SCENARIO-DRIVEN COMPUTER-BASED REGIONAL INCIDENT MANAGEMENT TRAINING

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ABSTRACT

Incident management is one of the most important functions of a Transportation Management Center (TMC). To efficiently and effectively manage complex regional incidents that affect transportation facilities under the jurisdiction of multiple agencies, TMC operators need to be trained appropriately. Recently, a team of universities, comprised of the University of Maryland, University of Virginia, and Rensselaer Polytechnic University, developed a computer-based regional incident management training tool for use by the I-95 Corridor Coalition. In their role on the team, the University of Virginia conducted research to support the development of detailed regional incident scenarios to provide content for the computer-based simulation tool. This paper presents the methodology created to develop the incident scenarios, with clear examples presented. The major findings from this research effort include the benefits of rapid prototyping, and the usefulness of Extensible Markup Language (XML) for structured content development.

Key words: TMC, operator, incident management, training, XML, scenario
INTRODUCTION

Incident management is, arguably, the most important operations’ function of a Transportation Management Center (TMC). The TMC operator plans, coordinates and manages incidents, and the accompanying traffic demand, by providing necessary resources and information updates to the various parties concerned with the incident. An incident affects both the mobility and the safety of the roadway. For example, during the off-peak, each minute of incident duration is estimated to result in 4-5 minutes of additional traffic delay (1). Therefore, an incident scene needs to be cleared quickly and effectively. In order to achieve this, operators must be well-prepared, and trained to work effectively in a fast-moving, chaotic environment involving numerous players.

Traditionally, incident training programs have focused on classroom-based training and in-field exercises for incident response and coordination. However, such “in-person” training is both resource-intensive, and expensive. Further, with more agencies working together to provide seamless services across an entire region or corridor, incident management continues to become increasingly regional in scope. As the geographic scope of regions grow, it becomes even more difficult to deliver in-person incident training in a cost-effective manner. Thus, there is a need for training tools that take advantage of information technology to “virtually” provide personnel with effective incident management training experiences in a regional context.

The I-95 Corridor Coalition recently sponsored the development of one such computer-based, regional incident management simulation training program. The focus of this work goes beyond simple incidents that impact a “local” single system, to managing regional incidents – which adds considerably to the system complexity. The University of Virginia (UVA) Center for Transportation Studies (CTS) was part of a team (along with the University of Maryland and Rensselaer Polytechnic Institute) that developed an interactive computer-based system, using an Extensible Markup Language (XML) framework. The UVA CTS role in the effort focused on developing the underlying content for this program, in the form of several incident scenarios. In other words, UVA CTS investigated how to take best advantage of information technology tools developed by others on the team. This paper focuses on the efforts of UVA CTS in creating the scenarios, along with the lessons learned in the process.

INCIDENT MANAGEMENT BACKGROUND

The Traffic Incident Management Handbook (2) defines incident management as the systematic, planned, and coordinated use of human, institutional, mechanical, and technical resources to reduce the duration and impact of incidents, and improve the safety of motorists, crash victims, and incident responders. The seven major components of incident management are identified in this handbook as incident detection, verification, motorist information, response, site management, traffic management, and clearance. Each of these seven major components requires the primary involvement of TMCs or their equivalent transportation system operating agency. Further, various incident management activities may be carried out...
by personnel from a variety of response agencies and organizations, such as fire and police. However, a TMC is usually the central agency coordinating the activities of those various agencies, from a traffic perspective.

For example, the TMC is often the first agency to receive information on traffic incidents. This is because operators continually monitor the highways for incidents and for general traffic surveillance. Next, they often have access to the necessary resources for incident verification, in the form of closed circuit television (CCTV) cameras and service patrols or highway patrols. A TMC could also significantly help with traffic monitoring and control in the vicinity of an incident, by informing other agencies for dispatching the required services (such as fire trucks, service patrols, posting traffic signs and cones etc), and by helping with determining detours. Further, the TMCs are also responsible for disseminating advisory information to the motorists and the media, and for coordinating the information channels across the various agencies involved with incident management. In summary, a TMC operator works in a fast-paced, uncertain, chaotic environment, in which good communications and coordination is an absolute must.

These very diverse and important responsibilities placed on the TMC operator mean that they also need to be well-prepared for such work. Further, the operators and the agencies cannot afford to make mistakes with real incidents. Incidents usually result in loss of mobility and safety for both the travelers and the field personnel managing the incidents. Severe and large regional incidents can result in more significant losses, due to their size and scope. However, managing such events regionally allow TMC operators to use a wider set of possible strategies. As such, appropriate training is of crucial importance to the operators and other field personnel. The best practices for incident management can be effectively instructed and reinforced through sound training programs. Furthermore, good training programs familiarize operators with severe incidents that occur rarely, but nevertheless need to be managed effectively.

A number of training programs are based on classroom courses and in-field hands-on experience (3, 4). In addition to classroom-based training, TMC operators can also benefit significantly from computer-based training. Using advanced technologies within information systems, incidents can be well simulated. Through interaction with the simulated incident, the operator can be taught and reinforced to use the best practices for managing incidents. To exploit such a system and reap large benefits, the underlying content in the form of incident scenarios has to be carefully developed. In short, without well structured, detailed scenarios, even the best information technology training platform is of little worth. The next section explains the details of developing scenarios for a regional incident management simulation training program.

I-95 CORRIDOR COALITION REGIONAL INCIDENT MANAGEMENT TRAINING

This paper describes the results of research conducted by the University of Virginia, in cooperation with the University of Maryland and Rensselaer Polytechnic Institute, sponsored...
by the I-95 Corridor Coalition. The I-95 Corridor Coalition is an alliance of transportation agencies, toll authorities, and related organizations, including law enforcement, from the State of Maine to the State of Florida, with affiliate members in Canada (5). The Coalition provides a forum for key decision and policy makers to address transportation management and operations issues of common interest. As one such issue of common interest, TMC operator training for managing large incidents with “regional” effects, and involving several agencies across the I-95 corridor was identified. The project goal was to fully develop a computer program for simulating regional incident events, supporting training and reinforcing identified best practices in managing incidents.

The project development team consisted of members from three university research groups, working under the guidance of the coalition members. The University of Maryland Center for Advanced Transportation Technologies laboratory (UMD CATT) coordinated the entire effort. Rensselaer Polytechnic Institute (RPI) developed the software. And, the UVA CTS developed several incident scenarios as the underlying content for this program. Whereas the capabilities and the user experience depend on the software, the quality of the final system itself (particularly the user training experience) depends largely on the underlying content.

The content for the program takes the form of incident scenarios. Early in the project, three incident scenarios (with different incident profiles, and extents of regional influence) were selected: a “normal” Woodrow Wilson Bridge Incident, I-95 Tanker Truck Fire incident near Baltimore (January 13 & 14, 2004), and Hurricane Isabel incident (September 15-20 2003). More details of these incidents, details of scenario development from conception to final delivery, and the team experiences from the process of developing these scenarios are presented in the next sections.

It should be noted that, early in the project, it was decided to use Extensible Markup Language (XML) as the framework for developing these scenarios. The main reasons for this decision were the structured nature of the incident scenario content, reusability of the code after developing once, and for future development of scenarios by the clients without having to go back to the developers. XML provides the flexibility for the developers and the clients to design custom tags that relate closely to the actual processes (and even words) used within the industry. For example, the tag <update_incident> is used in this project for updating the incident information in the TMS logs. Once the client develops a basic understanding of how the various tags and the program work together, the XML files can be edited easily in any standard text editor.

CONTENT DEVELOPMENT: INCIDENT SCENARIOS

An incident scenario forms the heart of the computerized incident management training program. Whereas the software program determines the capabilities and constraints, each scenario provides the content for simulating the incident and training the operator. An incident scenario may be described as a sequence of steps comprising: (1) the events occurring within the scope of the incident, and (2) the expected actions from the operator trainee.
Before the development of the scenarios in detail, the training goals for each scenario were determined. These objectives describe what the operator will learn when using the simulation, and aid in the overall focus of the project. For example, the three main learning objectives for the Hurricane Isabel scenario were identified as:

- Operators will gain experience in managing a multi-jurisdictional event in which there is advanced warning and predefined strategies to utilize.
- Operators will gain experience in a “long-term” incident due to hazardous weather.
- Operators will gain experience with communication and coordination with intra- and inter-TMC regional actors.

This step of defining the objectives should ideally go hand in hand with the selection of the actual incidents for developing the scenarios, so that the entire breadth of training objectives is adequately covered under the project. Brief descriptions of the three incident scenarios selected in this project are given below:

1. **I-95 Tanker Truck Fire Incident**: On January 13, 2004, at approximately 2:45 pm, a fuel tanker truck fell from a bridge on I-895, near Baltimore, onto the northbound lanes of I-95. The tanker exploded, resulting in fatalities and engulfed several vehicles traveling on I-95. The proximity of this location to the Baltimore-Washington airport and the magnitude of the explosion were initially interpreted by several agencies as a possible terrorist action. Both I-95 and I-895 were closed in both directions for several hours, leading to enormous congestion in the area, extending miles to the respective state borders. Fire, police and ambulance services, along with the service patrols cleared the incident. The information collection, fusion, and dissemination to various parties, along with long-distance detour determination and administration were the central roles of the TMC operator.

2. **Hurricane Isabel Incident**: In 2003, Hurricane Isabel grew to a category 5 storm as it moved towards the eastern seaboard. While its intensity reduced to a category 2 before making landfall on the Outer Banks of northeastern North Carolina, it was still a formidable event. Preparations to cope with the effects of the hurricane on the transportation infrastructure began as early as September 15, 2003, while the eye of the hurricane made landfall at 1:00 pm on September 18\(^{th}\). The storm caused massive, long-term flooding and power outages in North Carolina and Virginia. Evacuations were issued for Counties on the coast of North Carolina and low lying and/or vulnerable areas of Virginia and Maryland. Many residents in Virginia and Maryland voluntarily evacuated from the coastal areas. Much information about the fall of the hurricane, its expected path over time and space, and the potential threats to the infrastructure, safety and mobility are anticipated by the operators ahead of time. However, uncertainty prevails over what events occur when and where, and how they need to be managed. The scenario developed for this incident covers an intense one and a half day time period with many major events, from the morning of September 18\(^{th}\) to the afternoon of the 19\(^{th}\). This event also involves a large number of regional players.
3. **Woodrow Wilson Bridge Incident**: This scenario has the smallest regional scale, involving 3 neighboring transportation agencies – the Maryland State Highway Administration, the Virginia Department of Transportation and the District of Columbia Department of Transportation. While the first two incidents are quite large in scale – both in time and space, this incident was selected to familiarize the operator to the program, and to train management of an incident through appropriate information sharing, notification of motorists, and monitoring the incident using CCTVs. In this scenario, a debris incident occurs on the Woodrow Wilson Bridge, which carries I-95/I-495 across the Potomac River, between the states of Maryland and Virginia. This debris turns into a 2-car crash, which is cleared by the police, with the assistance of the Safety Service Patrol (SSP).

In spite of the differences in the scenarios and their scale of effect, the steps in developing the scenarios remain the same. The key steps in the development of each scenario are presented in Figure 1 below. Following this, each step is described in detail.

![FIGURE 1 Main steps in the development of incident scenarios](image)

1. **Collect and compile the actual incident-related data.**
2. **Identify elements of importance to be retained, modified, or added, to suit the training goals.**
3. **Identify the “golden path” for incident management.**
4. **Collect other relevant data, such as base maps, and equipment locations.**
5. **Code the XML scenario files.**
6. **Identify and create audio and video files.**
7. **Test extensively.**

An example of the final outcome from this step is provided in Figure 2. The three columns in this Figure fully describe the incident events, from the operator’s perspective. The first column presents the events pertaining exclusively to the incident, as the operator sees or receives them (if she/he were to be informed of each and every event). The second column presents the actions taken by the operator, in response to the actual incident event in column 1. Both these columns (1 and 2) are directly associated with the
timeline, along with the date, if the incident spans over a single day. Column 3 presents additional detailed information pertaining to either the incident events, or the operator actions. These details often add more specifics to the operator actions, such as the DMS message used and the DMS identifier.

<table>
<thead>
<tr>
<th>Incident Events</th>
<th>Operator Events</th>
<th>Additional Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2:00 p.m.</td>
<td>2:15-2:57 p.m.</td>
<td></td>
</tr>
<tr>
<td>Virginia</td>
<td>1. Enter downed tree and high water information into TMS</td>
<td></td>
</tr>
<tr>
<td>Emergency</td>
<td>2. Activate available DMS alerting motorists to debris and high water (TMS)</td>
<td></td>
</tr>
<tr>
<td>Operation Center</td>
<td>3. Rt. 460, 10, 175 - Enter maintenance request into TMS for incidents</td>
<td></td>
</tr>
<tr>
<td>Hurricane Isabel</td>
<td>1-664, I-64 - Enter events into TMS and contact SSP</td>
<td></td>
</tr>
<tr>
<td>Situation Report</td>
<td>4. Search for accidents on roadways using CCTV and detector data (TMS)</td>
<td></td>
</tr>
<tr>
<td>#3 (email)</td>
<td></td>
<td>DMS Messages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rt. 10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CAUTION HIGH WATER AHEAD TAKE ALTERNATE ROUTE</td>
</tr>
<tr>
<td>2:15 p.m. Debris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rt. 460 (CAD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:15 p.m. High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Rt. 10 (CAD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:30 p.m. Tree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Down I-664 (CCTV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:38 p.m. Debris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-664 (CCTV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:41 p.m. Debris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-64 (SSP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:56 p.m. Tree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Down Rt. 10 (CAD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:57 p.m. Tree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Down Rt. 175 (SSP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:00 p.m.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>City of Norfolk</td>
<td>3:00 p.m.</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>1. Enter information of all closings into TMS</td>
<td></td>
</tr>
<tr>
<td>Network Status</td>
<td>2. Activate available DMS and HAR alerting motorists to closures</td>
<td></td>
</tr>
<tr>
<td>Report 26 (email)</td>
<td>3. Update fire, police (phone) and media (email) with current information on roadways</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Search for accidents on roadways using CCTV and traffic detector data (TMS)</td>
<td></td>
</tr>
<tr>
<td>3:02 p.m.</td>
<td>3:02 p.m.</td>
<td></td>
</tr>
<tr>
<td>Winds exceed 45</td>
<td>1. Pull SSP from roadways (winds have exceeded 45 mph) (Nextel)</td>
<td></td>
</tr>
<tr>
<td>mph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:05 p.m. US 13/Chesapeake Bay Bridge and Tunnel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 2** Incident Timeline (from Hurricane Isabel scenario)

2. **Identify elements of importance to be retained, modified, or added to suit the training goals** – Next, changes were made on an as-needed basis to any or all of the equipment, agencies, or events in the scenario. For example, the original logs from the Hurricane Isabel scenario contained more than 51 downed trees over the entire event, covering a time span of one and one half days. It should be noted that several operators work cooperatively to coordinate clearance of the downed trees during the real incident. In contrast to reality, (a) The entire training (covering the 1 ½ days of the real incident) will have to be completed in a fraction of this time (possibly an hour or so), and (b) The operator trainee is obligated by the training program to respond in isolation to each incident event coded within the training scenario. Further, the sponsors desired for the program to include all the major incident events within the training scenario, even at the cost of dropping some minor or repetitive events. Therefore the final scenario for the Hurricane Isabel incident was developed to contain only 18 downed tree events (with diverse event profiles).

The sponsors desired the training program to be developed in the above manner, for several reasons including: (a) The operator needs to be familiar with all aspects of incident management, rather than just a few parts, and (b) So that the trainee becomes familiar with the worst case scenario when a diverse set of actions are required, but little to no help is available.
3. **Determine the “golden path” for incident management** - For each event occurring in the field, or information obtained by the operator, numerous diverse responses are possible. However, the best practices determine a hierarchy of priority levels to these responses. Some classes of responses are simply deemed inappropriate, while others do not possess any inherent priority levels. For example, incident information should always be verified, before taking any other action. Bypassing the step of incident verification is deemed inappropriate. However, the order in which Dynamic Message Signs (DMS) are posted with information may not be as critical. For this reason, the program was developed as a sequence of events and actions, and XML was therefore used for developing content.

The series of actions in response to each event or information that is determined as most appropriate, is defined as the “golden path” for that incident scenario. This path is determined by the best practices, and the experience of senior operators interviewed in the process of developing the scenarios.

4. **Collect other relevant data, such as base maps, equipment locations** - Good base maps for the area covered by the incident were obtained from the TMCs. In addition, geospatial information libraries were used to access publicly available imagery. All the equipment used within the scenario, as well as additional equipment (for potentially giving less desirable options to the trainee) should be coded into the maps.

5. **Code the XML scenario files** - The incident scenario is next coded into a set of XML files. The main scenario file contains all the events pertaining to the incident (these events happen in an order, irrespective of the operator actions). A number of supporting files contain information for potential operator actions such as: choices of messages for delivery to other agencies, choices of messages for posting to DMS etc.

The XML files are structured, and very easy to work with, once a level of comfort is established. The following notes will be helpful in a good understanding of how XML files can be utilized:

a. Words between the characters “<” and “>” are the XML tags. For example, `<report>`, `<radio>` etc. These are the tags or handles used by the program to parse (understand) the xml file and to execute actions based on them. As such, they should not be changed in anyway.

b. The characters in between tags should be changed to fit with the scenario being developed. For example, “49” between `<camera>` and `</camera>` signifies the camera with the identified 49. If the camera 107 is used in another scenario or in another part of this scenario, 49 should be replaced by 107.

c. An entire set of tags may be moved around, to fit a scenario. For example, the tags `<open_incident/>` or `<update_incident>` may be placed anywhere within the scenario. However, it belongs appropriately at only a few locations – depending on the scenario being developed.
d. Tags such as `<one_of>`, and `<all_of>` give further flexibility to the scenario developer in setting the priority levels and choices of trainee actions. For example, if the operator needs to inform the police, any one means of communication is appropriate: landline phone, cell phone or radio. Also, for posting DMS messages to group of DMS signs, there are no priority levels in some cases, and `<all_of>` tag can be used in that case.

An example of an XML file is illustrated in Figure 3.

```xml
<action>
  <all_of>
    <dms>Rt.58 East, 2</dms>
    <dms>Rt.58 West, 2</dms>
    <dms>Rt.299, 1</dms>
  </all_of>
</action>
<delay>1</delay>
<alert>
  <text>From the City of Norfolk, at 3:00 PM, 09/18/03 Transportation Work
  Report 26 Midtown Tunnel is Closed. HRBT (Hampton Roads Bridge Tunnel) speed
  reduced to 35 mph in both directions. MMBBT (Monitor Merrimac Memorial Bridge
  Tunnel) speed reduced to 35 mph in both directions.</text>
</alert>
<action>
  <update_log />
</action>
<alert>
  <text>Weather Alert Wind Speeds in Hampton Roads area exceeding 45 mph.
  Hazardous conditions to travel on roads. Date/Time: 3:02 PM, 09/18/03</text>
</alert>
```

**FIGURE 3 XML Incident Scenario File (from Hurricane Isabel scenario)**

6. **Identify and create audio and video files** - To create an environment as similar to the TMC as possible, audio messages (for radio, phone operations) and video (for CCTVs) were included in the training program. The actual content needs for these multimedia become concrete only after the entire scenario is developed almost completely. In some cases, the video could be reused within a scenario or across different scenarios.

7. **Test extensively** - As incident scenario content is being developed, it should be tested extensively, both in parts and as a whole. This step will ensure that the delivered content is really useful, and provides a training experience in line with the developer expectations, when run inside the software. For example, some text boxes showing messages to the operator trainee were too short or too long. In the former case, the full
messages did not get delivered. The latter case is an eye sore, and could also cause confusion for the trainee (creating an expectation of a longer message). Another example is the need identified for a <delay> tag, during the testing phase. The Hurricane Isabel incident scenario demands that the operator be presented with a number of messages, in quick succession, to mimic a sense of urgency. When tested with the latest version of the training software available then, all the messages simply overlapped each other, defeating the original purpose. The <delay> tag was then designed and introduced into the next version of the training software, to create and mimic the sense of urgency in a more realistic manner.

LESSONS LEARNED

Several important lessons surfaced from the research team’s experience in this project. All these lessons pertain to better understanding of computer-based incident management training, or the process of developing the incident scenarios. These lessons are documented in this section.

Incident Scenario Development Process

1. Rapid prototyping was key: Software and content development are inherently non-linear processes, because, from the outset, the various team members often conceptualize the final product differently from others. The actual, final product then emerges as these different visions merge and a consensus is reached. Rapid prototyping of the scenarios, and consistently soliciting stakeholder involvement from the beginning, and throughout the project, gave them the opportunity to provide regular feedback. This feedback was then incorporated into the next evolution of the scenarios. The rapid prototyping helped (and possibly forced) the various team members to go over the entire incident management process at each stage, and identify the critical aspects of the program, from their individual and agency perspective. Identifying the most critical aspects early on helped in steadily maintaining the project focus, and in evolving the final consensual product.

2. XML is an excellent format for developing scenarios: It is a mature format followed in many other industries. Its usability and benefits for developing incident management training scenarios are demonstrated in this project. The XML format allows for relatively easy updating, enhancing, or adding of new scenario content.

Incident Management Training

1. Time is a very important factor: Many of the incident events continue to happen regardless of the operator action, including the complete clearance. Of course, the sequence of the events could vary significantly depending on the operator actions. Good communication and coordination from the TMC operator could make the incident management and clearance much more efficient and effective, than otherwise. For these reasons, incident management training software should explicitly include the concept of
the “ticking clock” and the continuing course of the incident events, both (a) irrespective of, and (b) in line with the operator trainee actions.

Further, the sequence of the incident events is not fully rigid. Many events within an incident are often not sequential, in a preset order. Instead, they often occur in some haphazard, random way. This randomness is more apparent when different incidents (across a network) occur in overlapping time frames. Capturing this aspect of real life would add more complexity to the training, but would make it more realistic.

2. There isn’t one “right” way of doing incident management: This is the counterpart of the above observation of non-rigid timeline for the incident events. Given the incident events are not sequential; the same is true for operator actions. They need to go hand-in-hand with the needs in the field, rather than follow one fixed procedure. However, many computer-based training tools are geared towards the “right” procedure. Future training tools should therefore factor-in this finding.

3. Not “THE” only tool: The incident management training software developed in this project is good for first cut training - but much of incident management is about people, and coordination. We believe this training can help people become better prepared for more personnel intensive training approaches.

CONCLUSION

This paper documents the process of, and lessons learned from, developing content for incident management training software, in the form of incident scenarios. The various lessons learned from this project are useful for content developers for future training programs.

The key lessons learned in this research effort include:

1. Rapid prototyping proved essential in project management and consensus development.
2. XML provides a stable, yet flexible format for structured content.
3. The inherent nature of incident events and actions – i.e., unobstructed flow of time, and often non-sequential - should necessarily be reflected within the incident management training software programs.
4. Computer-based incident management training provides a good start, and can prepare the operators better for more intensive training approaches.
REFERENCES