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Feasibility of a human performance model in consequence management

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FEASIBILITY OF A HUMAN PERFORMANCE MODEL IN CONSEQUENCE MANAGEMENT

by

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ABSTRACT

Human civilization has always encountered unpredictable disasters as a result of natural events. Now it also faces the disasters caused by terrorist attacks. Governments must have consequence management plans in place to protect public health and safety, restore essential services, and provide emergency relief to affected businesses and individuals .

Human performance models predict outcomes in complex dynamic situations. Such models can simulate disaster management procedures under varying circumstances. This work applies human performance modeling in a terrorist situation and evaluates possible uses of such models by first responders in practical consequence management applications. It includes a case study of an attempted terrorist attack.

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1 INTRODUCTION

Consequence management constitutes actions taken in the aftermath of a disaster, which is defined as a life threatening or destructive event. The scope and the type of disaster define the categories of the consequence management. Recent events like the 9/11 attacks and Hurricane Katrina have underscored the importance of having systems in place to prevent confusion among the organizations that coordinate responses to emergency situations

1.1 NEED FOR CONSEQUENCE MANAGEMENT

1.1.1 Hurricane Katrina. Hurricane Katrina illustrates the need for consequence management. Some disaster recovery response to Hurricane Katrina began before the storm when the Federal Emergency Management Agency (FEMA) arranged to send refrigerated trucks to the mortuary teams. The relief work went on for six months after the storm.[1] The staff of many agencies became fatigued and were stretched too thin. Many even thought of quitting their jobs during the relief work. The government was criticized for its lack of leadership during relief work and mismanagement of the whole process. In many places, delays resulted in hundreds of lost lives. The government was accused of making things worse, instead of making things better, by impeding the work of others while delaying its own response. Investigation showed that the logistics capacity of FEMA and the Red Cross was insufficient support the massive number of Gulf Coast victims [2].

1.1.2 September 11, 2001. The events of 9/11 further show the need for better emergency preparedness. As a result of poor evacuation plans, some of the occupants of each tower above the point of impact made their way upward toward the roof in hope of helicopter rescue, but the roof access doors were locked. There were no clear plans for helicopter rescues during the tragedy.[3] The New York Fire Department had deployed 200 units (half of the department) to the site, and these were helped by numerous off-duty firefighters and EMTs.[4][5][6]. The New York Police Department sent emergency service units (ESU) and other police personnel. [7] Authorities were unable to estimate accurately the number of personnel needed. Dispatch operated on a case-by-case basis, rather than being guided by precalculated plans. The FDNY, NYPD, and Port Authority had no capacity to share information and coordinate their procedures during the response. Frequently during the rescue and evacuation operations the FDNY and NYPD were unable to communicate due to incompatible frequencies or malfunctioning communication towers. This lack of communication led to redundant efforts, poor coordination, wasted time, and delayed response.[7]

Other scenarios like the San Francisco earthquake of 1989, the Oklahoma City bombing, the Los Angeles riots, and Hurricane Andrew also show the need for effective consequence management. The examples discussed above reveal mismanagement that cost lives. Of major concerns are emergency plans inadequate to guide officials during emergency situations. In addition, emergency responses are often hampered by improper use of scarce resources, an inability to estimate resources and workforce, overworked response units, lack of communication, and delayed responses due to lack of coordination. Rapid and comprehensive responses are necessary in any kind of disaster. Although most authorities have recently improved their response readiness, their improvements are generally the result of trial and error. There is a need for models that can address uncertainties and evaluate risk factors as soon as a situation arises whether or not such an emergency had been encountered previously.

The first approach to building such models is be to establish common definitions, coordinate and delineate interagency roles, rapidly deploy appropriate response units, and develops a streamlined, clearly defined response channel. In a poorly coordinated organization and in absence of central authority, misunderstanding is inevitable; therefore the next step is to establish a crucial common point of reference. These steps are key to implementing rapid response plans. An effective model would design coordinated programs to replace current scenarios that work by accident rather than by design. Such a model would address a wide spectrum of contingencies on short notice. These Human performance models meet these criteria [9]. Human performance model systems such as IMPRINT developed by the Army Research Laboratory (ARL), and the ENCOMPASS developed by the Defense Advanced Research Projects Agency (DARPA), permit the smooth implementation of decision and action plans.

2 LITERATURE REVIEW

2.1 HUMAN PERFORMANCE MODEL

Human performance models (HPMs) are used to study and predict human behavior in complex-dynamic human automation integrated systems. They typically complete software that simulates some aspect of human performance within a limited domain. For example they may simulate the distance a person can reach without feeling the strain in the arm, the average amount of time a team takes to complete a series of routine procedures, or the reasoning used to identify a new radar track. Most human performance models are based on information processing theories [10].

Analysis in HPMs must include both a behavioral and a biomechanical component, addressing: 1) what people do, 2) why they do it, 3) how they do it, and 4) the consequences of doing it. Faced with a situation, an individual must decide on a course of action. If an appropriate behavior response is selected, then the task can be successfully completed. The selection of an inappropriate behavior can result from a number of factors, including 1) faulty expectations and assumptions, 2) faulty analysis, 3) limited or misleading sensory data, 4) inability to sense the necessary input data, 5) decreased vigilance, or 6) distractions or competing sensory data. As the individual proceeds with the task, adjustments may be necessary due to changes in the task demands or the environment, based on ongoing sensory feedback. The ability to adjust to these changes appears to be related to the extent to which the individual's perceptual image is confirmed. An individual who is still testing an image is more prepared for error and more likely to make successful adjustments to new task demands. On the other hand, an individual whose image has been confirmed (even if incorrectly), is less likely to expect error and might be unable to respond successfully to the change, perhaps responding inappropriately and thus causing an accident. A decrease in vigilance or attentiveness effectively shortcuts part of the feedback loop, resulting in the use of a previously selected behavior that is inappropriate for the new or modified conditions [11]. A critical aspect of this modeling process is the recognition of the role of expectations and the resulting assumptions made based on past experiences.

The human performance model is illustrated in figure 1. Goals are specifications or desired states for the given conditions. Training, information, and procedures influence an individual's understanding of a situation as he or she prepares to take action. Perception is one's understanding of a situation; it is influenced by past experiences and expectations. As a situation develops, one takes action based on perceptions and goals. The outcome of any action may be far from perfect due to disturbance, unpredictable conditions, or system status. Results of actions provide feedback that can either justify previous perceptions, prompt changes to them, or prompt the selection of a new action. [12]

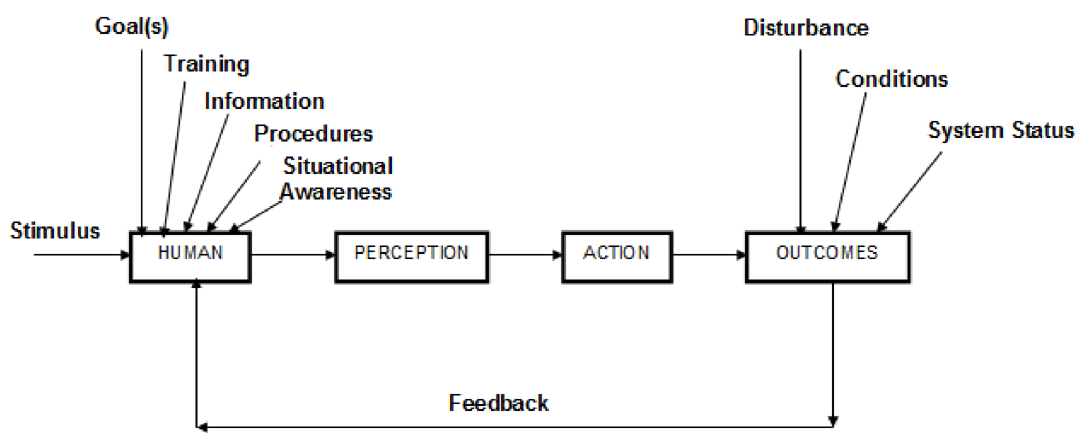

Figure 2.1: Human Performance System

A quality testing process provides an example of this model. An inspector examines a sample during the manufacturing process. The goal is to ensure that the product meets requirements. The inspector's actions will be influenced by this goal, by his or her perception of the sample quality and the standards, by information obtained about the samples during inspection, and by prior training and company inspection procedures. Whether the product fails or passes is influenced by external factors such as disturbances during inspection, conditions and restrictions applicable to the tests, and the system status. Whatever the outcome, the inspector gets feedback on the product, which may or may not change his or her perception of product quality.

This model has characteristics of a dynamic and stochastic discrete event network modeling tool designed to help assess the interaction between operator and system performance throughout a system's lifecycle. The model includes resources available, tasks to be completed, limitations, and deadline. The output is in the form of a flow diagram. The model can be used for evaluation, what-if analysis, and training, with the ultimate goal of improving an organization's performance.

Human performance models are important because they permit inclusion of quantification of human performance capacities and limitations n the analysis and simulation of engineering systems. The significant advantages of HPMs are:

- They are cost effective and much cheaper than real-time experiments and drills.
- They help set appropriate goals to keep the focus on the intended outcome.
- Their feedback helps assess and improve operator action.
- They identify and mitigate disturbance.
- They check the perception of the subject [12].

Human performance modeling is a viable and economic way of testing and has been in market for the last four decades [13]. A man-machine integration design and analysis system (MIDAS) is one such HPM tool. It aids in the design and analysis of complex human-machine systems such as aircraft cockpits. It allows users to perform human factor analyses of new designs at an early stage, prior to the use of hardware simulators or even human in-the-loop experiments [14]. Human performance modelling has also been used in many instances for simulating scenarios like driving heavy tanks for training soldiers.

Three basic ideas have informed the development of HPM. Manual control models based on engineering control theory, network models based on the definition of human reliability, and models based on cognitive architecture. The Siegel and Wolf network model, the Saint and Micro saint and the human operating simulator (MS HOS) are some of the human reliability models. Examples of cognitive process models include

SOAR, goals, operators, methods, and selection rules (GOMS), ACT-R, and MIDAS/D-OMAR. [15]

The effectiveness of HPM depends on constraints imposed by the environment. The larger the number of constraints, the more accurate the model. Adding details to a model makes it accurate but slows the simulation and creates little difference in the output. The American Institute for Research created a database of reliability statistics that indicate the probability of error for elemental human actions. The database contains probabilities for tasks such as reading dials, turning valves, and operating controls. This data has been used to analyze the cumulative effect of human reliability on system reliability.[15]. This database is referred to as AIR Data Store (Payne & Altman, 1962). The main goal was to facilitate prediction of human error in routine operations. Any human task can be broken down into elemental actions, and task analysis can be used to represents the various steps graphically with a branching structure. Applying standard reliability (as expressed in Equation 1) to this aggregation process yields a simple model that can predict the probability of human error.

$$P(Error) = Q(e) = 1 - [\prod_{k=1}^{n}\{1 - Q(ek)\}] \quad \text{.................................... (1)}$$

In Equation 1, the term Q(ek)s represents probabilities of error in each element in a particular path through the task. The probability of successfully completing each element, ek, is 1 minus the error probability. Thus the aggregate probability of error is 1 minus the product of the individual probabilities of success. When applied to task analyses using data from databases like AIR Data Store, this equation gives performance shaping factors (PSFs) that account for human individual differences, environmental variables, and so forth. Performance shaping factors permit consideration of specific contextual conditions that are postulated to exist in the task and working environment, thus allowing adjustments to the database entries [15].

2.2 CONSEQUENCE MANAGEMENT

Civilization has always been threatened by natural disasters like hurricanes, tornadoes, and floods. The threats have increased in recent times due to an increase in terrorist attacks. After 9/11, the approach to tackling these scenarios has changed from recovery to preparedness, concentrating on the safety and security of both people and infrastructure.

Many communities are still unprepared to handle such events even with the increased emphasis on such situations. They are aware of their vulnerability to possible threats and capable of addressing such events on a small scale. Often, however they have no established response procedures and policies for immediate recovery and restoration efforts in the wake of large scale disasters or unpredictable events. Natural disasters and terrorism do not recognize geographic boundaries. Therefore communities need not only to be self-sufficient in terms of infrastructure and crisis management procedures, but also to have policies regarding mutual assistance between neighboring communities. In many instances, and especially when the crisis is large scale, neighboring communities must work together to provide mutual aid and assistance during recovery efforts. Policies should include combined training and drill programs, information sharing protocols, and interagency coordination. They should encourage sharing of assets and infrastructure. Roles and responsibilities should be defined in writing for both local personnel and neighboring communities.

Initiation and communication processes among communities should recieve special attention. Communication patterns differ with the region, discipline, and expertise. During a time of disaster, rapid information exchange is difficult, prohibiting immediate action. To ensure the proper flow of information, data, and effective coordination; the emergency operations center or local dispatch center becomes communication hub for law enforcement, fire service, emergency medical services, and public works. The necessity for such a hub makes combined training and drill programs necessary. The doctrine followed by emergency personnel is based on emergency management principles, the incident command system (ICS), and the National Incident Management System (NIMS)[16].

The top three emergency management needs of local communities are:

1. assistance in planning/response to catastrophic events
2. graphical tools for local incident management; and
3. effective solutions for mutual aid, specifically asset and volunteer management.

At the onset of any catastrophe; the responsibility for response is understood to rest with the grass roots level of responders, or the first responders [16].

Many commercial business bodies are ready to provide various facilities and equipment that use latest technology, like chemical/biological decision aids for first responders. Such equipment includes syndromic surveillance, health alert tools, and mobile command centers filled with sophisticated communications equipment. These tools help first responders work at disasters or accidents, but they do not solve the crisis. Prevention of all incidents may not be possible, but the economic and humanitarian effects can be minimized, by participation in a national network and adoption of technologies that address the consequence management needs of local governments. Consequence management is a methodology that can direct emergency preparation and response initiation by control bodies during an emergency situation

> Consequence management includes measures to protect public health and safety, restore essential services, and provide emergency relief to governments, businesses, and individuals affected by the consequences of a natural or man-made hazard. Consequence management is based upon the emergency management principles of mitigation, preparedness, response, and recovery defined by the Federal Emergency Management Agency (FEMA) back in the 1970s with the creation of the Federal Disaster Response Plan. [16]

Consequence management increases preparedness for potential disasters, focuses on improved emergency response, and pursues constant, consistent actions to mitigate the risk of emergency incidents. During recovery efforts, consequence management helps track down key components of relief efforts for catastrophic emergencies like Hurricane Katrina. Volunteer credentialing and asset management are also covered by consequence management procedures. The Department of Homeland Security (DHS) further defines the components of a consequence management solution as shown in table 1.

Table 2.1: Tools and Their Applications

Assessment Tools	Planning Tools	Communication and Alert Tools	Medical Response Tools	C4I Tools	Recovery Tools
Hazard and threat vulnerability and emergency readiness assessments	Customize hazard-specific contingency plans for emergency response	Real-time messaging with chain of command notification	Syndromic surveillance/ disease tracking	Command, Control, Communication, Coordination and Information	Damage assessment and reimbursement
Human and physical resource catalogue (emergency response/ recovery assets)	Prebuilt standard operating procedure templates/checklists	Risk Surveillance and event prediction			Volunteer management/ credentialing and asset management (Mutual Aid)
	Geo-mapping and situational awareness (tools for mission planning, asset tracking and training/drill exercise)				

The components shown in table 1 combine to form a solution that focuses on a local response to any type of emergency based on coordinated efforts and improved situational awareness. This solution includes preparedness, planning, and training before the event; improved information exchange, communication, and coordination during the event; and recovery/remediation after the event, including the management of volunteers and assets from mutual aid partners. The need for a complete consequence management solution at the local level for better preparation and response to natural and man-made emergencies is clear. There are numerous and meaningful, measurable benefits to improving command, control, communication, coordination, and recovery within each community for all-hazards emergency situations as well as catastrophic events. Among the benefits for local communities of identifying and implementing a complete consequence management solution are:

1. saving of lives during a catastrophe
2. day-to-day value in improved communications between emergency service disciplines
3. faster, accurate, more precise messages between key personnel
4. improved preparedness in advance of potential disasters
5. better coordination among agencies during the response to an incident
6. real-time, accurate information regarding status of human and physical resources responding to an emergency
7. optimized deployment, control, and coordination of resources in the field
8. full, real-time audit and documentation of actions taken by incident responders
9. full documentation of mutual aid requests, and the community response to these requests
10. faster recovery from the event
11. complete control and coordination of simulation/drill exercises to identify weaknesses in emergency response plans by hazard type and to ensure full education/preparedness of response participants
12. ability to document improvements in incident response over time
13. a clear indication of positive actions taken to respond to the threat of terrorism and to protect the safety of citizens within the community

14. proof of steps taken to improve preparedness for, and response to, virtually any kind of emergency situation, and
15. lives saved as a result of a faster, coordinated disaster response[16].

Under the Nunn-Lugar-Domenici Act, the armed forces are responsible for training first responders according to the consequence management principles.[9] In 1997, the U.S. Army Chemical Biological Defense Command initiated a pilot program to train first responders in major metropolitan areas. Initial instruction was oriented toward training the trainers. Local and state agencies expanded their efforts as a result, often by integrating response plans with FEMA regional offices. In short, the Department of Defense (DOD) accomplished two goals: providing expertise to first responders and stimulating development of local emergency action plans. However, due to budgetary cuts, the DOD terminated training in 1999, and no other agency has offered to sponsor a replacement program. This program cancellation seriously eroded gains in response capabilities. Training for first responders should be continued until metropolitan areas are capable of initial incident management.[9]

In Australia, the State Emergency Management Committee (SEMC) has set up an emergency management training advisory group that consists of two representatives from the emergency services organizations, two representatives from each functional areas, and two district emergency management officers, the state training coordinator, and the SEMC secretariat, who chairs the group [17]. The group's goals are:

- to conduct training needs analysis for multiagency emergency management training, and to advise the SEMC on training needs,
- to advise on the development of competency-based curricula to meet training needs, and implement such curricula,
- to assess requirements and processes, and
- to review all course modules every twelve months to ensure accurate and relevant content and to implement changes based on relevant legislation, emergency management structure, and industry work practices.

The training policies for the SEMC are in accordance with its code of practice for emergency management training (outlined in Appendix A). The training needs and priorities center around two key areas:

- completing and implementing the restructure of emergency management training, as aligned with the emergency management competencies from the National Public Safety Training Package, and
- extending delivery training workshops in emergency risk management.

The SEMC secretariat monitors and provides funding for local emergency management training conducted by district emergency management officers. The funding is provided for local delivery of the courses listed in table 2:[17]

Table 2.2: Courses by SEMC

Course Title	**Number of Courses**
Emergency Management Arrangements	**31**
Introduction to Emergency Risk Management	**16**
Implementing Emergency Risk Management	**9**
Working in an Emergency Operations Centre	**13**
Evacuation Management	**4**
Exercise Management	**3**
Managing an Emergency Operation	**5**
Total	**81**

2.3 IMPRINT

Authorities following the consequence management policies envision a customizable human performance model system that would assist decision makers during crisis situations ranging from terrorist attacks to large-scale disasters and would provide responders, incident commanders, and officials at all levels with tools to share vital information during the planning and execution phase. Two such systems are IMPRINT developed by the Army Research Laboratory (ARL) and ENCOMPASS, developed by the Defense Advanced Research Project Agency (DARPA).

The Siegel Network Model is a task network with branching series of network nodes depicting the operation of the human-machine system. Each node or "action unit" has a probability of success and a statistical distribution of completion times moderated by a series of performance shaping factors (PSFs) or moderator functions. These factors were implemented globally as scale factors applied to the action units; that is, they were programmed to apply to all the relevant action units in a simulation. Aggregate probabilities of success and performance times were estimated by averaging multiple Monte Carlo simulation executions of the overall network [15].

To make this methodology more accessible, the U.S. Air Force funded the development of SAINT (System Analysis of Integrated Networks of Tasks), (Wortman, Pritsker, Seum, Seifert, & Chubb, 1974) a general-purpose discrete simulation language written in FORTRAN. This system was designed specifically to capture the methods and innovations introduced by Siegel, particularly the capability to define global moderator functions that affect multiple nodes (Wortman, Pritsker, Seum, Seifert, & Chubb, 1974.) the SAINT system was used to pilot drones remotely from a control facility (unmanned aerial systems, or UASs, in today's terminology), as reported by Wortman, Duket, and Seifert (1975)[15].

Very soon, SAINT was rewritten in a simpler form that would run on a PC; this revision came to be known as Micro Saint. The first commercial version was written in C. It captured the functionality of SAINT, thus tracing its lineage to the Siegel and Wolf models. Micro Saint, like SAINT, is fundamentally a general-purpose discrete simulation engine. The most prominent thread is implemented in an IMPRINT series of applications, which provide modeling templates specifically adapted to particular human performance modeling applications [15]. The IMPRINT system uses Micro Saint as its engine. Task-level information is used to construct networks representing the flow, performance time, and accuracy of operational and maintenance missions.

The IMPRINT system is a human systems integration (HSI) and manpower versus hardware integration (MANPRINT) tool developed by the Human Research & Engineering Directorate of the U.S. Army Research Laboratory. It is a dynamic, stochastic discrete event network modeling tool designed to assess the interaction of soldier and system performance throughout the system lifecycle, from concept and design through field testing and system upgrades[18][19]. This Micro Saint-based modeling tool is designed specifically for human operated systems. The primary function of IMPRINT is to calculate the performance time and accuracy of the system and to compare workload. It has a large built in data collection for user help [20].

IMPRINT estimates the performance of a system by building models of operational missions the system is expected to perform. Missions are broken down into smaller sub functions, and the mission as a whole is projected as a network of these functions. Each function is then further broken down into a network of functions and tasks. The system estimates of the time to perform the task, the workload, and the probability of success to support simulation of the mission. After the simulation, a range of reports and results is created to compare the minimum acceptable mission performance time and accuracy with the predicted performance and thus to determine whether the mission met the performance requirements. IMPRINT can simulate any process that can be broken down into sub functions or described as a flow of tasks. Along with operational missions, maintenance and logistic processes can also be evaluated in IMPRINT.

The operations modeling capability can estimate the number of people required to perform the tasks within the time constraint, the duration of the performance, and the likelihood of successful completion, while evaluating the crew workload. Workload can also be evaluated using the visual, auditory, cognitive, and psychomotor (VACP) method or the advanced workload method. These approaches provide a much more detailed look at the workload issue and examine the impact of workload management strategies.

Simulation of a model using this method will provide workload values over time for each system operator. Graphs show the workload peaks and indicate the tasks that contribute to the peak. Such tasks are then liable for redesign, automation, or reallocation among the crew. The workload modeling capability can reduce the amount of visual, auditory, cognitive and psychomotor efforts is involved during process performance and distribute tasks according to the current strategy. The advanced workload modeling capability can also help evaluate the impact of the workload or the redesigned automation on the mission performance, time, and accuracy.

IMPRINT has a define equipment module that estimates the number of human-hours required to maintain a system. Data regarding maintenance manpower pools, spare availability, combat damage potential, maintenance schedule; and maintenance action are fed into the module. The end result is a stochastic maintenance simulation that predicts the number of human-hours required to maintain system availability. The analysis also develops results such as predicted reliability, availability, and maintainability (RAM). Requirements are predicted by simulating maintenance procedures for units to be sent on a mission, maintenance of the units during the mission and return of the units. The system also accounts for complexities like prioritizing and scheduling repairs based on the pools of maintainers, their specialties, the constrained pool, spare availability, combat damage, maintenance shifting, and the criticality of individual component failures [21].

The manpower analysis capability provides data regarding the number of people required from every specialty, subsystems identified for maximum maintenance, and the effect of the failure of various subsystems on the entire system. The three categories of data required to perform this analysis are:

1. maintenance requirement description, including frequency, type, and duration of required maintenance, organizational and scheduled type, and maintainer type,
2. description of the scenario in which the mission must be carried out and the interaction detail of the system that determines system usage and the probability of combat damage, and definition of unit configuration and support parameters for

the scenario, i.e, a description of the operational crew, maintenance shift manning, and spare parts[21].

The define soldier module of IMPRINT indicates the type of soldier necessary in terms of personal characteristics and mental aptitude, determines the availability of that type in a given military occupational specialty (MOS), and estimates the availability of that type in the future. The reports generated under this module project the following characteristics

• gender tied very closely to physical differences that may impact performance on selected tasks required by a specific specialty).

• Education (high school graduate or non high school graduate, a good indicator of an individual's trainability and amenability to the discipline required to make it through basic training.

• Test Score Category (I, II, IIIA, IIIB, & IV, a good indicator of an individual's trainability and a good predictor of performance).

• Armed Services Vocational Aptitude Battery (ASVAB) score distribution (0 – 135, a good representation of the aptitude and knowledge required to perform tasks for a particular specialty).

• Reading Grade Level (<7 - >12, indicating the soldier's capacity to comprehend information in training materials, job aids, and instructional manuals),

• Weight Lift (tied very closely to the physical requirements to perform tasks required by a particular specialty) and

• Psychological, Upper Extremities, Hearing, Lower Extremities, Eyes,
Stamina (PUHLES) Eyes (1, 2, & >2, the eyes rating is tied very closely to the visual requirements of the tasks to be performed by a particular specialty [21].

Personnel characteristics are important because they can be good predictors of how well soldiers will perform mission critical tasks. Soldiers with higher mental aptitude scores perform most tasks, especially cognitive tasks, more accurately and in less time than soldiers with lower mental aptitude scores. As the army acquires more technologically sophisticated systems demanding cognitive rather than physical skills, it is important to determine whether current MOSs will have the types of people needed to support those systems. IMPRINT uses historical trend data to estimate the types of people likely to be in that MOS in future years.

The define force structure capability in IMPRINT is used to develop army-wide estimates for manpower required to operate, maintain, and support a weapon system. It does so by estimating manpower and personnel requirements, then extrapolating from these results to estimate requirements for other army units. The analysis evaluates aspects like an increase in performance standards after raising a cutoff score, the number of MOS available at various cutoff levels; the difference in performance among soldiers with various test scores, and the acceptable trade-off between performance and availability [21].

IMPRINT can modulate personnel characteristics, training frequency, and stressor data for any analysis. The training frequency option allows the modeler to review and edit training frequencies for each task. The level and frequency of training differ for various tasks, and an increase in training frequency normally decreases the time required to perform the task. System performance increases with an increase in the training. IMPRINT evaluates the frequency of the training, its impact at various levels and the acceptable tradeoff between performance and increased training frequency.

The five stressors identified by IMPRINT are cold, heat, noise, mission oriented protective posture (MOPP) gear for individual nuclear, biological, and chemical defense, and sustained operations (sleepless hours). Stressors may be reviewed and changed for each individual task, one at a time, or for an entire group of tasks all at once. Stressors can significantly affect the accuracy and time of the performance.An analysis including stressors can help evaluate factors like dexterity in a level IV MOPP, degradation of performance in extreme temperatures, the combined effect of two or more stressors on performance, the maximum impact among the multiple stressors, and maximum degradation among multiple tasks[21].

2.4 ENCOMPASS

Another tool for consequence management similar to IMPRINT and developed by DARPA is called Enhanced Consequence Management Planning and Support System, or ENCOMPASS. ENCOMPASS provides customized application that offers map-based situation assessment, situation-based response checklists, casualty tracking, and epidemiological surveillance.

For an appropriate decision making and coordinated response, a bidirectional flow of information is important (i.e a status report from the first responders to the high commanders and decisions conveyed from the high commanders to the responders).A sophisticated communication infrastructure is required for the smooth flow of information. Because of advanced communication technology that facilitates decision making and expedites actions, ample amount of information is available to responders and decision makers from various entities, including fire, police, emergency medical services, public works, and the building inspection department. Another example of important information is the emergency operation plan (EOP); an updated enumeration of the responsibilities shared by various personnel in various departments. This plan is distributed among all the personnel on various schedules depending on the level of government. Any improvement in the EOP brings significant improvement in the performance of responders.

ENCOMPASS addresses the need for information and its advanced communication during critical situations. It is a suite of software tools designed to coordinate among multiple responders and accommodate their varied requirements before, during, and after an event. The components of ENCOMPASS can function as a unit or independently, and they can be customized based on specific requirements. ENCOMPASS has the following features: [22]

1. Planning: helps the decision maker consolidate all data acquired from various sources and develop a plan of action for the response based either on standard operating procedures (SOP) or on the unique aspects of a given incident.

2. Casualty Tracking: monitors the location of all casualties, from the site of injury through transport to a medical care facility.
3. Resource Tracking: monitors the location of the personnel, equipment, and supplies necessary to respond to an event.
4. Medical Facility Tracking: monitors the status of medical facilities, including available beds.
5. Real-Time Incident Assessment: assists incident status visualization in a manner that can be customized for a given incident or decision maker.
6. Monitoring for Potential Biological Attacks: identifies biological attack by statistically analyzing casualty diagnoses.

Incident Documentation and Post-Event Analysis: retains information produced by ENCOMPASS components in a single repository that provides the basis for report generation and subsequent review. [22]

ENCOMPASS leverages the latest advances in information technology to deliver its services. User-customizable software components display information on desktop, laptop, or handheld devices. The system uses web-based and stand-alone software to collect and distribute dynamic data to and from multiple locations in real time, responding to calls for greater use of the Internet in emergency response. ENCOMPASS communicates over the Internet and local and wide area networks. Web technology makes information available to users without stringent system requirements and allows seamless, real-time access. Since communications are often unreliable in an emergency response environment, the ENCOMPASS architecture is designed to continue operating under intermittent communications.

ENCOMPASS consists of two subsystems and a repository that bridges the two to provide a consistent incident picture across components. To ensure that the repository is not a single point of failure, ENCOMPASS components connect to the repository using a flexible communication mechanism that accommodates periodic breaks in communication channel. The function of each component is described briefly below:

Incident Command Management System

1. Electronic Watchboard (EWB) : The centerpiece of the ENCOMPASS system, the watchboard offers each commander and responder a customizable view of incident characteristics, such as casualty counts and current weather. The watchboard provides incident commaders with a common operational picture of the incident.

2. eWebApps: A collection of web based interfaces, this application identifies incidents update and view casualty counts, monitor the status of medical facility resources, update operational checklists, reference emergency contacts, and find casualty locations.

3. FD on Scene: Supports Fire Department (FD) field operations with incident management, responder accountability, pre-incident planning, and map viewing. While FD on Scene is designed to exchange information with the ENCOMPASS system, or to operate as a standalone unit.

4. Tactical Medical Coordination System (TacMedCS): Enables electronic tracking of injured soldiers.

5. ViewPort: Provides map-based visualization of incident events and assigned resources.

6. Crisis Action Planner (CAP): Captures and analyses of response messages and creates PowerPoint briefs at the conclusion of critical phases in the planning cycle.

DARPA Syndromic Surveillance Sysem (DS3)

1. Web-Based Patient Data Collection: Captures symptoms of each patient who enters on emergency room.

2. MedView: Provides a spatial, map-based picture for medical surveillance.

3. Biological Agent Symptomology Identification System (BASIS): Provides proactive medical surveillance by statistically analyzing electronic medical data and alerting users to possible emergency medical situations [22].

3 THE CASE STUDY

3.1 THE INCIDENT

A university campus experienced chaos when a graduate student majoring in geotechnical engineering claimed to have a bomb and anthrax in a university building. The incident began shortly after midnight when the student arrived at an engineering building. The student prepared a multiple-page document allegedly describing an intricate plan for the destruction of multiple buildings on the campus.

The campus police received a call indicating that someone in the building had a knife, a gun, and some kind of powder, and was talking about destroying a target at 8 a.m. that day. The campus police responded and called the local police department to assist. Over seven agencies responded to the threat, including the local fire department, weapons of mass destruction team, the FBI, and the local unit of Homeland Security. Upon arrival, officers found a four-page letter outlining certain “missions” and a clear plastic bag containing a white powdery substance. The university police said the note contained references to suicide. The student, who was in the laboratory portion of a classroom had a hunting knife in one hand and was holding a blue drawstring bag in the other. He was screaming and claimed to have a bomb and anthrax in his possession. He said he was going to destroy the building. The police kept telling him to put the knife and the bag down, but he just kept screaming, waving the knife, and saying he had a bomb.

When the student did not calm down, officers prepared to use a taser gun to subdue him. The student continued to wave the gun, lunging forward and jumping back, while claiming he had a bomb. When he raised the knife as if to throw it at an officer, the officer tased him. The student held onto the knife and the bag. When tased a second time, he dropped the knife and fell against a table in the laboratory, eventually falling to the ground. The officers struggled to get the still-screaming student handcuffed. He still refused to comply with officers’ requests and was tased a third time to get his hands handcuffed behind his back.

Once handcuffed, the student was removed from the building, decontaminated, and questioned. Along with the four-page letter, police found an area plan of the building and a map of the campus. They discovered the knife was wrapped in layers of clear packing tape, although the tip of blade was exposed. The blue drawstring bag contained clumps of soil instead of a bomb. Law enforcement agencies tested the contents of the bag and the white powdery substance. The student had claimed he had anthrax but the white powdery substance was later determined to be powdered sugar.

Authorities took precautions to close the university in response to the bomb, anthrax, and terrorist threat. Eight students, one professor, 11 law enforcement personnel, one civilian, and two emergency medical technicians were detained and quarantined in another building after the powdered substance was found. Six felony charges were filed against the student [23].

Figure 3.1: Decontamination teams working carefully with samples of the white powdery substance found at the scene of the threat, later tested and found to be powdered sugar.

Figure 3.2: Response teams prepare outside of the decontamination tents in a parking lot.

3.2 MODELING

A model of the case study built using IMPRINT is shown in Figure 4. In all, three models were developed based on input from the responding agencies, including the campus police department (PD), the local PD, emergency medical technicians, the sheriff's department, the fire department, the FBI, the WMD team, and the local Homeland Security unit. The first model, as shown in Figure 4, was a detailed model of the campus PD acting as the responding agency.

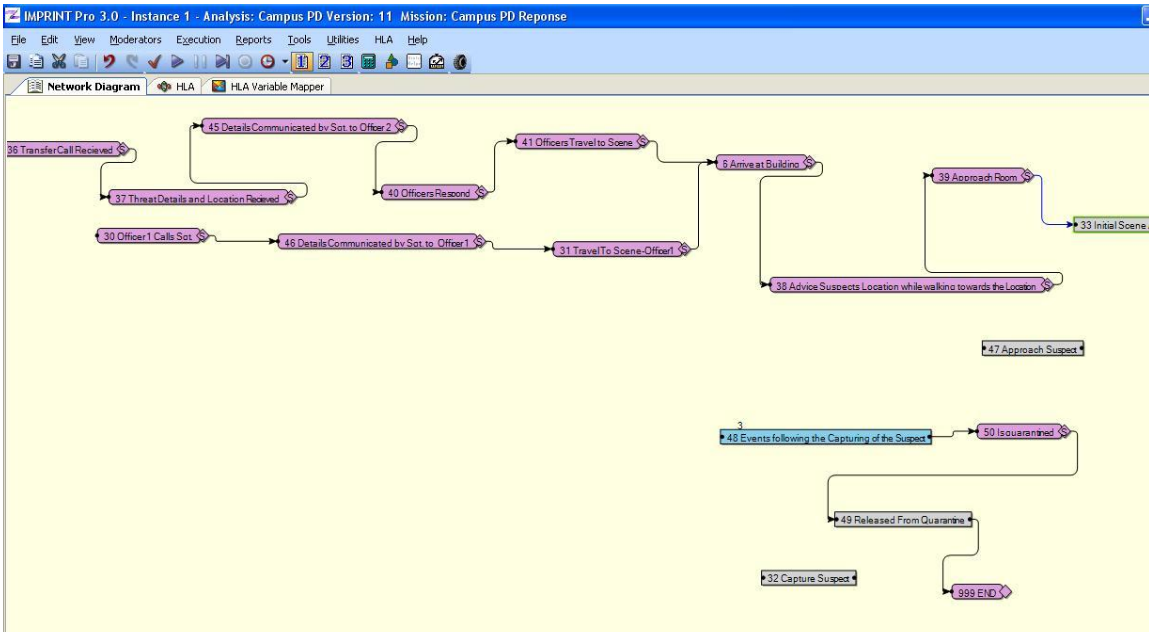

Figure 3.3: Campus PD Model

The Campus PD model is the most detailed network model. The action in the model starts with the node representing a suspicious call being received and processed by responding a campus PD Sergeant, Officer1, and Officer2. The three officers as shown in Figure 5, Campus PD Sergeant, Officer1, and Officer2 were the first to arrive on the scene; they made the initial scene assessments (Task 33), approached the suspect (Task 47), asked for back up, and captured suspect.

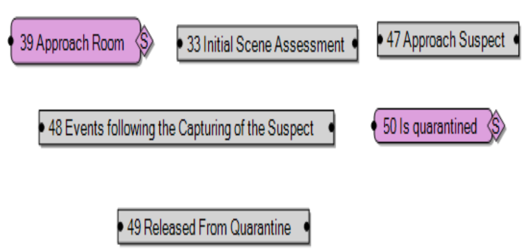

Figure 3.4: Campus PD Model Actions

Each action or node in Figures 4, 5, and 6 has the properties that must be fed manually by the modeler. Each node represents a function, and the functions are broken down into tasks. The properties of each task can are:

- Time and accuracy – How long a task should take is expressed in mean and standard deviation and failure rates.
- Effects – Sets the conditions at the beginning of a task and its effects on the rest of the model.
- Failure consequences – Indicate what happens should a task fail its accuracy criteria.
- Crew – Allows assignment of both primary and contingency operators to a task, and includes a workload management strategy when multiple tasks are required of the operator.
- Taxons – describes a task and sets associated stressors. Task types include perceptual, cognitive, motor, and communication.
- Paths – Assigns the networking branching logic of multiple (all subsequent paths taken each time), tactical (the first path with a "true" status is taken), or probabilistic (the path taken depends on probability) paths.

Workload demands – Describes the resources available to an individual (auditory, cognitive, speech, visual, and motor) and the interfaces (controls). Determines workload demands and resource conflicts.

In Figure 5, node 39 is the task "Approach Room". This task is performed by the officers responding to the scene. Data is input for time and accuracy of the task. The type of distribution can also be selected, such as normal, Bernouli, Pareto, the mean and standard deviation for the distribution are input by the modeller. For the "Effect", conditions for the response are set with output values depending on the outcome of the task as true or false. Under the "Analysis tree", the option "Warfighters" permits allocation of responders, and the capacity of each responder is defined according to position he or she holds. For example, a supervisor may be faster and more accurate than his or her subordinate due to experience. This measure of an officer's capacity is recorded in the model by allocating to him a *speciality, threshold level*. The "Crew" section of any node then permits allocation of the type and number of officers to the mission depending on the requirements. The ‘Failure’ tab addresses the probability that each aspect of the action will succeed and calculates the consequence if the task “Approach” fails. The “Taxons” application defines the VACP (visual, auditory, cognitive, and psychomotor) value for the officers approaching the scene. The “Path” determines the various ways the task can be achieved by the officers and the probability of each path, analyzing the possibility that each paths will return the value true or false. The “Workload” determines the workload the crew member will have to bear to approach the scene, considering that he or she must be alert for any kind of movement from the suspect and expect any suspicious behavior from the student.

The second model, shown in Figure 6, evaluates the action of the remaining responders. These agencies that responded to the call for back up talked with the original responding campus police officers and the suspect and decided to quarantine the building based on the threat information they gathered. The model traces the actions carried out by the command post from the time it was set up until the scene is considered safe and is handed back to the local PD.

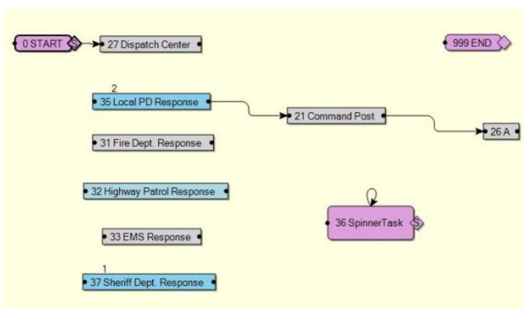

Figure 3.5: Campus Incident Model

The functions highlighted in blue in Figure 6 are called *scheduled function*. The schedule functions

- allow for more rapid and visual development of high level task networks,
- allow the user to dynamically move and resize parts of their network according to time, permitting various case study trials very applicable to CM operations, and

- permit the user to mix scheduled functions with more detailed and finite task networks in a traditional diagram.

The local PD response is also a scheduled function, and many data are available with respect to it. The schedule function capacity can be seen in use in Figure 7.

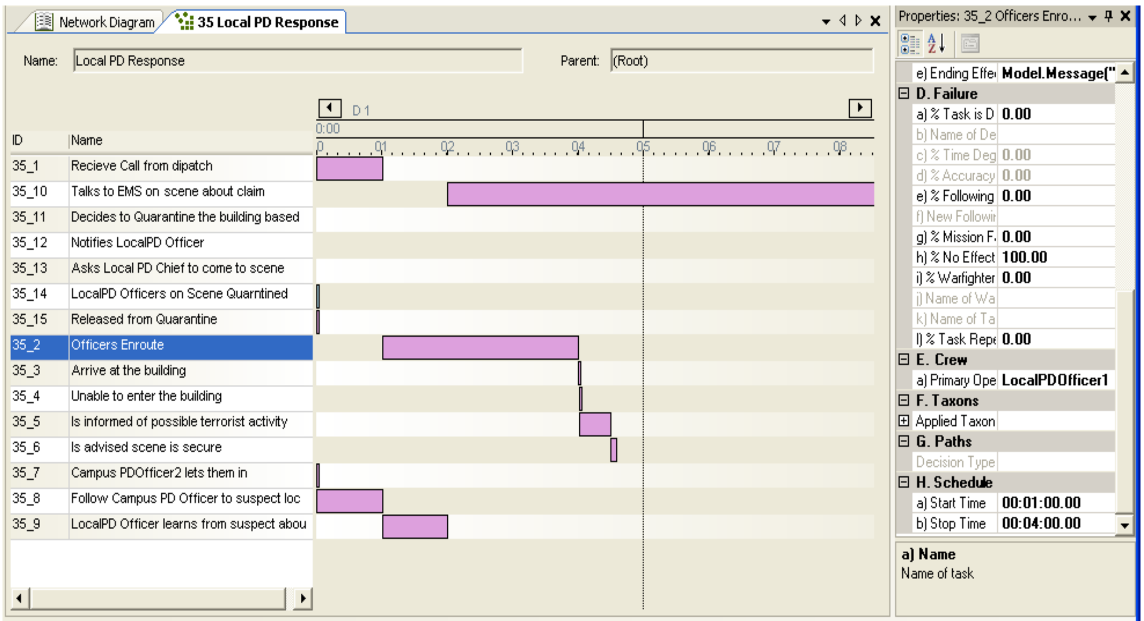

Figure 3.6: Local PD Tasks Set Up Using Scheduled Functions Capability

Figure 7 shows the timeline and the action assigned. These values can be changed for what-if-analysis. For example, the mean task time for Talk to EMS on scene about claim is changed from 15 minutes to 30 minutes by dragging the time line of the task, thus changing the mission time. Rerunning the model to incorporate this change takes about five seconds. The impact of changing the time of the task can be analyzed using the new model created after the rerun. This feature is useful to the user because it allows various case study trials very applicable to CM operations.

The third model combines the first two models to play the what-if scenarios effectively. The campus PD response is now a part of this model.

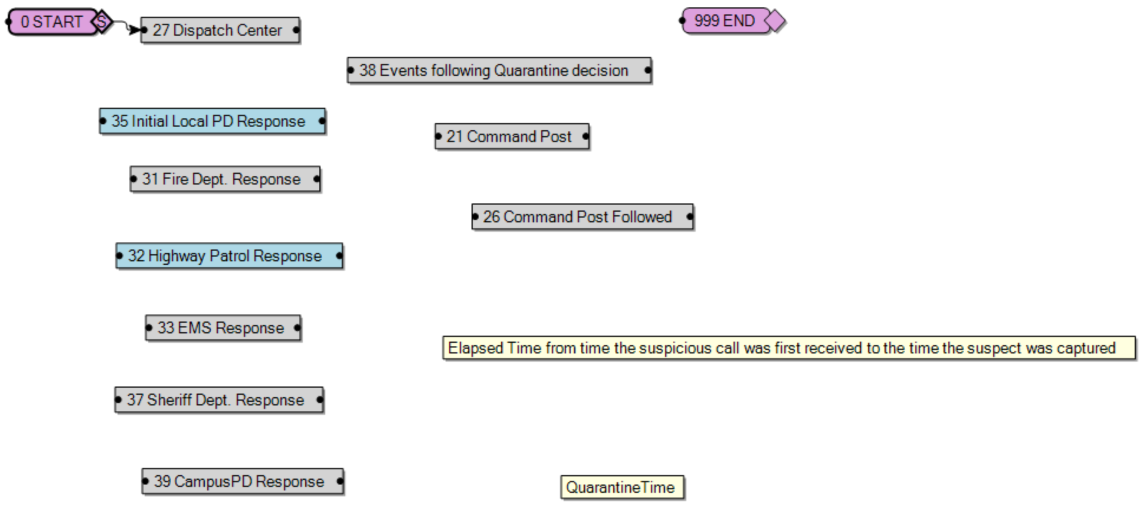

Figure 3.7: Combined Campus Incident Model

The what-if scenario can be helpful when evaluated with the models developed here. Some of the consequences that can be analyzed for the what-ifs are:

1. the impact if the emergency notification system [ENS] were activated.
2. the impact of activating the ENS at various times.
3. the impact if the incident occurred in another building.
4. the impact if the officers helping in evacuation had the list of names and number of people present in each room.
5. the impact if the number of responders changed.

Similarly, a number of what-if cases can be discussed and evaluated using this model. The what-if scenario with respect to the ENS is shown in Figure 10.

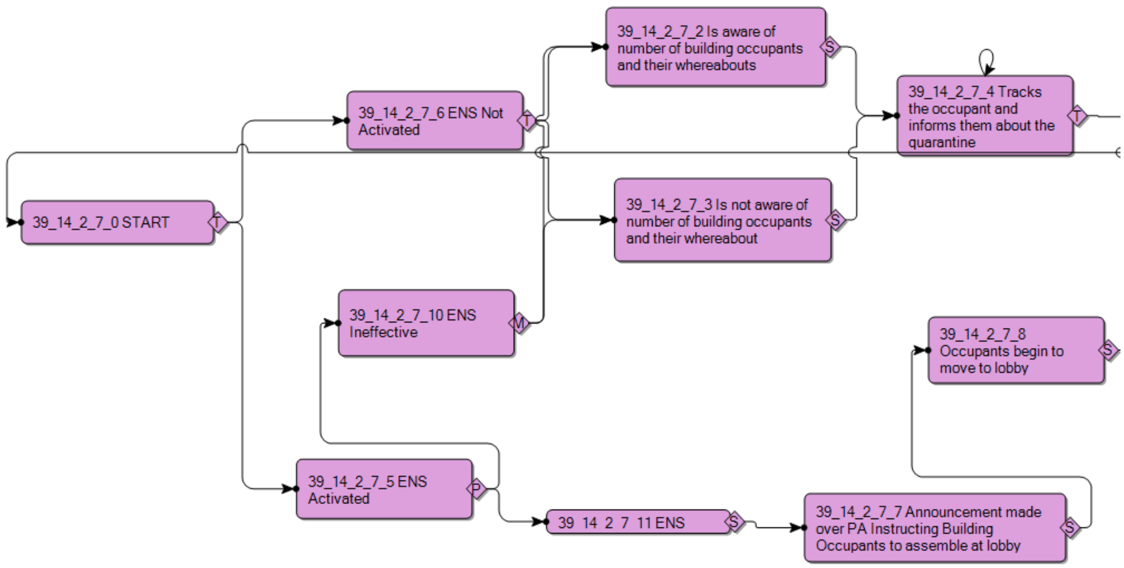

Figure 3.8: The ENS Evaluation.

The following discusses the effect of the ENS system on the whole of the system. In the same network we also discuss the possibility that the ENS might not be activated is also addressed, along with its effects. Comparisons can be drawn and analyzed. If the ENS system is activated, the extent to which it can be effective must also be considered. If it is effective, the action that follows is evaluated, such as the announcement of the alert message to threatened occupants, evacuation of the building, decontamination, and medical treatments. The overall properties of the node are input, and reports are evaluated for all the option of a what-if situation that branch out.

The case study shows the complex scenarios that develop during consequence management. With powerful tools such as human performance modeling, a modeler can examine multiple complex situations and predict their outcomes without having to go through an actual emergency event. This saves money, time, and efforts on the part of the management and the responders. The model is a good tool for training and preplanning practice. First responders can be trained to expect all possible scenarios and learn to handle any that arise.

4 MODEL ANALYSIS

First responders in this case study were the campus PD, the local PD, emergency medical technicians, the sheriff’s department , the fire department, the FBI, the WMD team, and local Homeland Security unit. The first officers who arrived at the scene were from the campus PD; their feedback was used to build the model in IMPRINT.

The model was demonstrated to the director of the campus police department. His opinion was sought regarding the various features of the model. He felt that personnel rise to the occasion and make the decisions based on their previous experience in the extreme situations like the one described in the case study; aspects of such situations change in split seconds, sometimes making them life-threatening events.

The director found the technology very new and said that he and his officers have never before come across such models. He was however, interested in the features that could help him determine the following:

1. number of personnel to be dispatched to the scene.
2. type of squads (bomb squad, fire fighters) involved in operation.
3. number of personnel required for each squad.
4. expected time to complete event, and milestones, like evacuating the potential threat location of any of its occupants, putting boundaries to the location, and setting up quarantine tents.
5. types and amounts of resources required to deal with the scenario.

He thought that if they could get personnel to operate the model the technology, it could be used effectively. The difficulty would be making the campus police department familiar with the technology and training officers to operate the model. To use the model in real time, a set of generic models would be necessary to allow modifications as events unfold. A promising possibility in the director’s view would be the use of models during officer training. He was open to using the model as a preplanning and training tool.

The concept of a human performance model was new and intriguing for officers. Most of the decisions made during the event were based on previous experience and training procedures. Officers were open to the idea of using models but were skeptical about applying them in real time because when an emergency situation arises there are many variables to be addressed and these can change in a fraction of a second. In a real-time situation, it would be nearly impossible to feed all the variables into the model and the wait for its response.

Events such as the one modeled in the case study are rare. Human Performance modeling offers police departments and other responders an effective method of training and evaluating responses. Features like the evaluation of the impact of changes in the number of personnel and the place or time of the event can train personnel to address multiple possibilities and what-if situations. The model can also be used as a tool to evaluate procedures and training methods.

PAPER

1 HUMAN PERFORMANCE MODELING FOR EMERGENCY MANAGEMENT DECISION MAKING

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1.1 ABSTRACT

Computer simulation model allows users to analyze problems and identifies improvements for systems in various fields. Human Performance Models (HPMs) are a type of computer simulation which is used to study and evaluate complex operations involving humans completing tasks. Recent events have increased the awareness of the importance of effective crisis response whether for a terrorist attack or a natural disaster. This paper describes the advantages HPM can have to those involved in emergency management.

IMPRINT Pro a HPM software package is a tool developed by the U.S. Army Research Laboratory. It is a stochastic discrete event network modeling tool designed to help assess the interaction of people with systems to evaluate systems' performance throughout their lifecycles. The model includes resource availability and limitations, tasks to be completed, success probability for each task and the mission as a whole, and other features to evaluate what-if scenarios. The results include flow diagrams and performance metrics. The models can be used as a pre-planning and training tool to improve an organization's performance.

To demonstrate the benefits of using the modeling software for emergency management, a case study of a combined anthrax and bomb threat made at a university is presented. Data from first responders including police and fire departments and the

procedures used are modeled. The human modeling software includes the effects of external and internal stressors on personnel performance, the workload demand, the branching of possible alternatives, the crew allocation and the effect on mission performance.

Keywords: Emergency Management, Human Performance Modeling, IMPRINT, terrorist attack

1.2 INTRODUCTION

Simulation refers to a broad collection of methodologies to mimic the behavior of real systems often using computers. Simulation has been applied to many fields with widely varying applications including flight simulators to safely and cost effectively improve crew performance to models of part moving through a factory used to identify bottlenecks and reduce manufacturing times. Simulation allows one to evaluate different possibilities or procedures without actually making changes to the real system. This not only saves time, money, and effort but it also allows one to consider situations that might not be possible in practical. For example, if one wanted to consider different layouts for a new factory it is not reasonable to build alternative factory designs, but one could model them on the computer and evaluate the performance of each quickly and determine the best design. Similarly, for emergency preparedness it would be impossible to evaluate differing response alternatives to a natural disaster. No two disasters are the same and they often strike with little warning. This combined with the real possibility that a poor response can cost human lives; make computer simulations a useful tool for emergency planning.

We will illustrate how emergency management can use simulation models to evaluate response procedures. Crisis models can serve important purposes including:

- Models allow for the creation of different situations and assessing likely results.
- Models allow for the evaluation of resource levels and deployment (i.e. first responders, K9 teams, emergency equipment) during a response.
- Models can be used as a planning tool to prepare for potential emergencies.

- Models can be used as training aides to prepare the responders for varying emergency situations.

1.3 HUMAN PERFORMANCE MODEL

In order to evaluate crisis situations from a human performance perspective and to understand IMPRINT modeling, it is important to understand human performance modeling. In this application the term model denotes a computer-based representation that mimics either the behavior of a single human or the collective action of a team of humans. The concerns addressed are: 1) What people do, 2) Why they do it, 3) How they do it, and 4) The consequences of doing it. (ARL, 2008) These models serve as a tool in training and analysis; they can be used in general training or in rehearsal to prepare for a specific operation. As an analysis tool the models can be used to evaluate systems, staffing, doctrine, and tactics. (Pew and Mavor, 1998) Inputs to the model include tasks to be performed and their time requirements. The outputs are performance measures such as resource utilization and time required.

Human Performance can be depicted as shown in the diagram in Figure 1. Goals are specifications or desired states for the given conditions. Training, information, and procedures influence the human's understanding of a situation as he or she prepares to take action. Perception is one's understanding of a situation. It is influenced by past experiences and expectation. As a situation develops the human tries to take action based on their perception of the situation in line with their goal(s). The outcome of the action can be far from perfect due to the disturbances, unpredictable conditions, and system status. The result of actions provide feedbacks to the human which can either justify its previous perception, changes to it, or prompt the human to select a new action.

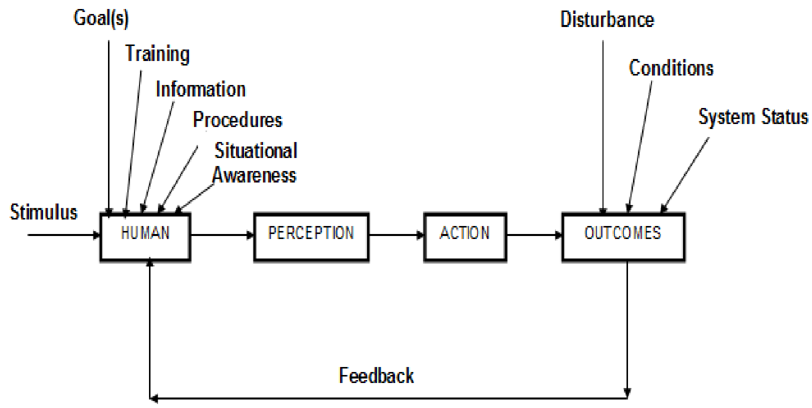

Figure 1.1: Human Performance Process

An emergency responder's action during an operation can be evaluated using the model. Emergency responders have a goal to protect public health and safety, and provide assistance to affected individuals. Responders are under the influence of many factors including any training that he or she has undergone and the procedures prescribed to tackle such situations. The responder also gains information from the actual situation such as the number of victims and their whereabouts. Based upon these inputs and the experience gained over the years, the responder develops a perception. According to this perception the responder takes action. The outcome of the action is under the influence of external factors such as limited visibility at the scene, equipment failure, or just plain bad luck.

HPMs build on the process approach shown in Figure 1. These more complex models are useful because they allow the quantification of human performance capacities and limitations to be included in the analysis and simulation of emergency response systems. Human Performance Models serve multiple purposes including:

- The models are less expense and easier than real time exercises and drills
- They assist in setting appropriate goals and intended outcomes
- They help in the assessment and improvement of actions of emergency responders

Models can identify significant factors that impact performance

1.4 IMPRINT

IMPRINT is a Human Systems Integration (HSI) and Manpower and Personnel Integration (MANPRINT) tool developed by the U.S. Army Research Laboratory, Human Research & Engineering Directorate. It is a stochastic discrete event network modeling tool designed to assess the interaction of soldiers and systems throughout a system's lifecycle from concept and design through field testing and system upgrades. As a system design and acquisition tool, IMPRINT can be used to set realistic system requirements; to identify human-driven constraints on system design; and to evaluate the capability of available manpower and personnel to effectively operate and maintain a system under environmental stressors. (U.S Army Research Laboratory website, Improved Performance Research Integration Tool, http://www.arl.army.mil/www/default.cfm?Action=445)

IMPRINT estimates the performance of a system by building models of operational missions the system is expected to perform. For example the software could be used to evaluate a new tank for the military. Missions are broken down into smaller sub functions and the mission as a whole is projected as a network of these functions. Each function is then further broken down into network of functions and tasks. A mission might be that the tank crew will patrol an area and evaluate threats. A task within this mission might be to collect an air quality sample. Estimates of the time that will be required to perform the tasks are added to the model. The workload for the crew during the tasks and the probability of the success for the tasks are included in the model to enhance the quality of the model. This could include detail such as the type of protective clothing that is worn or the frequency of the false positive test results.

After the completion of the simulation model, a range of results and reports can be created. These can be used to compare the minimum acceptable mission performance (in both time required and accuracy) to the predicted performance from the model. This type of analysis can aid in determining whether the mission will met the set performance requirements or if additional resources such as more personnel are required. IMPRINT can simulate any process which can be broken into sub functions and described as flow of tasks including emergency management operations.

Simulation models can estimate the number and type of people required to perform the tasks within the time constraint. It can predict the duration of the performance for an entire operation or a portion, such as securing a location. Simulation models predict the likelihood of successful while evaluating the workload demands of team members. Workload can be evaluated at a high level such as percentage of time someone is idle or it can be evaluated in a more detailed manner by using an advanced workload method using the visual, auditory, cognitive, and psychomotor (VACP) demands on an individual. This approach provide a much more detailed look at the workload issue and also helps examine the impact of workload management strategies such as rotating task assignments. Graphs can be plotted showing workload peaks over time and also indicating the tasks that contribute to these peaks. When peak tasks are identified they can be redesigning, automation, or reallocation among the crew. This workload modeling capability can help balance the amount of visual, auditory, cognitive, and psychomotor effort is involved during an operation and can evaluate the impact on workload of automation or task redesigning will have on performance time and accuracy.

IMPRINT has the capability to model the personnel characteristics, training frequency, and stressors for any analysis. The training frequency option allows the modeler to review and edit training frequencies for each task. The level and frequency of training can differ for different tasks. Typically an increase in training frequency will decrease the time required to perform the task and overall performance will increase. Simulation models can help evaluate the frequency of the training, its impact at various operational levels, and acceptable tradeoff between performance and increased training frequency.

There are five different types of stressors identified in IMPRINT; they are cold, heat, noise, protective clothing, and sustained operations (sleepless hours). Stressors may be reviewed and changed for each individual task, one at a time, or, for an entire group of tasks, all at once. Stressors can significantly affect the accuracy and time of the performance. An analysis with these stressors can help evaluate factors such as the loss of dexterity while wearing protective gear, degradation of performance in extreme temperatures, combination effect of two or more stressors on performance, the maximum impact among the multiple stressors, and maximum degradation among multiple tasks.

1.5 THE INCIDENT

To illustrate the application of human performance modeling to emergency operations a crisis event is modeled. A university campus experienced an emergency situation when an international engineering student claimed to have a bomb and anthrax in a university building. The incident began shortly after midnight when the student arrived at a campus building. The student had prepared a multiple-page document allegedly describing an intricate plan for the destruction of multiple buildings on the campus. The campus police received a call indicating that someone in the building had a knife, a gun, some kind of powder, and was talking about destroying a target at 8 a.m. that morning. The campus police responded and called the local police department to assist. Over seven different agencies responded to the threat, including the local fire department, a Weapons of Mass Destruction team, the FBI, and the local unit of Homeland Security. Upon arrival officers found a four-page letter outlining certain “missions” and a clear plastic bag containing a white powdery substance. The university police said the note contained references to suicide. The student was in the laboratory portion of a classroom. He had a hunting knife in one hand and was holding a blue drawstring bag in the other. He was screaming and claimed to have a bomb and anthrax in his possession. He said he was going to destroy the building. The police kept telling him to put the knife and the bag down, but he just kept screaming, waving the knife, and saying he had a bomb.

When the student did not calm down, officers prepared to use a Taser gun to subdue him. The students continued to wave the gun, lunged forward and jump back, while claiming he had a bomb. When the student raised the knife as if to throw it at an officer, the officer Tased him. The student held onto the knife and the bag. When Tased a second time, he dropped the knife and fell against a table in the laboratory, eventually falling to the ground. The officers struggled to get the still screaming student handcuffed. He still refused to comply with officers' requests and was Tased a third time to get his hands handcuffed behind his back.

Once handcuffed, the student was removed from the building, decontaminated, and questioned. Along with the four-page letter, police found an area plan of the building and a map of the campus. They discovered the knife was wrapped in layers of clear packing tape, although the tip of blade was exposed. The blue drawstring bag contained clumps of soil instead of a bomb. Law enforcement agencies tested the contents of the bag and the white powdery substance. The student had claimed he had anthrax. The white powdery substance was later determined to be powdered sugar. Authorities took precautions to close the university in response to the bomb, anthrax, and terrorist threat. Eight students, one professor, 11 law enforcement personnel, one civilian, and two emergency medical technicians were detained and quarantined in another building after the powdered substance was found. Six felony charges were filed against the student. (Martin, 2007)

1.6 METHODS

The case study simulation model built using the IMPRINT software is shown in Figure 2. This is an overall model of the incident that was developed. The lower level details were added to this model for various tasks performed. The model was developed based on the input from the responding agencies including the campus police department, the local police department, emergency medical technicians, the sheriff department, the local fire department, the FBI, the weapons of mass destruction team, and local unit of Homeland Security. The response in the model starts on the left with the 911 phone call that was received. Each oval is a node and it represents a task. The arrows in the network show how events unfold. After a task is completed, the next task is performed. The first few tasks in figure 2 show the communications between the officers and their arrival at the engineering building. These tasks were performed by three responding campus police officers. In the model they are labeled PD sergeant, Officer 1, and Officer 2.

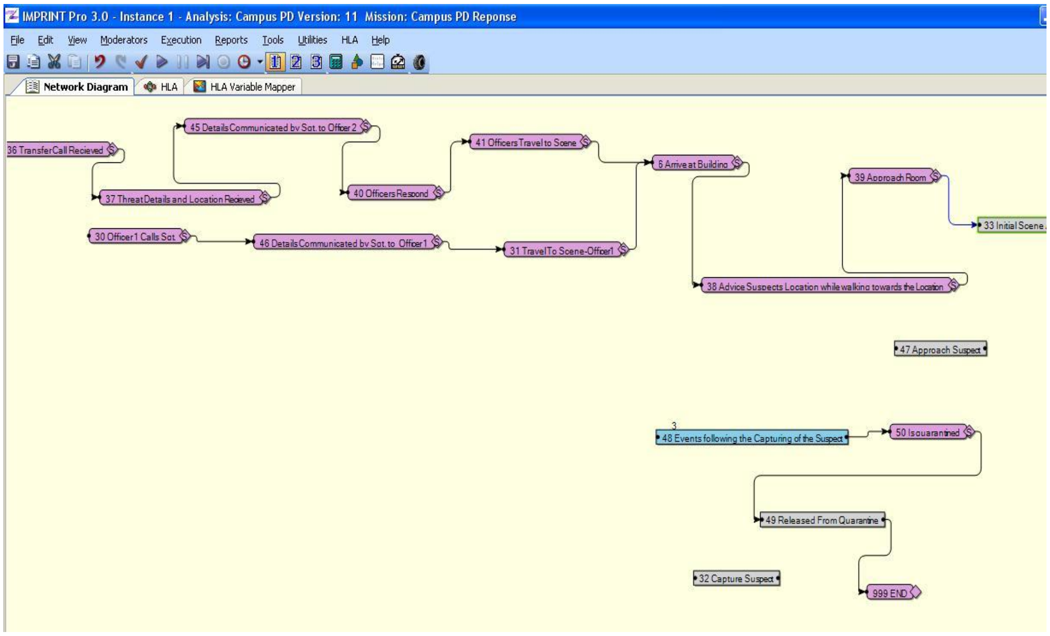

Figure 1.2 Campus Police Department Model

The detailed portion of the tasks performed by the campus police department is shown in Figure 3. This is the more detailed portion of the network model. The three officers were the first to arrive on the scene, make the initial scene assessments (Task 33), approach the suspect (Task 47), ask for back up, and capture suspect.

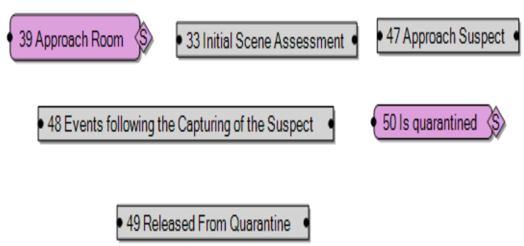

Figure 1.3 Detail Portion of Campus Police Department Model

Each of the activities in these figures has properties which are inputted by the modeler. High level functions (i.e. secure locations) are broken into task. Each task has properties including:

- Task Time and Accuracy
- Task Effects
- Failure Consequences
- Network Path(s)
- Crew
- Stressors
- Workload Demands

Task time and accuracy states how long a task should take to be completed. It is expressed in terms of a mean, standard deviation, and statistical distribution type (i.e. a normal distribution). This provides details about how long something takes on average and the range of times it can take. A failure rate can also be included. Example of a failure type that one might want to include would be if a test to determine a type of chemical explosive is only effective 90% of the time or if a bomb team is only able to defuse 75% of the types of bombs they are likely to encounter. A task effect sets the conditions at the beginning or end of the task. This can affect the rest of the model. For example, an analysis team may need to wait to enter a location until it is secure. A modeler can use the task effect setting to change the building's status for "not secure" to "secure" when the police officers finish a task. This change in setting would then cause the analysis team to begin their work in the simulation model. The failure consequence parameter for a task allows the modeler to determine what task will follow. If the K9 team determines the building is clear, one task may then start, however, if they fail to clear the building due to something suspicious then a different task such as calling in additional resources is then performed

With the crew feature on the tasks, the modeler is able to assignment both primary and contingency operators to a task. They can also includes workload management strategy when multiple tasks are required of the operator, such as do tasks on a "first come, first serve basis" compared to a "highest priority basis". Different performances can be set for different types of operators. For example, the same task performed by a firefighter versus an EMT can have different time and accuracy values. Or more senior personnel can be set to with shorter time values than junior, less experienced personnel. Network path defined for the tasks determines the branching logic of the following tasks. It can be multiple (where several subsequent paths taken each time), tactical (the first path with a “true” status is taken), or probabilistic (where which of several path to take depends on probability) paths.

Stressors (called Taxons in IMPRINT) can be added to a task. The stressor types include perceptual, cognitive, fine motor, gross motor, and communication. These can be used to adjust task performance. For example, if a task is modeled to take two minutes under typical conditions, when the modeler denotes the task will performed in protective clothing then time and accuracy values are automatically adjusted depending on the type of tasks (i.e. cognitive vs. fine motor) and the type of protective clothing. Workload demands describes the human’s available resources (auditory, cognitive, speech, visual, and motor) interfaces (controls). Workload demands and resource conflicts are determined by algorithms in the software.

In Figure 3 node 39 is the task “Approach Room”. This task is performed by the officers responding to the scene. As an example, data is inputted for this task starting with task time and accuracy of the task. A screenshot of the data input screen is shown in Figure 4. The mean task time was set as 30 seconds with a standard deviation of 6 seconds. The type of distribution can also be selected such as normal, Bernoulli and Pareto, for this task a normal distribution was used. The modeler has the option of setting the parameters discussed above or using the system default values. This allows the modeler the ability to make a model as simple or complex as desired. For this task “effect” and “failure consequences” were left at the default setting which has no impact on the flow of tasks in the model. The “crew” section of this task was set as the police sergeant. This determines who will perform the task and occupies the police sergeant for the duration of the task. This would prevent him from performing another task at the same time. This logic is controlled by the software and the modeler does not have to manage this level of detail while building the model. Since there were no unusual stressors for the task, these values are left blank in the input screen.

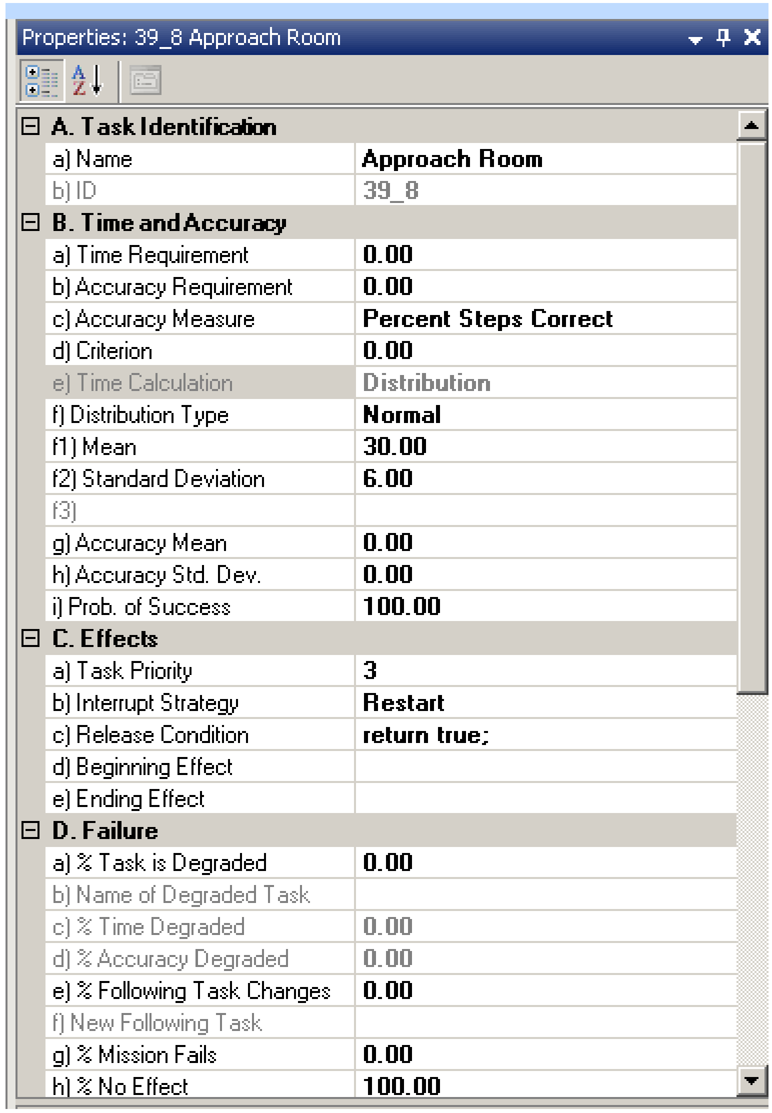

Figure 1.4 Input Screen for a Task

This process of building models and inputting task parameters is continued for the various emergency responders that were called to assist in the situations. Figure 5 shows the high level components of the model for the remaining responders. These agencies responded to the call for back up; after talking with the original responding campus police officers and suspect they decided to quarantine the building based on the threat information they gather. The model traces the actions carried out by the command post once it is set up until the scene is considered safe and is handed back to the local PD. As much or as little detailed information as desired is included in the tasks that combined represent these high level functions (such as Local PD Response). Using these high level functions allows for rapid visualization and development of high level task networks. During the analysis phase the user can quickly move from this level of detail to a lower level and back as desired.

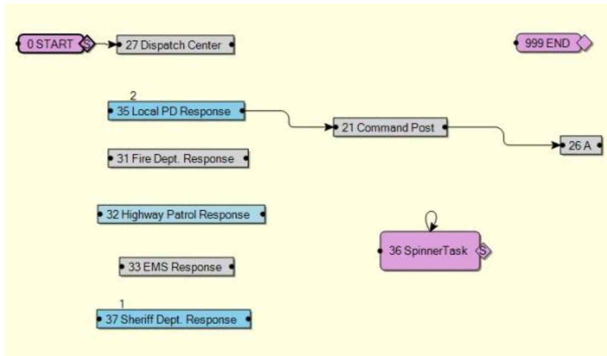

Figure 1.5. Campus Incident Model

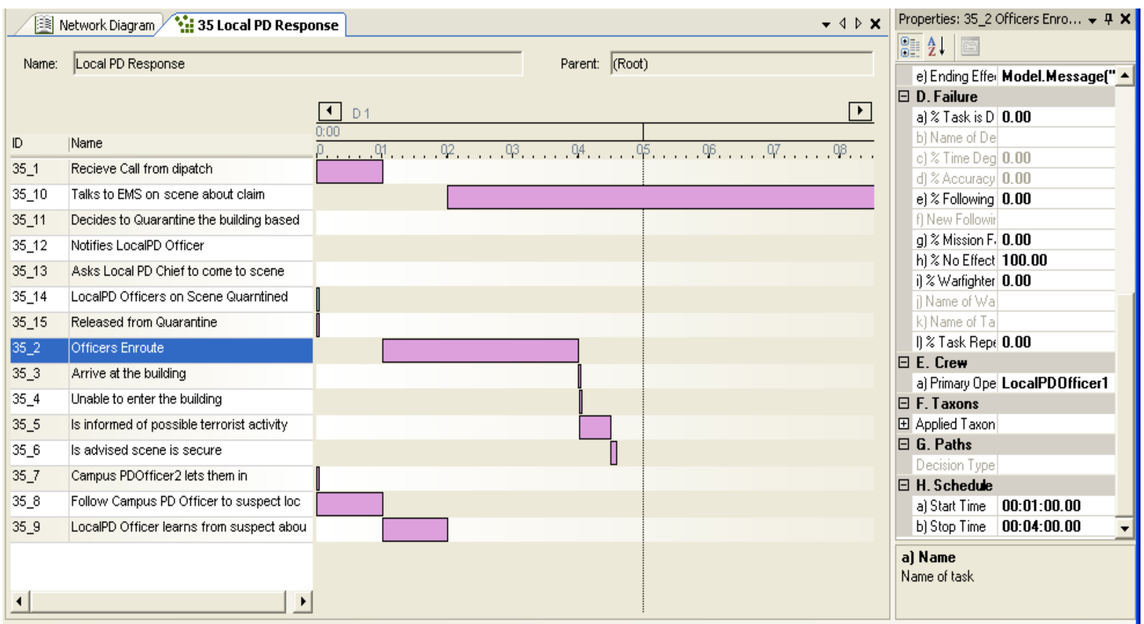

Figure 1.6. Local Police Department Portion of the Model

Figure 6 shows the timeline for the actions performed by the local police department. These values can easily be changed for what-if-analysis. For example, the mean task time for “Officers Enroute” can be changed from three minutes to six minutes by dragging the time line of the task to the right. This time change changes the timeline for all of the teams involved. After the individual task is changed, it takes about five seconds to rerun the model incorporating this change. The impact of increasing the task time can be analyzed on the revised model. This feature is very useful to the user by allowing for different case study trials very applicable to emergency operations. Changing the response time of the local police department had a surprise effect. When it was set to an average of three minutes the average overall emergency response took 11 hours and 14 minutes to be completed. When the time was increased to six minutes the overall emergency response on average decreased to 11 hours and 9 minutes. This result was surprising initially, but a review of the events showed that so many tasks were happening initially that a fast response time resulted in the first responders having more things happening at once and increased the total response time.

1.7 WHAT-IF-ANALYSIS

What-if scenarios can be used to evaluate a variety of situations for this case study. Examples of potential questions to be analyzed include:

- The impact if the sample analysis test has a success probability less than 100%
- The impact if more people were in the building when the event occurred
- The impact if the incident occurred in another building (a larger building would require more time to secure, other buildings may have additional hazards)
- The impact if the number of responders changed
- The impact of installing an emergency notification system to notify civilians of the emergency and given then instructions

In the incident emergency personnel collected a sample of the white powder and ran tests on it to determine if it was hazardous as the student had claim. One what-if situation that was analyzed was the impact if the sample analysis test does not provide correct results every time it is conducted. To do this the success probability on the "Analyze Sample" task was changed from 100% to 60%. The time to complete the whole mission was effected by this change. Twenty repetitions of each model were run for both probabilities. Each repetition is independent and time values will vary since some of the time values in the model included uncertainty and time values were from a range of data (this was done using probability distributions and standard deviations). With the 100% success rate the minimum time for the entire emergency was 9 hours and 28 minutes. The maximum time was 12 hours and 27 minutes with an average time of 11 hours and 13 minutes. When the success probability was changed to 60% the simulation provided a minimum of 9 hours and 28 minutes. This is the same value as before since the test was success on this repetition. The average increased to 11 hours and 14 minutes, an insignificant change. However, the maximum was increased to 14 hours and 51 minutes, a drastic increase. This was caused by a test failure result in delays as the test was repeated. This example shows the power of having variability in a simulation model. One can see the range of possible outcomes due to the uncertainty or randomness that occurs in a situation. In some applications users maybe more interested in the maximum rather than the average. An example would be when everyone has to be evacuated in a certain amount of time or when emergency personnel are using tanks of oxygen and have to exit a location within a set time period.

The simulation model can also be used to describe how procedural changes will affect an outcome. One such an analysis would be the what-if scenario of adding an emergency notification system (ENS). The first step is to model the task that would be involved with an ENS. This is shown in Figure 7. The network diagram depicts the impact of a notification system may have on the overall emergency response if it is activated and the possibility of it not being activated is also included. The model is run multiple times to draw a comparison. When the ENS system is activated another aspect which needs consideration is the extent to which it is effective with respect to the action that follows the alert message by the occupants who are in potential danger. The ENS's impact on evacuation of the building, decontamination, and medical treatments are evaluated. As with any computer model, the results are only as good as the data that goes into the model. The ENS was not in use when the incident occurred. However, after the system was installed the university conducted two tests of the system to determine how long it took to contact everyone registered in the system, the percentage of those contacted, and the percentage of those acknowledging receipt of the test message. These test results were used as data for the what-if-analysis. Based on the assumptions made about using an ENS, it was shown to be beneficial in reducing the time required for some of the intermediate goals of the emergency response including moving the individuals to the quarantine location.

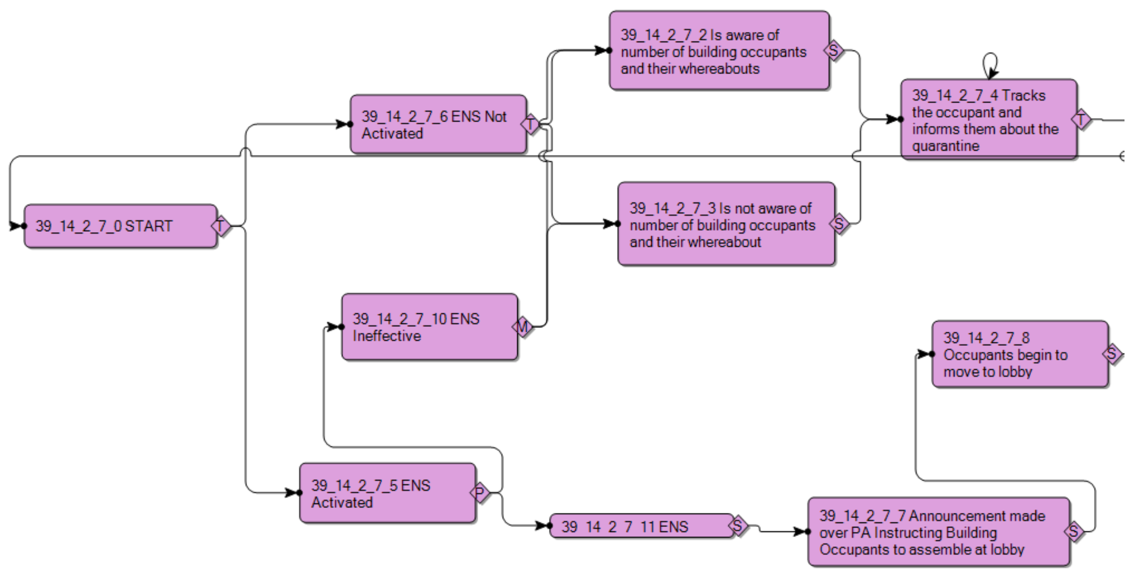

Figure 1.7. An Emergency Notification System What-If-Analysis

1.8 RESULTS

The case study shows the complexity of many emergency management situations. Human performance modeling is a powerful tool that can provide insight to different possibilities in these complex situations and can predict outcomes without having to go through an actual emergency event or costly drills. Computer modeling saves money, time, and efforts for emergency managers and responders. These models serve useful training and evaluation tools.

The model was demonstrated to the director of the campus police department (Bill Bleckman, May 4th 2009). His opinion was sought on the different features of the model. In his opinion, personnel rise to the occasion and make the decisions based on their previous experience in the extreme situations like the one described in the case study, aspects of the situation change in split seconds and these situations are serious life threatening events. The director found the technology very new and said that he and his officers have never come across such models before and the concept was new to them.

He was interested in the features which can help him decide the following aspect of the situation:

1. Number of personnel to be dispatched to the scene
2. The type of squads (bomb squad, fire fighters) involved in operation
3. Number of personnel required for the various squads
4. Types and amount of different resources required to deal with the scenario

Expected time to complete the event and milestone such as evacuating occupants of a location, establishing perimeters, and setting up quarantine facilities

The police director also thought having one of his officers trained to operate the model would be an effective approach. To be used real time a set of generic models would need to be in place to allow modifications as events unfold. A promising possibility in the director's view would be the use of models during officer training. He was very open to using the model as a preplanning and training tool.

The concept of human performance model is new and intriguing for officers. Most of the decisions that were made during the event were based on the previous experience and the training procedures that they have undergone. They are open to the idea using models but were skeptical about applying them real time because when an emergency situation arises there are many variables to be addressed and these variables change in a fraction of seconds. In a real time situation it would be nearly impossible to feed all the variables to the model and the wait for its response when the things change so frequently and rapidly.

Events such as the one modeled in the case study are rare. Human performance modeling offers police departments and other responders with an effective method of training and evaluating responses. The features such as evaluating the impact of changes in the number of personnel and the place or time of an emergency can provide unique insight into emergency management. Hindsight is said to always be 20-20. Computer models are a tool that assists decision makers by indentifying issues that might otherwise be overlooked.

1.9 RECOMMENDATION

For an emergency response organization interested in apply computer simulation models, we make the following recommendations.

Recommendation 1: It is important to educate personnel involved about the basic concepts of human performance model. They should grasp the basic concept and fundamentals of simulations before trying to apply any simulation results. The computer is not a magic black box. The results depend on the assumptions made and the quality of data used in the models.

Recommendation 2: Those involved with building the simulation models need a solid understanding of emergency procedures and the computer software used to develop the model. Software training familiarizes one with the system and not only what is required to build a model, but what to do with the output, the various software features available, and the advantages of various modeling approaches.

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5 CONCLUSION

5.1 LIMITATIONS

The limitations of this research are as listed below:

1. The model has never been used in a real-time mission. The first model was developed on the time log and information gathered from the security departments, which was very time consuming. In a real-time mission; many variables can change in split seconds, and these changes cannot be fed into the system quickly enough. The technology is still in its earliest stage and requires many improvements that will depend on feedback gathered from security personnel.

2. The director who was interviewed for his opinion on the model had limited time to become familiar with the model. The concept of HPM was new to him, and his opinions were based on an overview rather than on detailed experience with the model.

5.2 RECOMMENDATION AND FUTURE WORK

Recommendation 1: Personnel should be educated starting from grassroot level responders to higher management about the concept of HPM. They must grasp the basic concept and fundamentals of the technology before they can understand the working of the system.

Recommendation 2: Personnel should be trained in IMPRINT to familiarize them with the system and give them a fair idea of the input required to build a model, its output, its various features, its purpose, and its advantages.

Recommendation 3: Build the confidence of officers in the computer model. Officers currently rely on previous experience and training, so they must learn with models based on the situations they have dealt with in the past.

Recommendation 4: The administration should make provisions to train and recruit an expert who specializes in IMPRINT and security department procedures so that the technology is more accessible to first responders.

Recommendations for future work:

Future Work 1: The technology is in its nascent stage and requires many improvements that are possible only once security departments are familiar with the technology and feedback is obtained from grassroots level first responders on the features they want to see improved, changed, or removed altogether to increase the model's effectiveness for them.

Future Work 2: Speed is of great importance in real-time situations because the variables in a mission are numerous and they change rapidly. Much time is required to input the properties of variables and tasks to the model. Additionally, time is required to run the simulation, making it too slow for real-time applications. Work should be done to counter this system drawback.

Consequence management is a critical part of current security plans developed by the government officials. Human performance modeling provides a useful, contemporary tool for consequence management strategies. The discussion presented here of HPMs such as IMPRINT and ENCOMPASS highlights the need for such models and explains the crucial purposes they serve. Discussion of the practical applications of the IMPRINT model in real-time incidents clarifies its operation and supports the claim that HPMs are feasible for consequence management in disaster or emergency situations despite their limitations. These limitations can be overcome by following the recommendations made above and giving future work some serious thought.

APPENDIX

EMERGENCY MANAGEMENT TRAINING POLICY

INTRODUCTION

1. The State Emergency Management Committee's functions (Section 15.(2) of the State Emergency and Rescue Management Act 1989) include:

'To arrange emergency management training for individuals, including individuals employed in emergency services organisations and functional areas';

'To assist in the selection and training of district and local government personnel....'

AIMS

2. A. To provide policy for the development and delivery of emergency management training at all levels to emergency services organisations, functional areas, individuals and local government personnel in NSW.

B. To develop a Code of Practice which establishes the commitment of the Committee to the development of quality emergency management training, and the maintenance of high standards in its delivery throughout NSW.

TRAINING RESPONSIBILITIES

NATIONAL-LEVEL TRAINING

3. The Emergency Management Australia Institute [EMAI] conducts a range of Commonwealth funded residential and extension training activities designed to improve Australia's capability to cope with emergencies.

4. Activities conducted by the Institute, as notified in the Institute's annual Handbook, include:

- training and education courses delivered residentially, or as extension activities at selected locations in the States/Territories;
- studies conducted as seminars or workshops with awareness, promotional, information sharing or problem-solving goals.

AEMI Residential Courses.

5. The State Training Co-ordinator, Emergency Management [TCEM] processes all NSW nominations for EMAI residential courses, and allocates NSW vacancies for attendance according to the following criteria:

a. EMAI attendance criteria

b. Emergency management need

c. Nominee's emergency management responsibility

d. Nominating organisation need

e. Nominee's prior attendance at EAMI courses

The basic prerequisite to attendance at any EMAI course is completion of the "Emergency Management Arrangements Course" conducted by Districts.

6. District nominations are made to the respective District Emergency Management Officer [DEMO], who submits them direct to TCEM on the EMAI nomination form with recommendations of priority for attendance. TCEM liaises directly with DEMOs in respect of these nominations.

7. State-level nominations [from the Head Offices of agencies] may be made direct to **TCEM.**

8. Nominations are to be submitted to TCEM no later than 10 weeks prior to the commencement of a course. TCEM provides EMAI with details of the selected nominees 8 weeks prior to the commencement date. Joining Instructions are sent to the selected nominees direct by EMAI with details of travel arrangements. Unsuccessful nominations are held as reserves in case later withdrawals of selected nominees occur.

9. SEMC Secretariat and DEMOs may assist EMAI with the delivery of residential courses, at its request.

EMAI Seminars and Workshops

10. TCEM coordinates NSW representation on EMAI seminars and workshops, in accordance with the EMAI attendance criteria for each activity.

SEMC Secretariat arranges State-level emergency management representation, where appropriate, to these activities.

Records

11. TCEM maintains records of NSW participants on all EMAI courses. DEMOs maintain similar records for their District.

Emergency Management Australia [EMA] National Consultative Committees

12. SEMC Secretariat arranges emergency management representation, where appropriate, to EMA National Consultative Committees and Working Parties.

STATE-LEVEL TRAINING

13. SEMC Secretariat arranges for instructional staff to support EMAI extension courses conducted in NSW. Delivery and evaluation of these courses is co-ordinated by the TCEM.

General Emergency Management Training

14. SEMC Secretariat supports emergency services agencies, functional areas and other agencies in the conduct of emergency management training and exercises.

15. TCEM designs, conducts and evaluates emergency management and operational control training for SEOC staff.

DISTRICT-LEVEL TRAINING

"Emergency Management Arrangements" and other District Courses

16. DEMOs organise, conduct and evaluate "Emergency Management Arrangements" Courses within their Districts to meet their assessed training need and as a prerequisite to all other multi-agency emergency management training.

17. DEMOs will organise, conduct and evaluate such other multi-agency District and Local level courses as endorsed by the SEMC (see paragraphs 22-25). TCEM provides instructional and resource support to Districts in the conduct of these courses as required.

18. Courses accredited by VETAB are delivered under the direct supervision of accredited trainers who have completed Certificate IV in Assessment and Workplace Training. They may be supported by non-accredited presenters.

Training Support to Agencies

19 DEMOs provide support to emergency services organisations, functional areas and other agencies with their single-service emergency management training and exercises.

Training Resources

20. TCEM co-ordinates the design and preparation of emergency management training packages and other resource material to support District and Local level training. The packages incorporate learning outcomes and standards, which are aligned to the National Emergency Management Competency Standards.

TCEM evaluates the application and effectiveness of the packages and other resource material.

LOCAL-LEVEL TRAINING

21. DEMOs provide support to Local Emergency Operations Controllers [LEOCONS] in the conduct and evaluation of local emergency management training and exercises. DEMOs maintain records of local level training.

TRAINING FUNDS

22. Subject to the allocation of funding, the SEMC Secretariat may fund the delivery of multi-agency training for officials at local government level through the following approved courses:

Emergency Management Arrangements (1 day)

Evacuation Management (3 days)

Exercise Management (1 day)

Introduction to Emergency Risk Management (1 day)

Implementing Emergency Risk Management (2 days)

Managing an Emergency Operation (3 days)

Working in an Emergency Operations Centre (2 days)

23. Other activities, for example LEOCONs/LEMOs Workshop, and exercises forming a planned segment of the District emergency management training program, may also be considered for funding.

24. Districts are invited to bid for funding by 30 May of each year for the forthcoming financial year. Bids are to contain training proposals providing the following detail:

a. Course title

b. Proposed dates

c. Proposed venue

d. Number of participants

e. Names of all instructors

f. Estimate of:

. Cost of venue, including catering

. Accommodation cost, if necessary

. Instructors travel cost

. Course material cost

25. Following receipt of District bids TCEM will inform each District of its approved activities. TCEM will also produce, and provide to each District, emergency services agency and functional area, a training calendar detailing the activities to be conducted during the year.[17]

CODE OF PRACTICE - EMERGENCY MANAGEMENT TRAINING

Preamble.

1. Under Section 15(2) of the State Emergency and Rescue Management Act 1989, the State Emergency Management Committee (SEMC) is required to arrange emergency management training for individuals, including those employed in emergency services and functional areas, as well as assist in the selection and training of district and local government personnel.

2. In performing these functions, the SEMC is conscious of the need to develop quality emergency management training, and to maintain high standards in the delivery of this training throughout NSW.

3. This Code of Practice represents the commitment of the SEMC to meet these outcomes.

Training Standards

4. Emergency management training is developed from a training needs analysis conducted in consultation with District Emergency Management Committees, District Emergency Management Officers (DEMOs), emergency services organisations and functional area co-ordinators. The needs analysis is aligned to National Emergency Management Competency Standards.

5. Training module learning outcomes and assessment criteria are designed under the oversight of a Training Advisory Group comprising representatives of the SEMC Secretariat, emergency services agencies, functional areas and District Emergency Management Committees. Individual modules are specifically aligned to the Competency Standards.

6. Training modules are packaged in a standard format, and supported by participant handouts or workbook and slide show programs to ensure a standard and consistent delivery throughout NSW. Some flexibility is built into the modules, as appropriate, to allow reflection on local hazards, problems and individual participants’ roles in

emergency management.

7. Training and assessment is delivered under the direct supervision of accredited trainers / assessors who have completed Certificate IV in Assessment & Workplace Training, and who are current emergency management practitioners of at least two (2) years experience.

8. Courses are conducted in training venues which provide a comfortable environment, have adequate capacity for syndicate work, and are conducive to learning and participant success. Where necessary, training venues provide overnight accommodation and meals for participants.

9. The ongoing monitoring and evaluation of emergency management training is conducted under the oversight of the SEMC Secretariat. In particular, course evaluation sheets are completed by participants and responses checked for adverse trends following each course. Course instructors are asked to report any problems with module delivery. All course modules are reviewed by the Training Advisory Group each twelve (12) months to ensure that accuracy and relevance of content are maintained.

Marketing

10. Training is marketed to the emergency management industry by the SEMC Secretariat
and Districts with integrity, accuracy and professionalism, and avoiding vague and ambiguous statements. In providing information to individuals, agencies and functional areas, no false or misleading comparisons are drawn with any other training provider or course.

Trainee Information

11. Course Information Sheets are developed for each course which accurately describe the course content and admission criteria, learning outcomes and the participant assessment process. They are provided to course participants as their nominations are accepted, and no later than two (2) weeks prior to the commencing date of a course for all nominations accepted at that time.

12. Information provided to participants includes:

a. a copy of the SEMC Code of Practice - Emergency Management Training;

b. course admission procedures and criteria;

c. venue detail and accommodation / meal arrangements;

d. pre-course reading or participant activity;

e. course content and learning outcomes, and links with other courses;

f. competencies to be fully or partially achieved by participants;

g. participant assessment process;

h. certification to be issued to participants on completion or partial completion of the course;

i. course material and equipment provided;

j. participant grievance / appeal procedure, and support services available.

Participant Recruitment

13. Participant recruitment is conducted on a multi-agency basis, in accordance with the admission criteria established for each course. Decisions regarding participant selection are made on an equal opportunity basis and, provided that admission criteria are met, there are no barriers to course entry.

14. Whenever an applicant is unable to be allocated a vacancy on a course, the applicant is advised of the reason for non-selection and, where appropriate, invited to reapply for a future course.

Course Fees

15. For all emergency management courses funded by the SEMC, the cost of the course venue, participant accommodation and meals, and course materials is borne by the SEMC Secretariat. No course fees are payable by participants.

Participant Grievances/Appeals

16. In the case of participant grievances concerning course admission and/or assessment and certification, the District conducting the course discusses the situation directly with the participant and attempts to reach a mutually acceptable solution. Where a solution cannot be achieved, the matter is referred by the District to the SEMC Secretariat for investigation and further action, and advice to the participant.

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VITA

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