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Transport in Emergency Situations
Preliminary Communication
Submitted: June 10, 2014
Approved: Mar. 24, 2015

WEB GIS FOR AIRPORT EMERGENCY RESPONSE - UML MODEL

ABSTRACT

The main objective of integrating Web GIS in airport emergency response should be to provide the most appropriate geospatial information to all participants. Airport emergency response still needs a model that will explain its complexity: its participants, their tasks and information needs. This paper presents the UML model of airport emergency response. Such a model facilitates a common understanding of the system by participants coming from airport, police, fire brigade, etc. It also enables institutional agreements for sharing data. The developers have got specifications of geospatial data and GIS functions imposed by participants and standards. A prototype Web GIS application is developed and presented to the users for evaluation. The prototype has shown how GIS functions can improve airport emergency response. The users have shown great interest, and they have great expectations in further integration of Web GIS in airport emergency response.

KEY WORDS

Web GIS; airport emergency; UML;

1. INTRODUCTION

Airport Emergency Management (AEM) is a complex activity characterized by participants from the airport, but also from the surrounding communities. Every emergency management consists of four phases: mitigation, preparedness, response and recovery. The most demanding phase in terms of information flow is emergency response. A large number of participants and resources are involved in interrelated tasks and share the same data. Dynamic data from various sources, as well as geospatial and temporal information are needed. Where are the injured? Which roads are accessible? Emergency activity depends on reliable data access, data integration and distribution of the information between rescue teams, citizens, etc. [1]. A common operational picture among participants has been recognized as critical to successful emergency response. Traditionally, maps are created showing locations of rescue resources, incident location, etc. Today, Geographic Information Systems (GIS) can be used in the creation of situational awareness by combining data from various sources. Base maps are stored on database servers in mapping agencies, photos are received from mobile phones by ad-hoc participants, meteorological data are gathered from volunteers, rescue team positions are received by Global Navigation Satellite System (GNSS) and transferred via mobile network. Today, all these data can be integrated in real-time and represented as a common operational picture by the use of Web GIS services.

The main objective of integrating Web GIS in AEM should be to provide the most appropriate information to all AEM participants. It should improve communication and coordination of rescue teams; it should also make response time shorter and emergency operations more efficient.

There are many challenges associated with the development of Web GIS services for AEM. Some of them are as follows, for example, AEM is highly regulated by the international and national regulations and technical standards. Until now, Web GIS has not been included in the standardization for AEM. Therefore, its development requires additional effort and commitment of all participants. The participants come from various sectors, each having its operational practice. Fire brigade, police and ambulance have each their own dispatch centres, its own operations, vocabulary, etc. The institutional agreements between involved sectors are necessary to enable sharing of the operational data. Moreover, a common understanding of data among sectors must be reached in order to integrate operational data. There are still problems with the collection, access and usage of geospatial data mostly because geospatial data are managed by different systems (computer-aided design or GIS) and have sector specific object definitions and formats [2]. AEM participants are still not using geoinformation technology in daily routine, and there is a need for trainings and raising GIS awareness. Nevertheless, several studies and projects have shown that the AEM participants are highly interested in geoinformation sharing and that the use of Web GIS services will take a significant place in the near future [1].

To overcome the challenges described above, the development of Web GIS services for AEM should have an emphasis on the successful integration into organizations. From the technological point of view, the focus should be shifted onto users and their view of the system. In system development methodologies, the initial phase of development is the user requirements analysis that defines user specifications of a system or what the system should do. It is well known that the user requirements analysis is critical to the success of the new developed system or whether the new system will meet the objectives. The users and developers work together trying to describe system functionalities and performance. The users are domain experts and developers are technology experts and often they do not fully understand each other. Several techniques could be applied to elicit the requirements: from studying documentation, holding interviews, identification of use cases to prototyping. Today, object-oriented analysis and design techniques are used for complex domains such as AEM. The heart of the object-oriented techniques is the construction of a model, a simplification of the real world domain. It is a conceptual model consisting of objects, and it does not imply the way of implementation. Unified modelling language (UML) has emerged as a standard modelling language supporting all phases of system development. It is a formal and graphical language (uses well-defined notations and diagrams) and thus avoids ambiguity, but helps communication between the user and the developer.

AEM still needs a model that will explain the complexity of the AEM: AEM participants, their tasks and information needs. It is expected that such a model will facilitate common understanding of the system by participants coming from airport, police, fire brigade, etc. In addition, it will enable institutional agreements for sharing of data because the data sets will be identified and described. Considering common operational picture, the developers will get specifications of geospatial data and GIS functions imposed by participants and standards. Thus, the developed Web GIS services will achieve the AEM objectives.

Many projects examined broader issues such as geospatial information for crisis management. The Dutch projects Geographical Data Infrastructure for Emergency Management and Geo-information for Risk Management were dealing with emergency response for all types of disasters and for all administrative levels in the Netherlands. As a result, many papers were published describing user requirements [1-6], UML models [6, 7], e-services [8], geospatial data infrastructure [2, 4], data models [7, 9, 10] etc. The European projects ORCHESTRA and OASIS were dealing with interoperability among participants in emergencies and their proprietary information systems. Still, none of them have made the model for AEM.

Besides, airport operations are highly regulated, and many projects deal with geospatial information for airport operations. Baučić et al. [11] have made an overview of standards and projects for AEM and supporting geospatial information. The International Civil Aviation Organization (ICAO) develops international air transport standards and regulations. The main references for the airport emergency planning are Annex 14 to the Convention on ICAO, Volume I and Airport Service Manual (doc. 9137), Part 7, Airport Emergency Planning. The U.S. Department of Transportation, Federal Aviation Administration (FAA) has developed several geospatial information specifications mainly concerning aeronautical surveys and maintenance of airport data. The European organization for the safety of air navigation Eurocontrol is developing several standards: Aerodrome Mapping Data Base (AMDB), Aerodrome Mapping Exchange Schema (AMXS), Airport Mapping Exchange Model (AMXM) and Aeronautical Information Management (AIM). Still, there are no published specifications covering Web GIS support for AEM. Recently, FAA has published the Guidebook on Integrating GIS in Emergency Management at Airports [12]. The document emphasizes GIS as a productive tool to enhance AEM, and it stresses thoughtful planning and coordinating of all participants in GIS implementation, starting with user requirements. However, it does not provide any model for AEM.

A few attempts of modelling airport operations by UML can be found in the EDEMOI project [13, 14] for airport security operations and in the work of Ahmad et al. [15] for the air traffic control system. To our best knowledge, there are no such attempts for AEM.

This paper presents UML model of emergency response phase of AEM. All participants, tasks they perform and data are identified and described. Emphasis is given to geospatial data needs for the creation of common operational picture. The next section presents used techniques and the main features of UML model of Airport Emergency Response System (AERS). In addition to documentation study and interviews with the users, a prototype has been built. Section 3 discusses the achieved results, and the last section closes the paper with a conclusion and future work.

2. UML MODEL OF THE AIRPORT EMERGENCY MANAGEMENT SYSTEM

The first task was to elicit user requirements by studying the documentation and interviewing about operational practice. Based on that, a UML model is built. Finally, a prototype Web GIS application is developed and presented to the users for evaluation.

2.1 Eliciting user requirements

Airport emergency response includes operations of rescue and fire fighting, law enforcement, medical and care services and providing information to the public (*Figure 1*). The airport authority defines the participation of departments and agencies on the airport (e.g. rescue and fire fighting, airport police) and off the airport (e.g. local fire brigade, hospital). Eyewitnesses and volunteers can join the rescue operations and thus become ad-hoc responders.

The airport operations must be performed in conformance with the international and national standards and regulations. The emergency operations at airports are studied from the following relevant documents:

- ICAO Annex 14 to the Convention on ICAO, Volume I [16]
- ICAO Airport Service Manual, doc. 9137, Part 7 [17]
- FAA Advisory Circular, No. 150/5200-31C, Airport emergency plan [18]
- Official Gazette of the Republic of Croatia 64/12, Regulations on the Airports [19]

Each airport is prepared to cope with an emergency by the preparation of the Airport Emergency Plan (AEP). The AEP should include at least the following:

- types of emergencies planned for,
- agencies involved in the plan,
- responsibility and role of each agency, the emergency operations centre and the command post, for each type of emergency,
- information on names and telephone numbers of offices or people to be contacted in the case of a particular emergency, and
- a grid map of the aerodrome and its immediate vicinity.

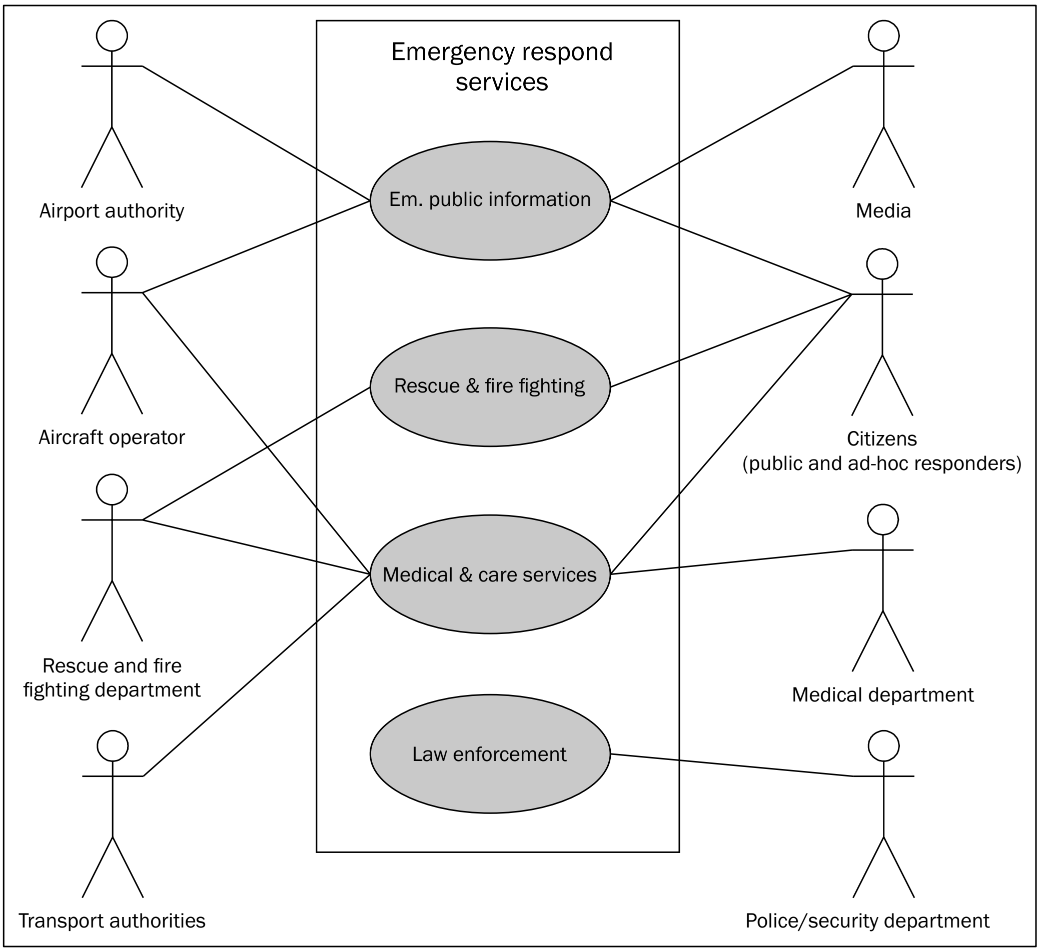

Figure 1 - Use case diagram of emergency respond services at airport

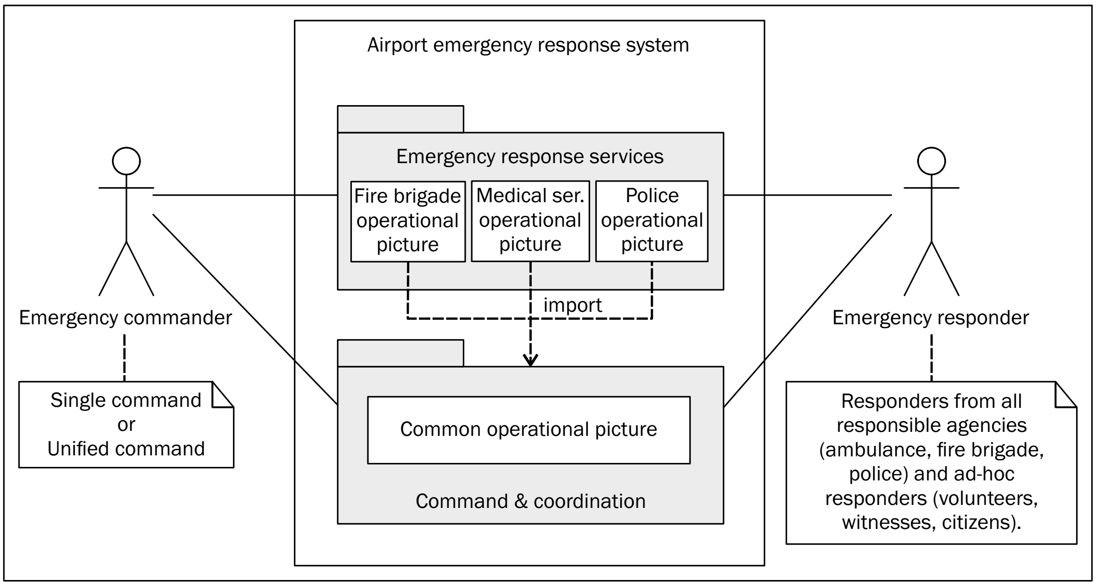

Figure 2 - Package diagram of Airport Emergency Response System

Airport Services Manual, doc. 9137, Part 7, Chapter 7 gives specifications and examples for two grid maps [17]:

- grid map of the airport depicting the confines of airport access roads, the location of water supplies, rendezvous points, staging areas, etc.,
- grid map of the airport and the surrounding community depicting appropriate medical facilities, access roads, rendezvous points, etc. within a distance of approximately 8 km from the centre of the airport.

The operational practice was studied on the Croatian airports (Split and Dubrovnik) by studying their airport emergency plans [20, 21], attending airport emergency exercise at the Split airport and by interviewing the participants.

2.2 UML model

UML model represents the blueprint of Airport Emergency Response System (AERS). The emphasis is given to geospatial information requirements.

Airport emergency response is a complex domain with hundreds of objects, classes (types of objects), activities, relationships, etc. In order to cope with such a complex model, its elements are organized into packages. *Figure 2* shows the package diagram of AERS. There are two packages: Emergency Response Services and Command and Coordination. The users can be viewed as Emergency Commanders or Emergency Responders (either from responsible agencies or ad-hoc responders). Emergency response services include their own operational pictures. In order to build a common operational picture, they must be imported into Command and Communication package. For illustration, *Figure 2* shows the main three operational pictures of emergency response services (there are more operational pictures).

The use case diagrams are used to model the functional requirements of the system. They show the actors and cases where the system is used to fulfil one or more user's requirements. Thus, it is a model of what the system is supposed to do from the user's point of view.

Because of AERS complexity, two levels of use case diagrams are developed. The high-level use case diagram has specified the main use cases and their main actors. The nine main use cases are identified. The Emergency Response Services package includes the four use cases: Rescue and Firefighting, Medical and Care Services, Law Enforcement and Emergency Public Information (*Figure 1*). The Command and Coordination package includes five use cases: Airport Operations, Alert and Notification, Establishment of Command, Assignment of Responsibilities and Coordination (with two subtypes: Local and Overall Coordination). The sixteen actors are identified.

The more granular level of use case diagrams is developed, one for each of the main use cases. *Figure 3* shows use case diagram of Medical and Care Services. There are eight use cases and eight actors. For all AERS and on this level of granularity, there are 26 use cases of emergency services and 20 use cases of command and coordination. The use cases represent the main functions in the AERS.

The emergency operations at the airport follow the procedures defined by the international and national standards and regulations, and by the airport emergency plan. The nine UML activity diagrams describe emergency procedures. *Figure 4* shows a part of the activity diagram for Medical and Care Services. It shows the actions performed by personnel with medical train-

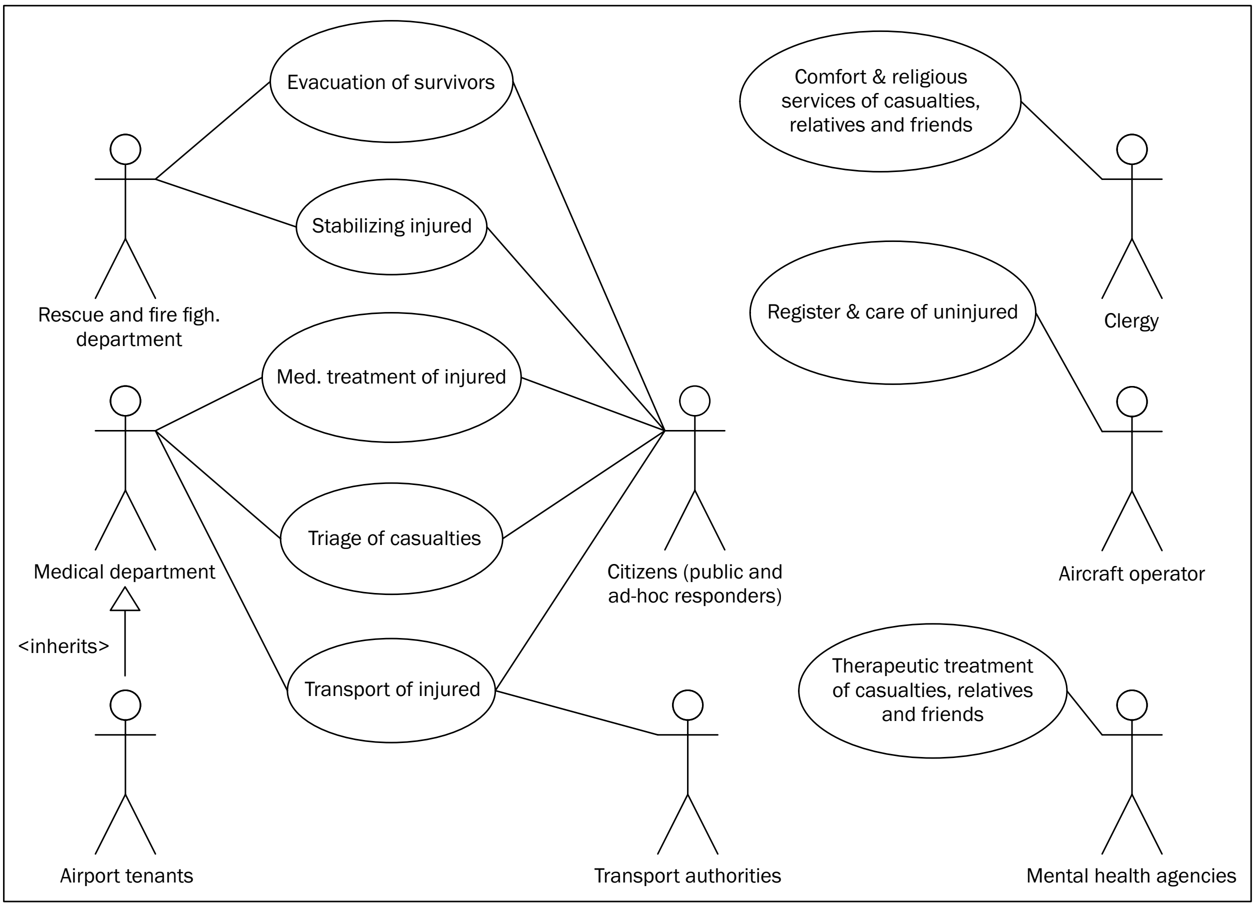

Figure 3 - Use case diagram of Medical and Care Services

ing (rescue and firefighting personnel, medical services personnel, airport and airport tenant personnel).

A class diagram shows the system structure. Classes (types of objects) and their relationships are abstract descriptions of the system parts. The high-level class diagram of AERS includes five main classes: Emergency, Emergency Procedure, Actor: Responder & Commander, Resource: Material & Equipment, and Communication Network & Device. *Figure 5* shows the main classes and their relationships. *Figure 5* shows a part of the class diagram for Medical and Care Services. Only a few associations are illustrated; e.g. Emergency Procedure uses Operational Common Picture, Actor works in the Agency. Class attributes and operations are omitted because of figure size constraints. So far, the class diagram is developed only for Medical and Care Services and it contains 43 object classes. The Medical and Care Services are chosen because they play a significant role in saving lives and require various geospatial information. The five types of Medical and Care Services are: triage (the classification of casualties accordingly to the priority for treatment and transportation); stabilizing seriously injured casualties before their transportation; medical care of seriously injured; first aid to less injured; transport to medical facility. These services differ in their courses of actions, required medicine competencies and materials, designated areas, responsible agencies etc.

The information needs are obtained from the developed UML diagrams. What is used and created information by the actor? What is used and created information by the action? The study is limited to geospatial information only. The previous study by Zlatanova et al. [10] has proposed data model for emergency response with two classes of information needed: static information, existing prior to the disaster; and dynamic information, collected during an incident. Dynamic information consists of situational information about the incident (e.g. incident location, the affected area, affected people, measurements) and operational information about the processes activated to handle an incident (e.g. locations of rescue teams, rendezvous points). We have identified the same main classes of geospatial data in airport emergency operations. Therefore, we have extended that model with the data needed in airport emergency.

Geospatial data are described by their scale, classification, coverage, graphical representation, attributes, source, etc. *Table 1* contains a list of required geospatial data sets. The scale varies from 1:5,000 to 1:50,000. Some data shall cover for airport vicinity (e.g. roads, settlements, hospitals) and some near airport vicin-

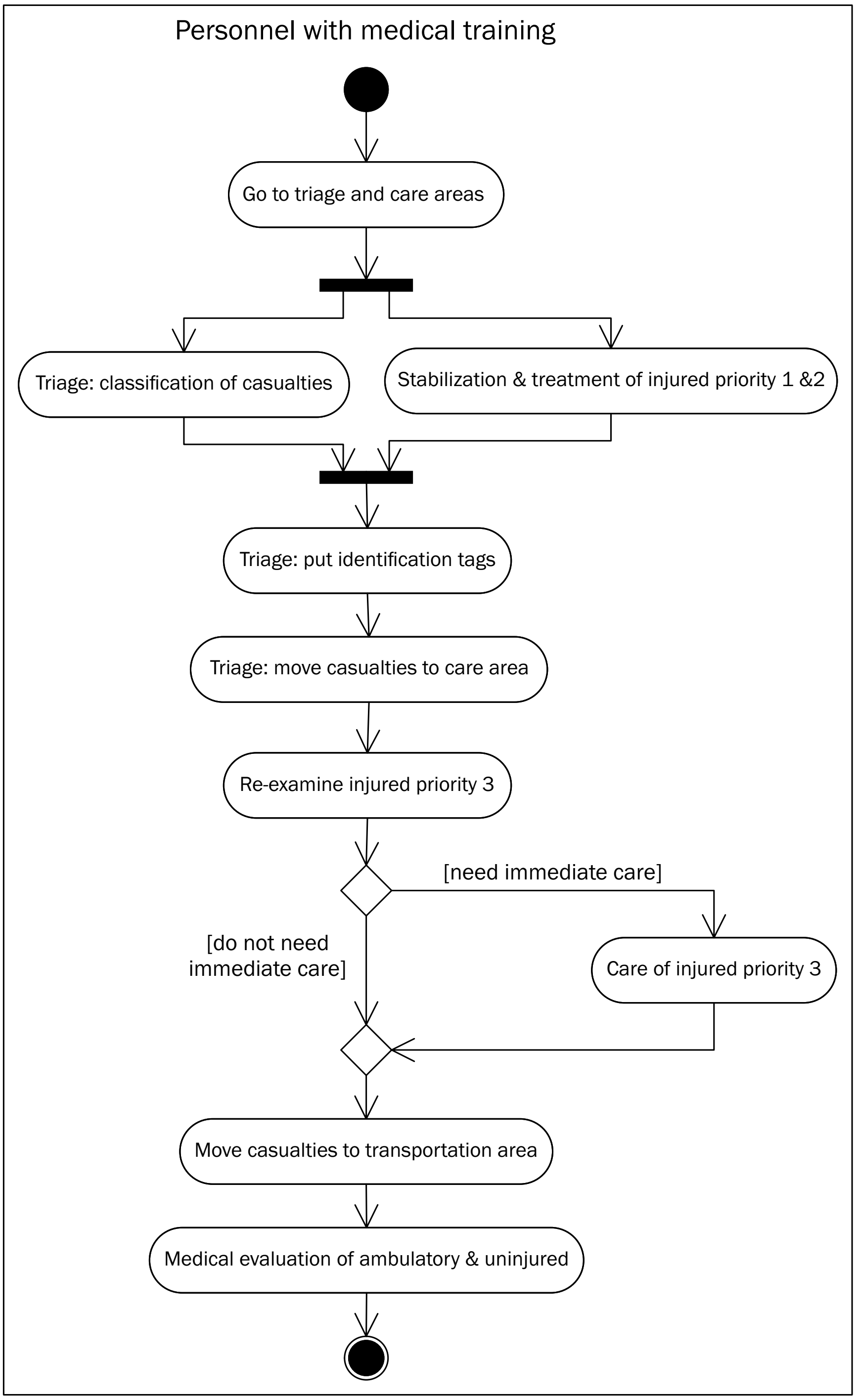

Figure 4 - Part of activity diagram for Medical and Care Services

ity (e.g. hydrants, airport objects, sites for emergency operations). Geospatial data are classified accordingly to emergency needs, e.g. roads are classified by width to show roads drivable for certain types of emergency vehicles. Hospitals are defined by medical procedures they provide and the number of beds. The main geospatial data sources are national mapping agencies, local authorities, utility companies, airport authority, emergency responders (fire brigade, ambulance, police, adhoc responders) and meteorological service. Together, the geospatial static and dynamic data sets compose the common operational picture for AERS.

2.3 Prototype application

The purpose of a prototype is to allow users to evaluate design of a new system by trying it, rather than by interpreting its description. A prototype of Web GIS application for AERS is developed for the Split Airport by Geodata Ltd., Croatia. So far, it encompasses all

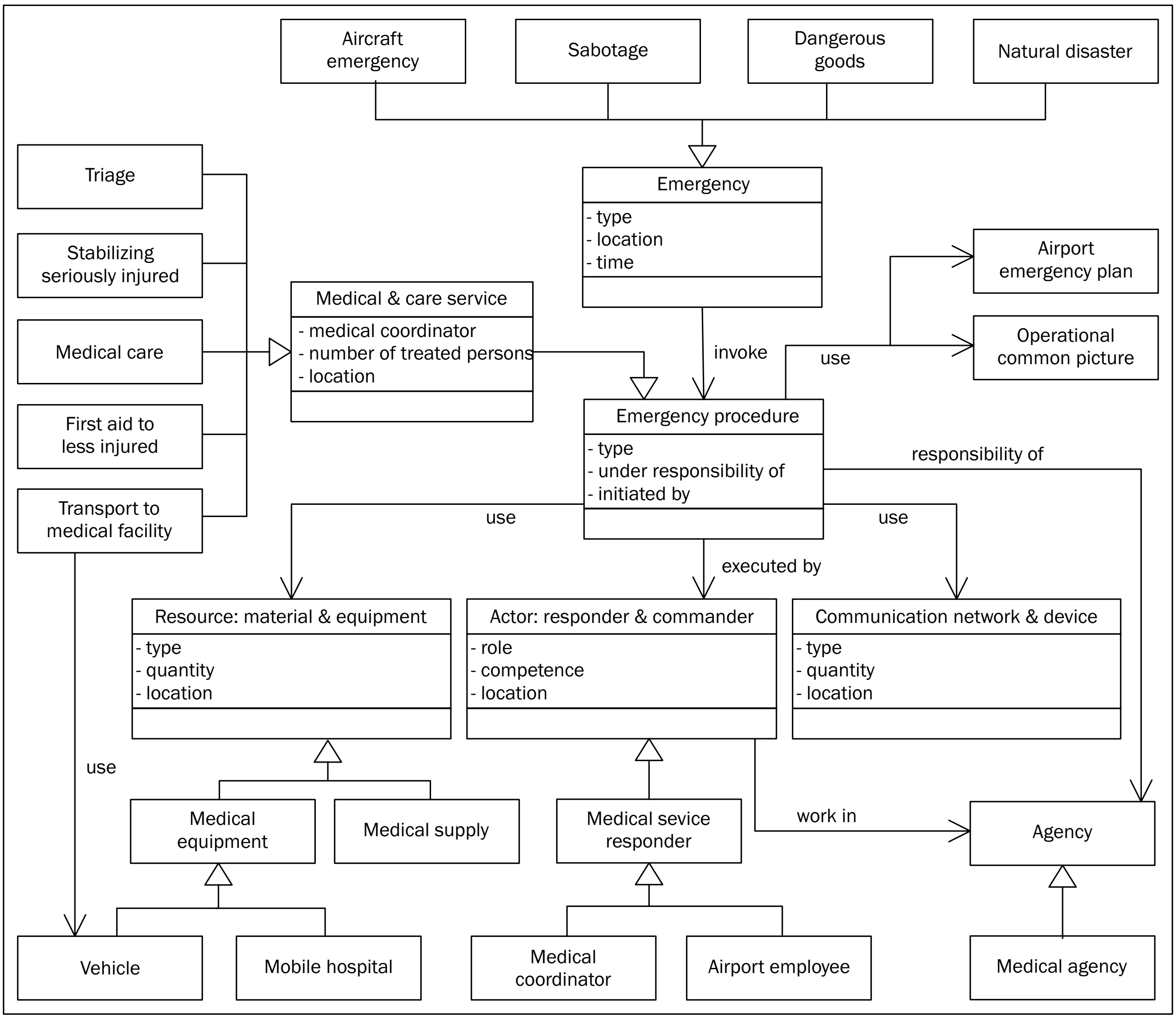

Figure 5 - Part of class diagram for Medical and Care Services

geospatial static data sets. More detailed description of the prototype is given in [11].

The UML use cases can be used as test-case scenarios in testing a prototype. The users have stressed the importance of the use case: the establishment of the ingress and egress routes. It is under the responsibility of police and security services, and the routes have to be immediately established for emergency vehicles. GIS routing function can significantly improve the establishment of the ingress and egress routes. The objective of GIS shortest path routing is to find the shortest route between locations, taking into consideration not only distance but also travel time, type of roads, etc. Hence, the routing function is developed for AERS. The user selects an emergency vehicle from the list and picks on the map the starting and the ending point of the path. Dijkstra algorithm calculates the shortest path considering distance and minimum road width for the selected emergency vehicle (Miler et al. [23] have discussed algorithms used in the shortest path calculations). The shortest path is displayed on a map, and driving directions are produced with driving guidelines, distances and travel time. The main application window is shown in *Figure 6*. It contains an interactive map, tool buttons (zooming and information functions), map scale bar, graphic and numeric scale, interactive map legend and GIS routing function.

There are other GIS functions which can improve AERS such as locating and dispatching response units and vehicles (via integrated GNSS and mobile network devices), finding the nearest resources (e.g. hospitals, hydrants), public information (producing maps) and finally, constructing a common operational picture. An overview of potential GIS application areas for AEM is given in [12].

3. DISCUSSION

Our attempt to model AEM has shown all its complexity: a large number of participants and involved agencies, an extensive range of various tasks and geospatial data needs, complex interactions of tasks

Table 1 - Geospatial information needs: the main data sets

Geospatial static data sets	
Topographic map (1:5,000; 1:10,000; 1:50,000)	Airport areas
Orthophoto map (1:5,000)	Airport buildings
Roads (classified by width)	Airport wire fence
Other traffic objects (tunnels, gasoline stations)	Airport gates and entrance ramps
Settlements (areas)	Airport parking areas
Significant buildings (public, industry)	Agencies at airport (e.g. air-traffic control)
Water supply network, hydrants and reservoirs	Airport fire brigade
Other significant objects (swamp, streams)	Airport fuel tanks
Reference grid (sectors)	Assigned places for emergency operations
Geospatial dynamic data sets	
Location of incident	Transportation area
Scene area	Morgue area
Airport entrance to be used	Location of mobile command post
Ingress and egress routes	Locations of rescue teams/personnel
Rendezvous points	Locations of rescue equipment and supply
Security check points	Locations of care facilities
Staging area	Locations of accommodation for uninjured
Triage area	Distances to hospitals
Care area	Meteorological data

and responsibilities, multiple roles of participants, etc. The development of Web GIS services for AEM should focus on the users in order to meet the objective: to provide the most appropriate information to all AEM participants. Object-oriented analysis and design techniques have been used in order to define the user's requirements, and the UML model is constructed.

Here, the UML has proven as an appropriate method for modelling complex domain of airport emergency response. The whole AERS is first divided into two subsystems or packages and further elaborated in two levels of use case diagrams. The high-level class diagram contains five main object classes, which means that every AERS object should belong to one of these classes. This gives a good overview of the main functions, actors and object classes.

To get more details, activity and class diagrams are developed. The activity diagrams are well suited for modelling of the prescribed emergency procedures. This will ensure compliance of AERS with the standards and regulations. The detailed class model is made for Medical and Care Services only, and it contains 43 object classes which again show the complexity of AERS. The identified geospatial data are classified as static or dynamic as previously proposed by Zlatanova et al. [10]. Our model identifies 36 geospatial data sets using classifications and attributes specific to emergency operations.

Figure 6 - The main window of prototype Web GIS application at the Split Airport, Croatia

By formalizing emergency response phase of AEM as a UML model, the following is achieved:

- the requirements coming from international and national regulations and standards are transformed to formal graphical model suitable for system development,
- the requirements coming from users practice are incorporated in the same model,
- the participants can agree on the requirements and can achieve standard interpretation of the specifications,
- the developers can build Web GIS services which will provide the most relevant data as soon as participants log in,

thus, the main objective of integrating Web GIS in AEM should be achieved.

The built prototype of Web GIS application for AERS was tested against the defined use case: Establishment of the ingress and egress routes. It shows the following:

- the users can use geospatial data in a new and enhanced way having the interactive map with standard GIS functions such as zoom and search,
- the tested use case is significantly enhanced by GIS routing function,
- the airport authority has a central place to maintain roads data that are crucial for the use case,
- all participants have access to the same and current geospatial data,
- all the ICAO requirements are fulfilled,

thus, the built prototype has proved GIS technology as valuable for AEM.

4. CONCLUSION

By investigating the user requirements for Web GIS application for AEM, a UML model of Airport Emergency Response System (AERS) was suggested. The developed model encompasses the requirements of the relevant ICAO standards and national regulations. The operational practice has been studied on Croatian airports and incorporated into the model. Geospatial data sets are identified and described. The proposed model should ensure that the newly built system would meet the objectives.

A prototype Web GIS application is built to evaluate the proposed model and to test it against the chosen use case. The prototype has shown how GIS functions can improve AERS. The users have shown great interest and they have great expectations in further integration of Web GIS services in AEM. They expect to have all actual documents, checklists, maps, medical information, photos from the incident site, as well as communication with command posts in their hands via smart phone application.

Future work will include extending the prototype with dynamic data (e.g. showing locations of emergency vehicles) and constructing a common operational picture from various data sources. In addition, currently we are working on the development of geospatial ontology schema for AEM that should enable ad-hoc data integration and better data search.

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SAŽETAK

Uključivanje Web GIS-a u izvođenje operacija u izvanrednim situacijama u zračnoj luci ima za cilj osigurati odgovarajuće geoprostorne informacije svim dionicima. Upravljanje izvanrednim situacijama u zračnoj luci traži model koji će objasniti svu njegovu složenost: sudionike, procese i informacijske potrebe. U radu je opisan UML model upravljanja izvanrednim situacijama u zračnoj luci. Takav model omogućuje zajedničko razumijevanje sustava od strane sudionika koji dolaze iz različitih sektora: zračne luke, policije, vatrogasne postrojbe i dr. Isto tako, UML model omogućuje izradu institucionalnih sporazuma za razmjenu podataka, a programeri dobivaju specifikacije geoprostornih podataka i GIS funkcija prema zahtjevima korisnika i standardima. Prototip Web GIS programske aplikacije je razvijen i dan korisnicima na evaluaciju. Prototip je pokazao kako GIS funkcije mogu unaprijediti izvođenje operacija spašavanja. Korisnici su pokazali veliki interes i očekivanja od daljnjeg uključivanja Web GIS-a u izvođenje operacija u izvanrednim situacijama u zračnoj luci.

KLJUČNE RIJEČI

mrežni GIS; upravljanje izvanrednim situacijama u zračnoj luci; UML;

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