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Improving disaster response efforts with decision support systems

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Abstract: As evidenced by Hurricane Katrina in August, 2005, disaster response efforts are hindered by a lack of coordination, poor information flows, and the inability of disaster response managers to validate and process relevant information and make decisions in a timely fashion. A number of factors contribute to current lacklustre response efforts. Some are inherent to the complex, rapidly changing decision-making environments that characterise most disaster response settings. Others reflect systematic flaws in how decisions are made within the organisational hierarchies of the many agencies involved in a disaster response. Slow, ineffective strategies for gathering, processing, and analysing data can also play a role. Information technology, specifically decision support systems, can be used to reduce the time needed to make crucial decisions regarding task assignment and resource allocation. Decision support systems can also be used to guide longer-term decisions involving resource acquisition as well as for training and the evaluation of command and control capability.

Keywords: disaster response; information systems; decision support; information technology.

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Walter Green directs the undergraduate Emergency Services Management and graduate disaster science degree programmes at the University of Richmond. His 35-year background in emergency management includes service as a military disaster preparedness officer, as a state agency disaster coordinator, and as designer of the successful online coordination system, The Virtual Emergency Operations Center. His specific research interests focus on the characteristics of disaster and the management of response operations.

Joanne Lapetina is an emergency medicine physician with over 17 years experience. Her background includes several governmental advisory committees including the Governor's Medical Advisory Board for the State of Virginia, and BTLS Director for the State of Virginia. In addition, Dr. Lapetina has published numerous reports on disaster response systems.

1 Introduction

Managers at Local, State, and Federal agencies charged with responding to natural and man-made disasters are routinely called upon to make decisions that impact possibly thousands of lives and billions of dollars in property. Making timely and effective use of available resources can minimise the number of fatalities and improve the likelihood that injured victims will survive. As a secondary concern, limiting the loss of property can decrease the amount of time needed to rebuild and preserve the economic viability of the affected areas. However, by their very nature, disasters represent chaotic decision-making environments where the problem is not so much a singular event, but rather a complex set of rapidly evolving problems. In such an environment, decision-makers must process large amounts of data, establish the authenticity of the data, and make critical decisions; all within a very short span of time. Often, cognitive heuristics, such as intuition, can become the primary mechanisms by which decisions are made.

Experience is to intuition what historical data is to forecasting. Since forecasting the future based on past data is like driving a car while looking at the rear view mirror, any additional data processing and real time information is expected to add to the quality of decisions made. And this is exactly what decision support technology is designed to do; provide the decision-maker with valid, meaningful and timely information. This, however, depends on the quality and availability of input data as well as the effectiveness of the techniques used to acquire and analyse the data. In this paper, we will discuss some of the issues surrounding when, and how, information technology and systems can be used to support decision-making in emergency situations. We will also introduce some of the scientific developments in decision theory that shows potential in overcoming some of these issues. The purpose of this paper is to explore the potential of decision support technology to aid disaster response managers in their efforts to save lives and protect communities.

The current landscape

Software products such as Emergency Information System (EIS), SoftRisk, EM 2000, and E-Team provide a range of emergency management decision support, resource management, and incident documentation functions to emergency managers (Green, 2001). The emergency management and operations research literature also contain a number of examples of Decision Support Systems (DSS) designed for specific scenarios or objectives. Table 1 provides a list of these systems.

Table 1 Examples of decision support systems in literature

Decision support function	*Systems in use*
Damage assessment	CATS (www.saic.com/products/simulation/cats/cats.html)
Emergency logistics	MCCADS (Belardo and Karwan, 1986)
	CALMS (www.nyc.gov/html/oem/html/response/calms/html)
	ARES (Brown and Vassiliou, 1993)
Evacuation	TEDSS (Hobeika *et al*., 1994)
	CEMPS (de Silva and Eglese, 2000)
	REMS (Tufekci, 1995)
Emergency management	CAMEO (Beroggi *et al*., 1995)
	MIND (Morin *et al*., 2000)
Incident specific	Flood: ARTEMIS (Hernandez and Serrano, 2001)
	Nuclear: RODOS (Hamalainen *et al*., 2000)
	CAIS (Kourniotis *et al*., 2001)
	Wildfires: METAFIRE (Simard and Eenigenburg, 1990)
	DEDICS (Wybo and Kowalski, 1998)

Lately the trend has been the development of computerised emergency management information networks that allow connectivity between local emergency response centres to boost data availability and solution capabilities. The leading push in the USA came with the National Incident Management System after the establishment of the Department of Homeland Security. A similar idea in Europe is GEMINI, the Global Emergency Management Information Network Initiative.

Although the examples above and in Table 1 all provide emergency managers with practical tools, the actual implementation, and subsequent evolution, of these systems presents a number of challenges because the necessary inputs are not reliable, not available, or represent an enormous amount of data. It is therefore worth exploring how decision support technology can be used under different conditions. At the same time it is important to be realistic when estimating the potential for computerised decision support systems to be used in the context of disaster response efforts. The implication is that it is important to not lose site of the complex nature of the decision-making environment that disaster response managers face. In fact, while the decisions at hand would be complex even under conditions of perfect information, the reality is that disaster managers must make decisions under conditions of less than perfect information.

During a disaster, the initial inflow of information stems from three sources. The public (*e.g.*, 911 calls, calls to emergency centres, and calls to the local media outlets) provides some level of reporting but the accuracy of that reporting is to some degree unreliable. News media coverage is an important early source of information, given the extensive technology available to the broadcast media; however, such coverage is based on snapshots of what is happening at a specific location. Finally, initial reports from regular public safety organisations are often distorted by the immediacy of the problems being faced, the stress on available resources, and freelance responses (Green, 2003). Reports from key centres that should be providing accurate data are often inaccurate due to the difficulty of gathering a complete picture of the event. Only later (and experience with reporting of casualties and damage in major disasters suggests that later may be days to weeks, see individual event entries in Green, 2005) does more precise information flow through detailed data gathering and survey efforts. Furthermore, managers must also process information about the resources that are available to mobilise in response to the disaster. Again, specific details emerge over time and at any given moment a manager may not have a completely accurate picture of what is available.

The presence of imperfect information in the context of a rapidly changing environment complicates decision-making. How decision support technology can be used to aid and improve decision-making depends on the type of problem that is being addressed and it would be naïve to assume that all problems facing disaster response managers can be supported in a meaningful way. In fact, it is certainly possible that attempting to use decision support technology to help solve a problem for which information technology is not an appropriate supplemental tool could result in worse outcomes than not using it at all.

2 The role of decision support in disaster response efforts

The term 'decision support technology' is a general one that covers a broad range of systems, hardware, and communication technologies. In some cases the technology involved is simple, for example, a paramedic using a cellular phone to consult an emergency medicine physician while treating a victim in the field. In other cases the technology is a very advanced combination of hardware and sophisticated software, such as the war game simulators used by the US military.

In this context, it is useful to highlight the distinction between improving decisions by using computers and communication technologies to speed the flow of information as addressed in Green (2001) and a true decision support system. Technically, anytime information technology is used to aid in the decision-making process, the associated tools can be considered to be a decision support system. However, from the standpoint of the design of specialised applications, the following definition provided by Gregory Vogl at Colorado State University is useful:

> "A highly flexible and interactive IT system designed to support decision making when the problem is not structured; an information system that utilizes decision models, a database, and a decision maker's own insights in an *ad hoc*, interactive analytical modelling process to reach a specific decision by a specific decision maker."[1]

As illustrated by Figure 1, a DSS serves as a conduit through which data is transferred and possibly analysed, filtered, or processed in some way. Figure 1 also illustrates the concept of middleware. Middleware is a software application designed to enable effective information exchange between two systems that are otherwise incompatible. The issue of compatibility as it relates to the widespread use of decision support systems in disaster response is addressed later in the paper.

Figure 1 Decision support system

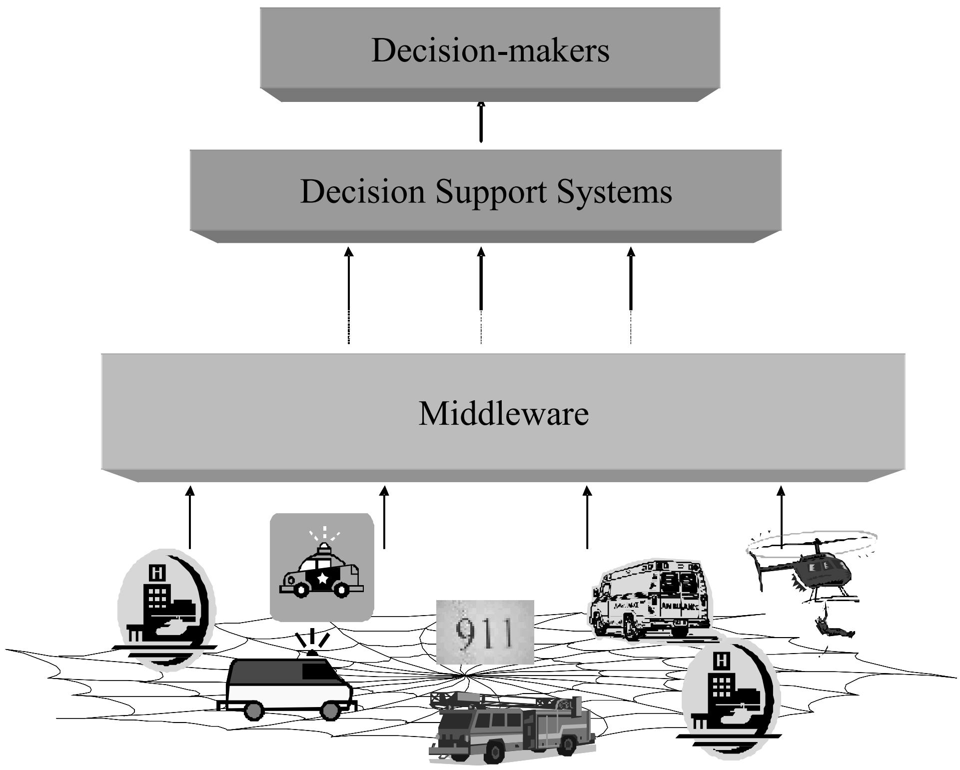

Figure 1 provides an illustration of where decision support systems fit within the decision-making process but it does not specify what a decision support system actually does. The answer to that question depends on the type of problem being addressed and the immediacy with which a decision must be made.

3 Decision support systems: linking problems with strategies

In addition to the amount of time available to process information and make a decision, problems are often described in terms of their structure. Concrete problems that are static in the sense that the problem can be explicitly stated and solved are referred to as *structured problems*. Problems that involve uncertainty but can still be modelled are referred to as *semi-structured problems*. Finally, problems that are completely chaotic and rapidly changing to the point that 'no one knows what will happen next' are referred to as *unstructured problems*. Decision support systems can be used to good effect on structured and semi-structured problems and to a lesser extent on unstructured problems. However, a variety of problems emerge during most disaster response efforts and all three-problem categories are usually represented.

Clearly, it is important to identify which problems are potential candidates for decision support. Table 2 illustrates some problem classifications specific to the disaster response domain.

Table 2 Different classes of problems

	Problem type		
Problem	*Structured*	*Semi-structured*	*Unstructured*
Extract victim from car			X
Assign ambulances to 911 calls	X		
Reposition area fire trucks during a multi-alarm fire		X	
Determine which hospital an ambulance should bring a patient to		X	

From Table 2, it is easy to see that certain types of problems facing decision-makers are difficult to support with decision support systems. Extracting a victim from a damaged vehicle is an unstructured problem because most of the information pertinent to determining the best course of action is situation specific and often only fully understood in the context of the responders' past experiences with similar events. In addition, the decision of how, exactly, to proceed must be made very quickly and there is little time to enter data into a computer and wait for the result.

On the other hand, decision support systems can be applied successfully to highly structured problems. For instance, the problem of assigning a group of ambulances to a set of 911 calls in order to minimise the response time is an optimisation problem where the necessary data is readily available and the solutions are exact.

Many problems fall somewhere between these two extremes. To illustrate a semi-structured problem that lacks a clear-cut answer with a real-world example, consider the problem of determining to which hospital an ambulance should bring a given patient. Conventional wisdom would argue that the victim should be brought to the closest hospital. However, disaster response managers, charged with looking at the bigger picture, may want to avoid overloading the closest hospitals with cases that are not immediately life-threatening in order to reserve capacity for those that are (Auf der Heide, 1989). In this case, decision support systems can be used to forecast the expected number of casualties and, in conjunction with information on local hospital surge capacity, provide recommendations to disaster managers.

3.1 Decision support for structured and unstructured problems

A structured problem can be represented by a mathematical model. It is then possible to either obtain the optimal solution to the problem, or find a 'very good' approximate solution. For example, consider the problem that arises when a large fire breaks out in a city. Multiple fire companies must be sent to quell the blaze, but this response leaves coverage gaps in other parts of the city. In order to address this problem, other companies in the city must be reallocated so that satisfactory coverage (in terms of capability and response time) is obtained. This allocation problem was addressed using mathematical optimisation techniques by Kolesar and Walker (1974). The resulting computer application was used by the NYFD for many years.

For structured problems the only barrier to effective use of decision support systems is time. For longer-term problems, such as the reallocation of fire companies, there is sufficient time to obtain, process, and analyse the data. The decision-maker also has ample time to evaluate the proposed solution and arrive at a final decision. For short-term problems, when the decision-maker may only have seconds or minutes to make a decision, even structured problems can prove challenging.

By contrast, unstructured problems can be very difficult to address using decision support systems. By their very nature, unstructured problems defy the codification necessary to apply most decision theory methods. This is especially true for short-term problems. That being said, case-based decision support tools have been developed and used to good effect in unstructured settings such as emergency medicine (Graber and VanScoy, 2003). These systems typically employ case-based reasoning, which involves using prior experiences to understand and solve new problems. In case-based reasoning, the decision-maker recalls previous situation similar to the current one and uses that to solve the new problem. Decision support systems can be very helpful in supporting case-based reasoning by storing large amounts of data on prior events and by helping the decision-maker identify associations between the current problem and the historical events. By storing prior information, the decision support system can contain information that goes well beyond the experiences of the user. In addition, by processing available information related to the current problem, the decision support systems can identify previous cases that seem 'similar', thereby minimising the need for the user to spend large amounts of time sifting through historical data to find relevant information.

3.2 Decision support for short-term semi-structured problems

Overwhelmingly, the problems faced by disaster response managers are semi-structured. In the context of semi-structured problems, decision support systems represent valuable tools that can augment both short-term 'command and control' decisions as well as longer term 'strategic' decisions.

In the context of managing disaster response efforts, the current state of command and control capability is represented by so-called disaster operations centres. Examples of fairly large-scale disaster operations centres are evidenced by the American Red Cross and the US National Disaster Medical System (NDMS).[2–3] These virtual centres are designed to be utilised during large-scale disasters that exceed the capability of local agencies to respond. During an event, the disaster response managers can use the services provided by these centres to create a focal point for information gathering, processing, response planning, and inter-agency coordination. As such these sites serve as *portals*, sometimes referred to as meta-sites, through which information can be posted and shared.

While there has been some work on the design of decision support systems it has for the most part been focused on forecasting. For example, estimating earthquake casualties (Aleskerov *et al.*, 2005) and the time and size of a bioterrorism attack (Walden and Kaplan, 2004). While speeding the flow of information and forecasting are both very important contributions, additional opportunities abound. In particular, decision-making techniques that involve the processing of large amounts of data into useful information, thereby avoiding the problem of information overload, have a great deal of promise.

In the context of large-scale events, the field of *Complex Adaptive Systems* has yielded tremendous insights into how seemingly chaotic environments can be managed by focusing on the elements of the problem domain that are well-behaved while decisions pertaining to the essentially unpredictable elements are made on an *ad hoc* basis. An example of employing this approach can be found in Hoard *et al.* (2005) where a system is developed that allows disaster managers to pose 'what-if' questions to a simulator in order to evaluate the short- and long-term effects of a decision. This automates a process that has already been successfully employed in large-scale military operations (Pagonis and Cruikshank, 1992).

Researchers have also made tremendous strides in the area of *evidential reasoning* which, rather than focusing exclusively on decision-making, explores and models how decision-makers come to understand complex environments. The process of 'connecting the dots' is as crucial to good planning as immediate decisions because it enables the manager to take the big picture into account. Companies such as SRI International have developed evidential reasoning applications designed to help convert evidence, which the company defines as "…information that is potentially incomplete, inexact, inaccurate, and from diverse sources",[4] into probabilistic information about an event. Decision support systems that use evidential reasoning have been successfully used in a variety of applications ranging from battlefield intelligence to the diagnosis of medical conditions.[5–6]

3.3 Decision support for long-term semi-structured problems

While short-term operational decisions are typically thought of as the domain of the response effort, it is important not to lose sight of the fact that decisions made during the planning stages impact the range of choices that are available to the decision-maker during the response phase. This is because the number and type of resources that are available are determined during the planning and preparedness stages that precede the response phase. Here, again, decision support technology can be used to evaluate the impact of resource acquisition and allocation plans on the ability of disaster managers to respond effectively to different types of disasters on a variety of scales.

Two related areas that are highly relevant to emergency response managers, and also the focus of a great deal of military interest, are *planning for adaptiveness* (Davis *et al.*, 1996) and *capabilities-based planning* (Atkinson, 2004). Decision theorists have long recognised that, in many cases, the underlying problems are so complex that it will never be possible to develop a model that yields the 'correct' answer. In the case of planning for adaptiveness, the emphasis is on making decisions such that the cost of changing the decision later, in response to new information, is as low as possible subject to meeting the primary objective. In fact, some problems are so complex that predicting future events is often not possible. In these cases, techniques such as *exploratory analysis* can be used. Exploratory analysis foregoes prediction in favour of identifying a strategy that is robust in the sense that it is still a 'good' strategy under a wide range of possible future scenarios.

Regardless of the specific technique employed, planning for adaptiveness is ultimately a strategy designed to minimise risk. In this case, the goal is to minimise the risk associated with committing resources based on current information, only to find out later that the 'true' problem at hand is different than initially thought, and therefore necessitates an alternative deployment of resources. Given the prevalence of imperfect information in most disaster response settings, techniques designed to ensure flexibility and the ability to respond to either changing events or changes in the understanding of the details of an event are important.

Capabilities-based planning can provide insights into how a given system will perform, given current resources, in response to different events. Loosely stated, capabilities-based planning is the process of determining the right combination of plans, people, equipment and activity to maximise the ability of the organisation to fill its assigned roles. Capabilities-based planning is useful in guiding decisions pertaining to investment in equipment and the acquisition of additional personnel subject to budget constraints.

Decision support technology has been used successfully by the US Military to support capabilities-based planning. For instance, in order to accomplish a mission, a commander must have more than just weapons and soldiers. She must also have logistics, command and control capability, medical support, *etc*. Capabilities-based planning aims to ensure that the proper portfolio of assets is available to support a range of missions. Sometimes this involves investing in assets that are not typically considered essential to combat, such as fuel trucks, but are in fact critical to a successful mission.

The problem with capabilities-based planning is that when planning for complex, multi-faceted projects, it becomes difficult to determine which resources are in short supply and to what extent. This is especially true in the context of joint military operations involving, say, the Navy and the Marines. Decision support technology is used to simulate complex environments and evaluate the incremental value of each additional asset. This enables decision-makers to determine what types of resources are needed and identify when a point of diminishing return has been reached such that additional accumulation of a given resource does not improve overall capability.

The analogy to disaster management is clear. As with military operations, disaster response involves the coordination of a number of agencies in the context of a complex, adaptive decision-making environment. In this context, the responding agencies are charged with filling a role and working collaboratively to achieve the best possible outcome. Using decision support technology to simulate disaster environments not only enables disaster response managers to hone their decision-making skills from a command and control perspective, but also guides the strategic investment of limited resources such that optimal overall outcomes can be achieved.

4 Barriers to widespread development and implementation

While the case can be made for the need and potential benefit of using decision support systems to aid in disaster response efforts, there exist a number of barriers to the large-scale implementation of these applications. First, decision support systems require timely data in order to provide high quality recommendations. In fact, existing research (Dragoni, 1997) suggests that incorporating outdated information into decision support systems can result in significant negative outcomes. The difficulty currently facing disaster response agencies (and all healthcare agencies) is that, due to the high degree of fragmentation within these industries, system interoperability between organisations is low. This translates into difficulties moving data between organisations in a timely manner. In extreme cases, this can necessitate that data be transcribed manually from one system into another. This is problematic because prior research (Mathew, 2005) illustrates that high-quality information from a variety of sources is critical to an effective disaster response.

Even in cases where information technology is being used on a relatively large scale, such as the mandatory syndromic and bed availability reporting required of hospitals in the State of Connecticut, the process by which data is gathered is slow and manual. In both cases, the systems that track the prevalence of certain disease symptoms and the number of different types of beds available in a given hospital are manually updated once or twice each day.

While certainly an improvement over the previous method, such systems result in providing data to emergency managers that is not current and only accurate for a small interval of time. Given the 12-hour to 24-hour time lags between updates, the difference between what these systems report and the true current bed availability or the true current number of patients presenting with, say skin lesions, can potentially be dramatic.

Furthermore, any attempt to increase the frequency with which these systems are updated requires an individual to separate from the response effort and focus on the gathering and entry of data. Clearly, during a disaster response, it is preferable for those with skills that can be put to use saving lives focus on such efforts rather than data entry. In fact, research has found that the quality of data entered into these systems becomes less reliable as the event becomes larger (Green, 2003). This suggests that individuals are redirecting their efforts to tasks that are perceived as more urgent, such as saving lives, at the expense of tasks that are perceived as less urgent.

In addition, even though the large number of disparate, incompatible systems is detrimental to public health and safety, the reality is that the cost of updating all of these systems is enormous and not likely to happen in the short term. Therefore, if the benefits of decision support systems and real-time data transfer are to be realised, a strategy that enables decision support that is not dependent on multi-billion dollar system enhancements is needed.

There have been a number of efforts to develop large software packages that provide some capability to manage data needed for medical response. For example, the Federal Emergency Management Information System (known by the acronym FEMIS) developed by Pacific Northwest National Laboratory provides a platform capable of sharing a wide variety of data across jurisdictional and functional boundaries (Pacific Northwest National Laboratory, 2003). The National Emergency Management Information Systems, developed in part using one of the commonly available commercial emergency management software applications, EIS Infobook, provided a broad range of data across programmatic phases (Cormack, 1999). Other efforts have been undertaken to standardise software languages (Wyke, 2003) and to develop laboratory test beds (Morentz, 2004) as a framework for increased interoperability. And commercial off-the-shelf software packages such as SoftRisk (SoftRisk Technologies, 2005), E-Team (E-Team, 2005), and Disaster LAN (Buffalo Computer Graphics, 2005), offer individual jurisdictions information management and decision support solutions that work well in an Emergency Operations Centre environment with a trained staff.

A possible solution

The presence of incompatible systems poses two fundamental problems. First, many of the systems are simply not capable of sharing data with each other. Second, even if data transfer is technically possible, many of these systems use different terms and scales to describe the same data. A rough analogy can be drawn to spoken language. Systems that are incompatible are, in essence, speaking two different languages. The information that has meaning to the system that sent it is perceived as gibberish by the system that receives it. The presence of different terms and scales is equivalent to the use of different dialects. For instance, the term ‘subway’ has a very different connotation in the UK than in the USA.

The same problem can emerge when information systems use the same term to describe different things or different terms to describe the same thing. For example, some emergency departments use five-tier triage scales while others use three-tier triage scales. If a decision support system was attempting to determine which emergency department was experiencing the highest workload, it would not be possible to compare the two. And, as a result, the system would not be able to provide an emergency manager with a recommended destination for an ambulance.

These kinds of problems are not unique to healthcare and disaster response and, in other industries, have been dealt with effectively through the use of middleware and meta-data. Middleware is a specialised software application that is built to take data from a number of systems that are not capable of communicating with each other and transforming it into a common format. In this sense, middleware can be thought of as serving the same purpose as a translator.

Meta-data is information about data. That is, meta-data describes the data elements in use so that meaningful comparisons are possible. For instance, meta-data describing the different triage scales mentioned earlier could be used by a decision support system to understand that a 3 on a three-point scale is equivalent to a 4 or a 5 on a five-point scale.

In order to effectively use meta-data and middleware to link disparate systems and to eliminate the need for middleware solutions in the future, it is critical that data standards be established. Fortunately a number of initiatives are currently underway by various organisations attempting to tackle the tasks of creating industry-wide American National Standards Institute (ANSI) approved standards. The American Society for Testing and Materials (ASTM, 2006) Committee E31 on healthcare informatics “develops standards related to the architecture, content, storage, security, confidentiality, functionality, and communication of information used within healthcare and healthcare decision-making”. Health Level Seven (HL7) is an ANSI-accredited Standards Developing Organization (SDO) that produces the accepted messaging standard for communicating clinical data.[7] The Healthcare Information Technology Standards Panel (HITSP, 2005), an ANSI standards panel, was "formed to facilitate the harmonisation of consensus-based standards necessary to enable widespread interoperability of healthcare information in the United States". The Coalition for Healthcare eStandards (CHeS) focuses on standards that will improve the accuracy and efficiency of the healthcare supply chain.[8]

In addition to creating standards, there are several societies focusing on the use of healthcare IT. The Healthcare Information and Management Systems Society (HIMSS, 2005) focuses on "providing leadership for the optimal use of healthcare information technology and management systems for the betterment of human health". The American Health Information Management Association (AHIMA) hopes to advance health through quality information.[9] The Certification Commission for Healthcare Information Technology's (CCHIT) goal is to certify healthcare information technology products.[10]

The US government responded to the interoperability issue by authorising the Commission on Systemic Interoperability. The Commission released its report (the Report) to Congress and the American public on 25 October 2005 detailing its strategy to make healthcare information instantly accessible at all times by consumers and their healthcare providers. The Report can be found at http://endingthedocumentgame.gov/. The Report acknowledges that interoperability "makes possible a powerful public-health resource against bioterrorism, the spread of disease, and other nationwide medical concerns". The Report also acknowledges that there are over 300 interoperability projects underway nationwide. In fact, one of the projects of The Center for Health Information and Decision Systems at the Robert H. Smith School of Business at The University of Maryland tracks the various federal, state, and private HIT initiatives across the USA. This HIT Dashboard can be found at http://www.hitdashboard.com/default.aspx.

The initiatives for creating ANSI-approved standards are a good start. The fact that there are over 300 interoperability projects underway is encouraging. However, in order for some of the ideas introduced here to work effectively new standards are needed and a more coordinated effort to the establishment of standards is required. One example is the need to establish a standard that enables the exchange of information regarding the mix and acuity of hospital patients. Furthermore, as standards are established, organisations must be encouraged to adopt them, which may require a federal mandate.

5 Conclusions

The potential benefits of implementing decision support systems in support of disaster response efforts are enormous both in terms of human life and reducing the costs associated with inefficient response efforts and reconstruction. The most significant barrier is the current inability to transmit data freely and quickly among individuals and organisations. The root cause of this barrier is the fact that the industry is comprised of a large number of organisations, each with their own systems and technologies. The end result is a large number of disparate, often incompatible information systems and the ability to disseminate important data is limited. While these problems are not insurmountable, they are significant and efforts to eliminate them by establishing data standards are crucial.

In this paper, we have discussed the necessary conditions for decision support technology to effectively support emergency managers in making their decisions. We also introduced some of the scientific developments in decision theory that seem to overcome the aforementioned barriers. Our goal was to explore the potential of this technology in decision-making in emergency situations and we believe that decision support technology can be useful to emergency managers if they understand its limitations and capabilities.

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Notes

1 www.321site.com/ greg/courses/mis1/glossary.htm

2 http://www.redcross.org/news/ds/doc/010221a.html

3 http://www.oep-ndms.dhhs.gov/, respectively

4 http://www.ai.sri.com/~gister/

5 http://www.ai.sri.com/~gister/ipb.html

6 http://www.ai.sri.com/~gister/heartache.html

7 http://www.hl7.org

8 http://www.chestandards.org/

9 http://www.ahima.org

10 http://www.cchit.org