A Position Paper on Improving Preparedness and Response of Health Services in Major Crises

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Abstract. There exists a huge variety in the occurrence and characteristics of major incidents. Incident management stakeholders and in particular emergency health service providers have to deal with two basic challenges: The disproportion between the needs and the available human/material resources in the response capacity and the inherent time constraints of an emergency. These critical factors play a seminal role in the decision-making process during a crisis event, which affects all levels of command & control (strategic, operational, and tactical). The drawback with current health emergency management systems lies with the command & control operations that should coordinate the actions of the separate services and turn them into an effective, multi-faceted crisis response mechanism. IMPRESS improves the efficiency of decision making in emergency health operations, which has a direct impact on the quality of services provided to citizens. Furthermore it provides a consolidated concept of operations, to effectively manage medical resources, prepare and coordinate response activities, supported by a Decision Support System, using data from multiple heterogeneous sources. The proposed solution facilitates communication between Health Services

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(and Emergency Responders) at all levels of response and the crisis cycle with the necessary health care systems support, supervision and management of participating organizations. It will assist health services in becoming more proactive, better prepared and interoperable with other emergency response organizations.

Keywords: Incident management · Emergency health services · First responders · Decision support systems · Crisis management

1 Introduction

Countries are facing major challenges to protect their populations from an increasing number of potential health threats in the future. Preparedness and prevention plays a significant role in ensuring an efficient response to national and international crises. Emergency Medical Services (EMS) systems form an integral part of any public health care system: their primary function is to deliver emergency medical care in all emergencies, including disasters and crises. It is widely recognized that an effective disaster response is heavily dependent on pre-existing local system capacity and capabilities than on external assistance. In the early stages of a health crisis, the ability to respond depends on the level of preparedness of the local community (citizens and volunteers) and health services. An efficient and well-structured EMS system ensures the achievement and maintenance of the skills necessary to deal with disasters, while disaster preparedness doesn't help to identify organizational gaps (WHO 2008) but in many cases helps to minimize the consequences of a hazardous event so mitigate the risk and avoid potential crises.

Between 1990 and 2010 approximately 47 million people in the WHO European Region were directly affected by natural disasters that resulted in over 132 000 fatalities. This does not include the wars and violent conflicts that have killed over 300 000 people in the Region over the last 20 years. Other severe events of the recent past include the Chernobyl (former Soviet Union) nuclear power plant accident in 1986, which affected several million people according to United Nations estimates, and the Marmara earthquake (NW Turkey) that killed nearly 18 000 people and injured close to 45 000 people in Turkey in 1999 (WHO 2012). During the same year (1999), a big earthquake (magnitude 5.9) struck Athens, Greece, revealing its disrupting potential in terms of residential structural damages, injuries, social effects and financial consequences. This disastrous event and the subsequent crisis have stressed again the importance of prevention and preparedness actions in aim to enhance interoperability and coordination among the public Emergency Services including Health Services (e.g. EMS). Another relevant incident is the Japanese earthquake and subsequent nuclear reactor crisis, which provided us with a catastrophic scenario that would present formidable public health and healthcare challenges to the EU, if such an incident occurred here. Moreover, the 2009 H1N1 pandemic, though mild in comparison to the anticipated morbidity and mortality of a H5N1 pandemic, stressed the interdependence of the public health, pre- and post-hospital care, primary care, and hospital care systems (US Department of

Health and Human Services 2011). The ongoing – since 2014 – Ebola outbreak in West Africa although mostly confined in three countries (Liberia, Sierra Leone and Guinea), stressed the medical and health care systems of many countries in two continents (North America/US and Europe/Spain-Italy-UK-Germany-Denmark).

Although all examples mentioned above were natural disasters and accidents or combinations we must also consider the Tokyo subway sarin incident (1995) that had an enormous impact on the Japanese megapolis, despite the small number of lives lost. It was the first and so far the only chemical warfare agents' release in urban environment during peace time worldwide. The 2001 anthrax letters' scare that caused certain deaths in the US is still a threat that occasionally tests national preparedness and response in various countries' around the globe.

1.1 Background

There exists a huge variety in the occurrence and characteristics of major incidents. In general, an adequate major incident management has to deal with two basic challenges. First, there is a disproportion between the needs and the available human and material resources: limitations in the response capacity (coordination, triage teams, search & rescue, Advanced Life Support and transportation squads, ground vehicles, and other health and psycho-social interventions), not only with respect to the number of people affected (quantity) and the time constraints (emergency), but also concerning the nature of the needs (quality). In disasters, characterized by disruption of infrastructure, facilities and/or services, this imbalance is even more serious and long-lasting. Secondly, very often there is inadequate information, low levels of risk perception and possibly scientific uncertainty or public concern and awareness with respect to the causes, nature and extent of the health issues involved and the risks that may represent. The field on which this situation is more dramatic is that of medical rescues, where every minute of delay means death and suffering for numerous victims. In a society, that regularly reminds us of the vulnerability of man in the face of natural or man-made events, one of the major tasks for governments and crisis managers is to ensure attentive prevention and an appropriate response to disasters. On the other side of the spectrum, the critical factors are more related to analysis and decision-making. A situation e.g. where there is an actual or potential risk of a major exposure to an unusual serious health hazard for a community (or which is perceived as such) can result in a public health crisis.

A Decision Support Tool (DST) needs to be capable to deal with the whole scope of health emergencies, from a single accident, over multi-casualty and mass-casualty situations to the most complex disasters. For health professionals to be able to use this tool in extra-ordinary situations, they must have experience in using its functionalities in daily practice. The extra-ordinary approach and special arrangements, does not only relate to the emergency response, but must be implemented for all phases of the management cycle.

All types of emergency situations require – from a health perspective - extra-ordinary competencies, skills and attitudes, and thus specific education and training, the broader scope of which is commonly called 'disaster health'. Mass emergencies, like major accidents and classical disaster, must be dealt by a structured mobilization of additional or specialized material and teams, combined with a more efficient use of the available resources (e.g. using methods of noria and triage, improved coordination, etc.). Public health crises require surveillance with early detection and early warning, extra-ordinary (often cross-border) decision making and control strategies, follow-up research & structural measures, all of which relies on timely (pro-active) and adequate exchange of information and communication. The EUSDEM consensus approach is to logically link terminology with the scope and conceptual framework of major incident and emergency situations (Archer and Seynaeve 2007; Seynaeve 2003; Seynaeve 2008). There exists of course an enormous variety in the occurrence and characteristics of major incidents. It is obvious that understanding the pathogenesis of major incidents, the pathway and mechanisms leading to health emergencies, contributes to better preparedness and response. Although every disaster is unique and always has specific characteristics, it is possible to develop a generic conceptual framework explaining in general the health impact of extraordinary events and how it can be mitigated by certain measures. Also, after a major emergency it is essential to provide on-going assistance, restore key services and infrastructure, organize socio-economic recovery, reconstruction and development as well as integrate lessons learned in future risk management and preparedness. In a nutshell, previous incidents confirmed the need for a "whole of community" approach in planning and responding to a disaster, and confirmed that a healthcare preparedness program must address the entire healthcare community in its preparedness activities. Regardless of the threat, an effective medical surge response begins with robust hospital-based systems and effective Healthcare Networks to facilitate preparedness planning and response at the local level. Simply put, strong and resilient Healthcare Networks are the key to an effective state and local emergency response to an event-driven medical surge. In addition, trauma Centers, Hospitals, and Healthcare Systems face multiple challenges daily in addition to the growing list of man-made and natural threats. Emergency department overcrowding, the rising uninsured, and an aging population all inhibit the healthcare system's ability to respond effectively.

1.2 Use of Decision Support Tools in Emergency Situations

In an emergency situation, organization leadership and management needs clear, accurate real-time information about the effect of the disaster upon human resources and the readiness status of the organization. One of the key IT elements for emergency response is the availability of decision support tools (Graves 2004). Today, the decision support in emergency situations represents a current issue that is being researched in various fields. The complexity of the problem and the corresponding incident resolution approaches, methodologies and support tools ask for intertwining knowledge out of fields such as computer science, psychology, sociology, medicine, biology, chemistry and knowledge engineering. Currently, there is neither an integrated plan nor a complex set of procedures that would unite principles, rules and regulations for emergency response operations.

1.3 Tools and Procedures for Preparedness of Emergency Health Services

Traditionally, crises have been conceptualized as having pre-impact, impact, post-impact and recovery phases. In most studies of crises, the following simplified sequence uses the terms pre-event, event and post-event/long-term recover. Pre-event activities include risk assessments, mitigation and preparedness. The event may be either static, as a single point in time, or dynamic, evolving over time. Response and recovery occur during the post-event. Preparedness behavior includes a variety of actions taken by families, households, communities, governments and emergency responders to get ready for a disaster. Preparedness activities may include devising disaster plans, gathering emergency supplies, training response teams, and educating residents about a potential disaster (Mileti 1999).

Preparedness is the phase of crisis management, which refers to activities, programs and systems existing prior to a crisis that are used to support and enhance emergency response. They actually mitigate the risks and inhibit the threatening events to become crises. The crisis managers prepare resources including staff and equipment and develop plans of action and procedures for use when the crisis strikes, i.e. planning to provide the capability to deal with emergencies, and preparedness is the discipline, which ensures an organization, or community's readiness to respond to a crisis in a coordinated, timely, and effective manner. The crisis preparedness includes information and public awareness campaigns, education, exercises and training, early warning and emergency plans.

1.4 Interoperability of Health Services in Emergency Situations

The post-impact, emergency response stage of a disaster is characterized as the immediate aftermath of a disaster, typically including the first hours or days, perhaps up to one week, depending on the event. In a disaster or emergency situation, there is a need for EMS and hospitals to be able to communicate with each other and with other members of the emergency response community. The ability to exchange data regarding hospitals' bed availability, status, services, and capacity enables both hospitals and other emergency agencies to respond to emergencies and disaster situations with greater efficiency and speed. In particular, it allows emergency dispatchers and managers to make reliable logistics decisions - where to route victims, which hospitals have the ability to provide the needed service. Some hospitals have expressed the need for, and indeed are currently using, commercial or self-developed information technology that allows them to publish this information to other hospitals in a region, as well as EOCs, 9-1-1 centers, and EMS responders via a Web-based tool. The fact is that most of the systems that are available today do not record or present data in a standardized format, creating a serious barrier to data sharing between hospitals and emergency response groups. Without data standards, parties of various kinds are unable to view data from hospitals in a state or region that uses a different system – unless a specialized interface is developed. Alternatively, such officials must get special user accounts and toggle between web pages to get a full picture. Other local emergency responders are unable to get the data imported into the emergency IT tools they use (e.g. a 9-1-1 computer-aided dispatch system. They too must get a user account and visit the appropriate web page. This is very inefficient. A uniform data standard will allow different applications and systems to communicate seamlessly. Both HL7 and OASIS are dedicated to providing open standards for the exchange, integration, sharing, and retrieval of electronic information. While HL7 focuses on health information that supports clinical practice and the management, delivery and evaluation of health services, the EDXL suite of messaging standards (CAP, EDXL-SitRep, EDXL-RM, EDXL-DE, EDXL-Have, EDXL-TEP/TEC) published by OASIS focus on information that supports emergency and disaster response, management, and coordination across jurisdictions, organizations, and professions. In addition, a multi-agency, multi-discipline coordinated and timely response is needed to deal with a disaster or large-scale incident. Although first responders have the technology to help accomplish this — in this case, pre-established and pre-programmed Shared Channels/Talk-groups in their portable radios — there are no Standard Operating Procedures (SOPs) to help guide the responder interaction and provide greater coordination through enhanced communication. As a result, interoperable communication is fragmented and action is delayed. The lack of a set of interoperable communication SOPs has been identified as the primary impediment to a timely and coordinated response.

2 IMPRESS Decision Making and Response Levels

The success of every operation depends on the hierarchical structure of the organizations and units involved. The hierarchical structure allows acting quickly and responding to different situations very effectively. Therefore, the hierarchical structure of the EMS domain is based on command and control structures as well as reporting rules. Since EMS organizations do not only operate inside the limited timescale of an operation, there exists a general hierarchical structure (administration) and the hierarchical structure of the incident scene (operational structure). The general hierarchical structure differs throughout the EU in the ways the responsibilities are distributed. However, there always exist a strategic (gold), a tactical (silver) and an operational (bronze) level of command. These levels of command exist in the general hierarchical structure as well as in the hierarchical structure of the incident scene. The following paragraphs position the IMPRESS DSS functionalities at all levels of decision making.

Strategic Level. In strategic level, the main engaged organization is the National Control Center operating in the field of Health Services, which has the overall supervision of all the engaged entities (Hospitals, Critical Infrastructure, Government, Civilians, Public Safety Agencies, Volunteer Organizations, Private Sector, and Businesses) in regional or national level. IMPRESS strategic level functionalities include:

- Allow interoperability between health services operating across different regional, governmental and cross border levels.
- Information exchange will be used to optimally allocate resources in response to major disasters and also facilitate the cooperation between operating teams of different cultural and operational background.
- CECIS type of layer functionality, allowing for exchange of data between international organizations.

- Necessary tools for strategic level decisions with resource allocation, scenario analysis and definition of operational procedures.
- Post crisis module for registering, evaluating and exchanging lessons learned with all related information.

Tactical Level. At this level, a Regional Command and Control Center is operating, represented by an Incident commander who coordinates all the relevant Health Sector Agencies. IMPRESS tactical level functionalities include:

- Provide coordination layer of the Health Services that will ensure (a) cooperation with the relevant agencies and (b) the readiness of the Health Sector services according to the requirements and evolution of the envisaged incident.
- Functionality for evaluating and optimally utilizing the available resources, analyzing and predicting the evolution of the incident and providing an efficient cooperation system.
- Collect and transmit biomedical and other patient data between emergency responders and health services. Logistic component for assessing the needed stockpiles of necessary equipment, medications, vaccinations and personal protective equipment, their positioning and restocking, will be established.
- Appropriate component providing easy forms for exporting such goods for cross-border missions.
- Mathematical modeling tools will be integrated for (i) enhanced surge capacity (ii) statistical recognition of events (iii) evolution models for major crises (iv) bio-mathematical modelling and simulation of patients and first aid activity.

Operational Level. The third level to structure the EMS domain is managed by the Local Health Control Center. Vehicles in the EMS domain are distinguished by their use for example Emergency treatment and transport, Doctor Transport, Non-emergency transport, Transport of highly infective people, Command and control, etc. IMPRESS operational level functionalities include:

- Processing and entry of data into a single, appropriately structured geographic database,
- Processing and customization of map data
- Providing appropriate tools (Web Services) to exploit specialized medical functions.

2.1 IMPRESS High-Level Architecture and Main DSS Components

IMPRESS will develop and integrate into a holistic concept of operations the following distinctive components, which will expand beyond the present state of the art in response and preparedness capabilities of health services. Figure 1 shows the high-level architecture of the envisioned IMPRESS DSS in relations to these components and other auxiliary modules, which will form the solution as a whole.

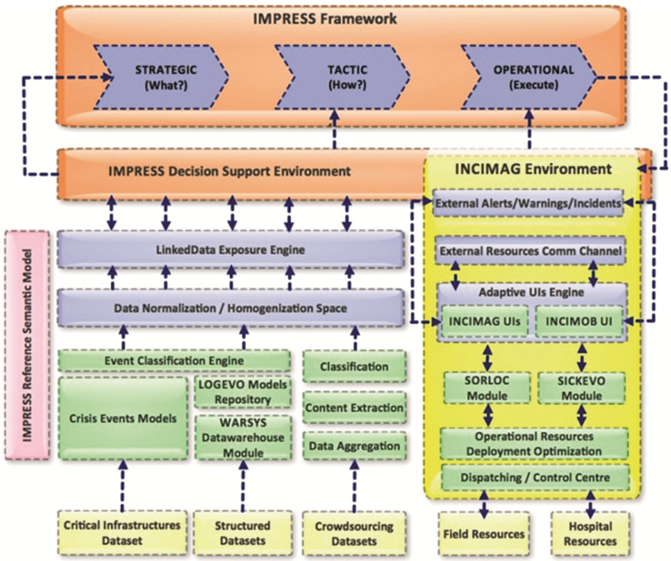

Fig. 1. IMPRESS high-level architecture

The IMPRESS architecture is divided in three main layers: The bottom layer consists of the data resources, which IMPRESS will use to facilitate the decision making process. They can be either structured or unstructured sources including data coming from the field (through crowd sourcing or first responders), data retrieved from hospital records on supplies, personnel, medical incidents and more.

The second layer consists of the core data infrastructure of IMPRESS which will form the point of collection and processing of gathered data to provide the required "intelligence" to decision makers at different levels of intervention. The **WARSYS** database structure will be developed within IMPRESS, with a view of extracting in real time medical and logistics information from available repositories (such as hospital information systems). It will be accompanied by the IMPRESS Reference Semantic Model, which will enhance this layer into a semantically enhanced data repository in order to provide more advanced knowledge management and inferring capabilities. This layer will contain DSS components, which will support the project's objectives as follows:

The SOuRce LOCation (**SORLOC**) tool will (among other functionalities) automatically interrogate hospital records and use model comparison techniques to improve on the rapidity and accuracy of contaminant source localization. The SICK patients physiological EVOlution forecast (**SICKEVO**) module, will address physiologic trajectory assessment and forecast. The main improvements that SICKEVO will present will concern the level of detail in physiology representation, and the automatic interaction with actual observations and hospital records. Finally, the **LOGEVO** suite will enable the use of models for the LOGistics EVOlution of health care resources, focusing in particular on models of hospital surge (expansion of offer with current resources). The third layer of the IMPRESS DSS will provide the decision support environment, which interfaces with the layers below through a linked data exposure engine to provide end users with the necessary information in the appropriate format. Key to this role is the INCident MAnaGement (**INCIMAG)** tool, which is an integral part of the overall IMPRESS DSS and will work in tandem with other components. It will allow an efficient response of emergency agencies by connecting them among themselves, with other emergency responders, with dispatch centers and with international relief agencies. An extension to INCIMAG is its mobile version, **INCIMOB**, which will allow live data from the field relative to e.g. structural damage to buildings, emergency calls for help, identification of deceased individuals, identification of cleared or unprocessed areas etc., to flow into the IMPRESS platform data warehouse system WARSYS. Specific needs of medical first responders (eTriage, eVitalSigns) will be contemplated by INCIMOB. INCIMOB will also allow volunteers and affected people to submit data that will be used for crowd sourcing. This part of INCIMOB is strictly separated from the part for medical personnel and allows a more or less structured communication between the incident management and the public.

3 IMPRESS Use Cases

3.1 Use Case 1 – Cross-Border Perspective (Greece-Bulgaria)

The particular use case involves all the planning and deployment required to create the necessary conditions for the Greek-Bulgarian crisis validation scenario: Earthquake scenario at E79 motorway near Greek-Bulgarian border, with two impacts: Firstly an overflow of the river Strimona causing a landslide of the side of the road and secondly a sliding of large stones in the street. All the above caused a large number of injured drivers and passengers in urgent need of medical attention and transportation to nearby hospitals triggering essentially a cross-border emergency operation, which will initiate the full scale of the IMPRESS solution. The collapse of E79 motorway is caused due to a large earthquake. The effects of this natural phenomenon is both the overflow of the Strimonas river which flows parallel to the road and secondly several rock-falls phenomena causing damages to the road. The overflow caused a landslide of the side of the road, so a land mass collapsing into the river together with parts of the lane, sweeping away several vehicles and colliding with each other, resulting in many passengers to be injured. The landslide also blocked a tunnel at some point of the road network, causing damages to vehicles while falling on them or due to collisions between the vehicles trying to avoid the rocks and a truck have skidded. The collapse of E79 motorway is caused due to a large earthquake. The effects of this natural phenomenon is both the overflow of the Strimonas river which flows parallel to the road and secondly several rock-falls phenomena causing damages to the road. The overflow caused a landslide of the side of the road, so a land mass collapsing into the river together with parts of the lane, sweeping away several vehicles and colliding with each other, resulting in many passengers to be injured. The landslide also blocked a tunnel at some point of the road network, causing damages to vehicles while falling on them or due to collisions between the vehicles trying to avoid the rocks and a truck have skidded. All the above caused a large number of injured drivers and passengers in urgent need of medical attention and transportation to nearby hospitals.

A cross-border perspective is attributed to this emergency medical operation due to the fact that the overall incident is located near the Greek- Bulgarian borders and the injured passengers will be carried both in Greek and Bulgarian hospitals in order to have more efficient response. IMPRESS DSS aims to reduce the time of providing pre-hospital medical services, enhancing the coordination of Emergency Responders (Dispatch centers and ambulances) from both engaged countries and by fully integrating all medical units to the response operating environment of the hosting nation. Moreover, IMPRESS will provide a valuable tool for Field Units and Incident Commander by providing them a channel of communication and exchange of medical information (e.g. surge capacity, availability of personnel, tracking of patients, examination information) and resource allocation (availability of beds, medicines, medical equipment, etc.). So the most appropriate unit, concerning the medical equipment and the knowledge of the personnel needed, will deal with each incident and each injured person will be routed to the most appropriate hospital, regarding the type and availability of medical staff, equipment and resources not only needed but also exists inside each Hospital or Clinique.

3.2 Use Case 2 – Palermo Use Case

The work on the Palermo scenario is divided into two logical segments, a preparation phase A (partially historical, partially live) and a simulation phase B. This scenario concept moves from the availability of actual data from a historical fire, which developed in the Palermo waste dump of Bellolampo between July 29 and August 7, 2012. The fire released a variety of toxic compounds, but it turned out that during a fire in a waste dump relatively low levels are produced of those toxicants (nitrogen oxides, sulphur oxides) which may represent an acute threat to the neighboring population. In these cases there is typically the liberation of compounds (like dioxin), which enters the food chain (through deposition in pastures etc.) and which produces chronic intoxication with increased frequencies of tumors. These however do not seem very interesting for an acute crisis scenario.

However, in an industrial fire accident many of the same compounds are released as in a waste dump fire, only at higher concentration levels (able to induce acute respiratory embarrassment and possibly death). The possibility therefore exists to model the spread of these toxicants (nitrogen and sulphur oxides), given their volatility and tendency to be absorbed by the vegetation etc., match the model against available Palermo waste dump fire data and then extrapolate the model to (possibly cross-border) industrial site fire scenarios. The Palermo scenario therefore will simulate the sudden liberation of high concentrations of toxic compounds from a tank fire developing on-board a ship moored in the Palermo harbor. The relevance of the simulation to potential cross-border situations in Europe is immediate, if one thinks about the Mediterranean coast of France (e.g. the Nice-Genova area), or the Baltic. The advantage of developing the entire analysis in Palermo stems from the possibility of characterizing in detail the geography over an area where actual historical data of toxicant diffusion are available.

Phase A will consist of two simultaneous activities. In activity A1, the sensor archives will be interrogated and data on toxicant concentrations will be aggregated in appropriate Analysis Data Sets (ADSs), together with geolocation data. Also, a map of the relevant Sicilian area will be digitized and relevant diffusion parameters will be associated to homogeneous subareas in it. In activity A2, a number of logistic parameters (transfer times between structures and locations as dependent over variations of the traffic density over the day, number of the police force patrolling the city again at different times of the day etc.) will be measured.

Phase B will consist of the development of the spread and contamination model and of the population reaction model as they pertain to the specific geographic area of the Palermo harbor. Both models will be intrinsically stochastic and will accept parameterized input, so that several (thousand) runs of the combined models will allow the determination of a distribution of possible responses given the same basic scenario. These will then be available for further analysis comparing different strategies and their expected effectiveness over a range of possible scenarios.

By allowing obtaining scenario results in the presence and absence of IMPRESS procedures and methodologies, and with incorporation or exclusion of the effects of the IMPRESS incident management tool, the Palermo testbed will allow the demonstration of the main features of the IMPRESS-solution against a historically validated, geographically realistic situation.

4 Limitations

The IMPRESS concept is by itself a self-standing medical DSS that would allow emergency medical services to be able to fully cope with different types of emergencies ranging from large-scale mass events to multiple incidents. Such large-scale systems have many fine points that need to be fully accounted for in order to maximize its benefit to the community.

- The interoperability of IMPRESS with legacy systems at all crisis governance levels is critical to its success. Therefore, prompt considerations of the existing DSS or its modular components must be taken into consideration.
- IMPRESS DSS has been designed to receive real time sensor and emergency resource operational data from the incident and presents this information to medical personnel at the time and place that they need it to enable more effective patient management. The number of sensors is currently limited to fit to the needs and requirements of the existing components, although its expansion is something to be discussed in the future.
- A potential limitation is that software components will have trouble to communicate or being impractical to integrate or that are unable to deliver the required functionality on time due to various factors (such as loosely defined and/or changing requirements, inaccurate estimation of the time and resources needed for the development, etc.).
- Specific care must be given to the cultural and ethical dimension of the emergency responders and the victims. This has to be portrayed in a medical DSS, so that responders are fully aware of the procedures needed to be applied in such situations.

5 Conclusions

This paper describes the conceptual framework for the development of a holistic emergency medical DSS that has started to be implemented in the framework of the FP7-project IMPRESS. It aspires to be a major step forward over current health emergency management systems in terms of command & control operations that should coordinate the actions of the separate services and turn them into an effective, multi-faceted crisis response mechanism. The proposed solution aims to improve the efficiency of decision making in emergency health operations, which will have a direct impact on the quality of services provided to citizens, by providing a consolidated concept of operations, to effectively manage medical resources, prepare and coordinate response activities, supported by a Decision Support System, using data from multiple heterogeneous sources.

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