporary housing safety after natural disasters", *Journal of Infrastructure Systems*, 16 (2), pp. 138-148.

El-Anwar, El-Rayes & Elnashai (2010) indicate that, in the aftermath of large-scale natural disasters, the public expects emergency management organizations to provide safe temporary housing for a large number of displaced families and to ensure that these housing arrangements are not located in hazardous areas (2010, p. 138).

The authors' paper presents a novel methodology that is implemented in three main phases. The authors designed the first phase to enable decision-makers to objectively estimate the vulnerability of available temporary housing to potential post-disaster hazards and calculate safety indexes that represent the safety level of each temporary housing alternative. This phase considers the important characteristics of the temporary housing building types, the nature of the potential hazards, and the distances between the temporary housing units and hazards. The second phase analyzes and models the required expenditures for each proposed configuration of temporary housing arrangements. The third phase utilizes the findings of the first two phases in order to identify optimal configurations of temporary housing arrangements that maximize safety while minimizing expenditure (El-Anwar, El-Rayes & Elnashai, 2010, p. 139).

El-Anwar, El-Rayes & Elnashai claim that their safety model provides the capability of the following (2010, p.145):

- Calculating safety distances between all temporary housing alternatives and potential post-disaster hazards using graphic information system capabilities and identifying feasible temporary housing alternatives
- Computing a newly developed building performance index that represents the extent of expected damage in each temporary housing alternative if it is subjected to post-disaster hazards
- Evaluating a safety index for each temporary housing alternative that considers the probabilistic nature of post-disaster hazards

The authors develop a large-scale application of their methodology (used in an earthquake simulation) to illustrate the use of the developed models and demonstrate their unique capabilities in generating optimal trade-offs between maximizing the safety of temporary housing and minimizing public expenditures. The models should prove useful to emergency management agencies at the state and federal levels and can be used to support decision-makers in optimizing temporary housing decisions after natural disasters.

In the previous section, the work of Sorvari and Seppala (2010, p.1787) reflected that practical factors such as time and money have driven typically decisions on risk management of contaminated sites in Finland. The point to make in this section is that the authors incorporated a number of different aspects of environmental safety issues into the decision support system to include items such as:

- Risk reduction
    - Health risks
    - Ecological risk / terrestrial ecosystem
    - Ground water quality
- Environmental effects
    - Soil loss
    - Groundwater loss
    - Energy consumption
    - Emissions to air
    - Waste generation
    - Space use
- Other factors
    - Ecological impact

- Image aspects

The authors suggest that this approach can be used for a variety of infrastructure projects to highlight the specific environmental risks that may occur so that proper planning for these risks can be undertaken.

Sun et al (2008) examined safety issues associated with the extensive construction that occurred prior to the Beijing Olympics in 2008. The authors identified and assessed safety risk factors inherent in Beijing Olympic venues construction. The previous section lists the top 25 safety risk factors that they captured in their risk register (Sun et al, 2008, p. 40). Many of the risks were directly related to the lack of safety management processes and procedures.

The authors suggest that infrastructure project managers can use the procedures and outcome of this paper in managing safety risks inherent in all construction programs.

Summary

In this week, we covered six principal topics:

- Security threat identification
- Safety issues identification
- Security and safety management in infrastructure projects

The articles presented this discussed a number of new analytical methodologies or frameworks to consider for planning for and managing safety (especially work safety) and security issues in infrastructure project management.

References

Articles

Arboleda, C., Abraham, D.M., Richard, P.P., and Lubitz, R. (2009) “Vulnerability assessment of health care facilities during disaster events”, *Journal of Infrastructure Systems*,15 (3), September, pp. 149-161.

El-Anwar, O., El-Rayes, K. and Elnashai, A. (2010) “Maximizing temporary housing safety after natural disasters”, *Journal of Infrastructure Systems*, 16 (2), pp. 138-148.

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