Using Web Service Architectures and Advanced Simulation Tools to ensure that Cost Savings in Strategic Funding for Emergency Services do not Jeopardize the Safety of Local Communities

S. Raue; Department of Computing Science; University of Glasgow, Scotland, UK
C.W. Johnson, DPhil; Department of Computing Science; University of Glasgow, Scotland, UK

Keywords: Emergency Planning, Fire Safety, Simulation, Systems Engineering, Web Services

Abstract

Performing effective and efficient emergency response is essential to maintaining public safety. The use of emergency planning systems therefore plays a critical role in ensuring that the emergency services can respond to a wide range of adverse events, including everything from domestic fires to terrorist attacks or natural disasters. Software supporting resource deployment for emergency response create particular challenges, such as reflecting updates in infrastructure, population and buildings and changes in services provision. These different factors require the input data from multiple sources to help inform the planning processes that guide our response to emergencies and help to protect the safety of the general public. This paper therefore describes an advanced approach to Emergency Planning through web service architectures. The approach is analyzed regarding possible benefits and drawbacks. A case-study is introduced, presenting the development of a web services-based application, enabling the evaluation of different 'what-if' scenarios within the operational planning process of the UK Fire and Rescue Services, although we would argue that the approach has a more general application. The results of our initial work raise a number of questions about the suitability of these web-based technologies for primary or secondary planning systems in the emergency response domain.

Introduction

Performing effective and efficient emergency response is essential to maintaining public safety. Emergency service providers are facing changes in their area of responsibility. Terrorist attacks on the World Trade Centre or the London Bombings in 2005 (Murphy 2006, Johnson 2008) have significantly increased the scale of some threats. Natural disasters, ranging from Hurricane Katrina in 2005 (Daniels 2006) through to the 2007 UK floods have revealed how much public safety depends upon effective crisis management (Penning-Rowsell 2006, Blackburn 2008, Pitt 2008). Emergency response planning systems help Fire and Rescue Services (FRS) to improve the mitigation, preparedness, response or recovery to a number of heterogeneous scenarios.

The scenarios of an emergency are often very complex, so are the systems used to process information and support decision making. It can take many person months of effort to program a single new adverse event into simulation and decision support tools such as those described in (Raue and Johnson, 2010). It is, therefore, important that we develop appropriate techniques that minimize the costs associated with data integration and functional enhancement so that we can help the emergency services use existing software to consider a wider and wider range of threats to public safety. This paper presents different categories of applications that support emergency planning. The first part distinguishes between technologies, architectures, frameworks and explains the relationship between planning tools and simulations. The increasing importance of web technologies as an enabling architecture for information exchange between various government agencies justifies a deeper analysis of whether a range of novel architectures might be used to enhance existing emergency planning systems. The focus thereby lies on web service architectures, a form of distributed computing providing a standardized framework for system development. The web has traditionally been used to distribute information. By using new interoperability architectures that employ web services, the web is also able to provide computational capabilities. Web services are thereby defined as "software system designed to support interoperable machine-to-machine interaction" in order to provide computational services over a network (W3C 2004, Stair 2003). Investigating the feasibility and the potential impacts of new technologies is important because government agencies are notoriously slow to benefit from leading edge techniques within the field of information processing.

The second part of the paper introduces a case study, involving the Fire and Rescue Services in the UK. The planning processes and a strategic planning application are described and challenges for the enhancement of existing large scale IT emergency planning systems are outlined. Based on the functionality provided by a web service, an application is developed for use by the UK FRS to evaluate different operational planning scenarios in order to tackle the problem of unwanted fire signals. These false alarms are a significant drain on existing resources and, therefore, threaten public safety. The closing sections use the analysis conducted to raise further questions about the suitability of web technologies for emergency response systems and derived applications leading to future research.

Background: Planning and Managing Emergency Response

First responders have to prepare for a range of scenarios. Within each of these cases, they also have to consider a number of different priorities including both their immediate response to any risks but also the longer term consequences of their actions, increasingly focusing on the problems of environmental contamination after major fires. Emergency planning systems, therefore, have to reflect the complexity of these events. They must also provide a sufficient level of detail to support critical decision making before any future incident occurs. Considering the different perspectives on the planning process a variety of supporting software systems has been developed. Decision Support Systems (DSS) or Management Information Systems (MIS) are able to handle large amounts of data often from multiple sources, providing information to decision makers on operational and strategical planning levels. The information in these systems enables reporting as well as complex data analysis. Making hypothetical changes to the underlying data of a problem field "what-if" scenarios can be used to evaluate the impact of changes, e.g. in corporate processes. Additionally simulations based on models of the underlying system are often used, to get a better insight in the consequences of changes. In conjunction with recent visualization techniques these simulations can then be used to support tabletop exercises in a more effective manner. A wide variety of other is systems e.g. solely specializing on financial aspect, such as cost benefit analysis tools, or others modeling real-world scenarios, e.g. to investigate the impact of heat and smoke in fire scenarios, are available. So even though DSS and MIS are often employed on a managerial and strategical planning level, there are various issues, such as training of emergency responders that are supported by other types of computer systems, e.g. virtual reality trainings tools. In order to introduce more clarity in the categorization of such system and their functionalities, a number of frameworks have been developed (Careem 2006, Jain 2003a).

The Integrated Emergency Response Framework (iERF) classifies emergency planning systems using three major criteria - *disaster event*, *application* and *entities of interest* (Jain 2003b). The *disaster event* has an impact on the complexity of the system to be developed. In the iERF it is further divided into natural and man-made disasters, each covering a number of additional sub-categories describing the emergency in more detail. Indentifying the *entities of interest*, it can then be determined, who and what is impacted by the scenario. This helps to identify the entities which need to be modeled. Hence, allowing the development of simulations that could be used to investigate the impact of different behaviors or strategies within a chosen scenario.

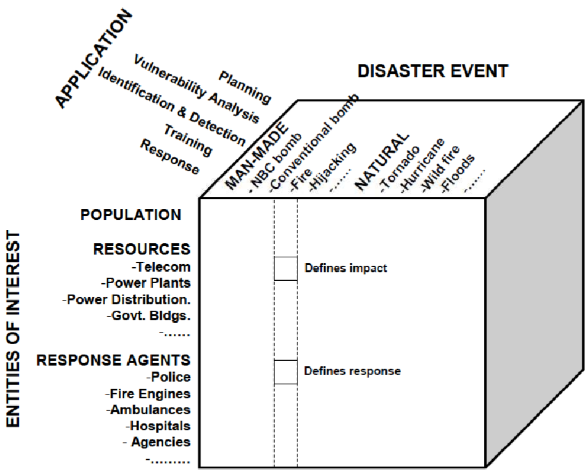

Figure 1: Integrated Emergency Response Framework (iERF) - (Jain 2003b)

As the emergency response domain covers many areas of application, the system design is determined by the purpose of the overall system. The iERF therefore introduces the third dimension *application*, which covers the processes of mitigation, preparedness, response or recovery, by five application areas – see *figure 1* (Jain 2003b).

This paper is mainly concerned with the process of planning and the suitability of planning applications to support decision-making for emergency services in their particular field of responsibilities.

The application area of an emergency planning system plays an important role in determining the detailed system requirements. For example, evacuation simulators can be used to help plan for egress from large public buildings (Johnson, 2010). However, these systems do not need to model every aspect of the hazards that trigger an evacuation. They can still provide useful insights even if they do not distinguish between electrical fires or fires ignited by smoking materials. Similarly, the numerical results from these tools do not always require complex three-dimensional visualizations to provide architects within information that can inform their subsequent design work. On the other hand, simulated trainings scenarios, e.g. for fire fighters or the military, would benefit from realistic visualizations and a higher degree of veracity in the detailed modeling of individual scenarios. The range of technical requirements could lead to a further categorization of the underlying system components, focusing on technical specifications.

A number of different research areas have emerged to support emergency planning. For example, some groups have focused on improved algorithms, e.g. for fire or smoke spread, or new behavioral models, e.g. for evacuation simulations. (Berry 2005) Other groups have looked at mixed, virtual or augmented realities. (Balasubramanian 2006, Chittaro 2008) Progress in the area of agents and agent-based systems has also led to improvements in the modeling of interaction in emergency planning scenarios. Focusing on the bigger picture, other research is carried out, focusing on the architecture of complex systems to generate new knowledge about the combination of these improved system components. This area of research includes data exchange standards and architectural concepts (Iannella 2007, OASIS 2006). The aim is to offer a wide range of component functionality, which is easy to integrate in the overall system structure (Jain 2008). As we are investigating the suitability of web services, we are further focusing on the architecture of emergency response systems.

The US Department of Defense (DoD) has been an early adopter of simulation technology for contingency and emergency planning. Based around the requirement to use more than a single simulator, in order to increase the capability of their systems, the need for distributed application architectures evolved. The concept of High Level Architecture (HLA), defined in IEEE Standard 1516, enabled the DoD to support the development of powerful distributed simulation applications. Even though HLA is used for applications outside DoD, it is only one of several competing approaches. For instance, the Model Driven Architecture was proposed by the Object Management Group (OMG) as a design approach, and adopted across various industrial sectors (Brown 2004). This introduces the concept of model-driven software engineering and is based on platform-independent models, which describe the system functionality (Soley 2000, Siegel 2001). The benefits and future of each technology, as well as comparisons have been discussed by a number of researchers (Parr 2003, Tolk 2002).

Developing an application that is distributed, might on the one hand increase the complexity of the overall system, but one the other hand it introduces a number of possible benefits, especially in the complex domain of emergency planning; some types of disaster events need to be managed by multiple agencies. Therefore on an administrative side, distributed applications can be used to integrate information across several different data sources without relying on any single point of storage. It is, therefore, surprising that so many emergency planning tools simply access monolithic databases that are formed by government agencies that subsequently experience great difficulty in maintaining the data that is initially provided by many other departments of government. There are further benefits from a more distributed approach. In systems that have to plan for the simultaneous intervention by paramedics, by fire and rescue services and by security agencies, it is possible to develop a modular approach. Changes in the Standard Operating Procedures (SOPs) of each service can quickly be introduced by using different models for each agency.

From a technical point of view, executing complex simulation in distributed systems, might lead to improved response times and lower cost computation. (Jennings 2001, Jain 2003b) The use of a distributed architecture can also enable multiple/simultaneous access to shared planning systems. In the future, this might be extended to include data not only about the behaviors and procedures of individual emergency services but also to integrate data from sensor networks as actors in the systems, e.g. smoke or fire alarms, which can trigger emergency routines and provide information in real-time (Berry 2005). Emergency Planning Systems will thereby facilitate the merging process of important data from multiple information sources. Based on the underlying data aggregation, models of problem or planning scenario can be built, which are than employed as the foundation of simulations, e.g. helping to understand the impact of different decisions.

The next section provides an overview of the strategic planning process within UK Fire and Rescue Services and introduces an application, which these organizations use to develop long term management plans. This case study helps to identify the challenges that arise from the enhancement of existing large scale emergency planning systems using web service architectures.

Strategic Planning for the Fire and Rescue Services in the UK

The field of responsibilities of the Fire and Rescue Services has been changing significantly within the last decades. The increasing risk of terrorist attacks and a series of natural 'disasters' have motivated the FRS to conduct detailed reviews of their strategic planning. This is necessary to be able to provide effective services in time of crisis and to ensure that the service responds to the changing demands of the twenty-first century. This review has also been instigated by changes in the legislative regime for the FRS, e.g. to protect communities from the effects of fire (CLG 2008a). In other words, there is an increased emphasis on assessing the risks to a local population from, for example, the loss of major employer in an area rather than simply looking as the value of buildings in terms of their net cost to replace.

The Civil Contingency Act 2004[1] identifies the Fire and Rescue Services as Category 1 responders. This group additionally includes police forces and ambulance services. So called Category 2 responders are defined as organizations co-operating as part of the emergency response and recovery work, mainly including private sector bodies ranging from gas to transport to telecommunication providers (CabinetOffice 2004, CLG 2008b). The exchange of information between different bodies, within the Category 1 and Category 2 responders is essential for emergency planning and has been criticized, for example in the Pitt review of the 2008 floods. Further changes were triggered by the Fire and Rescue Services National Framework 2008-2011. This has encouraged the FRS to produce Integrated Risk Management Plans (IRMP). (CabinettOffice 2004, CLG 2008a) These are the result of a risk-based management process, in order to "identify measure and mitigate the social and economic impact that fire and other emergencies can be expected to have on individuals, communities, commerce, industry, the environment and heritage." (StrathclydeFRS 2006) One important foundation for the decision-making process within the integrated risk management planning is the Fire Services Emergency Cover toolkit (FSEC). This software system enables the collection and interpretation of information about different risks within the UK (CLG 2008c, StrathclydeFRS 2006).

FSEC integrates a geographical information system that provides a common interface to all Fire and Rescue Services in the UK. Geographical, social and organizational data is integrated in the system. This includes information about the location of fire stations and available resources, alongside with the capabilities of those resources to respond to different forms of adverse events. This data is based on historical data about previous fire incidents. FSEC is intended to support the decision-making processes for the Fire and Rescue Services on a strategic level. The rich data that is stored in FSEC is periodically updated to include details about the latest incidents across the UK. Further data is derived from fire safety audits; these provide information about buildings that have not been involved in a fire. FSEC also includes data about changes in the road traffic network, information on fire stations, including crewing and available vehicles, as well as changes in the social structure of areas. The demographic input comes from census data amongst other sources (CLG 2008c). The aim is to provide decision makers with integrated access to the heterogeneous data sources that they require in order to develop strategic plans that ultimately will help to determine public safety in local communities for many years to come. To assess the most suitable strategy for a region, the FSEC toolkit provides the functionality to simulate strategic plans. Users can ask what might happen to response times if they open a new fire station or if additional appliances are moved to an existing location. Conversely, it is possible to use FSEC to identify any adverse consequences for the local community if cuts are proposed to the level of emergency provision. The results can then be displayed using the map-based system, see figure 2.

---

[1] The Civil Contingency Act 2004 declares among other things a single framework, with a set of roles and responsibilities, for civil protection. (CLG 2008b)

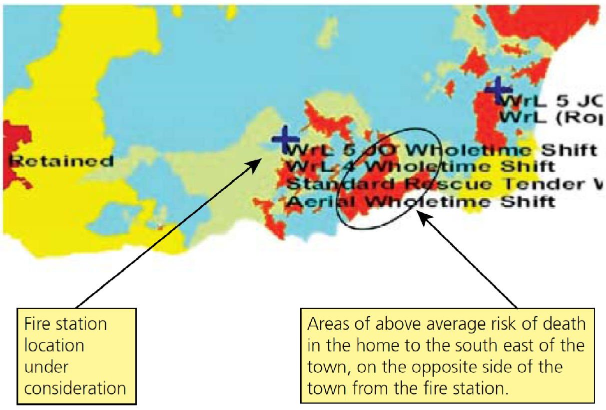

Figure 2: Anonymous Example of a Risk Map within FSEC (CLG 2008c)

Simulating planned strategies, e.g. moving fire stations or changing the crewing, allows the responsible mangers to assess the impact of changes. Up to a certain level of detail this allows the modeling of various “what-if” scenarios in order to find the best strategy to mitigate the risks in a certain community. Through the use of such large-scale systems, like FSEC, the emergency response planners can inform their decisions using a variety of information and predictions. However, it is important to acknowledge the limitations of even the most advanced planning tools. FSEC provides significant support but it can lack detail in the modeling, for instance of economic consequences or safety implications from the reassignment of existing resources. Equally, it is important not simply to add new functionality without carefully considering the impact that this might have both for the usability of the resulting system but also on the veracity of the final predictions.

What are the challenges in adding functionality to existing large-scale Systems?

The decisions that are informed by tools such as FSEC have a profound impact on public safety. It follows that the underlying information provided needs to be correct, therefore validating and testing new functionality is a major issue in enhancing existing large scale emergency planning systems. Additionally, previous research has argued that combining information from various heterogeneous information systems introduces a wide range of challenges associated with interoperability.

On the systems’ side it is thereby related to e.g. the use of different platforms, hardware and file types of the underlying systems. Information systems heterogeneity might introduce issues in regards to the operated Database Management Systems in each tool and the differences in their capabilities. This is a major issue for consuming the data, as different systems will also have an effect on the information itself. Dealing with the data within the system, assumes that the input data obtained from a range of information sources, e.g. different government agencies, have to be transformed into a uniform format, ready to be processed in an Emergency Planning tool. Standardized ways to exchange information, similar to those evolved from research in the area of web services architectures (W3C, 2004) could help to overcome the outlined interoperability challenges in information systems.

Improving and adding features therefore possibly introduces a new source of failure within the applications. Therefore every new release needs to be validated and tested carefully. This can be done, to a limited extent, by simulating the effects of changes that have already taken place. Historical data can then be used to determine whether or not the prediction tools anticipate the consequent changes that have already been witnessed. However, this approach cannot easily be used to test predictions about new working practices or the introduction of fire safety features into communities that are only just being developed. The effort of implementing new functionality is thereby mainly determined by factors, like complexity, technology, and architecture of the existing system, which needs to be assessed by experts.

Increasing interoperability of service based applications also raises a host of questions about the veracity of data that is collected for one, possibly non-safety related, application and is then used by safety-related systems, such as emergency planning systems. An example might be the manner in which FSEC relies upon UK census data to reflect the changing demographics in local communities (Johnson and Raue, 2010).

How to possibly overcome these challenges?

Previous sections have argued that emergency planning systems rely on the integration of data from multiple sources – ranging from incident databases through to demographic details about changing populations as well as more detailed audit data on building usage and protection. It is also important to ensure that this information is updated on a regular basis. At present this is done by the manual or semi-automated transfer of data from other sources, such as census data, into a standalone application. As this is expensive and time consuming updates are limited. It can also be error prone. A more automated approach would not only offer the opportunity of significant savings, it would increase the recency of data and also reduce the opportunity for error by careful validation of integration algorithms,

The existing emergency response system could be used as an underlying source for information. The information would then be processed in the new external application to be developed. This could lead to a faster development of the new application, as the developers are not necessarily constrained by the existing system. As only the components need to be tested and validated by the customer, the release could be quicker as well. Functionality that is required to be for regional authorities only, could be developed apart from the existing system and therefore keep the maintenance and deployment effort on the same level. The benefits overall are lying in the possibility to develop applications in a faster and more flexible way, as developers are not constrained to technologies used in the underlying system. The automated updating of integrated applications also raises concerns when, for instance, errors in one system will quickly be propagated across many different client systems. In some potential applications, the impact of these errors may not be transparent to the users who can be unaware of the updates in second or third party systems.

The integration of external data sources raises a number of more detailed design concerns, For instance, the speed of an emergency planning tool such as FSEC could be adversely affected if data had to be processed from an external source every time a query was made. Integration can also introduce significant interdependencies. For instance, significant redevelopment might be required if an external data repository changed their data format (Vassiliadis 2002). Finally, security issues can limit opportunities for integration of multiple data sources. The process of sharing data can create mutual vulnerabilities, for example to requests for information that should not be permitted. This creates concerns given that each component of an integrated system might have to maintain and check access privileges for each of the other components to ensure that security policy is not violated.

The results of the cost-benefit analysis or the risk-assessment in terms of data and system security, which need to be carried out, are mainly dependent on the type and complexity of the underlying system. Furthermore, a consideration of the existing legislations, e.g. data protection act, as well as an assessment of the system security, need to be carried out. As the outlined benefits are mainly lying in the flexibility and the increased development times, the next section is going to investigate how web services might fit in this development scenario.

Web service architectures provide ways of addressing many of the concerns mentioned above. They have the additional benefit that they also coincide with government policy in many states, promoting common access criteria for the exchange of information both with the public and between different internal departments within the security and integrity constraints, mentioned in previous sections. The following chapter therefore introduces the case study and outlines how web services could be employed to enhance functionality of an existing Emergency Planning tool used by the UK Fire and Rescue Services.

Case Study: Background Information

The Fire and Rescue Services respond to an amazingly wide variety of ‘emergencies’ ranging from fires to flood, from rescuing trapped animals to providing elevated access to other primary responders. However, their core competency is the protection of communities from fire-related losses. To be considered as a “modern und effective fire and rescue services” in the sense of the Government the services must amongst other things be carried out “providing value for money (CLG 2008a). This introduces the need to analyze planned and existing operations in regards to operational costs. At the highest level, the effectiveness of prevention and protection measures for the Fire and Rescue Services can be measured using the number of lives saved as against the costs for property damage.

Research in the area of Fire-Safety has characterized relationships between property damage, injuries and fatalities in fires and the response time of the services (Halpern, 1979; Challands, 2009).

The problem of 'false alarms' can be used to illustrate the way in which web service architectures might be used to support the development of emergency planning tools that go beyond the existing template provided by FSEC. Even though the overall number of fires and false alarms in the UK recently decreased, the rate of false alarms amongst these incidents is still more than 50 percent. This results in the deployment of limited FRS resources to places, where their help is not needed. Events like unwanted fire signals or false alarms threaten public safety when appliances cannot be repositioned in time. In the period from 2008 to 2009 more than 396,000 false alarms were raised in UK, leading to the mobilization of one or more fire engines. These resources would not be able to attend a simultaneously occurring real emergency within the normal response times. The cost related to the mobilization and the resulting delayed response times of the FRS resources is estimated to be around £1 billion (approx. $ 1.52 billion). (CFOA 2008) At the same time, changes in safety legislations have led to the increasing deployment of smoke and heat sensors. The aim of is to increase safety by providing early warnings of a potential fire. However, the side-effect is to simultaneously increasing the number of false alarms. A recently opened department in a hospital now includes more than 8,500 detectors, allowing detecting fires rapidly, but at the same time statistically increasing the UK-wide risk of false alarms by 2.5 percent. (CFOA 2008)

The introduction of additional sensing technology is only one of the reasons for recent increases in the number of false alarms. Irrespective of the detailed causes of this problem, it is clear that the Fire and rescue Services have to alter their strategy for dealing with these events in order to mitigate the increasing drain on finite resources at a time of budget cuts for the FRS in many European and North American communities. Fortunately, integrated emergency planning tools can be used to identify the costs and benefits of strategies that have been proposed by fire safety officers to address the problem of false alarms. These strategies include on-site call filtering allowing a local responder to confirm a firm within a given amount of times or scenarios in which fire officers adopt a paramedic role and are dispatched in rapid response vehicles to confirm that an alarm is genuine before any further resources are committed. The costs and benefits of such initiatives must be analyzed because there is a danger that any additional delays e.g. for the paramedic approach would undermine the additional warnings provided by advanced sensors. Conversely, the costs of introducing these officers might easily outweigh the savings from the inadvertent deployment to a false alarm. Existing systems, e.g. FSEC in the UK, cannot easily be used to simulate such specific scenarios because they involve considerable changes in standard operating procedures.

Case Study: Operational Planning Application Functionality

The process of operational planning an incident level is generally more detailed than strategic planning. The following sections outline application architecture and the information sources used to develop the prototype. It is thereby illustrates how the data from existing planning systems could be used as input for an additional, external component to enhance functionality without impacting the underlying planning systems. The system's functionality will be introduced in more detail before the systems design, involving web services architectures, is described.

As the additional functionality results from the capabilities of the application to evaluate different response strategies to fire-related incidents, the involved process are outlined firstly. Given a default mobilization process for the FRS, where a number of units are deployed to an incident, once an alarm is raised. Thereby, every alarm leads to a deployment of resources. An advanced mobilization process is visualized in Figure 3. On-site call filtering is introduced, e.g. to allow proofing the existence of a real fire within a given time, before the FRS resources are deployed. Once an alarm is raised, it will firstly be evaluated if the facility has on-site call filtering facilities in place. Given the case, this is true the mobilization of the FRS resources is postponed until either the on-site call filtering mechanism confirms a fire or the delay for response goes over a pre-defined threshold. In case, no mechanism is employed for on-site call filtering, the alarm results in an automatic deployment of the FRS. This would be similar to the default mobilization process based on predetermined resource allocation according to the risk category of each building type.

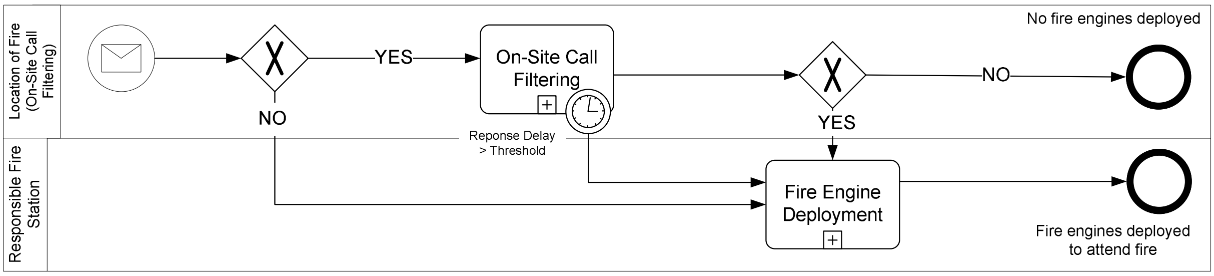

Figure 3: Process of Unit Deployment (On-Site Call Filtering)

Given the fact that the on-site call filtering is only suggested for premises other than private dwellings, the analysis furthermore focuses on the small number of buildings, which are responsible for generating disproportionately high number of fire alarms. This is assuming that, the positive impact of changing the processes for those buildings would be much higher. Buildings belonging to that category are for example student accommodations and hospitals, which are furthermore, introducing the problem of complicated environments for evacuations (DoH2009, CFOA 2008). The application developed focuses on the aspects related to the mobilization of the fire and rescue units only.

The information required to evaluate the different strategies can mainly be obtained from existing systems such as FSEC, providing data on building types, fire stations, crewing, available resources and geo codes for buildings. Additionally, information on previous incidents is delivered, therefore a number of high false alarms in certain types of buildings can be identified, e.g. hospitals. The information used in the system was received from FSEC and the Fire Damage Reports (FDR) individually collected by each FRS in the UK.

Case Study: Operational Planning Application System Design[2]

The operational planning application was developed with the intention to enhance the functionality of currently used planning system in regards to operational planning. Furthermore, it was emphasized to create an easy, but reasonable example conducting the case study. The system prototype is divided into several components, grouped in different application layers: data layer, business logic and presentation. Thereby the business logic was implemented using Microsoft C#, employing WPF capabilities to enable flexible development of desktop and web-interfaces to present the results. Figure 5 visualizes the system architecture and the data flow of the prototype in more detail.

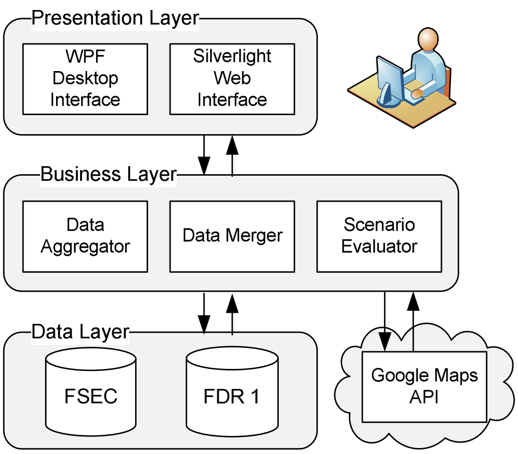

Figure 4: Data Flow and System Architecture of the Developed Prototype

[2] At the time of writing some aspects of the system still need to be completed.

The data layer builds the foundation of the application including two separate data sources in the form of database shadows of the productive FSEC and FDR1 databases. On request the information is send to the business logic, which mainly consists of three components. At the core is the data aggregator, employing the information sources on the data layer, to deliver the appropriate data to the data merger. According to the given task, the data merger then combines the data of the different data sources in order to collect all necessary input for the scenario evaluator. Within the process of the merging the data a web service[3] is used, providing information on travel distances and time, for a combination of geo codes related to the incident point and the responsible fire station.

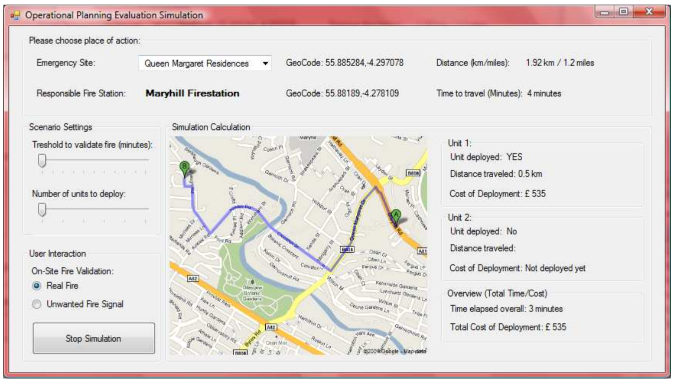

Figure 5: User-Interface prototype for conducting Operational Planning Evaluations

The presentation of the prototype has been implemented as a desktop application. The user interface is presented in the Figure 5. It displays a map and the route between fire station and incident, alongside with parameters used to define the response scenario, e.g. number of units responding. The scenario is evaluated using the number of resources deployed, the travel time and the average cost for mobilization of each unit to quantify the monetary outcome of an operational response strategy applied to a scenario.

Conclusion and Future Work

This paper described how web services enables application could be employed to enhance the functionality of existing planning systems. Due to the changes that the emergency service providers are facing in their area of responsibility, the use of emergency planning systems plays a critical role in order to perform effective and efficient emergency response and maintain public safety. Preparing for the wide range of adverse events often requires multiple agencies to work together, increasing the need for information sharing across agency borders. The planning process of the Fire and Rescue Services in the UK along with the related planning applications has been described. Challenges, such as system testing and verification of large scale systems, associated with a functional enhancement of these planning systems were outlined. The possibility to build applications employing existing systems as information sources, merging data and using web services functionality was discussed. The case-study introduces an application allowing to evaluate the impact of different response scenarios of the FRS to tackle the problem of false alarms. The system was developed using data from multiple existing information systems. Based on a flexible, component-based system design, a web service was included delivering spatial data that was combined with data from existing sources. As the existing planning systems were employed providing data only the resulting loose coupling allowed an easier testing and validation of the newly developed system enhancement. The question was raised if web services in general provide enough security to process such sensitive data. Furthermore, making external web services part of a safety critical emergency planning system the reliability of each underlying component needs to be considered, especially if the system to be developed should support real-time decision making for incidents. Therefore, as part of the future work the hazards of web services architectures and their suitability for primary and secondary response planning systems is going to be investigated.

[3] Google Maps API – http://code.google.com/apis/maps/

Acknowledgement

The work described in the paper has been supported by the UK Engineering and Physical Sciences Research Council grant G026076/1; Evaluation of Prevention and Protection Activities On Commercial, Public and Heritage Buildings.

References

1. Balasubramanian V, Massaguer D, Mehrotra S, Venkatasubramanian N. DrillSim: A Simulation Framework for Emergency Response Drills. In: *1. Balasubramanian V, Massaguer D, Mehrotra S, Venkatasubramanian N. DrillSim: A Simulation Framework for Emergency Response Drills.* Berlin / Heidelberg: Springer; 2006:237-248. Available at: http://www.springerlink.com/content/lr73000468p0r648.
2. Berry D, Usmani A, Torero J, et al. *FireGrid: Integrated emergency response and fire safety engineering for the future built environment*. Nottingham, UK: UK e-Science Programme All Hands Meeting (AHM-2005); 2005. Available at: http://hdl.handle.net/1842/1217.
3. Blackburn M, Methven J, Roberts N. Large-scale context for the UK floods in summer 2007. *Weather*. 2008;63(9):280-288. Available at: http://dx.doi.org/10.1002/wea.322.
4. Brown AW. Expert’s voice Model driven architecture: Principles and practice. *Software and Systems Modeling*. 2004;3(4):314-327. Available at: http://www.springerlink.com/content/bqrgrgjmlflyh2y0/.
5. Careem M, Silva CD, Silva RD, Raschid L, Weerawarana S. Sahana: Overview of a Disaster Management System. In: *International Conference on Information and Automation*.; 2006:361 -366.
6. Challands N. The Relationships Between Fire Service Response Time and Fire Outcomes. *Fire Technology*. 2009. Available at: http://www.springerlink.com/content/l504425760780402.
7. Chittaro L, Nadalutti D. Presenting Evacuation Instructions on Mobile Devices by means of Location-Aware 3D Virtual Environments. In: *MobileHCI '08: Proceedings of the 10th international conference on Human computer interaction with mobile devices and services*. Amsterdam, Netherlands: ACM; 2008:395-398.
8. Daniels RJ, Ketl DF, Kunreuther H. *On Risk and Disaster: Lessons from Hurricane Katrina*. (Daniels RJ, Ketl DF, Kunreuther H). University of Pennsylvania Press; 2006:293.
9. Department of Communities and Local Government. *Fire Service Emergency Cover Toolkit: Executive Summary*. Wetherby, West Yorkshire (UK): Communities and Local Government Publications; 2008:25.
10. Department of Communities and Local Government. *IRMP Steering Group Integrated Risk Management Planning: Policy Guidance for Business Continuity Management*. Wetherby, West Yorkshire (UK): Communities and Local Government Publications; 2008. Available at: http://www.communities.gov.uk/publications/fire/irmpbusinesscontinuity.
11. Department of Communities and Local Government. *Risk Assessment tool, techniques and data for the Civil Contingency Act and Integrated Risk Management Planning*. Wetherby, West Yorkshire (UK): Communities and Local Government Publications; 2008. Available at: http://www.communities.gov.uk/publications/fire/riskassessmenttools.
12. Department of Health. Reducing False Alarms in Hospital Premises. 2010. Available at: http://www.spaceforhealth.nhs.uk/articles/minimising-unwanted-fire-signals.
13. Soley R, OMG Staff Strategy Group. Model Driven Architecture. *Management*. 2000:1-12.
14. Halpern J. Fire Loss Reduction: Fire Detectors vs. Fire Stations. *Management Science*. 1979;25(11):1082-1092.
15. Iannella R, Robinson K, Rinta-Koski O. Towards a Framework for Crisis Information Management Systems (CIMS). *Distribution*. 2008.
16. Intelligence And Security Committee, Murphy P. *Report into the London Terrorist Attacks on 7 July 2005*. London (UK): The Stationery Office Limited; 2006. Available at: http://www.official-documents.gov.uk/document/cm67/6785/6785.asp.
17. Jain S, Mclean CR. Components of an Incident Management Simulation and Gaming Framework and Related Developments. *Simulation*. 2008;84:3-25.
18. Jain S, McLean CR. Modeling and Simulation for Emergency Response: Workshop Report, Standards and Tools. *Manufacturing Engineering*. 2003.
19. Jain S, McLean CR. A Framework for Modeling and Simulation for Emergency Response. In: *Proceedings of the2003 Winter Simulation Conference*.Vol 1. New Orleans, LA; 2003:1068-1076.
20. Jennings NR. An agent-based approach for building complex software systems. *Commun. ACM*. 2001;44:35-41.

21. Johnson CW, McLean K. Tools for Local Critical Infrastructure Protection : Computational Support for Identifying Safety and Security Interdependencies between Local Critical Infrastructures. In: *System Safety, 2008 3rd IET International Conference on*.; 2008:1-6.

22. Johnson CW, Raue S. *On the Safety Implications for e-Governance: Assessing the Hazards of Enterprise Information Architectures in Safety-Critical Applications*. Vienna, Austria; 2010.

23. Siegel J. Developing in OMG's New Model-Driven Architecture. *Management*. 2001.

24. OASIS Emergency Management Technical Committee. Emergency Data Exchange Language (EDXL) Distribution Element, v. 1.0. 2006. Available at: http://www.oasis-open.org/committees/download.php/18772/ EDXL-DE 1.0 Standard.pdf.

25. Parr S, Keith-Magee R. The Next Step - Applying the Model Driven Architecture to HLA. In: *In Proceedings of 2003 Spring Simulation Interoperability Workshop*.; 2003:paper 03S-SIW-123.

26. Penning-Rowsell E, Johnson C, Tunstall S. Signals from pre-crisis discourse: Lessons from UK flooding for global environmental policy change? *Global Environmental Change*. 2006;16:323-339. Available at: http://www.sciencedirect.com/science/article/B6VFV-4K8S5PS-1/2/96c14835b27fd70a8b51f8fe755d256c.

27. Resilience Cabinet Office UK. Civil Contingencies Act 2004. 2004. Available at: http://www.ukresilience.gov.uk/preparedness/ccact.aspx.

28. Strathclyde Fire And Rescue Services. Performance Report 2004-2007 and Integrated Risk Management Plan 2007-2010. 2007. Available at: http://www.strathclydefire.org/pdfs/ppr/ IRMP2007-2010.pdf.

29. Stair R, Reynolds G. *Principles of Information Systems*. 8th Edition. Course Technology Press; 2007.

30. The Chief Fire Officers Association. CFOA Policy for the Reduction of False Alarms & Unwanted Fire Signals. 2008;(September). Available at: http://www.rbfrs.co.uk/pdfs/cfoa-policy-rofaaufs.pdf.

31. Tolk A. Avoiding another Green Elephant - A Proposal for the Next Generation HLA based of the Model Driven Architecture. In: *Proceedings of the 2002 Fall Simulation Interoperability Workshop (SISO Fall)*. Orlando, Florida; 2002:paper 02F-SIW-004.

32. Vassiliadis P, Simitsis A, Skiadopoulos S. Conceptual Modeling for ETL Processes. In: *DOLAP '02: Proceedings of the 5th ACM international workshop on Data Warehousing and OLAP*. McLean, Virginia, USA: ACM, New York, NY, USA; 2002:14-21.

33. World Wide Web Consortium. Web Service Architecture. 2004. Available at: http://www.w3.org/TR/2004/NOTE-ws-arch-20040211.