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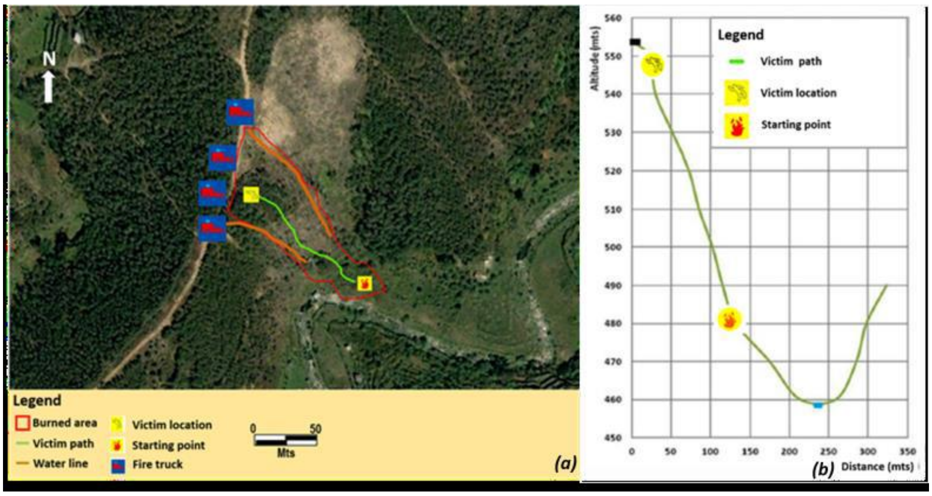

Description of Vasco Esteves de Baixo events (b) victim path

The International Emergency Management Society Newsletter - Scientific Articles Part

TIEMS network constitutes a large international multidisciplinary group of experts, with different educational backgrounds and various experiences. Their knowledge and experience are important to share with other experts worldwide. TIEMS has therefore decided to issue this new part of TIEMS newsletter, which we call TIEMS Newsletter - Scientific Articles. We have received nine scientific articles for publication in this first issue, which we nominate issue no 1. Depending on the response, in form of feed-back and new scientific articles to be published later, we will consider continue with issuing the scientific articles part of the newsletter together with the regular newsletter, or we may have to have a less frequent publication of this part. Time will show, but please, give us feed-back and send us new articles for publication.

Alex Fullick
TIEMS Newsletter Editor

Articles in this issue

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Introduction by TIEMS President

As mentioned by TIEMS Newsletter Editor, Alex Fullick, TIEMS global network of chapters and members worldwide, constitutes a large international multidisciplinary group of experts, with different educational background and various experiences in the field of emergency management and disaster response. They represent a unique source of expertise and ideas, which are important assets for research and technology development activities.

However, dissemination and publication of the results of their research is as important as the research itself. It is important to share the results and conclusions of their work with other experts in the emergency management and disaster response community. We need to learn from each other and share experiences to be able to progress with excellence in global emergency management and disaster response.

I am therefore pleased and proud to present this first issue of TIEMS Newsletter - Scientific Articles Part as an addition to the regular TIEMS Newsletter.

This first issue comprises nine scientific articles, and we hope this issue is welcome by the emergency management and disaster response community as an additional and interesting publication channel for scientist in the emergency and disaster management community. We reach today approx. 100 000 experts worldwide with the distribution, and we hope this could lead to improved contacts and exchange of expertise between worldwide experts and lead to more cooperation and new and excellent ideas to be explored in the emergency management and disaster response field,

Depending on the response and feed-back of this first issue, we will consider if we will be able to continue with this Scientific Articles Part and how frequent we can issue it. Our hopeful plan is to issue it at the same time as the regular TIEMS Newsletter. So please, send us articles for publication, so we can continue this effort.

Today the articles are reviewed only by the editor, but depending on the response, we will consider to establish a review panel and have a peer review of the articles.

Our readers decide the future of this TIEMS Newsletter - Scientific Articles issue, so please, send us feed-back and constructive critics and also articles for publication.

Oslo 7th December 2015
K. Harald Drager
TIEMS President

Emergency Management with Interdependency Modeling in the URANIUM Project

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1. INTRODUCTION

Modern societies are highly dependent on the continuous operations of their critical infrastructures that deliver critical goods and services. These include electricity, drinking water, information and communication technologies and waste disposal. Interruptions can have repercussions on the population and may affect other critical infrastructure through the domino effect: for example, a large power outage will affect immediately drinking water supply, telecommunications and rail. The European security as well as the quality of life of its citizenry depends on the continuous reliable operation of a collection of complicated interdependent infrastructures including transportation, electric power, oil, gas, telecommunications and emergency services. A disruption in one infrastructure can quickly and significantly impact another one, causing ripples across the nations. The importance of critical infrastructure is also clear from the fact that they can be defined as those industrial capabilities, services and facilities that in case of interruption of their normal operation can affect people's lives and, most important, can damage or destroy people's lives. During last decades, infrastructures are increasingly reliant on new information technologies, that allow for enormous gains in efficiency but they also create new vulnerabilities against natural disasters or terrorist attacks. Among international organizations critical infrastructure protection concerns, NATO was the first to be involved in this field. In 2009, NATO issued a series of definitions in the field, supported by all Member States and partner:

- critical infrastructure are those facilities, services and systems that are so vital to the nation, that their removal from service or destruction is potentially destabilizing national security, economy, health of the population and the effective functioning of government;
- CIP includes programs, activities and actions taken by governments, owners, operators and shareholders to protect these infrastructures.

Senior Civil Emergency Planning Committee within NATO has notified the eight subordinate committees to find solutions as an integrated approach to issues such as criteria for determining critical infrastructure, risk analysis methods and identifying vulnerabilities and their methods of protection. In particular, there are different forms of natural disasters, as typhoon, heavy rains, sea level rise, flooding, earthquake, etc. These natural disasters have caused significant economic, social, financial, property, environmental degradations, infrastructure damages and also tragic loss of human lives. When an emergency occurs, the relevant management personnel or decision-makers (DMs) need to decide what actions to take instantly to mitigate or minimize the negative effects. Such catastrophic incident reveals the need for efficient planning and the need for careful decision to be taken during the first few minutes following an incident. Decisions are critical to successful mitigation, damage management, death prevention, injury, structural loss, and the overall solution of the crisis. Project URANIUM consists of an intelligent decision making system that optimizes the allocation of resources following an infrastructure disruption and suggests how the resources could be utilized during disaster response. It provides a timely and an efficient tool for decision support that is simple to use also in complex emergency scenarios. This paper is organized as follow: First, a short overview of related research and work will be presented. Second, the decision-making problem in emergency response will be defined, and URANIUM solution will be introduced. Third, the discussion of the obtained results and the future work will be presented.

2. RELATED WORK

This section describes related work in the areas of disaster response, in particular critical infrastructure modeling and decision support making by Multi-Criteria Decision Method.

2.1. Critical Infrastructure Modelling

A survey of the modelling and simulation methods is presented by Satumtira and Duenas [17] , presenting an exhaustive and critic presentation of the most famous approaches. Their survey highlights that most of the existing strategies are not competing but rather complementary approaches, such as stochastic interdependence, cascading failures across systems and the establishment of risk mitigation principles. The modelling approaches include techniques based on game theory, graph theory, risk based model, Petri net or Bayesian networks. However, many of these interdependency models are used in a conceptual phase, or apply in simple and high-level scenarios. Rahman et al. in 2008 developed a simulator called Infrastructure Interdependency Simulator (I2Sim) based on the cell-channel model. The infrastructures and their interconnections are represented using cells and channels. A cell is an entity that performs a function: for example, a hospital is a cell that uses input tokens, such as electricity, water, medicines, and produces output tokens, such as beds served. A channel is a means through which tokens flow from a cell to another one. The interdependencies between different infrastructures are non-linear relationships summarized in Human Readable Tables (HRTs). I2Sim helps the decision maker optimizing the resources and the priorities in system restoration after critical events. I2Sim is also the core element of an advanced disaster management tool, called DR-NEP (Disaster Response Network Enabled Platform), based on a web services infrastructure where also domain simulator is included. The modelling technique has been validated in several case studies, such as Vancouver 2010 Winter Olympics. The case studies are mainly related to natural disasters and do not consider the impact of possible cyber attacks. In literature, the majority of the simulators are implemented as agent-based solutions (CAS - Complex Adaptive Systems), where a population of autonomous interacting agents coordinates their decisions to reach a higher-level global objective. The main feature of the CAS is usually the ability to create an overall infrastructure starting from the web of interconnections. The interdependencies are modelled as edges among agents allowing them to exchange information: each agent receives inputs from other agents and sends them back, see Nieuwenhuijs for further explanations. CISIApro (Critical Infrastructure Simulation by Interdependent Agents) is based on the CAS framework where each agent has a high-level description of the internal dynamic. This CAS simulation model has the main disadvantage to acquire detailed information about each single agent, but CISIApro aim is limited to the study of faults/threats propagation and performance degradation. Another recent trend is the co-simulation framework: several domain specific simulators are connected using a well-defined and generic interface (API) for simulation interoperability. The main goal of this framework is to re-use existing models in a commune context to simulate complex scenarios in order to evaluate control strategies. The MOSAIK ecosystem is validated in Smart Grid Scenario where telecommunication network and power grid simulators are integrated. The authors pose much attention on the integration of different simulators for the electric side to include models of electric vehicles in Python, photovoltaics in MATLAB/Simulink, residential loads as CSV timeseries, and two different distribution grids based, again, on Python. The main result is related to the ability to cope with different temporal resolutions (continuous, around each minute, every 15 minutes or no time at all), but the framework is at an early stage of development. In next paragraph, some approaches on how to assess impact of different cyber threats will be outlined.

2.2. Decision Support System

The existing studies have made significant contributions to decision analysis in emergency response. In several studies, various decision-making methods have been proposed according to the characteristics of different actual emergency events, such as flood disaster and fire hazards etc. For example, Hämäläinen et al. [6] proposed a multi-attribute risk analysis method to select a strategy for protecting the population in a simulated nuclear accident. Shim et al. [7] developed a decision support system (DSS) for controlling river basin flood. Fu [8] proposed a fuzzy optimization method for selecting the most desirable action to control the flood of reservoir. Geldermann et al. [9] proposed a MCDM-based evaluation method for nuclear remediation management. Lim and Lee [10] proposed a spatial multi-criteria decision analysis approach for evaluating flood damage reduction actions. Peng et al. [11] proposed an *incident information management framework* based on data integration, data mining and multi-criteria decision making. Ergu et al. [12] proposed a simple consistency test process to make ANP more suitable to solve decision-making problems in emergency cases. Qin et al. [13] developed an MCDM-based expert system to tackle the interrelationships between the climate change and the adaptation policies in terms of water resources management in the Georgia Basin, Canada. Tinguaro Rodrıguez et al. [14] applied a data-driven, two-level knowledge decision support system (DSS) prototype to support humanitarian NGOs in response to natural disaster. Technique for order preference by similarity to ideal solution (TOPSIS), known as one of the classical MCDM methods, originally proposed by Hwang and Yoon [15] for solving the MCDM problems Armaghan and Renaud et al [16] apply MCDA (ELECTRE) in the retrieval phase of Case-Based Reasoning.

3. INTEGRATED DECISION MAKING

Critical infrastructures have always been the most sensitive and vulnerable of any system and process. They are critical not only due to the attacks, but also due to other causes, both human and technical, some of them being difficult to identify and analyze. The threat of cascading failures due to dependency and interdependency aspects requires new concepts and tools for analyzing the behavior of these systems and their impact on infrastructure they serve. This section describes the URANIUM approach. It consists of is two cascading modules: the first is CISIApro tool for evaluating risk of interdependent Critical Infrastructures (CIs) and the second is an expert system for managing Civil Protection operations. CISIApro tool fuses data and information coming from SCADA systems in order to understand the consequences of negative events, and models infrastructures and their interdependencies using an agent-based technique where each agent evaluates its own risk using information coming from its neighborhood. The expert system is based on structured decision support methodologies. It provides a suggestion for managing and optimizing the intervention procedures of Civil Protection. Decision support is realized using a hybrid procedure based to MCDM (ELECTRE).

3.1. Features of CISIApro Simulator

3.1.1. Mixed Holistic Reductionist (MHR) Approach

The Mixed Holistic Reductionist (MHR) approach, proposed by [1], was created to exploit the advantages of holistic and reductionist methods. In holistic modelling, infrastructures are seen as singular entities with defined boundaries and functional properties. On the other hand, reductionist modelling emphasizes the need to fully understand the roles and the behaviour of individual components to truly understand the infrastructure as a whole. Different levels of analysis require one or both of the two point of view and their boundaries are lost in event of complex case studies. With the MHR model, relationships between infrastructures could be seen at different levels through either a top-down or bottom-up approach. A key element of operators is the quality of Services towards customers. This analysis strengthens the addition of another layer, called service, describing functional relationships between components and infrastructure at different levels of granularity. In MHR, services to customers and to other interconnected infrastructures are explicitly considered as a middle layer between holistic and reductionist agents.

3.1.2. CISIApro Simulator

CISIA simulator is an agent-based simulator, where each agent has the same structure, see Fig. 1. Each agent receives resources and failures from the previous ones. A resource is a good, a service or a data produced and/or consumed by the agent, represented in CISIA as an entity. The ability to produce resources is summarized by the concept of operative level, depending on the availability of received resources, on the propagation of faults, and on the functionality of the entity itself. The entity receives also failures coming from the upstream interconnections and spreads it to the downstream ones. The considered classes of interdependencies are physical, logical, geographical and cyber. The complete analysis of the CISIA simulator is reported by De Porcellinis et al. in [2]. Usually, risk index is evaluated as impact, threat and vulnerability:

$$\boldsymbol{Risk} = \boldsymbol{Impact} \times \boldsymbol{Threat} \times \boldsymbol{Vulnerability} \qquad (1)$$

Typically, risk is a numeric value, from the impact severity, the likelihood of occurrence or threat, and the vulnerability analysis. In CISIA applications, the likelihood of occurrence is substitute with the trust of the information. For each entity, the user can add also a vulnerability variable, but in the following case study, we suppose that the vulnerability depends only on the distance from the source and on the persistence of the attack itself. The operative level of each agent is associated to a risk level: the risk is the amount of harm due to specific events, such as a failure, and can be evaluated as

$$\boldsymbol{Risk} = 1 - \mathit{Operative\ Level} \qquad (2)$$

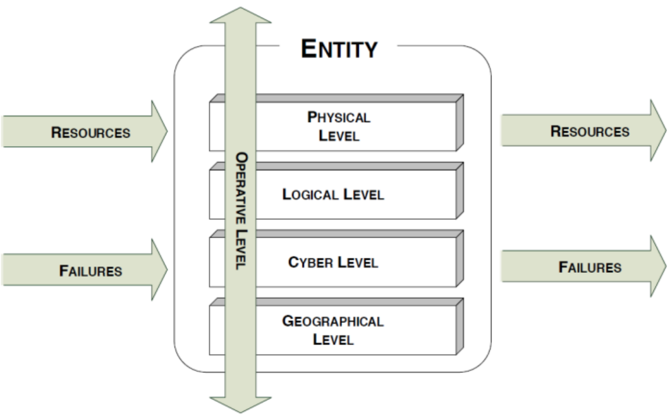

Figure 1. CISIA entity diagram

In 2014, CISIA has been re-design in order to overcome some implementation issue; the new simulator is called CISIApro. The main problem was related to the possibility of infinite logic loops when resources are instantly exchanged. CISIA main thread buffers all the information exchanged among entities in a time step. If the transfers are circled, then the simulation time step never ends. In CISIApro simulator, the information flow is well defined with a threshold of maximum executions in a time step in order to avoid logic loops, see also Fig. 4. Another disadvantage of CISIA was the long time needed to debug the software. In CISIApro, an efficient Graphical User Interface is provided for create entities and connect them in easy way, adding also the exchanged resources, as in Fig. 2. After the creation of the entities with their interconnections (i.e., interdependencies) and the exchanged resources, the users need to implement the behaviour of each entity, see Fig. 3.

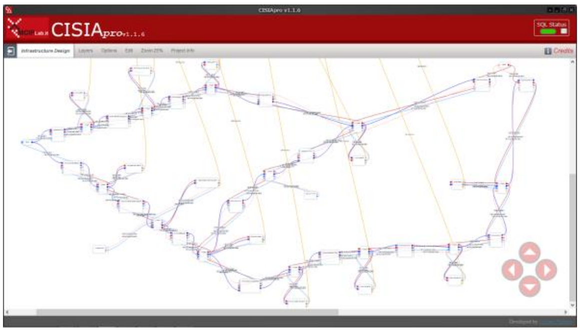

Figure 2. Example of CISIA Graphical User Interface

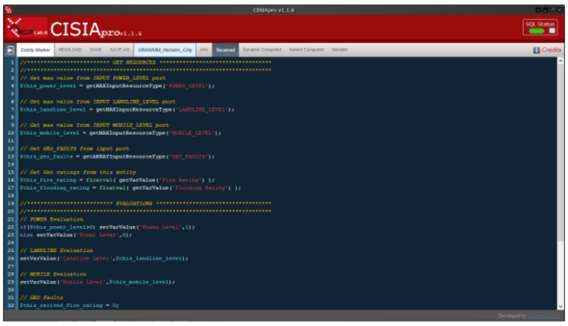

Figure 3. Snapshot of the entity maker inside CISIApro

Each entity is made of four modules that are executed at run-time, see Fig. 4: the evaluation of received resources and faults (RECEIVED), the implementation of dynamic and instant evolution (DYNAMIC COMPUTED, INSTANT COMPUTED, respectively), and finally, the evaluation of resources sent towards downstream entities (SENDED). CISIApro is designed over a database in order to distinct the construction design phase and the output storage with the proper graphical interfaces. CISIApro has a database structure, depicted in Fig. 5, memorizing all the information needed for the representation of several Critical Infrastructures and their interconnections. Each entity is an instance of an entity type and has a status made of variables. Each entity has ports for exchanging resources creating MHR layers. Each layer has proper interdependencies. Outputs of CISIApro is stored in a different database, see Fig. 6, with specific features, such as the record time-stamp in terms of date, time and milliseconds.

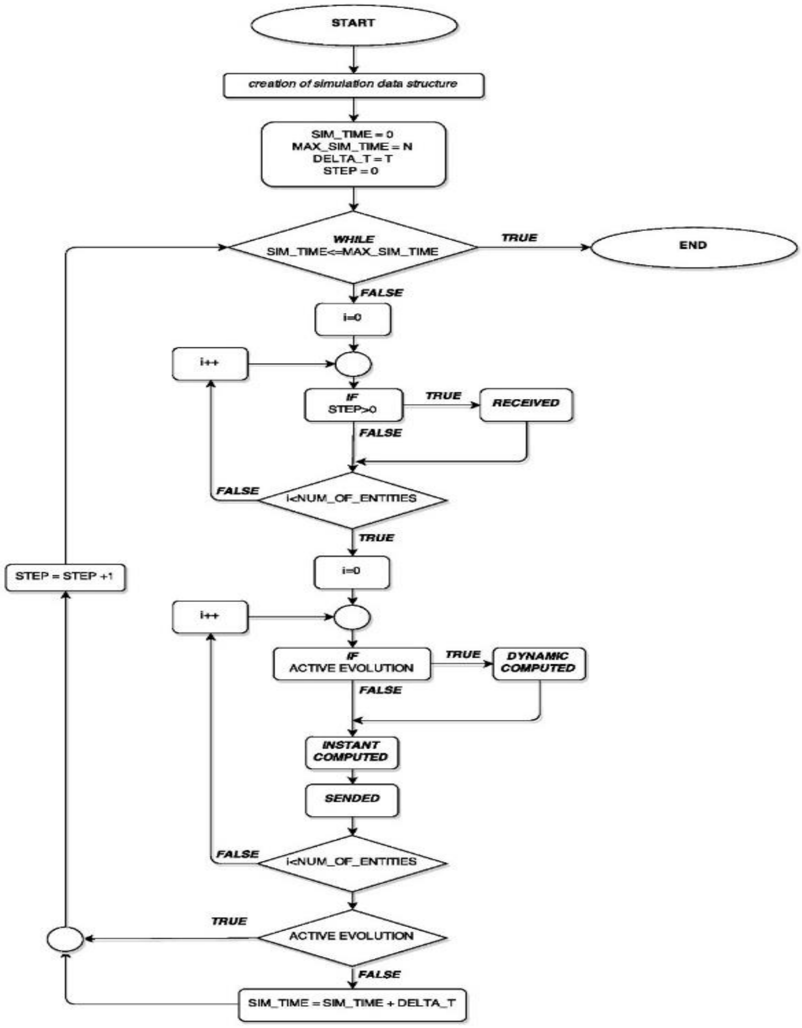

Figure 4. Flow diagram of the CISIApro simulation

Outputs of CISIApro is stored in a different database, see Fig. 6, with specific features, such as the record time-stamp in terms of date, time and milliseconds.

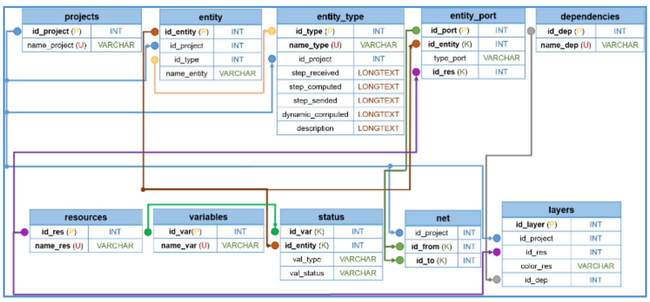

Figure 5. The representation of the CISIApro database

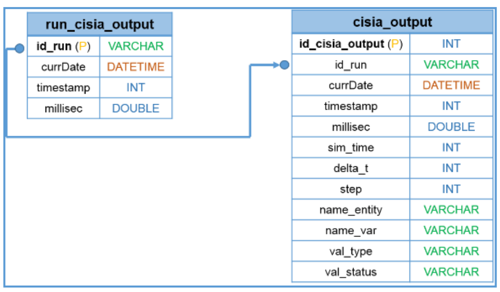

Figure 6. The representation of CISIApro output database

In CISIApro, the adjacency matrices, representing the interdependencies among entities, are generating during the design phase. During the simulation, the matrices are represented as queue data structures for fast computing. CISIApro has been validated in two European projects: FACIES [3] and CockpitCI [4]. In both scenarios, the aim is to help operator in decision-making process.

3.2. Decision Support System implementation

We distinguish four stages of decision making where the developed Decision Support System is crucial in processing the collected data and providing high-level information.

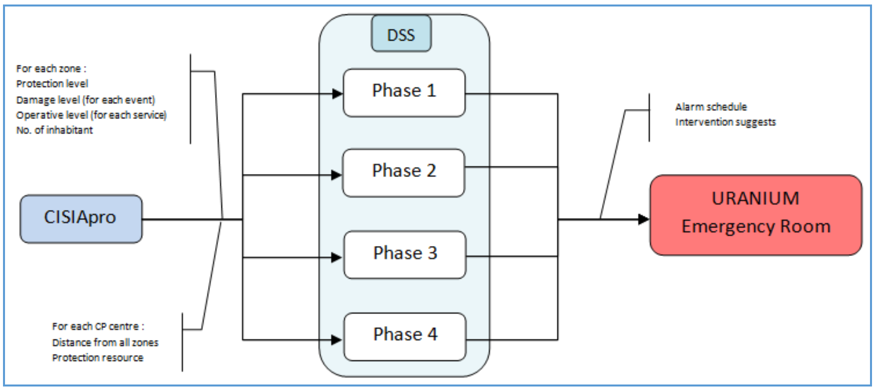

Figure 7. DSS information flow

We modeled the magnitudes in analysis as follows:

Protection level, represents the capacity of each zone to contrast the emergencies. It can assume values between 0 and 1.

- Value 1 : operational resources available
- Value 0,5 : operational resources not immediately available
- Value 0 : operational resources not available

Damage level, represents the damage value created by the particular event. It can assume values between 0 and 1.

- Value 1 : maximum damage, all infrastructures are damaged
- Value 0,5 : medium damage, some infrastructures are damaged
- Value 0 : no damage, all infrastructures work properly

Using CISIApro, the component of damage is spread to other cities in order to represent the scenario evolution in the short term. Propagation model regards the geographical interdependence. Damage decreases as one moves away from the catastrophe epicenter. This behavior is achieved by operational level degradation in the cities of epicenter neighborhood. Damage and operatives value correspond to the city damage state and city operatives state, in according with Civil Protection standards. These states are:

- Normality state
- Attention state
- Early warning state
- Warning state
- Emergency state

We introduced threshold values useful in the process of determining the status.

Threshold values (unique value for all city area, defined for each primary service or each event):

- *Attention threshold* divides the *normality state* from *attention state*
- *Early warning threshold* divides the *attention state* from *early warning state*
- *Warning threshold* divides the *early warning state* from *warning state*
- *Emergency threshold* divides the *warning state* from *emergency state*

3.2.1 First phase

The objective of DSS in this case is to determine the operative level scenario areas, comparing operative levels with predetermined threshold values, obtained according to CISIApro standard output. One-to-one correspondence is established between standard collateral information and each alarm. This provides important information on areas access, or communications malfunctions, to share with the Civil Defense. Additional information is sent to URANIUM Energy Management Room to report critical situations.

Input:

- Lop_{hj} = operative level of primary service *j* in city *h*
- Threshold value :
    - S_j^N = Attention threshold of primary service *j*
    - S_j^P = Early warning threshold of primary service *j*
    - S_j^A = Warning threshold of primary service *j*
    - S_j^E = Emergency threshold of primary service *j*
- Database of intervention suggests to Civil Protection

Output :

- Type and alarm level of primary services for each city
- Operative suggests to Civil Protection

3.2.2 Second phase

The DSS will proceed to identify the alert level in each area and for each type of event, by comparing the particular damage level with some preset values named values alarm threshold. For each alarm, there is one-to-one correspondence with an operating standard. This will provide important information to share with Civil Protection:

- Type of warnings for each area
- Units to alert and send to contrast current events

Input:

- d_{hj} = damage level of event *j* in city *h*

- Threshold value:
    - D_j^N = Attention threshold of primary service *j*
    - D_j^P = Early warning threshold of primary service *j*
    - D_j^A = Warning threshold of primary service *j*
    - D_j^E = Emergency threshold of primary service *j*
    - Database of intervention operative standard

Output:

- Type and alarm level of primary services for each city
- List of Civil Protection vehicles suggested to be sent in each city to face the particular event
- List of city with an emergency in place

3.2.3 Third phase

The DSS has the objective of identifying one or more solutions, alternatives, that best conform to preset requirements, criteria using MCDM approach. These techniques can be used to identify desired measures among a variety of alternatives through analyzing multiple criteria, by which the strengths and weaknesses of various adaptation options are evaluated. Five recommended MCDM methods, including AHP, PROMETHEE II, and TOPSIS are used yet to process the disaster data. In URANIUM DSS, the optimal solution among all of the feasible alternatives are ranked and recommended by ELECTRE II method. Multi Criteria Decision Making methods defines criteria/alternatives matrix whose elements are the enhancement of damages, caused by the particular emergency. The Final level of damage is considered as a function objective to minimizing. The choice fell upon these methods of resolution because they take into account the leak of rationality and conforms best to reality, considering that the involved factors of disasters are normally intangible, and the judgments made by experts are usually imprecise and uncertain.

Input:

- d_{hj} = damage level of event *j* in city *h*
- a_h = No. Inhabitant of city *h*
- Lop_{hj} = operative level of primary service *j* in city *h*
- w_i = weight of criterion *I*
- Threshold value:
    - T_C^d = Threshold of weak concordance
    - T_D^d = Threshold of weak discordance
    - T_C^f = Threshold of strong concordance
    - T_D^f = Threshold of strong discordance

Output: Ordered alternative according with intervention priority

Each alternative corresponds to the intervention in the particular city that is in state of alarm. Criteria considered are the type of event, the operative state, and the number of inhabitant of each city. Exploiting the principle of dominance the DSS outputs the ranking of alternatives that correspond to timeline of alerts to be considered.

3.2.4 Fourth phase

Once having outlined the scenario and emergency alarm level for each area, the DSS will provide the optimal allocation of emergency operating centers based on hourly distance and on the level of protection that each presidio provides.

This will provide important information about the operator's emergency management responsibilities that each presidio has in combined operation of the joint group.

Input:

- p_k = protection level of Civil Protection presidio *k*
- d_{hj} = damage level of event *j* in city *h*
- Database of distances from each presidios to all cities

Output: List of operating presidios needed to face any emergency in place

DSS assigns the emergency to the closer operating presidio using the ranking obtained in the previous phase. If resources of the presidio are not sufficient to contrast the situation, DSS provide to define a joint action of other operating presidio in the scenario considered.

4. EXAMPLE SCENARIO

This paragraph uses a case study to demonstrate the application of the URANIUM process to a smart rural and urban area. The aim is the optimal allocation of emergencies to operating presidios of Civil Protection, in order to provide an adequate and timely response to the catastrophic events in place.

4.1. Scenario description

To particularize the interventions in considered scenario, a census of dangers that could occur in the area of Latina is useful.

Starting from the study of documentation issued by the Prefecture, is carried out an analysis of the risks that might occur in scenario's areas and leading to emergency situations that having to manage. The results obtained show events:

- Earthquakes
- Adverse climatic events
- Forest fires
- Hydro geological events
- Industrial hazards

A census of critical infrastructures considered in the province of Latina is as follow.

4.1.1. Power Distribution Infrastructure

To model this process we will consider the transmission system that includes 2 Primary Cabins (PCs) and, for the distribution system, the 18 Switches in the selected area. We consider each PC as a subsystem composed by two main transformers located in a small building inside a private area. Each transformer can be managed remotely and has also the usual electric protections that will automatically intervene when an electric fault occurs (e.g., short circuit, over load, over heating, etc.). The small building has sensors (and local subsystems) for smoke detection, temperature excess, flooding. Those sensors are connected to a central operational room and related local subsystems can be managed (reset, etc.) remotely. The small building is also protected against intrusion and this subsystem is connected to the central operational room. The private area that surrounds the small building is also protected against intrusion and remotely controlled. To access the PCs for maintenance or normal operations, the operators must follow an access procedure, which uses badges to open the gate of the area and the door of the building. This procedure is remotely controlled and must be executed in a defined time lapse.

4.1.2. Gas Distribution Infrastructure

We consider two Pumping Stations (PS) connected to the transmission and distribution pipelines. These PS are located in buildings inside the private area. The scenario includes also a storage that intervenes, for a limited time, in case of fault of a PS and consequent shortage of gas in the distribution network. We consider each PS as a subsystem composed by two compressors located in a building. Each compressor can be managed remotely and has also the usual protections that will automatically intervene when a fault occurs (e.g., compressor block, failure to open valve, loss of input pressure, etc.). Loss of electric power is also considered a fault. The building has sensors (and local subsystems) for smoke and fire detection, ventilation loss, gas leaks, temperature excess, flooding. These sensors are connected to a central operational room and related local subsystems can be managed (reset, etc.) remotely. The building is also protected against intrusion and such subsystem is connected to the central operational room. The private area is also protected against intrusion and remotely controlled. To access the PS for maintenance or normal operations the operators must follow an access procedure, which uses badges to open the gate of the area and the door of the building. This procedure is remotely controlled and must be executed in a defined time lapse. When a PS is unavailable (fault, maintenance, etc.) the scenario will include the storage that intervenes to compensate the loss of gas. The operation of the storage is modelled in two possible ways: one way considers a constant request of power and consequently is time-based; the other is based on the consumption request by the network and is flexible.

4.1.3. Telecommunication Services

Telco infrastructure has a certain level of mobility; its interdependent and interconnected structure presents both challenges and opportunities in coordinating the preparation of public and private crises, also regarding the Civil Protection activities.

4.1.4. Transport Infrastructure

Another relevant sector for URANIUM project is the Transportation one. With a view on rural areas, our main focus in that field is the ground transportation system. In an emergency case it is mandatory to provide for both resident and emergency responders the access at the evacuation routes. During emergencies, Civil Protection is in charge of the protection of the citizens. Several actors play crucial roles in the Civil Protection countermeasures:

- Police force;
- Fire-fighters;
- Coast guards;
- Hospital volunteers;

Each of these actors provides their means for the welfare of the people. Hence for the ground transportation system, our modelling choice has been the individuation of several principal and secondary routes to connect cities of the rural area.

4.2. Timeline and case study

The following frames summarize the timeline of the process, in Fig.8, that leads to the definition of operating tips for Civil Protection in a particular case study:

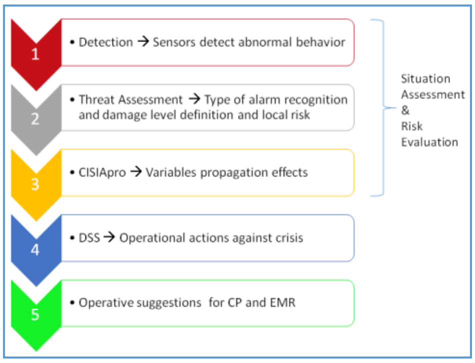

Figure 8. URANIUM process timeline

Step 1 – Detection (Fig.9)

Sensors indicate abnormal findings in Sezze, San Felice Circeo e Sperlonga.

Figure 9. Case study detection

Step 2 – Threat Assessment (Fig.10)

In this step, type and size of events will be defined.

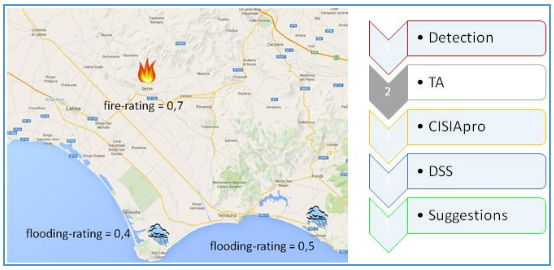

Figure 10. Case study threat assessment

Step 3 – CISIApro evaluation (Fig.11)

CISIApro makes the propagation of damage in the neighbouring cities. The operational level of urban centers decreases according to the modelling already introduced.

Figure 11. CISIApro risk prediction

Step 4 – DSS evaluation (Fig.12)

DSS defines the alarm level, the operative level for each city and suggests the time sequence of operations to be performed.

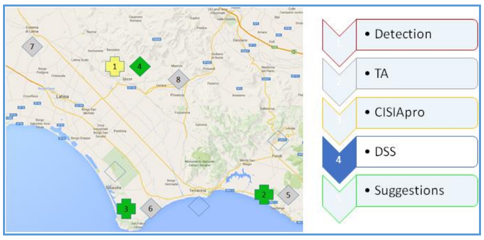

Figure 12. DSS output (crosses represent emergency intervention, rhombuses underline future risks)

DSS also defines the operational centers responsible for any emergency and the deployment of the vehicle suggested to return from the crisis, see Fig.13 .

Figure 13. DSS suggests deployment of Civil Protection vehicles

Step 5 – URANIUM suggestions (Fig.14)

Uranium provides tips and important information to Civil Protection for the management of the event.

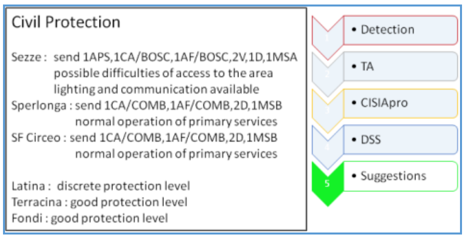

Figure 14. URANIUM suggestions snapshot

Final choice is left to the operator that has the possibility to check the scenario simulated evolution after the application of the countermeasures recommended by DSS.

5. CONCLUSIONS

Observing obtained results, we notice the optimum behaviour of risk predictor and DSS that are able to suggest a correct and weighted answer to face the particular emergence scenario, after few seconds of abnormal finding. CISIApro helps decision maker to evaluate the damage propagation and the CIs potential risks. DSS gives to operator the possibility to set emergence priority based on particular events in place, city population, etc., using a different criterion weight. Concordance/discordance threshold values tuning is an important instrument gave to operator. He is able to set the degree of confidence about the collected data.

The project presented in this paper is an innovating approach for studying natural or human-made disasters on CIs, and for optimally allocating of Civil Protection resources during disaster response. This approach is experimentally tested on a realistic and quite complex case study of a smart area. The efficiency of emergency procedures is improved in terms of cost and time by means of a semi-automatic process where decision makers are needed. The complementary nature of these instruments and their strong tendency to optimization allow a great innovation, introducing the possibility of creating a SCADA component that allows, if properly synchronized, the automated management of crisis situations in every scenario.

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Low Pressure Water Mist Fire Fighting Systems - The Alternative to Traditional Systems

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WATER MIST DEFINITION AND STANDARD

The water mist is defined as a water spray for which the diameter $D_{v0,90}$ measured in a plane 1 m from the nozzle at its minimum operating pressure is less than 1 mm.

The system are defined by the following values according to the design pressure:

- for low pressure systems: up to 12.5 bar;
- for medium pressure systems: higher than 12.5 bar, but below 35 bar;
- for high pressure systems: 35 bar and higher.

The ETEA MIST LP systems are low pressure water mist systems.

The standards related to the water mist system are the CEN/TS 14972 – "Fixed firefighting systems – Water mist systems - Design and installation" and the NFPA 750 – "Standard on Water Mist Fire Protection Systems".

They specify minimum requirements and give information on design, installation and testing and give criteria for the acceptance of fixed land based water mist systems for specific hazards and provides fire test protocols for a variety of hazard groups.

The documents are not universal design manuals for water mist systems, as different systems have different characteristics and hence follow different design criteria to satisfy their duty requirements.

In the absence of a generalized design method, it is the intent of the standard that water mist systems are full-scale fire tested and its system component evaluations are conducted by qualified testing laboratories. Therefore for each kind of application water mist systems shall be tested in a full scale fire test in accordance with the annexes of the standards and certified by a recognized authority.

ETEA MIST LP SYSTEM

Etea Sicurezza developed the nozzles internally, taking care of the design of the nozzles themselves with mechanical and fluid dynamic studies, and of all of their components such as escutcheons, filters and gaskets.

Etea Sicurezza developed both automatic systems, with the closed head nozzles called ET3 and ET3 IDF, and deluge systems, with the open head nozzles called ET1 and ET2.

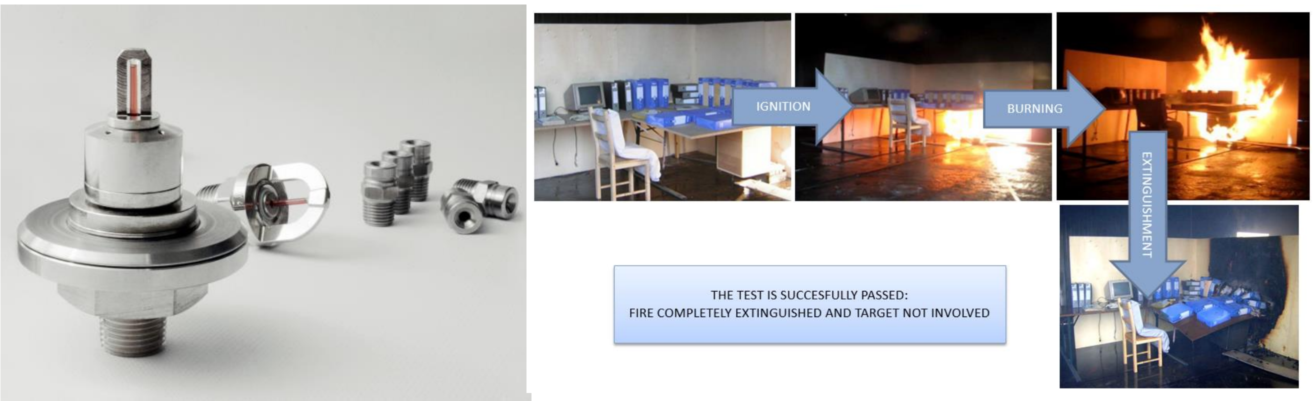

Figure 1: Etea Sicurezza LPWM nozzles and a system performance fire test

Etea Sicurezza tested the nozzles on full scale fire tests, according to the CEN/TS 14972, at TE.S.I. S.r.l., a laboratory accredited by the Italian Ministry of Interior.

The ETEA MIST LP systems provide a wide range of applications depending on the different activities exposed to fire risk: hotels, schools and offices, public areas, museums, libraries, archives, technical spaces, garages, warehouses and industrial building.

The table below summarize the successful fire tests performed by Etea Sicurezza.

Table 1: Fire tests successfully performed by Etea Sicurezza

Etea Sicurezza's LPWM nozzles	Nozzle Type	Hazard class**	Scenario	Results
ET1	Open head	OH3 ST1	Stacked wooden pallet	FIRE EXTINGUISHED
		HHS4 ST4	Racked cardboard boxes filled with EPS cups	FIRE EXTINGUISHED
		OH3 ST4	Racked empty cardboard boxes	FIRE EXTINGUISHED
ET2	Open head	HHS4 ST1	Stacked wooden pallets + bags filled with EPS pellets above	FIRE EXTINGUISHED
		HHS4 ST4	Racked cardboard boxes filled with EPS cups	FIRE EXTINGUISHED
ET3 IDF	Closed head	HHS4 ST4	Racked cardboard boxes filled with EPS cups	FIRE EXTINGUISHED
ET3	Closed head	HHS2 ST5	Paper archive	FIRE SUPPRESSED
ET4	Closed head	OH1	Office furniture	FIRE EXTINGUISHED

**According to UNI EN 12845:2009

HOW WATER MIST ACTS AGAINST FIRE

Combustion is the reaction between fuel and oxygen, in presence of an ignition source.

Water fights the fire because, by evaporating, it absorbs heat from the burning fuel, lowering its temperature under the flammable conditions. The way the water is spread out over the fuel is a key point in its effectiveness in fighting fires.

Traditional sprinkler systems are based on nozzles that create droplets with average diameters larger than 1 mm. This means that the main principle through which sprinklers fight fires is flooding fuels and the areas protected by the systems. The consequences are as follows:

- large reservoirs of water are needed to make sprinkler systems effective against fires;
- the objects (paper documents, furniture, goods, etc.) reached by water result irreversibly damaged.

Water mist systems are based on nozzles that create droplets with average diameter slower than 1 mm. This gives to water mist systems the capability to act against fire through three different principles:

- Cooling: heat absorption is a consequence of water evaporation. Evaporation rate is strictly related to surface – to – volume ratio of the droplets: the lower the droplet dimensions are, the higher the absorption rate is. The fine dispersion of droplets of water mist systems is able to evaporate and absorb heat much more fast and effective than traditional sprinkler systems.
- Inertization: when evaporating, water increases its volume up to 1640 times, which causes a rarefaction of the oxygen present in the air, at the source of fire.

The oxygen content is reduced near the origin of the flames, while the normal oxygen content in the environment around is maintained in all of the remaining room.

In this process, the extinguishing inertization means is not carried to the flame source from the outside, but it is produced only in direct proximity to the fire.

- Shielding effect: the droplets of water present between the flames and the combustible surface strongly reduce the heat irradiation. The combustion rate decreases and the overheating of the surrounding possible flame sources is reduced. This prevents the possible spreading of the flames.

PROTECTION OF PEOPLE

The capability of water mist to reduce the temperature more quickly than traditional systems and to wash away the residual gases is of vital importance in the protection of the people.

In normal circumstances, also the reduction of the oxygen present in the air does not represent any danger because it occurs only in proximity to the fire. The fire is usually extinguished with an oxygen concentration of about 16-18% by volume (those oxygen concentration are not deemed harmful for the people).

The radiant heat blocking also helps to protect against structural damage by protecting the building from the heat caused by the flames.

The entrance of the Fire Brigades in the areas where a water mist system has just fired, becomes then considerably safer.

COMPARISON BETWEEN ETEA MIST LP SYSTEMS AND TRADITIONAL SPRINKLER SYSTEMS

The low pressure water mist systems are more effective and efficient against fire than traditional sprinkler systems. Thanks to the fine dispersion of droplets that the ETEA nozzles can create, the water is used more efficiently: compared to classic sprinkler systems, ETEA MIST LP consumes up to 70 % less water. This allows to allocate a smaller water reservoir; the reduced space requirements lead to construction cost savings.

The use of smaller pipe (diameters predominantly DN20 to DN50 instead of DN20 to DN150), makes it possible to save space for the piping paths, and to reduce the purchasing and installation costs.

The minimal water consumption, compared to usual sprinkler system, warrants in the case of a fire a minimal damage caused by the water.

The table below shows the density discharge and the minimum duration of the discharge used in fire tests carried out by Etea Sicurezza with the LPWM nozzles, and the minimum density discharge and the minimum duration of the discharge that should be used with a traditional sprinkler system (SPR) in accordance with existing regulations. Taking into account both parameters, the saving water is evaluated.

Table 2: Saving water

Etea Sicurezza's LPWM nozzles	Fire hazard class**	Discharge density [mm/min]		Minimum discharge duration [min]		SAVING WATER
		LPWM	SPR	LPWM	SPR	
ET1	OH3	3.9	5.0	30	60	61%
	HHS4 ST4	4.41	15	60	90	80.4%
	OH3	3.36	5	60	60	32.8%
ET2	HHS4 ST1	7.84	10	30	90	73.9%
ET3 IDF	HHS4 ST4	6	15	60	90	73.3%
ET3	HHS2 ST5	2.9	7.5	90	90	61.3%
ET4	OH1	2.3	5	60	60	54%

***According to UNI EN 12845:2009*

Figure 2: Comparison of the spray between an ETEA MIST LP nozzle (on the left) and a traditional sprinkler head (on the right)

COMPARISON BETWEEN ETEA MIST LP SYSTEMS AND HIGH PRESSURE WATER MIST SYSTEMS

In the low pressure water mist nozzles, swirling and rotational motions are generated, increasing the water kinetic energy, and giving rise to very fine droplets, even at low pressure; the operating pressure of the ETEA's nozzles is generally 6 bar. Instead in a high pressure water mist nozzle the mist is generated thanks to the high value of the pressure, generally between 80 and 120 bar.

The ETEA MIST LP systems employ components normally used in common sprinkler systems. Therefore the low pressure water mist systems are significantly cheaper than high pressure water mist system.

The electrical pumps require significantly less power, which in turn reduces the connection and running costs.

The necessary maintenance is similar to that of a sprinkler system. A qualified installer can perform easily it, following the manual for installation, use and maintenance. The maintenance time is very low, this contributed to reduce the downtime of the company or of the activities performed in the ambient in which the ETEA MIST LP system is installed. While the high pressure water mist systems require a special and detailed maintenance, carried out by a qualified company.

ETEA's nozzles have larger outlet orifices, this in turn reduces the risks due to clogging of pipes or nozzles.

In case of non-sufficient reservoir, supplying water can be drawn from the municipal hydraulic piping, while the high pressure system cannot share the water reservoir of others.

CONCLUSIONS

The low pressure water mist systems have relevant benefit if compared with the other water based extinguishing system. Low pressure water mist systems create a fine dispersion of droplets that, thanks to their high surface-to-volume ratio, are able to quickly evaporate and absorb heat; the homogeneous mist generated by the systems, also, limits the radiant heat of the flames and helps to smother fire, due to a process of partial replacement of oxygen with the water in the area surrounding the fire.

Low pressure water mist systems ensure, against fires, the same performance as sprinkler systems, using 30 to 50% lower amount of water. This allows to allocate a smaller water reservoir and, in case of fire, limits the damage to objects and structures caused by the water flowed from the firefighting system.

All the Etea Sicurezza's nozzles have been testing on full scale fire tests at a laboratory accredited by the Italian Ministry of Interior.

In addition to the positive results already obtained, Etea Sicurezza is developing new nozzles and will carry on new fire test.

Supporting Decision Makers In Crisis Management Involving Interdependent Critical Infrastructures

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1. INTRODUCTION

Critical Infrastructure Protection (CIP) is a concept that relates to the preparedness and the response to severe incidents involving the critical infrastructures of a country. These events such as 9/11, Katrina, and others, showed that considering infrastructures separately was not sufficient to prepare for and respond to large disasters in an effective manner that might prioritize not the individual infrastructure states but the overall societal impact. When a specific perturbation, such as an earthquake, hits a system of Critical Infrastructures (CI), the “primary effects” or "No-CI related Consequences" of the damages produced by the event can be expressed in terms of the number and the economic value of the collapsed buildings, the number of casualties or the economic losses related to the disruption of a given production. In addition, there might be “secondary effects or “CI related Consequences” connected to the degradation of CI services (e.g., electricity, water, gas) that can be exacerbated by cascading effects. In general, No-CI Consequences are limited to the area affected by the natural events whereas the area to which CI-related Consequences refer to, can be much larger than the area affected by natural events. A typical example of this situation is the 2003 Italian blackout where the large CI related Consequences caused by an extended and prolonged electrical blackout were triggered by a collapse of a high tension pylon that produced very small No-CI Consequences blackout. Prediction and a rapid assessment of both kinds of consequences in a critical scenario can be thus a major breakthrough for increasing preparedness and mitigation actions. To this end, a major goal could be represented by a correct prediction of the course of events, starting from the prediction of the occurrence of natural hazards and of their strengths to the resulting effects that they will produce in reducing supplied services and the further consequences on relevant areas of societal life. The realization of a similar object, cast in the form of a Decision Support System (DSS), is one of the objectives of the EU FP7 CIPRNet project. The designed DSS implementing the above mentioned risk assessment workflow other than predicting the extent of the expected crisis, can also be used to "weigh" the efficacy of the proposed mitigation and healing actions and thus being a valuable tool for supporting emergency managers e.g., CI operators, Civil Protection and fire brigades. Whether No-CI related Consequences can be evaluated on the basis of the produced damages, the transformation of them into CI related Consequences is much more complex and requires the introduction of a further term, which we indicate as "impact" and that identifies the resulting effects of damages on the services produced by the CI (e.g., the damage of an electric distribution substation that produces an electric outage in a city area for a given period of time as well as disruptions in the telecommunication network). Once having the complete assessment of the impact, one can evaluate the CI related Consequences by transforming impact into well-being societal variation. The proposed DSS advances the state of the art by including in a unique framework the prediction of natural hazards and the estimation of their effects on CI and the societal life. The latter is realized by implementing novel models to propagate the interdependencies between a power grid and its SCADA system and to quantify the reduction of wealth of the population imposed by the absence of CI services.

The work is structured as follows. Section 2 describes related work in the area. Section 3 presents the main functionalities of the DSS required to implement the risk assessment workflow. Section 4 focuses on the DSS impact and consequence analysis modules and present the procedure that allows to propagate the predicted damages in the considered CI in terms of short time scale impact and effects on the citizens and to define possible mitigation strategies of the crisis. In Section 5, we present a case study where we apply our methodology to estimate the consequences to citizens' residents in an area of Rome due to disruptions occurring in the electric-telecommunication system. Finally, in Section 6, some conclusions and ideas for future work are drawn.

2. RELATED WORK

This section discusses related work on DSS for natural hazard primary effects estimation, models for impact assessment and metrics for evaluating the CI related consequences i.e., the societal well-being degradation due to the loss of critical infrastructure services.

Kamissoko et al. (2013) have developed a DSS that estimates the vulnerability of infrastructure networks taking into account interdependency phenomena. The DSS models network dependencies through the graph theory and is able to infer vulnerable areas, critical components and the most threatened stakes (e.g., a firm, a habitation, a government institution) by specifying the probability of a natural hazard and the state of the system. The European UrbanFlood (2012) was aimed at developing an Early Warning System (EWS) for the prediction of flooding in near real time. The system was validated in the context of dike performance in an urban environment and uses sensors monitoring network to assess the condition and likelihood of failures. The system employs flooding specific modules including dike breach evolution and flood-spreading models. In the context of the European Earth observation program Copernicus (2010), a European Flood Awareness System (EFAS) was developed to produce European overviews on ongoing and forecasted floods to support to the EU Mechanism for Civil Protection. The Italian national project SIT_MEW (2010) has focused on the implementation of an EWS to predict potential impact of seismic events on structures and buildings immediately following an earthquake. However, existing DSS do not take into account simultaneously environmental forecasts and interdependency phenomena of critical infrastructures.

Regarding the latter, Ouyang (2014) has reviewed all the research in modeling and simulation of interdependencies of critical infrastructures according to six branches: (i) empirical; (ii) agent based; (iii) system dynamics based; (iv) economic based (v) network based, and (vi) other approaches based on High Level Architecture (HLA) and Petri-net techniques. Our DSS employs network-based approaches which model the performance of each network through topological properties of the network such as the connectivity loss, the number of normal or failed physical components, the duration of components unavailability, the number of customers served or affected. Other network based approaches include Rosato et al. (2008) which modeled an electrical network through Direct Current (DC) power flow model and investigated the relation among the variation of Internet Quality of Service (QoS) and the variation of the QoS of the electrical network using a data packet model to model the Internet communication layer in order to test mitigation and healing strategies. Moreover, Rahman et al. (2008) developed a tool, called i2Sim, which models each CI as a matrix that defines how quantities of input resources should be combined to produce quantity of output resource. i2Sim was applied in several real cases including the campus of the University of British Columbia (UBC) that has the properties of a small city with several dependent systems.

Regarding the metrics for evaluating societal well being due the loss of services, there is a large and lively debate on the use of specific indices, which goes beyond the simple economic indices such as the Gross Domestic Product (GDP). Influential scientific literature (see, e.g., Costanza et al., 2009) considers a number of low correlations between GDP and suggests the use of other types of measures with sample a larger area than the mere economical subsystem. The International Wealth Index (IWI) defined by Smits and Steendijk (2009) is a wealth index that allows to compare the performance of societies with regard to wealth, inequality and poverty. IWI can assume values in between 0 and 100, with 0 representing households having none of the assets and lowest quality housing and 100 representing households having all assets and highest quality housing. Other indices such as the Social Vulnerability Index (SoVI) defined by Cutter et al., (2003) measure the social vulnerability to environmental hazards i.e., those social factors (e.g., employment loss, gender in a certain census area) that influence the susceptibility of various groups to cope with a disaster.

3. OVERVIEW ON THE CIPRNet DECISION SUPPORT SYSTEM

The DSS can be logically represented in terms of five functional components (Bn) which leverage on a large database containing GIS data of CI elements, assets, geographical, social, economical information of the area under control. These are:

- **Monitoring of natural phenomena (B1)**: This functional block acquires geoseismic, meteorological forecasts and nowcasting data, other than sensor field data when available.
- **Prediction of natural disasters and events detection (B2)**: This block, based on information of B1, predicts, within an estimated temporal horizon, the strength of a limited set of natural phenomena occurring in the specified area.
- **Prediction of Physical Harm Scenarios (B3)**: This block evaluates the probability that each CI component, located in a certain area, can receive a damage if hit by the predicted natural events with a certain strength. The association "event strength-damage" of a physical component c_i of the *x*-th CI by a threat manifestation T_j is performed by considering the intrinsic vulnerability of c_i w.r.t. the intensity of T_j (output of B2). The outcome is a set of affected CI physical components with the extent of the estimated physical damages called *Physical Harm Scenario* (PHS) defined as:

$$PHS = (c^{\mathsf{T}}, d^{\mathsf{T}}) \qquad (1)$$

where: $c^{\mathsf{T}} = (c_1^{s_1}, \dots, c_R^{sR})$ is the set of CI components belonging to the infrastructure s_i that, at time t=0, are expected to receive an over-threshold probability to be damaged; $d^{\mathsf{T}} = (d_1^{s_1}, \dots, d_R^{sR})$ is the set of the extent of estimated damages for each CI component; R is the number of possible damaged components; $s_i \in \{1, \dots, U\}$ and U is the total number of CI considered.

- **Estimation of Impact and Consequences (B4)**: This block estimates the impact that the PHS may produce on the services delivered by the CI and the resulting consequences for the society. Based on the PHS and models to propagate damages of the physical components across different CI, the DSS is able to produce an *Impact Vector* I(t) containing the set of the functions of the QoS Q(t) associated to each CI. The generic Impact Vector estimated over the time T of the crisis is defined as:

$$I(t) = (\Delta Q(T)^{\mathsf{T}}) \qquad (2)$$

where: $\Delta Q(T) = (\Delta Q_1^{v_1}(T), \dots, \Delta Q_L^{vL}(T))$ is the set of the QoS variations of the CI over the time T; L is the number of services considered and $v_i \in \{1, \dots, U\}$. In Section 4.2, we define the Consequence

Vector $C(t)$ that assesses the consequences due to the reduction of CI services by introducing the concept of wealth of the society.

- **Support of efficient strategies to cope with crisis scenarios (B5)**: This block provides crisis managers with a decision list of actions in those cases where the DSS can provide further information needed to support a crisis solution.

In the next Section, we focus on B4 by first recalling the network based approach to estimate the Impact Vector in a power grid and then present our metric to assess the relative consequences on the society due to the degradation of power services.

4. CRITICAL INFRASTRUCTURE RELATED CONSEQUENCES

4.1. Estimation *of Impact*

The estimation of impact is performed through a network based procedure developed by Tofani et al. (2015) that takes into account the interdependency mechanisms existing among a power grid and its SCADA system. This approach is based on the real properties of the electrical distribution grid of Rome consisting of several High Voltage (HV) Primary Substations (PS) and Medium Voltage (MV) Secondary Substations (SS) that are connected to PS through backbones according to a serial configuration. Each SS can satisfy the electrical demand of a district approximately composed of 100 households. The interdependency phenomena between the two CI stand as the electrical SS supply energy to specific Telecom devices, called Base Transceiver Stations (BTS) that in turn ensure tele-control capability to the electrical grid. In addition, the BTS, installed in each mobile antenna, require energy to function that is provided through the electric SS. Considering their strong interdependency, damages occurring in the electrical SS and/or the BTS, can cause disruptions that hold in the short time scale (from a few minutes up to some hours) leaving people without power and mobile communication services. Based on the interdependency information regarding the two systems and the PHS (periodically estimated by the DSS B3) including the possible damaged electrical SS and Telecom BTS, the impact estimation procedure emulates the restoration procedure of the electrical operator to infer the possible evolution of the electric grid in the medium term. In particular, the procedure identifies those SS that, because of the loss of tele-control capability, require manual intervention and those that can be reconnected via the electric SCADA system. Then, considering the average time required by the emergency teams (that are limited in number) to reach specific electric SS and reconnect the relative users (e.g., using UPS), the procedure estimates the Impact Vector I(t) in terms of the electric power profiles that are generated by each specific SS. It is clear that, according to the sequence of manual actions executed by the emergency teams, there might be different impact outcomes. In fact, some SS can supply several households w.r.t. other ones or the reactivation of some of them be preparatory for other restoration and/or enabling some actions to be performed more rapidly. Let K be the number of available emergency teams and M be the number of electric SS to be reconnected. We define the ordered sequence $O_l = (SS_1^l, SS_2^l, \dots, SS_M^l)$ of SS that are reconnected by the *l*-th emergency team with $l \in \{0,1,\dots,M\}$. Thus, depending on the sequences O_l implemented to cope with a crisis, the DSS estimates the relative consequences for the citizens as their well-being is influenced by the availability of services delivered by CI.

In the next Section, in order to provide a criterion on how to reactivate the faulted SS, we present a metric to assess the ultimate consequences for the citizens and show in Section 5 how specific sequences can reduce the ultimate effects for the citizens.

4.1. Estimation of Consequences

In order to define the significance of the impact produced by the disruption or destruction of one (or more) CI, the European Council Directive 2008/114/EC (see European Commission, 2008) proposes that such effects should be assessed in terms of cross-cutting criteria. These include: (i) Casualty criterion assessing the potential number of fatalities or injuries; (ii) Economic effects criterion assessing the significance of economic loss and/or degradation of products or services including the potential environmental effects; and (iii) Public effects criterion in terms of the impact on public confidence, physical suffering and disruption of daily life including the loss of essential services.

Based on the latter, we summarized in a unique list of criteria, a number of domains that express the criteria above mentioned whose well-being reduction could be estimated both in the No CI and in the CI-related Consequence analysis. We identified four criteria (called CA Criteria) as defined in the following:

- **CA Criterion 1: Citizens.** It relates to population, to citizens and encompasses the reduction of well-being to the most vulnerable population layers (e.g., elderly people, children).
- **CA Criterion 2: Services.** It relates to the primary services that affect the wealth and the well-being of the population (i.e., hospitals, schools, public offices, public transportation).
- **CA Criterion 3: Economy.** It relates with the economic losses that depend, in turn, on the integrity and the lack of production hours/days due to services outages. (i.e., primary, secondary and tertiary sectors).
- **CA Criterion 4: Environment.** It relates to the environmental damages that can be produced by disruptions (e.g., landslides, flooding etc.) but also by secondary effects (e.g., pollution, leakages from plants) on specific assets (i.e., forests, protected areas, sea and shores, basins).

The DSS provides an estimate of the No-CI and CI related consequences performed according to the previously defined criteria in the time interval predicted for the crisis. In particular, the impact estimation module will result in the prediction of the loss or reduction to the QoS of one or several CI services provided in the form of a vector $Q_i(t)$ for each service i coming from the damage of CI physical components. On the basis of this data, the consequence estimation module generates the relative consequences in terms of variations of wealth of each criterion. Such quantities are provided as a Consequence Vector C(t) defined in the following:

$$C(t) = \{C^{cit}(t), C^{ser}(t), C^{eco}(t), C^{env}(t)\} \quad (3)$$

where $C^{cit}(t)$, $C^{ser}(t)$, $C^{eco}(t)$, and $C^{env}(t)$ represent the consequences for citizens, primary services, the economy and the environment respectively, predicted over time t. In this paper, we limit our analysis to the evaluation of the consequences on the citizens. To this aim, in the next Section we define a metric to evaluate the wealth of citizens w.r.t. the variation of specific CI services.

4.2.1 Wealth Index

In order to define a wealth index for the CA criteria, we introduce, in analogy with the International Wealth Index IWI previously mentioned, what we call SAWI (Service Access Wealth Index), which allow us to define the variation of wealth for the CA criteria due to the reduced accessibility to relevant services enabled by technological infrastructures. Limiting our analysis to the wealth of citizens, let us define the wealth $W(t,e_j)^{cit}$ of the Citizen CA Criterion element e_j as a function of the available services k with the relative QoS $Q_k(t)$as follows:

$$W^{cit}(t,e_j) = M(e_j)\sum_{k=1}^{N} r_k(e_j)Q_k(t) \quad (4)$$

where:

- N is the number of the services, which contribute to wealth.
- $M(e_j)$ is the total number of citizens in the same age group e_j which would be maximally perturbed by the unavailability of the k services.
- $r_k(e_j)$, with $0 \leq r_k(e_j) \leq 1$ is the relevance of the *k*-th service to enable the achievement of the maximum level of the wealth quantity $M(e_j)$ associated to e_j.
- $Q_k(t)$, with $0 \leq Q_k(t) \leq 1$ measures the QoS of service k over time where $Q_k(t) = 1$ represents the full availability of service k whereas $Q_k(t) = 0$ the unavailability of service k.

Table 3: SAWI matrix for the Citizens CA Criterion.

CA Criterion Elements	**Relevance of Electricity for e_i**
Population (0-5) e_1	$r_1(e_1) = 32\%$
Population (18-64) e_2	$r_1(e_2) = 87\%$
Population (65 or older) e_3	$r_1(e_3) = 100\%$

In Table 1, we report the relevance $r_1(e_j)$ (assumed independent on time) of the electricity service for citizens in the same age group. We considered children and elderly people as different groups as they are regarded as most vulnerable to cope with crises as remarked by Ngo (2001) and Cutter et al. (2003). In general, $\sum_{k=1}^{N} r_k(e_j)$ accounts for "all the well-being due to CI-enabled services", and in this paper, the only CI-enabled service considered is electricity. The lower value for children means that segment is not very vulnerable to loss of power.

The $r_1(e_1)$ values have been elicited by processing the data available about the bill the different population segments pay for the electricity as it accounts for both consumption and willingness to pay.

Such data have been provided by the Italian National Institute of Statistics (ISTAT, 2014), which carried out a survey focusing on different aspects of daily life of households including the economic conditions and the average monthly expenditure. It is worth noting that, although we expected the energy expenditure increased with the age of household members (mainly because "*elderly people generally prefer higher room temperature for space heating*", spend more hours at home and live in less energy-efficient houses (Deutsch, 2013)), the two values are actually comparable. This is certainly due to the fact that in Italy space heating is fuelled by gas. Nonetheless, even if the total consumptions were similar, the time profiles of the consumption would be different and would significantly impact the consequence estimation. Therefore, to take into account these aspects, a refinement of such indexes will be addressed in a further work. In this paper, however, having less accurate values will not impair the workflow and the added value of the DSS. As far as the other parameter $M(e_1)$ is concerned, the values for each census parcel, as provided by ISTAT, have been employed.

4.2.2 Consequence Vector

In the following, we define the consequence $C^{cit}(T, e_j)$ as the wealth variation of citizens e_j associated to the variation of the QoS of the infrastructure services k (see Table 1) over the time duration T of the crisis. Let us first define the maximum wealth $W_0^{cit}(e_j)$ during time T with full availability of services k:

$$W_0^{cit}(e_j) = M(e_j)\sum_{k=1}^{N} r_k(e_j) \tag{5}$$

We can now define the $C^{cit}(T, e_j)$ as the difference between the maximum wealth $W_0^{cit}(e_j)$ and the effective wealth integrated on time duration T normalized w.r.t. $W_0^{cit}(e_j)$ as follows:

$$C^{cit}(t, e_j) = \frac{W_0^{cit}(e_j) - M(e_j)\sum_{k=1}^{N} r_k(e_j)\int_0^T Q_k(t)\,dt}{W_0^{cit}(e_j)} \tag{6}$$

We can now define the consequence $C^{cit}(T)$ where we consider N=1 service (i.e., electricity) and H=3 classes of citizens as reported in Table 1:

$$W_0^{cit} = \sum_{j=1}^{H} W_0^{cit}(e_j) \tag{7}$$

$$C^{cit}(T) = \frac{W_0^{cit} - \sum_{j=1}^{3} r_1(e_j)\int_0^T Q_1(t)\,dt}{W_0^{cit}} \tag{8}$$

The resulting consequence $C^{cit}(T)$ is a number varying in between 0 and 1 (with 0 indicating no consequences and 1 severe consequences) expressing the possible variation of wealth of the citizens over the time T of the crisis due to the degradation of the electricity service.

Table 4: Case study: Consequences on citizens in four census parcels of Rome (ISTAT data).

CA Criterion Elements	**Area 1**	**Area 2**	**Area 3**	**Area 4**
Population (0-5) e_1	2	4	1	0
Population (18-64) e_2	71	119	25	7
Population (18-64) e_2	16	20	3	0
Consequence $C^{cit}(T)$	**Area 1**	**Area 2**	**Area 3**	**Area 4**
with sequence O_1	58.6%	58.0%	57.6%	29.0%
with sequence O_1^*	29.3%	29.0%	28.8%	58.0%

5. CASE STUDY

A real case study is shown in Figure 1 where we represent a section of the electric distribution grid serving an area of Rome consisting of: (i) two electrical PS (PS_1 and PS_2); (ii) 8 electrical substations (SS_{91} – SS_{98}) where the orange circles denote the remotely controlled SS and (iii) one Telecom BTS (bts_1) providing tele-control capability to SS_{92}, SS_{94}, SS_{95} and SS_{97}. Each electric SS serves a specific census parcel (or “area”) that is characterized by a share of citizens in the same age group as shown in Table 2. The Telecom bts_1 is supplied power by the electric SS_{93}. SS_{94} is the terminal node of the backbone and contains a normally open switch that, in case of a failure in the considered backbone, can be closed to connect SS_{94} to SS_{95}. Five main assumptions are made on the case study: (i) the PHS estimates a disconnection of SS_{93} and SS_{96}; (ii) only one emergency team is available to the electric operator to reach, and then to reconnect, the isolated SS; (iii) no power backup is available to bts_1; (iv) we do not consider the moving time required by the emergency team to reach the electric SS and (v) one hour is the average time to perform a manual intervention in any SS of the district of Rome.

Considering such assumptions and the properties of the considered electrical grid, the impact estimation procedure described in Section 4.1 estimates the following subsequent events:

1) At time t_1=0, SS_{93} and SS_{96} are disconnected;
2) At time $t_2 \approx 0$, all electric SS in the backbone will automatically disconnect (due to the failure of SS_{93} and SS_{96}).

At this stage, considering that no electric SS can be reconnected through tele-control actions due to the loss of supply to bts_1, a manual intervention to be performed by the emergency team is required.

In addition, considering that the emergency team is only one, a choice about which manual intervention to be implemented first, should be taken by the electric operator. In Figure 1, we report the Impact Vector I(t) in terms of QoS reduction relative to the following sequences: $O_1 = \{SS_{96}, SS_{93},\}$, $O_1^* = \{SS_{93}, SS_{96}\}$.

Considering O_1, the following events are generated:

i. SS_{96} is reactivated manually in about one hour;
ii. SS_{97} and SS_{98} are now supplied;
iii. SS_{93} is reactivated manually in about one hour;
iv. SS_{94} is reactivated about five minutes later (average time to perform SCADA operations) through tele-control operations (due to the reactivation of bts_1).

Considering O_1^*, the following events are simulated:

i. SS_{93} is reactivated manually in about one hour;
ii. bts_1 is now supplied by SS_{93} and allows the execution (five minutes later) of the tele-control operation to reactivate SS_{94} and SS_{95} (through the closure of the normally open switch);
iii. SS_{96} is reactivated manually in about one hour;
iv. SS_{97} and SS_{98} are also supplied.

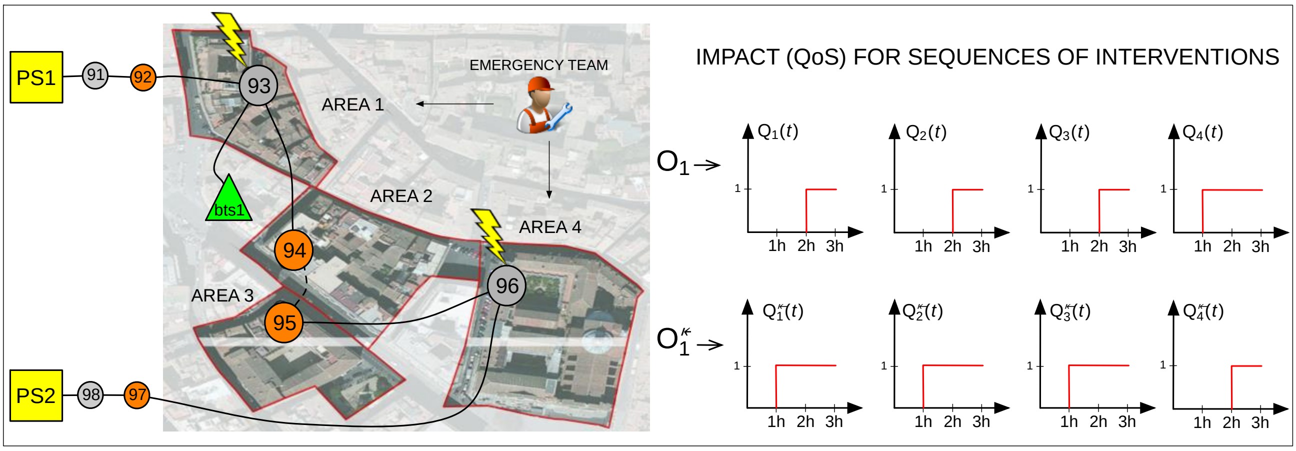

Figure 3 Case study: Estimation of impact in specific census parcels of Rome due to disruptions in the electric distribution grid.

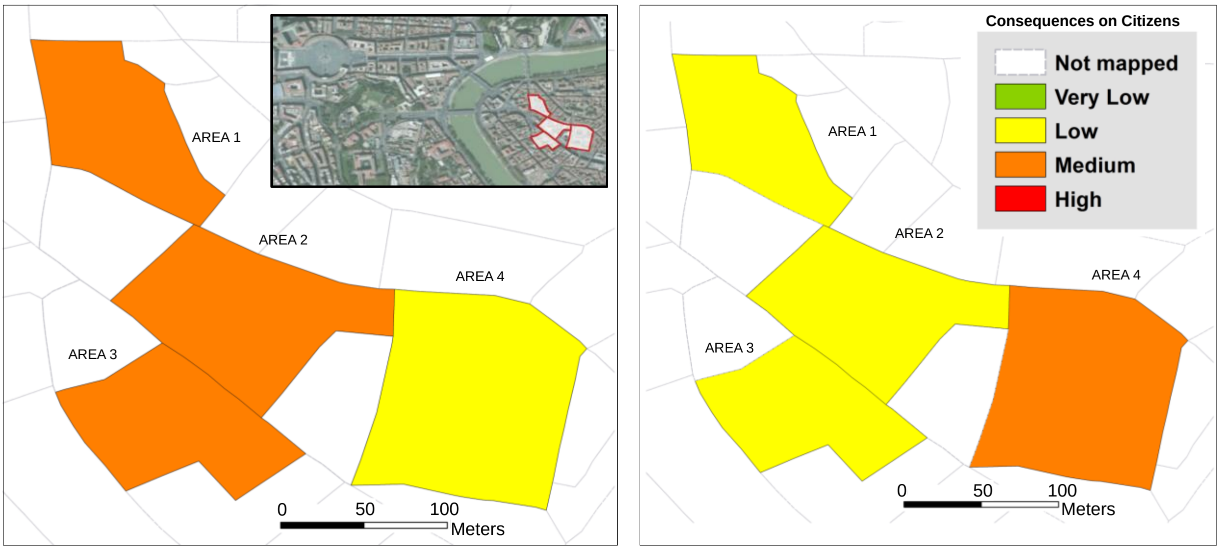

Figure 4 Case study: Consequences on citizens in four census parcels of Rome.

Based on the Impact Vector I(t) produced for the two sequences O_1 and O_1^*, the relative consequences $C^{cit}(T)$ are estimated as the wealth variation of citizens associated the QoS variation of the electricity service delivered by each SS over the time duration T = 3h of the crisis. Figure 2 and Table 1 report the relative results obtained for each census parcel for both sequences. The results obtained for the sequence O_1 show an improvement of the ultimate effects on the citizens in the census parcels Area_1, Area_2 and Area_3 that is mainly due to the lower time duration of electric outage in the three areas obtained through the reactivation of bts1 that, in turn, allows the reactivation of SS94 and SS95. Moreover, results reveal similar figures for $C^{cit}(T)$ in Area_1, Area_2 and Area_3 as such areas exhibit a similar proportion for the share of citizens.

In this case study, we only considered one backbone and two possible sequences to evaluate the relative consequences on citizens. However, wanting to consider the whole electric distribution grid of Rome and the different failures that can affect the electric SS, an optimization technique can be used to reduce the time required to find the best sequence O^* that minimises the ultimate effects for the citizens.

6. CONCLUSIONS

The proposed DSS employs modeling and simulation techniques based on weather forecasts and interdependency properties of the electrical and telecommunication grid to estimate the well-being of citizens that are affected by electric and telecom outages. To this aim, we defined a metric, based on electric consumption data of Italian residents, to relate the loss of electricity service in specific parcel areas to the well-being of citizens of different age groups. This information may be useful for decision makers to know, before a crisis scenario occurs, those areas with high share of vulnerable citizens (e.g., elderly people), which may be severely affected by the unavailability of electric power. The case study shows how the DSS may be able to suggest actions to decision makers that would not be considered by contingency plans of infrastructures, which usually do not take into account interdependency phenomena. Future work focus on the extension of the approach to consider additional CI services (e.g., telecom, water, gas) and the application of optimization techniques to reduce the actions to be taken with the aim of minimizing the consequences for the citizens.

ACKNOWLEDGEMENT

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Interactive Virtual World Models for Crisis Preparedness – Better Than the Real Thing?

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ABSTRACT:

Success of crisis management largely depends on: (1) inherent resilience of the society; (2) preparedness level of the first responders; and (3) right "gut feeling" of crisis managers. "Learning by doing" to improve resilience and planning is difficult to do, especially for low-probability/high-impact events and for multi-hazards with cascading effects. Due to rarity of such events, many crisis managers, regional planers and other stakeholders have no first-hand experience in handling them. The best available alternative is learning by doing in a simulated crisis situation or during an exercise.

The EU FP7 project CRISMA (www.crismaproject.eu) – "Modelling crisis management for improved action and preparedness" has developed a methodology and software framework for simulation-based decision support systems. CRISMA targeted use cases in the preparatory phase of crisis management: short and long-term planning, desktop training and assessment in field trainings. Application prototypes cover different risk (floods, snowstorms, earthquakes, forest fires, accidental pollutions, mass accidents) and illustrate how the CRISMA framework can be used in a relatively simple but integrated manner to develop fully fledged decision support applications [Dihé et al., 2013]. This paper illustrates how each of these cases has been realized, explains how this work can be used to advance different aspects of crisis management preparedness and discusses if and why learning in virtual worlds can be more effective than from real world events.

KEYWORDS:

Crisis management, decision support, resource planning, resource management, multi criterion ranking, interactive virtual world model

1. INTRODUCTION

Crisis situations are a fact of life, but many of catastrophes can be avoided or at least mitigated through improved preparedness. Resilience can be influenced at various levels [Walters, 2013], including e.g.: (1) exposure of the property and population; (2) resilience of the infrastructure; (3) availability of crisis management resources; (4) quality of the crisis management plans; and (5) experience of the crisis managers and first responders.

In theory, reaching a high level of resilience and preparedness for re-occurring crisis situations is easy. In reality, we often fail to learn from past events, e.g. because experimenting with alternative solutions is too costly in terms of real or perceived consequences [Donahue & Tuohy, 2006]. Preparing for low-frequency/high impact events is even more difficult because the population is less aware of the danger, political and economic decision makers are less willing to finance measures and the first responders less well prepared to react.

CRISMA primarily addressed following event types: coastal floods, winter storms with blackouts, accidents with mass-casualty-incidents, chemical spills, and earthquakes with cascading effects such as forest fires [Garcia-Aristizabal et al., 2015]. The choice is based on two criteria: (1) these events are "rare" (at least) for local responders and exceed their "daily business" activities by far; and (2) stakeholders involved in the project agreed that preparedness and resilience for these crisis types needs to be improved. This opinion is validated in a new survey on disaster preparedness [SA & Syed, 2015].

2. DECISION SUPPORT IN CRISMA

Decision makers in crisis management face many possible futures and interdependent consequences of alternative options. During a crisis, they have to quickly understand the situation and prioritise tasks at hand, taking into account the, often conflicting, business targets, reference values and priorities of the involved stakeholders. Especially for large crisis events, the available information is often incomplete, and the available time (for decision making) and resources (for resolving the issues) are insufficient. Decision making in such situations is often a combination of standard procedures and "gut feeling" [Rosqvist, Meriste, & Havlik, 2015]. CRISMA Decision support paradigm aims at improving both these aspects.

A generalized workflow of a CRISMA application is depicted in the Figure 1: The applications allow the decision maker to visualise the state of the world during the evolution of a crisis and help to compare such a state with possible alternative states that may be the result of certain decisions and emerging events. The selection of alternatives to be simulated and the selection of criteria and ranking criteria that are used for world state comparison are normative decisions. Depending on the concrete application, these decisions can either be taken in the setup phase or within the interactive decision-simulation-assessment loop. CRISMA applications do not impose decisions, but allow comparing effects of various decisions (e.g. alternative investments or tactical measures) [Taveter et al., 2014].

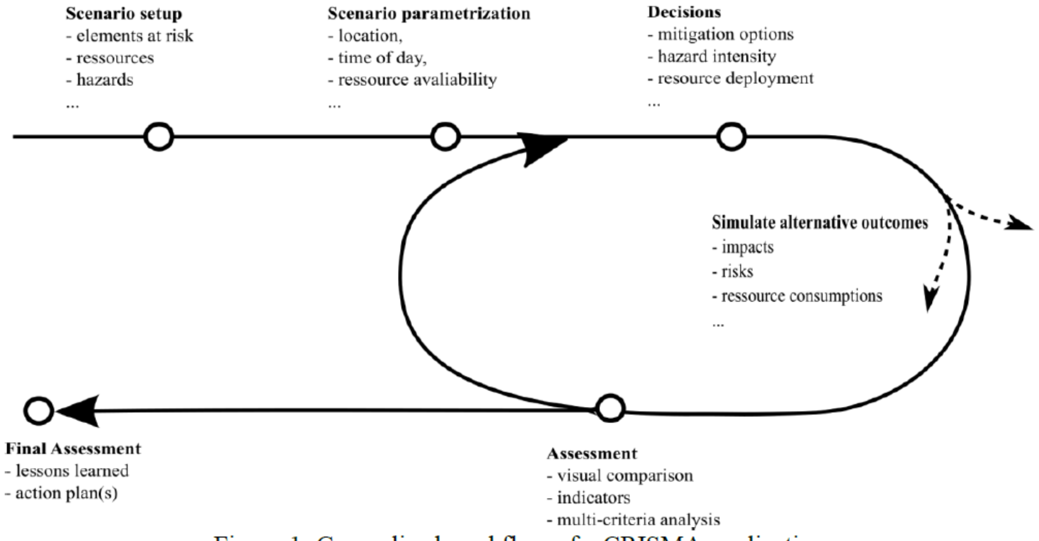

Figure 1: Generalised workflow of a CRISMA application

In order to simplify application development and data analysis, CRISMA applications always produce a series of snapshots of the simulated world [Dihé et al., 2013]. Such snapshot is called “world state”, and it contains all information that is needed to analyse the situation or re-start the simulation from a particular point. A change from one world state to another is called world state transition (Figure 2). The world state transition maintains the structure of the world state and does neither change the dimension of the simulated world nor the type of elements that constitute the world state.

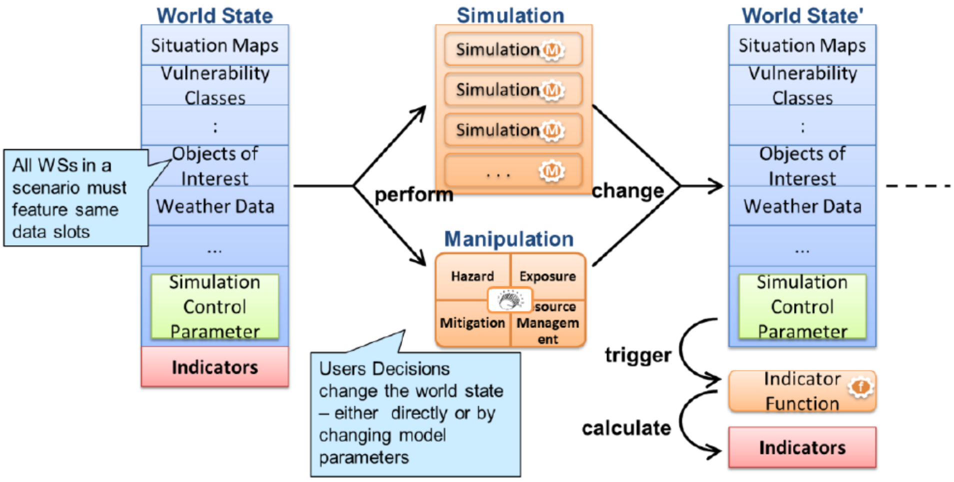

Figure 2: World-states and World transitions (from Dihé et al, 2014)

The creation of a new world state triggers the production of values of the corresponding indicators (aggregated data). Indicators serve as common denominator between world states and for a crisis management simulation analysis (e.g. economic impact analysis) [Engelbach et al., 2014]. Analysis of often complex simulation results can be further simplified by so-called criteria. Criteria are defined by mapping the indicators into 0-100% level of satisfaction. Unlike indicators, criteria can be easily visualized as a set of red / yellow / green color-coded gauges or semaphores representing e.g. level of satisfaction with cost of operation or human losses. They can also be further combined in a multi-criteria ranking function to assess the overall level of satisfaction with the given solution. A summary of the CRISMA decision-support concepts is shown in Figure 3. From left to right, the amount of information is reduced from “complete world data” to a single number.

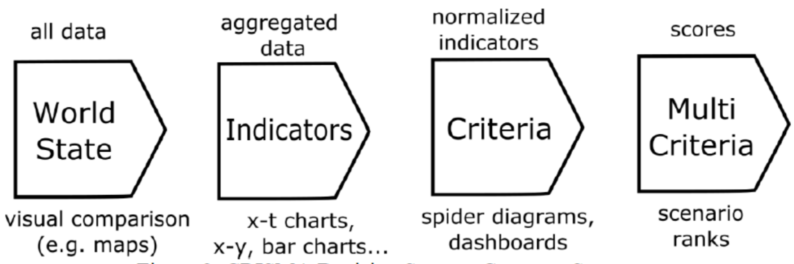

Figure 3: CRISMA Decision Support Concepts Summary

CRISMA decision support methodology and software emphasise on the fact that criteria and ranking functions represent opinions and not facts. They are highly situation dependent and different stakeholders are likely to disagree on definitions and relative importance of different criteria. Users are therefore encouraged to define several sets of criteria and ranking functions and compare the outcomes.

3) APPLICATION EXAMPLES

The main decisions in crisis management that CRISMA intends to support are related to infrastructure (long-term) planning, tactical alternatives and resource management. Infrastructure planning is always a long-term activity, whereas tactical alternatives and resources management can be simulated both within actual crisis or exercise situations and in the context of the long-term planning. Examples for the latter are decisions about investments in additional crisis management resources, or risk assessments.

In order to test the re-usability of the CRISMA methodology and software, all CRISMA applications were developed as generic reference applications first and then configured and if needed extended (e.g. by interfacing the CRISMA software with existing systems) for use at a particular pilot location [Dihé et al., 2013; Havlik et al., 2015]. This adaptation is performed at three levels:

- Setup of a new CRISMA application by a **CRISMA developer**. This step may, for instance involve extending simulation models or adapting the user interfaces.
- Configuration of a new simulation case by a **CRISMA setup expert**. This may involve defining new types of local resources (e.g. faster ambulances, helicopters, etc.)
- Parameterisation of a new simulation run by a **CRISMA end-user or steward**. Such parameters may e.g. change the population exposure or amplitude of the event.

The relation between six CRISMA reference applications and five simulation cases that were realized in the project is illustrated in Table 1. Each of them focuses on a specific hazard, with different time and space scale to relate with, involving end users with different organisational backgrounds, emergency management responsibilities, and tasks with respect to the timeline of the evolution of the crisis.

Table 1: CRISMA reference applications and realized simulation cases

Reference application	**Scenario type**	**Specific simulation case**	**Country**
Nordic Winter Storm	Resource planning	Electricity outage in the far north of Finland.	Finland
Coastal Submersion	Regional planning	**Coastal submersion defence** for Charente Maritime region	France
Accidental Pollution	Desktop training	**Accidental spillage** from a container at large city port	Israel
Earthquake and Forest Fire	Regional planning	Earthquake and forest fire application	Italy + Portugal
Resource Planning	Resource planning	**Mass casualty incident**	Germany
Resource Management Training	Training assessment and model validation		

These applications can be roughly grouped in two categories: the French and Italian applications target long-term planning, whereas the Finnish, German and the Israeli applications target short-term resource management planning and training. This paper concentrates on French, German and Israeli applications that cover all aspects of the "virtualized learning by doing" loop:

- "Coastal submersion defence" (France) application simulates the effects of a coastal flooding and allows users to experiment with long-term measures for mitigating such effects. It is an example of regional long-term planning CRISMA application.
- "Accidental spillage" (Israel) application simulates the effects of resource management decisions on outcome of a crisis as an interactive desktop training.

- "Mass casualty incident" (Germany) application covers two aspects of the loop. First, how to improve the resource management plans. Second, how real world information (in this case from field training) can be captured and used both to assess the exercise and to validate and improve the simulation models.

3.1 Regional planning

Two of the CRISMA pilot applications target long-term planning. The Italian application simulates a re-occurring earthquake with secondary forest fires, whereas the French application supports the decision makers in identifying the impact and cost of coastal submersions and other flash floods (Figure 4). In both cases, the goal of the application is to simulate the long-term effects of the investments in resources, organisation and infrastructure on the outcome of the crisis.

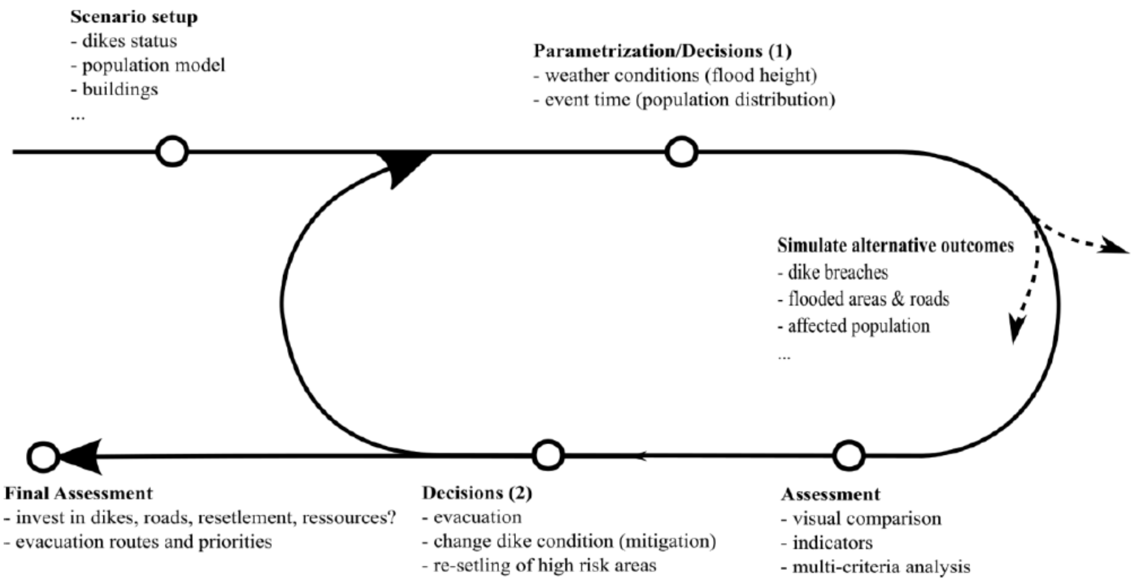

Figure 4: Coastal submersion scenario workflow

Coastal submersions are of rising concern in coastal regions, as storm surges with strong winds are becoming more likely due to climate change. Coastal submersions cover large areas, where buildings, dikes and other infrastructures are at risk to be severely flooded and damaged and citizens to be lost or badly injured. Stakeholders need means to:

- Assess multiple flooding scenarios by simulation of costal submersion events and evacuation behaviours.
- Assess the vulnerability of dikes and buildings for identifying endangered regions.
- Assess the impact of different mitigation options, like the modification of dikes' resilience, eventually reducing the impact of a possible flooding scenario.

The main goal of the French CRISMA pilot application is to enable local authorities to compare prices and effects of various long-term investments on a local scale and thus to find the most suitable solution for a specific region. For example, the user may decide to work with a limited budget in mind and compare effects of investing different portion of the budget in population re-settlement, improving dikes or improving the capacity of first responders. Alternatively, the user could decide to explore the "return of investment" at different investment levels and then argue with the authorities that a certain level of investment in infrastructure or resources is necessary to keep material losses manageable and to assure the safety of the population. In the later context, it is essential to also perform simulations with realistic population distributions. This is why the French and the Italian applications both feature a dynamic population model [Aubrecht, Steinnocher, & Huber, 2014].

3.2 Resource management planning

The German and Finnish CRISMA applications focus on resource planning. Creating resource deployment plans for MCIs is challenging for local first responder organizations because: (1) this type of accidents demand efficient deployment of a large amount of resources from different organizations in a very short time; and (2) the relation between deployed resources and the operation success is not easily deductible [Sautter, J. et al., 2014]. In the case of the German application, the underlying issue is a mass casualty incident (MCI) – an emergency situation with a large number of injured or affected persons that cannot be managed with regular emergency medical services (DIN13050 2009).

In this application, the users can test the effectiveness of different resource management tactics for a specific type of mass casualty incident at a specific location. Tactic is configurable by the user in three steps: (1) set tactical areas (treatment, staging, loading and advanced medical post) on the map; (2) decide which resources to ask for and when; and (3) decide on maximal resource allocation for each of the tasks as well as on the relative priorities of the tasks. The simplest possible resource allocation tactic is illustrated in Figure 5. In this example, no treatment area has been defined. As a result, the number of options is low and the relative priority of activities is practically “set in stone”. The only “free” parameter is de-facto the number and types of vehicles assigned to each of the tasks. LF, RTW, KTW, NEF, MTW and KOM in Figure 5 represent standardized resource types used by the German Red Cross. The application is aware of their capabilities as well as of the standard tactics for their use. For example, the rapid response vehicle (NEF) is the only vehicle with an emergency physician on board and therefore the only resource type that can be assigned to triage.

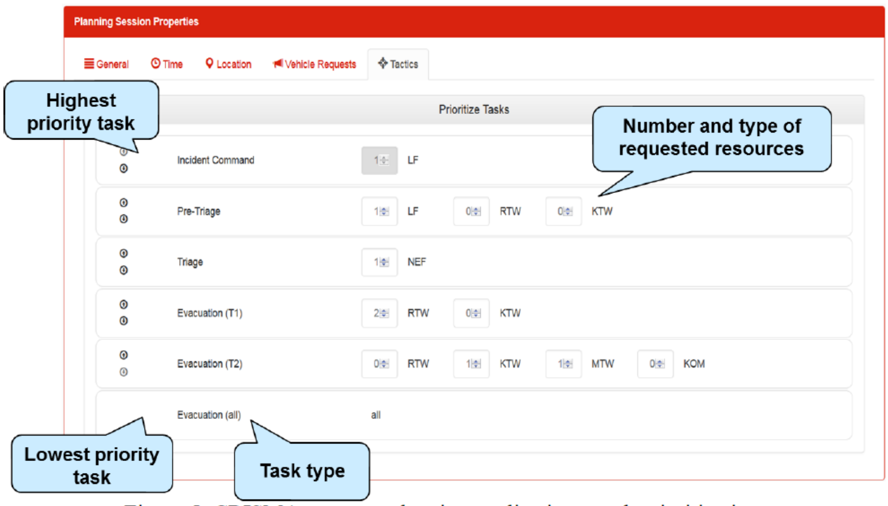

Figure 5: CRISMA resource planning application – task prioritization.

In more complex cases, the user has to prioritize much higher number of activities. The number of available resources is often lower than the number of resources that should be assigned to each of the tasks, especially at the start of the action. As in the real life, some of the activities will only be performed once the higher-priority activities have been finalized.

3.3 Desktop resource management training

In Israeli CRISMA application, the users are confronted with a serious game in which they give explicit orders to simulated resources and the application executes the orders and calculates the new world states [Havlik et al., 2015]. The application can be used in two ways: as a standalone serious game or as a background application only used by the trainer in a table-top-exercise.

In the first case, the trainees can immediately see the effects of their decisions and test alternative decisions by moving back-and-forth on the simulation timeline. In the second case, the trainee is only presented with a portion of information corresponding to the information available in a real world emergency by the trainer and forced to issue commands orally. The first usage pattern is better suited for self-study, whereas the latter is closer to decision making in real world emergencies and better suited for knowledge assessment. Main training user interface of this application is illustrated in Figure 6.

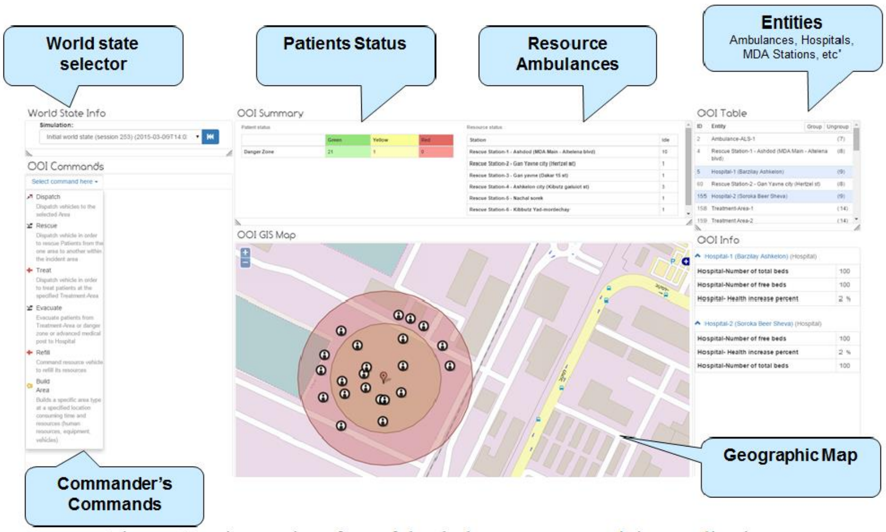

Figure 6: main user interface of the desktop resource training application.

3.4 Event assessment and model calibration

The CRISMA "exercise support" application simplifies the task of assessing the results of a field exercise. It allows gathering of real times that have been needed for various first-responders activities by a specific emergency response unit in field exercise trainings. The application provides templates for all patients with their postulated status (red/yellow/greenand injury type), placeholders for data on timings and results of various activities as well as the separate input methods for capturing of the resource arrivals and departures and capturing of the site-related information. Part of the "capture" view of this application is shown inFigure 7.

Figure 7: Exercise support application – patients' information (fragment)

In CRISMA, the exercise support application was used to capture key performance indicators related to times needed for various activities, such as the "triage duration per patient" (Figure 8).

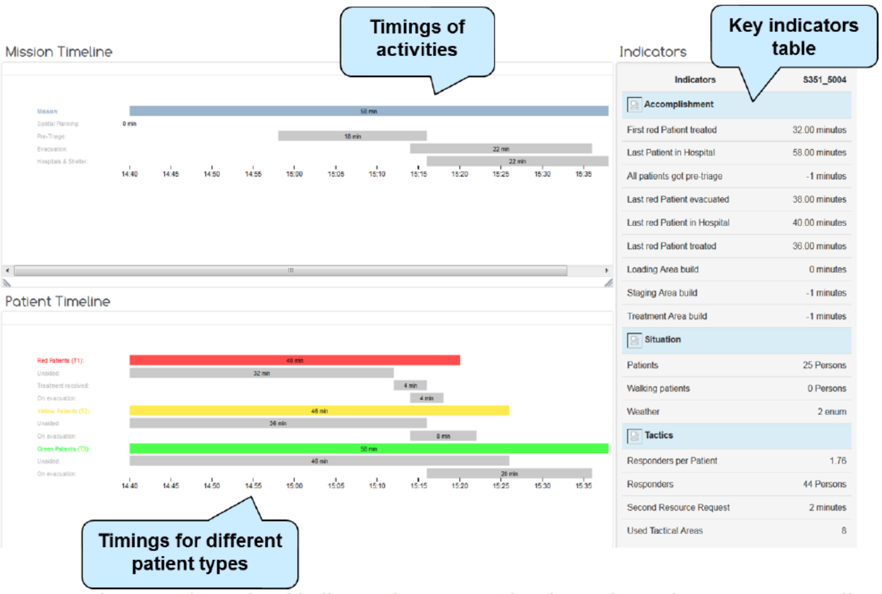

Figure 8: Time-related indicators in resource planning and exercise assessment applications

The information captured during the exercise can be used to improve exercise debriefing and field training assessments. More importantly, the field training situation can be made sufficiently similar to the one in the simulation model used in other CRISMA applications to support validation and calibration of the simulation models used in these applications.

4) DISCUSSION

The CRISMA applications allow playing with varying assumptions in the preparedness phase of crisis management. Users can learn from own "mistakes" in a simulated reality where experimenting and making mistakes is encouraged rather than sanctioned. This type of learning is inherently well suited for the crisis management since the underlying problems are very complex and the available time is often too short to fully analyze the situation.

Our application tests have indeed shown that the users will often compare more alternatives when using a CRISMA application than would be possible in real exercises or in the classical studies. Simulations can thus improve the capability to understand the potential impact of various short and long term measures (infrastructure investments, land use planning, resource management etc.) on crisis development and outcomes. However, it is important to keep in mind that the simulated world is always just a simplified model of the reality. For example, in the German application the patient models have been simplified by assuming that the health status declines linearly and that appropriate care measures can slow down or even reverse the decline. This is an appropriate reduction of complexity for training of control center staff, but may not be detailed enough for on-site response training simulations. Defining the appropriate level of abstraction for a simulation model and understanding the inherent limitations of the model when interpreting the results is extremely important and the “right” choice depends on the intended usage context. Accurate estimates of the underlying data (e.g. population at risk or building condition) and reliable natural hazard modelling are often more important for the use of simulation-based systems in planning applications than a number of available options. Opposite is true for the training applications where a possibility to issue different commands and observe their qualitative effects is often more important than accuracy of the models.

Moreover, the reduction of the problem complexity from “real world” over “world model”, “indicators”, “criteria” to “multi-criteria ranking” is both necessary and dangerous. In this process, the usability of the information for decision making rises but so does a possibility for misinterpreting the results. In the worst case scenario, the users belief in accuracy of the application predictions and appropriateness of the indicators and criteria could lead to overestimating of the own competences and negatively affect the usability of the preparedness plans or a performance of the trainees in the real crisis.

As a part of the analysis, decision makers therefore have to consider the limitations of the models with respect to the scale in time and space, the details of the models and the quality of data. Thus, the usage of CRISMA applications assumes mental interaction of the decision maker, and many conceptual considerations therefore affect the mind-set and usage context, not only the internal logic of the CRISMA applications. In our experience, the interaction in front of a simulation application is often at least as relevant as the simulations done by the computer system. In particular, defining the criteria and multi-criteria ranking functions and using these to assess and rank possible solutions can, and in our opinion should, be done iteratively by a group of stakeholders with different interests: Stakeholders explicitly express own preferences through definition of the criteria, ranking functions calculate and compare various options, and then the stakeholders can discuss the possibilities for reaching a compromise solutions in a systematic manner.

5) CONCLUSIONS

Virtual world applications that encourage testing and comparing of alternative scenarios and decisions are well suited for decision support in preparedness phase of the crisis management, but must be used with care. Although a simulated world may feel realistic, the underlying models inevitably reproduce only a small part of the worlds’ complexity and may indeed produce wrong results if misused [Coden et al, 2012]. The same is true for the use of indicators, criteria and multi-criteria functions for analysis and assessment of the virtual world states [Erlich *et al*, 2015]. This reduction of problem complexity is both necessary and dangerous. In the worst case, this reduction of complexity can lead to, allegedly scientifically founded, misunderstanding of the problem at hand.

Unfortunately, learning from past crisis events is difficult –even for re-occurring crisis events [Donahue & Tuohy, 2006]. In spite of the limitations mentioned above, we can therefore often learn more about the effects of various events and decisions on the crisis development and outcomes by experimenting on the virtual world models than in any other way. In this sense the interactive virtual world models for crisis preparedness may indeed be better than the real thing.

At a technology level, the consequent use of world states, indicators, criteria and multi-criteria ranking in all CRISMA applications has allowed to simplify application design and fostered the development of reusable software components. For example: (1) the analysis functionality is completely decoupled from the simulation and therefore reusable in all CRISMA applications; and (2) the patients and resources in Israeli and German pilots are simulated by same agent model(s) – inspite of the very different use cases.

The "less is more" visualization approach of CRISMA that is illustrated on figures 5-8 is in sharp contrast to the overall trend towards 3D immersive reality and realistic real-time serious games that utilize rich multimedia technologies for pre-specified CM tasks [Ahmad et al., 2012], [MacKinnon & Bacon , 2012], [Coden et al., 2012]. In our opinion, the problems addressed by CRISMA are (too) complex already and *should*be presented to users in simplified form. In addition, simplified presentation is a good way to remind users of the limited accuracy of the underlying virtual world models. This should be seen as a best practice for development of preparedness applications that address tactical and strategic levels of decision making.

6) ACKNOWLEDGMENTS

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What You Really Need to be Prepared?

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INTRODUCTION

There have been many articles written about the preparedness. Preparedness obviously means our ability to cope effectively and efficiently with something we do not expect in the very moment. Or something, we do not understand to be a part of a standard living or work process. But also for something which will definitely come in a future, but we do not know all the details and we are not sure about our capabilities to handle it, for example the Graduation test. Our preparedness to wake up in the morning and go to the work is obviously far better than our preparedness for a car accident, industrial disaster, flood or terrorist attack. To prepare itself and keep to be prepared cost some effort, time and money and has no apparent measurable benefit. The preparedness is hard to measure. The final judge is the exceptional situation itself – when a disaster strikes. After it we obviously know very well what was necessary to do while reacting to it. After it we know, what we could do better if we were prepared.

And it applies both to us as individuals and us as organizations. The examples are numerous; one of them might be the City of Prague, which was very seriously hit by the floods in 2002, leaving lot of serious damages. The review and actions which followed up the disaster dramatically improved the preparedness in many dimensions (risk mitigation by investment, modelling, rescue coordination, …) which paid off about 10 later during another huge floods, which were handled much better. [1] [2] [3]

What is the preparedness and how to measure it?

The **Preparedness** has many definitions, mostly tied to war. But for our purposes the UN definition is very close to what we are discussing here: “Forecasting and taking precautionary measures prior to an imminent threat when advance warnings are possible" [4]

In this case we are looking for methods how to assure the best possible preparedness of an organization to any exceptional situation which might arise. By this statement we are making it hard. It could be much simpler – asking about “preparedness for flood”, “preparedness for forest fire”, “preparedness for earthquake” or even “preparedness for massive immigration”. The task targeting to the “universal” or “undifferentiated” preparedness does not lead to perfect plans, procedures, systems etc. but rather to the capabilities of the management team to handle any exception. All the other “partial plans” are just a “must to have” and they are often required by the law, by the company owners or by the common meaning of trustful organization and its reputation. They are also a part of a business continuity plans or risk management, as no big organization can put it behind.

There is another term, which is important to the preparedness: **AWARENESS.**

We may use Cambridge dictionary for the definition: “Knowledge that something exists, or understanding of a situation or subject at the present time based on information or experience”[5]

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[1] http://en.wikipedia.org/wiki/2002_European_floods
[2] http://en.wikipedia.org/wiki/2013_European_floods
[3] Editors: Schanze, Jochen, Zeman, Evzen, Marsalek, Jiri (Eds.): Flood Risk Management: Hazards, Vulnerability and Mitigation Measures, ISBN 978-1-4020-4598-1
[4] https://en.wikipedia.org/wiki/Preparedness
[5] http://dictionary.cambridge.org/dictionary/english/awareness

What is a relation between Preparedness and Awareness?

We have to be aware to be able to get ourselves prepared. It is logically very simple, but it does not necessarily work automatically. It works better in a short term (several days of heavy raining makes us aware of a possibility of floods), but not so easy in a long term (theoretical studies on droughts hardly persuade politics about huge investments, with probably no practical effect in their active life).

How to measure the preparedness? At first there has to be an interest to measure. An interest to discover an answer to the simple question: "How are we doing?". If we are aware of the fact, that our survival, quality of life, profit, position or salary depends on our ability to handle extraordinary situations, we can ask this question to ourselves, to our hired management or to our elected politicians. To prepare answer to such a question may be very hard. We may hear a simple one – "Yes, we are prepared well!" or on the other hand we may obtain a pile of detailed documentation, describing how to handle almost any critical situation.

The only objective preparedness test is the disaster itself – the aftermath analysis can show the reality without any discussions. But it is not probably the optimal assessment method. There are some other ways how to measure our preparedness, even it is something very intangible and relative.

Preparedness assessment

Preparedness assessment is obviously a standard part of risk management. It may differ in procedures if treated on the governmental or region level or in the power distribution company or other organization from critical infrastructure.

There is an ISO[6] standard for the Business Continuity published, which contains a comprehensive description of all the aspects, requirements and evaluation procedures.

To assess the preparedness we may use:

- Documentation assessment

  To formally review all the documents which are required to handle critical situations – crisis plans, continuity plans, notification and warning schemes, resources mapping and availability assurance, legal issues coverage, models, responsibility matrices, communication channels, …

  Those activities can be done internally or with a help of external analytics or companies.

- Personal assessment

  Investigation of knowledge, skills and abilities of individuals. It reflects a quality of education and training, creativity, proper decisioning and engagement. Usually the people exposed to risk and high responsibility activities are a subject of such a review.

  Combination of e-learning/e-assessment tools together with HR managers and psychologists reviews are used to support such assessments.

- Process audit

  This is a most complex activity which includes aforementioned ones. Mostly used for overall review of all standard processes, together with analysis of the consistency of

[6] http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=50038

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alternative processes used in case of failure or emergency. The audit can show the compliance to standards, legislation and compliance of the knowledge of personal to the processes description.

Exercising

There is a method "in the middle" between the formal assessment and real impact analysis after disaster. It is **exercising**.

No formal procedure can show as close to potential reality the real capability of the management team to handle exceptional situation as the exercise. For our purposes we may define the scope of exercise as follows:

EXERCISE is a scenario-based review activity which includes all potential actors which may play a role in such a situation. In our concept the exercises is rather a tabletop one, which no necessity to alarm and move rescue forces, build the protection walls or masquerade the death and wounded bodies full of blood. This "real exercise" may be, of course, part of the game, especially for the reason it is good for the PR. Rescue forces themselves obviously know their job perfectly, as they are daily "in fire".

Our Exercise is close to the verbal and communication game, reflecting the current configuration and nature of the team, the current knowledge and capabilities, with no firm structure. It leaves enough space for creativity, improvisation and unexpected events – as it is in the normal life.

The metrics are then similar to the aftermath analysis. It just deals with estimated damages rather than real ones.

What we really need to be prepared?

Based on the above-mentioned facts, we tried to develop an optimal method how to reach the optimal preparedness, especially in an organization, which has some non-negligible importance for the citizens, owners or customers. It may be government, city management, company management or any other important organization, which may be affected by unexpected event.

All the formal assessments or audits are necessary, but there is still a gap between their impact and better possible preparedness level. All the formal checks might be OK, but the real situation will develop differently than expected.

When the disaster strikes,

Nobody will start to look for the crisis plan and learn procedures, as the actual situation will obviously differs and there is a time pressure. All the routine jobs are usually fulfilled by routine service people and what remains is to carry out important decisions at the top management level. It requires actual, instant, synthetic and understandable information, qualified council of responsible persons, modelling of the potential situation development and consequences overview on resources and fast feedback on the measures taken. Simply it requires a harmonized and experienced team, which does not to waste time by exploration of impasses.

There is a wonderful way, how to ensure to be prepared, how to build and maintain the preparedness. It is an Exercising.

Compared to other methods, it brings several clear advantages:

- The assessment is driven by flexible scenario

It allows to adapt the assessment process to real challenges moderated by the actual performing team

- All important “players” are present

  and left in a position to really react to the situation in scenario and to the behavior of other team members. It usually confronts the “expected” or “planned” to the real possibilities and resources of actual persons and their respective sub teams.

- The exercise run is fully documented

  which allows to record real discussed procedures, which may differ from those “artificially” designed during preparation of crisis manuals

- The experience and knowledge stays in heads of attendees, that means that each participant knows better his counterparts and understand better what he may expect and what is expected from him or her
- The optimal way, how the information basis for decisions is presented during the exercise may be preserved for the future, to recall fast it in the real similar situation
- The scenario may be standardized and disseminated through similar organizations to compare the behavior or to share the know-how.
- The exercise may be repeated regularly, to
  - Improve the performance
  - Maintain the capabilities
  - Introduce new team members and adapt them to the team
  - Adapt to new external conditions (legislation, technology, …)

How to benefit from exercising

The exercising based on open scenarios requires a bit of responsible braveness of the stakeholders or managers. It is clear that in contrary to the well planned structured exercises some skeletons of the cupboards are discovered during the game of this kind. But the results are rewarding. They help to banish those skeletons in time of real disaster and save lives, environment and money.

To get out as much as possible from the exercise, it is advisable to **inherit exercising to the standard structure and operation** of the organization. The people are then accustomed to work in the same environment and utilize the tools available more often than in time of crisis.

In a lot of articles about management the *organizational memory* term appears. Most of the times it is described as some documents, processes etc., keeping the knowledge regardless of the people coming and going. It works fine in large organizations with stable processes and in stable times. For the crisis management purposes we see some other definition: The organizational memory consists of all the documented processes together with the people and their knowledge and skills. It may vary in time due to the team members changing and the optimal method how to keep and possibly improve it is by regular exercising. It simultaneously educates and trains the people and on the other side modifies the stored information to up-to-date content, reflecting the actual composition of the team.

Scenarios may be either focused to some weaknesses discovered by other methods used in Human resources management. For example we may use the psychological profiling of individuals and the team to find potential weaknesses[7].

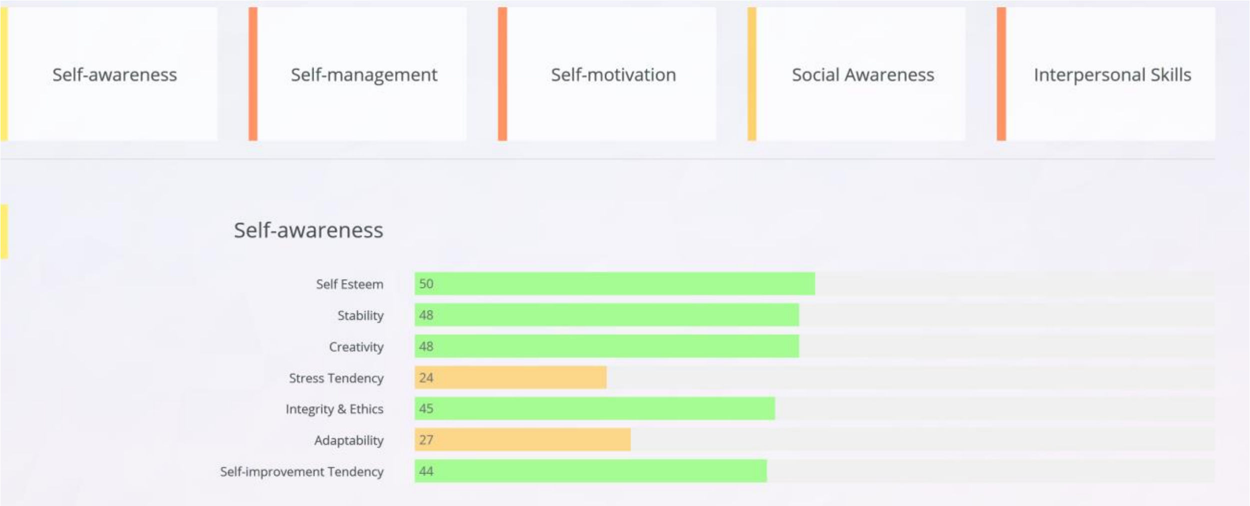

Figure 1 Personal profiling

Based on the results we may tailor specific exercise scenarios and customize them for the particular team. Later we may monitor how the harmony in the team improves the orchestration of the whole organization during the exercises and what influence the exercises have to the team profile and relation of the individual profiles to it.

Scenarios developed and refined during the exercises serve as a good base for support in the real crisis. This is the same with the templates for gathering and visualizing information. By the way – this becomes the real crisis plan, with all actual contacts, resources, warnings and tradeoffs.

Having this done, we may expect much better performance of our organization in hard times.

About tools

To reach high preparedness of our organization to the exceptional situations, besides accepting the exercising as the basic method we may make our work more effective by using some tools. Based on years of experience in the development of software systems in the area of crisis management, we found two basic tools which can help the organizations to design and operate regular exercises and at the same time use them in case of real crisis.

We developed two basic systems – PRACTIS[8] and SITUNET[9]. They were successfully used for example at the large exercise BLACKOUT PRAGUE 2014[10]

SITUNET

The key factor enabling the collaboration of the heterogeneous team as a crisis staff is the clear and simple common situation picture. It needs to visualize the information for everybody, from the expert in power distribution through the city mayor to the citizen. It requires substantial integration

[7] https://www.balancemanagement.com
[8] http://www.tsoft.cz/en/practis
[9] http://www.tsoft.cz/en/situnet
[10] Hudecek T, Juranek J, Pejcoch J: Blackout 2014 Exercise - Prague, The Capital of the Czech Republic, TIEMS Conference Proceedings 2014, Niigata, Japan

of current documents and links to the external data sources with a result at dynamic map, capable to visualize the situation in time, both real and simulated.

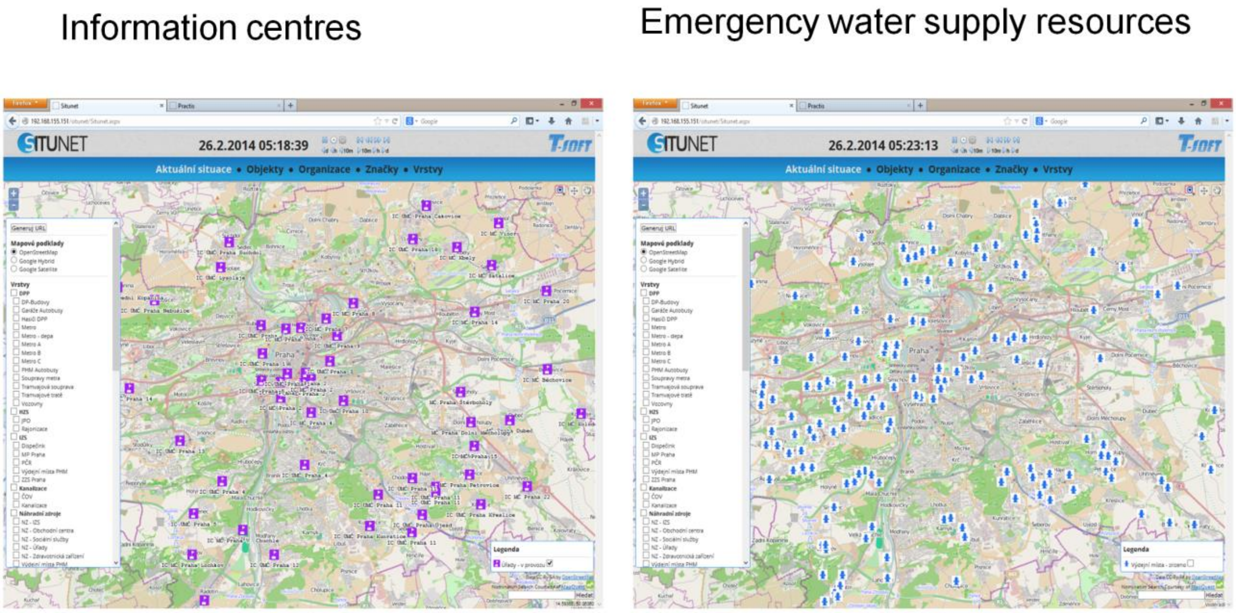

Figure 2 Common situation picture – Prague blackout 2014

PRACTIS

This is a tool for structured design of scenarios which can support the design of them in a linked objects form and then interpret it in the linear timetable form, which allows the execution in the real or simulated time with a possibility to add and modify scenarios on fly and create comprehensive documentation.

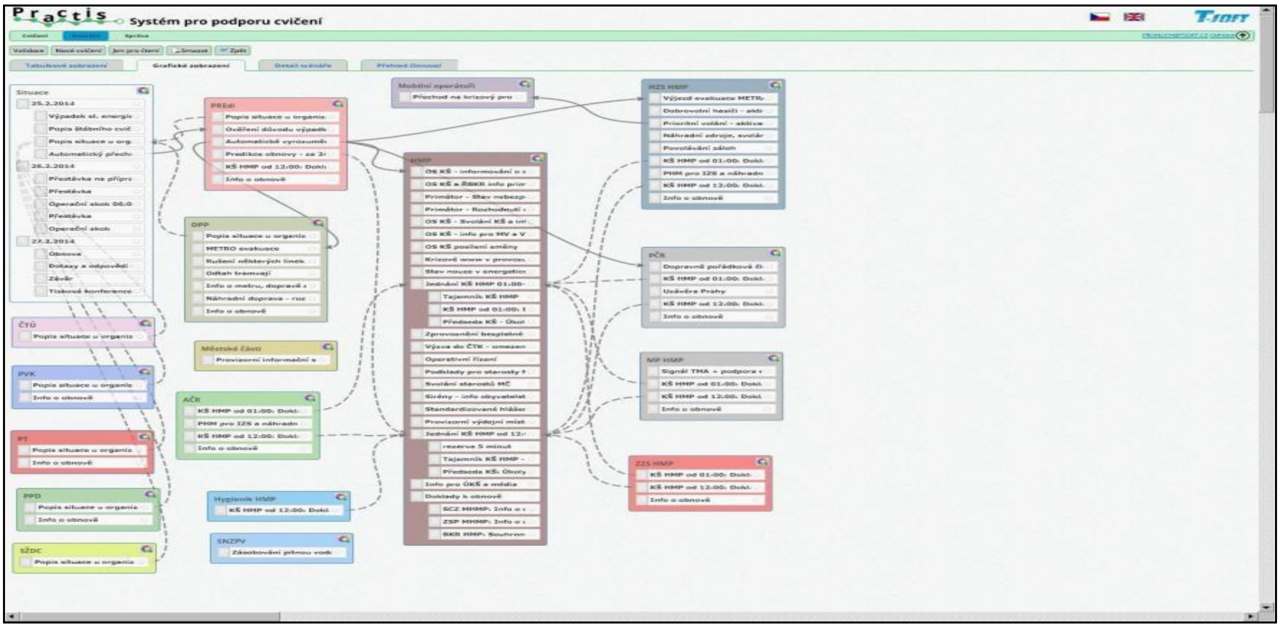

Figure 3 Scenario in Practis – Prague blackout 2014

Conclusions

The answer for the question “What you really need to be prepared?” in the title might be as simple as this: You need a support from all who have the right to decide on the top level, you need enough resources and strong and experienced management team.

What is also necessary is to make stakeholders aware of the potential risks and of the necessary level of ability to handle it effectively and efficiently.

The discussion above shows that the exercising might be the excellent tool how to improve and maintain the preparedness of an organization to exceptional situations. The justification is based on the fact that the formal documentation reviews, people examining and process audits are not capable to reflect fully the special nature of critical situations and their treatment. Due to the complexity and variability of crises, the standard operation procedures and predefined decisioning are not sufficient to cover the wide spectrum of possibilities. There is a big responsibility laying on ad-hoc teams, assembled to resolve the crisis. The formal crisis plans and systems do not help much with ready-made solutions. Ad-hoc teams need quality ad-hoc information and its presentation to provide quality decisions.

The preparedness can be improved and maintained by the periodical exercising – on any level of the team, on any separated segment of the organization. It does not mean that other methods as risk analysis, e-learning, training, resource management do not play in this game – they are for sure necessary part of the preparedness building.

We identified, that the exercising, combined for example with the personal and team profiling and supported by two basic tools – Standard situation picture and Scenario-based practicing is the basic need for any organization, from the state through cities to important companies. The biggest exercise organized and supported by those tools was the Blackout Prague 2014 as was described at TIEMS conference in Niigata, Japan last year. On the other hand – the method and tools are useful to use also at the standard SME company as T-SOFT. For example standard scenario of the fire in the datacenter brought several new views and ideas never discussed before.

The periodical exercising is an optimal tool to build preparedness to the potential crises of any kind.

After all – the exercising might be an interesting game, if taken seriously. It's like with children - they learn best by playing.

Strategy Research of City Infrastructure Vulnerability Appraisal and Slow-Down Adaptation Due to Climatic Change

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Foreword

Cities often are centers of a country or certain region politics, the economy and the cultural, are regions which the population and the capital gather highly. But the city infrastructure is the urban development precondition. The city infrastructure takes the carrier, its safety or not is the urban economy social product life order development foundation, is safeguards the city to be able the normal work support system, also is the important essential for the city sustainable development..

Along with technical development, urban economy society's unceasing reform and progress, the people in aspects and so on disaster defense as well as rescue have yielded many results. But the city modernization advancement speed is quicker, generally speaking, the city scale is bigger, the modernized level is higher, its latent disaster type are more, each kind of disaster occurs the frequency is higher, the risk is also bigger. But the climatic change also is one of important challenges which the city must face. The short-term looked that, the climatic change biggest threat is the frequency which the extreme weather event occurs increases, the harm degree is more and more big. The perspective city present situation, the climatic change already posed the serious threat safely to the city infrastructure construction and the city, moreover the extreme climate event recent years had the frequency and the scope has the obvious ascension tendency, to the social economy influence which the disaster linkage and brought also day by day serious. Looked from the domestic and foreign city infrastructure resistance risk ability situation that, the urgent need takes the corresponding measure to enhance the city infrastructure plan and the construction potency, practically enhances the city infrastructure withstanding extreme climate change to bring the disaster ability, strengthens the city infrastructure safe fortification, has the vital significance regarding the city normal work and the sustainable development, is a country social economy healthy development and the city safe operation provides the solid foundation.

1. Impact of climate change on urban infrastructure

1.1 Impact of climate change

The climatic change influence is various, during various factors which affects is produced the chain interaction, its influence type may divide into the direct influence and the indirect influence approximately (really celebrates dragon, 2004), may divide into specifically the climatic change influence three levels, see Table 1.

Table 1. The level of climate change impacts

Influence level	Affect the subjects		Influence type
First - level influence	Natural ecological subsystem	Non biological factors change	direct influence
Secondary effect		Biological factors change	direct influence
Three stage influence	Social economic subsystem	Production and life changes	indirect influence

As seen in Table 1, the climatic change level and two levels of influences may induce into the climatic change direct influence, main function in city natural ecosystem, including offshore sea ecosystem, farmland ecosystem, forest ecosystem, rivers lake ecosystem and shallow seas and tidelands wetland ecosystem and so on. Among them, the level influence is the climatic change to the nature Asia system Central Africa biotic factor influence; two levels of influences are the climatic change to in the natural ecosystem biotic factor influence, mainly manifests in to the biological resources quantity, the structure, the distribution and in the behavior influence. The climatic change three levels of influences for asked meets the influence, the main function in the city social economy Asia system, including the economical industrial development, the energy expends, the human health, the city infrastructure as well as the human occupies the environment and so on. This article angle of view mainly based on climatic change one of three level of influences - - to city infrastructure influence.

1.2 The city infrastructure system and receives the disaster ability

The city infrastructure is the city livelihood and the development foundation, is the city synthesis service function material carrier. The city infrastructure took city this complex huge large-scale system a sub-system, it includes the transportation system, the energy dynamic system, the correspondence information system, for the drainage system, the environmental protection system, the disaster prevention system six sub-systems, is provides the basic infrastructure for the city people which the production and the life must. They have the linkage organic whole. The city infrastructure movement is in certain situation, between each subsystem has the mutual synergism, when if the disaster approaches, in this system subsystem is mutually uncoordinated, has the problem, the overall system cannot the normal operation, be able to have partial or the whole paralysis. Thus after the city infrastructure disaster prevention, resists natural calamities the whole which, the disaster relief and the disaster restores to receive the disaster ability to affect the city movement situation directly, is the city sustainable development key.

The I... ociety (www.tiems.org)
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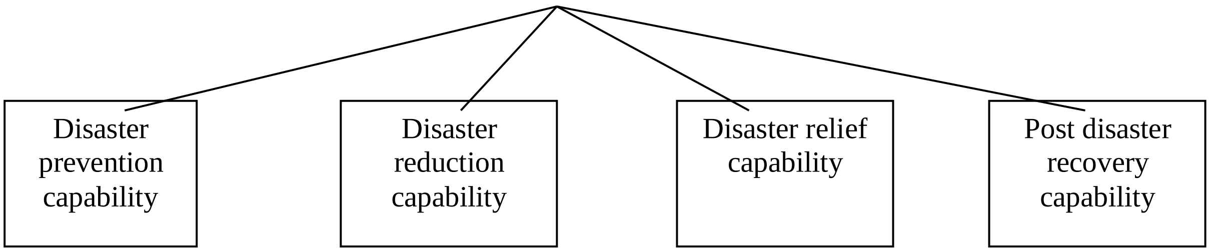

Fig.1. The city infrastructure receives the disaster ability the constitution

There are at least two reasons for the major disasters of urban infrastructure. On the one hand has not carried on the maintenance routine and the renewal to the infrastructure, like this can because cannot maintain and strengthens the city infrastructure function lack receives the disaster ability, cannot satisfy the urban development continually the request, cannot achieve in the city infrastructure function security resists the disaster the request. On the other hand is in city infrastructure plan and construction time standard excessively low, to environmental condition and disaster rank underestimate, thus cannot resist the burst characteristics disaster to safeguard the city system effectively the normal operation and promotes the city sustainable development ability.

1.3 Receives the disaster ability based on the climatic change city infrastructure the quality synthetic evaluation

1.3.1 Receives the disaster ability appraisal target system based on the climatic change city infrastructure the determination

Receives the disaster ability based on the climatic change city infrastructure is refers, emergency is connected the sensitivity at the extreme climate event and the coordination which essential factors and so on government apparatus, manpower, resources display, makes every effort the personnel casualty, the economic loss and the environment destruction who creates in the short time achieve the smallest synthesis handling ability. Should to the climatic change be a dynamic process, after the disaster prevention, resists natural calamities, the disaster relief and the disaster restores four abilities, involves to aspects and so on physical features, social essential factor, human resources, emergency system, is a compound concept, is city integrated development ability manifests importantly.

Establishes the city infrastructure to receive the disaster ability appraisal target system, when selection appraisal target:①The target system should conform to the systematic characteristic, both must synthesize, comprehensively, and must avoid the system too being tedious as far as possible, complex, as well as the target overlaps overlapping.②The target system design should simultaneously satisfy the theory and the actual two aspect demand, the system establishment cannot too academic, does not favor the actual operation, simultaneously cannot too simple rough, should in the science, in the integrity foundation guarantee the target is objective, is real.③The target system establishment should be feasible. The target system design should be advantageous for the user to accept, this includes the data easy to gain the degree as well as the model computation simple degree.④The target system establishment will be supposed to focus on the future. Should while satisfy the present stage city infrastructure to receive the disaster ability appraisal request, will take a broad view as far as possible in the next city infrastructure development change and the development direction, will serve for the next city infrastructure construction and the improvement.⑤The target system both must have the crosswise comparability, and must have the longitudinal comparability.

Establishes the city infrastructure to receive the disaster ability appraisal target system, in which weight coefficient is determines (Table with the analytic hierarchy process 1).Because each target unit is different, in order to calculate convenient, needs to carry on zero dimension processing to each target.

Regarding is most greatly most superior the target, the formula:

$$X'_{ij} = (X_{ij} - X_{min})/ (X_{max} - X_{min}) \quad (1.1)$$

Regarding smallest most superior target, formula:

$$X'_{ij} = (X_{max} - X_{ij})/ (X_{max} - X_{min}) \quad (1.2)$$

In the formula X_{ij} is the ***i***th object jth target primitive value, X'_{ij} is the ith object jth target quantification value, X_{min} and X_{max} , respectively is this target maximum value and the minimum value. May see through the formula $X'_{ij} \in [0,1]$.

Table 2. Receives the disaster ability appraisal target system based on the climatic change city infrastructure

		Specific index X	**Weight W**
Disaster prevention capability (PI)	Disaster prevention measure investment ability	Risk index of pregnant disaster environment	
	Disaster analysis and monitor forecast ability	Risk index of disaster causing factors	
	Seeks asylum place emergency adaptability	Vulnerability index of the bearing body	
	Environmental protection	Content integrity of emergency plan； Emergency drill number (times / year)	
Disaster reduction capability (FI)	The transportation system resists natural calamities ability	Per capita highway traffic mileage； Roading density： Total length of subway project；	
	The communication system resists natural calamities ability	Total postal service； The average per household has	

		telephone quantity；	
	The energy system resists natural calamities ability	Average per person life electricity consumption； Gas penetration rate；	
	Resists natural calamities ability for the drainage system	Water consumption per capita； Per capita total mileage of underground sewage； Water supply comprehensive production capacity；	
Disaster relief capability (EI)	Material reserve system	Emergency communication equipment	
	Ability of medical aid	Million people have bed number； Million people have a number of doctors	
	Government emergency management capability	Comprehensive capacity index；	
	Capital investment intensity		
Post disaster recovery capability (RI)	Post disaster reconstruction capability	Tents and sleeping bags	
	Ability to deal with the aftermath	Number of personnel	
	Social security compensation mechanism	Labor quantity； GDP ratio	
	Funds in place	Capital investment	

1.3.2 Receives the disaster ability appraisal model based on the climatic change city infrastructure

According to the disaster emergency management cycle theory, the risk management theory and the city infrastructure receive the disaster ability appraisal target system, the use weighting quality synthetic evaluation law and the analytic hierarchy process, establishes the following city infrastructure to receive the disaster ability appraisal model:

$$CIEI = PI \times W_{PI} + FI \times W_{FI} + EI \times W_{EI} + RI \times W_{RI} \quad (1.3)$$

$$PI = \sum_{i=1} A_{PI} W_{PI} \quad (1.4)$$

$$FI = \sum_{i=1} A_{FI} W_{FI} \quad (1.5)$$

$$EI = \sum_{i=1} A_{EI} W_{EI} \quad (1.6)$$

$$RI = \sum_{i=1} A_{RI} W_{RI} \quad (1.7)$$

CIEI is the city infrastructure receives the disaster ability index, it expressed the city infrastructure the disaster bearing capacity which brings to the climatic change. PI, FI, EI, RI respectively be the disaster prevention ability index, resist natural calamities ability index, the disaster relief ability index and restore ability index, WPI, WFI, WEI, WRI expressed correspondingly disaster prevention ability, resists natural calamities ability, disaster relief ability, restores ability the weight, in the above equation, after $\mathbf{A_i}$ is the target i quantification value, W_I is the target i weight.

Based on the climatic change to the city infrastructure bearing capacity appraisal is an extremely complex work, involves many factors, must think the complete quota accurate carries on appraisal existence certain difficulty to it, in the appraisal target selection possibly can have is short of, can cause the appraisal result to receive slightly affects. Here is only an attempt, but also has some insufficiencies, from now on will also have to consummate in the target formulation aspect.

2. The main strategy to strengthen the city infrastructure construction to the climatic change

Appraises the city infrastructure based on the climatic change to receive the disaster ability, finally is should provide the policy-making basis and the science support for the formulation to the climatic change related strategy. In order to enhance to the climatic change adaptability, avoids the climatic change has the adverse effect for the urban economy society and the ecological environment, should changes two aspects from the slow-down and climatize to formulate comprehensive should to the strategy.

2.1. Main principles of response to climate change

2.1.1 Integrates the climatic change factors to the city sustainable development plan and the implementation.

The climatic change to the city nature, the economy and the society and so on various subsystems will bring each kind of adverse effect. Therefore, in formulates the city industrial structure adjustment, the energy developmental strategy, the ecology construction and the protection and so on involves the sustainable development in the plan and the implementation process, should consider fully the climatic change factor, simultaneously integrates the climatic change latent influence and the slow-down and the climate change positive role the correlation plan in the formulation and the implementation process, thus realizes truly under the sustainable development frame solves the climatic change problem.

2.1.2 Strengthens the international cooperation, should together to the climatic change.

Use international climatic change domain fund, the technology and the mechanism, embark from the local actual situation, enhancement multilateral or bilateral international cooperation, attracts more funds, the technology for the local sustainable development. Discuss together through the experience share and the countermeasure, further advances the whole world to be supposed together to the climatic change.

2.1.3 Adhere to the principle of mitigation and adaptation.

The slow-down and the climate change is should to the climatic change challenge two organic constituent. The slow-down strategy is in order to slow down reduces the greenhouse gas which the whole world climatic change adopts to discharge as well as to increase each measure and the policy which the greenhouse gas collects. The measure to actual or the estimate climatic change influence vulnerability which the adaptation strategy for reduces the city compound ecosystem which proposes the proposal and adopts.

2.1.4 Overall plan low-carbon urban development and other urban development prospect, enhancement climatic change related science and technology research and innovation.

"The low-carbon city" is under the whole world climatic change background the city sustainable development effective pattern. Should practically grasp and be clear about "the low-carbon city" the concept and the connotation, plans under fully the sustainable development frame the city other development prospect. Should have to display the advance in technology and the technological innovation function fully to the climatic change, enlarges to the climatic change correlation science and technology work organization coordination and investment dynamics, speeds up the slow-down and the climate change domain significant technology research and development, the demonstration and the promotion.

2.2. The slow-down climatic change brings influence

2.2.1 Optimization industrial structure, transformation economy growth pattern.

The optimization industrial structure, speeds up the development tertiary industry, specially develops the modern service industry, reduces the national economy development the excessive dependence which grows to the industry; Supports the low-carbon industry and the green product development positively, the promotion industry competitive power enhancement, reduces the traditional industry the fixed effect; Advances the high-tech industry positively the development, suppresses consumes energy high, the high pollution profession; Enhances the market access standard, eliminates gradually falls the after-birth energy, reduces the unit GDP carbon emissions effectively the intensity, reduces the economical growth pattern to the energy demand dependence.

2.2.2 The improvement energy consumption pattern, enhances can the effect.

Presently, mostly was the city energy consumption pattern still by the fossil energy primarily, an energy structure still occupied the main status by the coal, the petroleum next best. Should enlarge the new energy and renewable energy development use support dynamics, develops and promotes the new energy and the renewable energy as circumstances permit; Through formulation and implementation policies and so on subsidy, preferential benefit tax revenue and price, low-interest loan, develops and promotes the nuclear electricity, the solar energy, the wind electricity and the small water and electricity massively and so on the renewable energy and the new energy technology; By energy sustainable development support economic society sustainable development.

2.2.3 'Low-carbon city 'spatial plan strategy.

The city space expansion took the urbanized coercion the composition factor, affects the urban climate change vulnerable important risk essential factor. Slows down the city carbon emissions through the optimized space pattern to include specifically: Avoids the city disorder spread growing, optimizes the urban setting reasonably, constructs the city space compact multistage network development pattern; Constructs the sustainable transportation system, reduces the journey demand and the journey distance, develops the mass transit vigorously; Encourages the different city function with the place mix use, avoids the simplification the function district, enhances the short distance journey proportion; The community space stratification plane, emphasized the mix use and the moderate high density develop the strategy; Develops the walk, the bicycle and the public transportation vigorously and so on the highly effective green transportation vehicle, satisfies the city peoples, the association and the social mobility request.

2.3. To adapt to the impact of climate change

2.3.1 Raises entire society climate change consciousness.

Using each method popularization climatic change aspect related knowledge, emphasized enhances the entire society to participate in the climate change vigorously consciousness and ability, enhances to the climate change importance and the pressing understanding, builds all the people climate change the good environment, urges the public positively to undertake the climate change social responsibility.

2.3.2 To develop regulations to adapt to climate change

Formulation compatible technology standard, and through establishment responsibility system impetus realization all levels of administrative department's compatible motion. Carries on the climate change the model district construction, the formulation seacoast protection and the development plan, and develops coastal and in the marine important project production construction plan at the coast region urban construction considers the climatic change factor. Advances the profession and the region adaptation plan gradually, the basis country adaptation goal determination profession and the region adaptation goal and first the item, the formulation adaptation course of action.

2.3.3 Establishes the effective climate disaster emergency and the response mechanism.

Along with the city fast expansion, the population and the economic output swift and violent growth, the loss which the same intensity catastrophe weather climate event (for example typhoon, rainstorm, storm unrest, snow disaster and so on) will create obviously is enlarged. The municipal government various departments should act according to the national natural disaster special emergency predetermined plan and the department responsibility, the formulation have the operational predetermined plan implementation means and the emergency operation regulations; Enhancement extreme weather and climate event monitor, early warning, forecast ability, promotion extreme climate event emergency capability: The enhancement climatic change emergency relief maneuver and enhances the resident to against disasters the skill knowledge.

2.3.4 Carries out the city vulnerability appraisal and the key technologies research.

The climate change belongs to "the public goods" purely, the vulnerability appraised in particular needs the massive foundational data, needs the country to aim at the city, in particular the super city development vulnerability appraisal key technologies research and the demonstration, determined reduces the climate risk the goal and the way. Should integrate the city plan, the land use management, the infrastructure investment, the service supply, the construction and in the plan design standard adaptation strategy practice motion the risk to the measure, establishment department information communication or policy-making platform, science reasonably overall assessment and government climate risk.

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Nepal Earthquake 2015: Lessons Learnt and Way Forward

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Keywords

Earthquake, Proactive, Impact, Management, Legislation, deficiencies

Abstract

Nepal is prone to various types of disasters such as: earthquakes, floods, landslides, fires, epidemics, avalanches, windstorms, hailstorms, lightning, glacier lake outburst floods, droughts and extreme weather events. Among all these disasters – earthquake is the most scary and damaging. The effects of a disaster, whether natural or human induced, are often far reaching. In addition to the natural factors, the losses from disasters are increasing due to the human activities and absence of proactive legislations. Fundamentally, the weak structures have been found as the major cause of infrastructure collapse in earthquakes. This emphasizes the need for strict compliance of town planning bye-laws and earthquake resistant building codes. Thus, proactive disaster management legislation focusing on disaster preparedness is necessary. This paper analyses the critical gaps responsible for emphasizing the seismic risk and of factors that would contribute towards seismic risk reduction to enable various stakeholders to address the critical areas for improving seismic safety in Nepal and other earthquake prone countries. Additionally, this paper aims to pinpoint the deficiencies in disaster management system in Nepal with reference to the devastating earthquake of 25 April 2015 and suggest appropriate policy and advanced technical measures.

1. Background

An earthquake disaster is the most terrifying disaster in Nepal but Nepal is no limited to just earthquakes; there are also disasters such as floods, landslides, fires, avalanches, windstorms, hailstorms, lightning, glacier lake outburst floods, epidemics, droughts and so on. There have been many occurrences of earthquake disasters in Nepal that have caused heavy casualty losses and physical property damages, adversely affecting the overall development of the country. Nepal's proximity to earthquake hazards is mainly due to her young and fragile geology. Haphazard and unplanned settlements and poor construction practice are the other reasons that have made her highly vulnerable to earthquake impacts. Nepal may have encountered many earthquakes throughout history; it has the record for the greatest loss of life dating back to the 12th century. Since then Nepal has encountered 16 major earthquakes, including the recent devastating earthquake of 25 April 2015.

2. The Devastating Earthquake of 25 April

A 7.8 magnitude earthquake struck Nepal on 25 April 2015 (11:56am local time). It occurred in a geological collision zone, where the Indian tectonic plate pushes north into the Eurasian plate, moving the ground an average of 2cm a year.The epicenter was in Barpak Village of Gorkha district which is 81 km northwest from Kathmandu (the capital city). The devastating earthquake killed nearly 9,000 people, injured over 22,000 and rendered millions homeless. More than one hundred thousand households in the urban and sub-urban areas of Bhaktapur and Lalitpur were either totally destroyed or severely damaged, and their inhabitants have been displaced. The situation in rural areas was much worse. The damage was worst in the districts of Gorkha, Dolkha, Sindupalchiok, and Dhading, where many households live in poverty in extremely remote, rural, secluded and hilly villages. In general it was the oldest and most poorly built houses which were most likely to collapse, which were typically inhabited by the poorest, more vulnerable households. The earthquake was followed by a number of aftershocks throughout Nepal, with one shock reaching a magnitude of 6.7 on 26 April at 12:54 am local time. In addition to a number of human casualties, Centuries-old buildings were destroyed at more than five different UNESCO World Heritage sites in the Kathmandu valley. This earthquake was the largest to hit Nepal since the 1988 Nepal earthquake and the Nepal–Bihar earthquake of 1934. All these major earthquakes established that the casualties were caused mainly due to the collapse of infrastructures. Before that Saturday in April 25, 2015, seismologists had been warning of another Big One for years. However, it was shallow, causing violent shaking on the surface. Fortunately, this one was smaller than anticipated. This earthquake also affected some parts of India, Bangladesh, and the Tibet Autonomous Region of China. Tremors were also felt in Bhutan and Pakistan.

On 26 April 2015, the Government of Nepal declared an emergency in the worst affected districts and requested for international humanitarian support.

Picture 1: Damaged Kathmandu Durbar Square which is a Cultural Heritage

On 12 May 2015 at 12:50 local time another strong earthquake measuring 7.3 magnitude struck with the epicenter in Sunkhani of Dolkha district. The epicenter was 76 km northeast of Kathmandu. This area was already affected by the 25 April quake. The initial quake was followed by several aftershocks including a 5.6 magnitude. This quake toppled already weakened buildings, triggered a series of landslides, which further hampered relief efforts. This quake alone killed more than 100 people. The casualty was extraordinarily low given the extent of the damage, due to the time of day of the quake.

According to the Department of Survey of the Government of Nepal, the movement of tectonic plates that triggered massive earthquake in the country on April 25 caused the altitude of Kathmandu Valley to increase by 80 centimeters. In total 376 numbers of aftershocks with Local magnitude>= 4 have been recorded till 13 August 2015.

ore the earthquake (left) & after the earthquake (right)

Picture3: Avalanche in Mt. Everest where dozens of people died

3. Particulars of the Earthquake

Details of the earthquake are given below in Figure 1.

Figure 1

2015 Nepal earthquake

Date	25 April 2015
Origin time	11:56:26 NST[1]
Magnitude	7.8M_w[1] or 8.1 M_s[2]
Depth	15.0 km (9.3 mi)[1]
Epicenter	28.147°N 84.708°ECoordinates: 28.147°N 84.708°E[1]
Type	Thrust[1]
Areas affected	Nepal,,India, China, Bangladesh

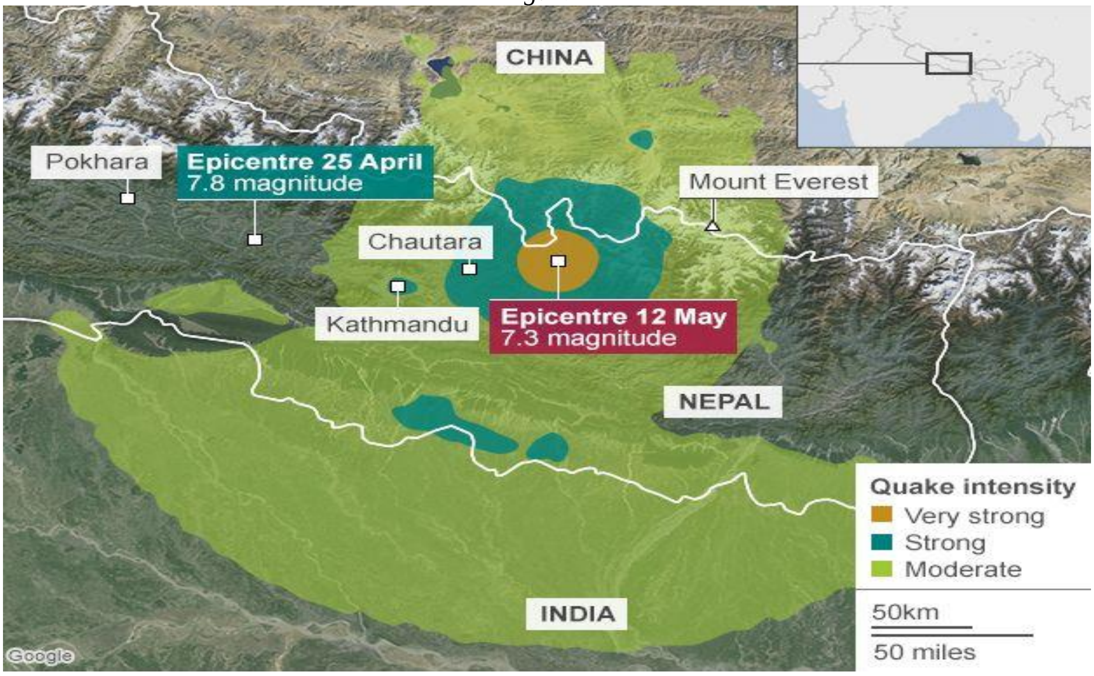
Total damage	≈$5 billion (about 25% of GDP)[3]
Max. intensity	IX (*Violent*)[1]
Aftershocks	7.3M_w on 12 May at 12:51[4] 6.7M_w on 26 April at 12:54[5] No. of aftershocks(>=4ML)=365 (as of 31 July 2015)[6]
Casualties	8,844 dead in Nepal (officially) and 9,017 in total[7][8] 22,307 injured (officially)[7]

Source: (1) United States Geological Survey. 25 April 2015. Retrieved 12 May2015 (2) China Earthquake Networks Center. 25 April 2015. Retrieved28 April 2015 (3) economist.com (4) "M6.6 - 49km E of Lamjung, Nepal"(5) usgs.gov. (6) National Seismological Centre, Nepal(7) Nepal Disaster Risk Reduction Portal. drrportal.gov.np. Retrieved 28 May 2015 (8) The Times of India. 7 May 2015. Retrieved 9 May 2015.

The 2015 Gorkha earthquake affected 31 districts out of which 14 districts namely; Gorkha, Sindhupalchowk, Dhading, Kavre, Dolakha, Nuwakot, Ramechhap, Sindhuli, Rasuwa, Kathmandu, Lalitpur, Bhaktapur, Makwanpur and Okhaldhunga were hard hit.

Please see Figure 2 below for the ramification of the 12 May 2015 earthquake:

Figure 2



Source: USGS

Until now, this devastating earthquake caused 8,844 deaths and 22,303 injuries, flattened hundreds of thousands of homes, and disrupted community lives.

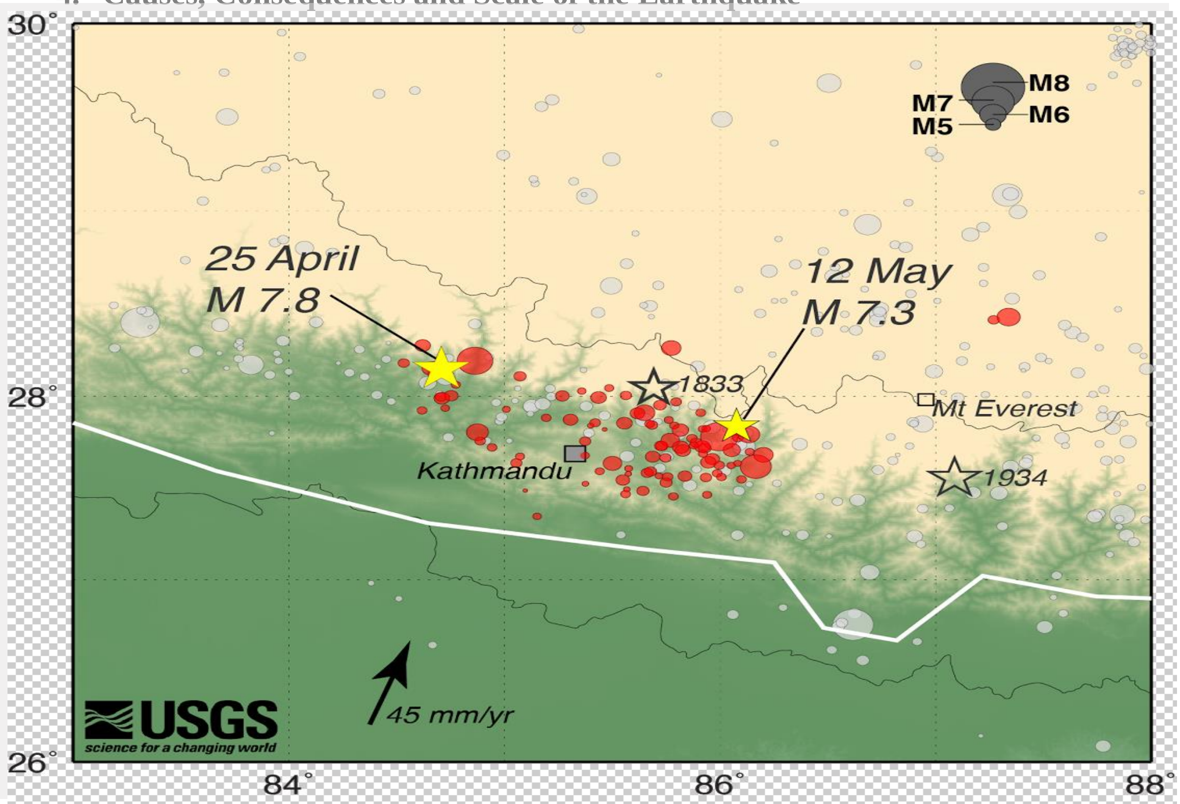
Please see Table 3 below for detail data.

Table 3: Losses due to the Earthquake (As of 27 May 2015)

Particulars	Nos.
Persons dead	8,890
Missing	198
Injured	22,303
Affected Families	11,24,358
Displaced Families	6,51,675
Houses Damaged (Fully)	5,98,401
Houses Damaged (Partially)	2,83,553

Source: Ministry of Home Affairs, the Government of Nepal

4. Causes, Consequences and Scale of the Earthquake



Source: USGS

This earthquake occurred in a geological collision zone, where the Indian tectonic plate pushes north into the Eurasian plate, moving the ground an average of 2cm a year. Over decades, stress built up along a stretch of the fault line, which is called the Main Himalayan Thrust (MHT) fault, close to Nepal's capital Kathmandu. In this area, the boundary between the two plates had become locked - stuck together by friction and so immobile - building up energy that only a major earthquake could release. Prof Jean-Philippe Avouac, University of Cambridge believes that the quake on 25 April only released part of this pent-up pressure. "If the earthquake had ruptured all the locked zone all the way to the front of the Himalayas, it would have been a much larger earthquake," says Prof Avouac. Some other researchers believe that some of this stress has shifted west, to an area stretching from the west of Pokhara in Nepal to the north of Delhi in India. A major earthquake there is already long overdue: the last happened in 1505 and is estimated to have exceeded M8.5. The researchers say the new stress that has moved there could already be adding to the tension that has been building up over five centuries. "At the moment, we are quite worried about western Nepal," said Prof Avouac.

New data has revealed that the devastating quake that hit Nepal in April did not release all of the stress that had built up underground, and has pushed some of it westwards. The research is published in the journals Nature Geoscience and Science. Its authors say more monitoring is now needed in this area. Prof Jean-Philippe Avouac, from the University of Cambridge, told BBC News: "This is a place that needs attention, and if we had an earthquake today, it would be a disaster because of the density of population not just in western Nepal but also in northern India, in the Gangetic plain." "We don't want to scare people, but it is important they are aware that they are living in a place where there is a lot of energy available," Prof Avouac clarified.

Commenting on the research, Prof David Rothery from Open University said: "Monitoring techniques have now advanced to the stage where we can work out how a previously 'locked' fault has 'unzipped' during the couple of minutes that it takes a major earthquake to happen. "Lives would be saved by drilling school children in western Nepal and the nearby plains of northern India in how to react in the event of an earthquake, and in ensuring that at least school buildings are adequately constructed to survive seismic shaking."

5. Response

Immediately after the earthquake, although there was chaos, confusion and distress -- National Emergency Operation Centre (NEOC) of the Ministry of Home Affairs was activated at level-IV by following the National Disaster Response Framework-2014 and Standard Operating Procedure (SoP). Soon after the quake the Prime Minster, Home Minister, other Ministers, Chief Secretary, Secretaries, high level officials and the security forces were present at the NEOC. Central Command Post was established and Security forces were mobilized immediately for Search and Rescue (SAR) operation with heavy equipment and helicopters. Altogether 66,069 Nepal Army personnel, 41,776 Nepal Police, 24,775 Armed Police Force and 22,500 Civil Servants were mobilized for response. Helicopters were used in remote areas for SAR operation from Nepal Army, India, China, U.S.A. and private sector. In total 7,606 people were rescued by 4,299 flights of Nepal Army, foreign and private sector helicopters. A total of 4,689 people were rescued by land route. Helicopters were mobilized in the command of Chief District Officers (CDO) of Sindhupalchock, Dolakha, Dhading, Nuwakot, Rasuwa and Gorkha districts.

A significant number of volunteer groups and amateur aid workers also provided some assistance. There has also been a considerable amount of aid distributed by various social organizations and also individuals who have collected cash and kind on their own initiative. This includes skilled technical personnel such as doctors, nurses, and engineers as well as unskilled personnel making in-kind distributions. The overall biggest amount of recovery assistance came from cash directly to households from remittances as well.

Although the Nepalese government and security forces - particularly the military - played a significant role in response works, there was serious lack of capacity and resources.

6. Damage Pattern

Mostly, old infrastructures were collapsed and/or severely damaged by the earthquake. Some buildings which seemed quite stable were also damaged because of the poor quality of construction materials, and poor construction supervision. In the sub-urban areas of Kathmandu valley, houses are built with bricks or mud. Outside the Kathmandu valley, particularly in rural areas, the houses are built of mud and mortar with thatch or brick roofing, which easily collapsed in the earthquake. In Tarai and in poorer villages also houses are built with bricks or mud. In the hilly region, stones and mud walls are very common. Poor people use bamboo-reinforced mud walls. The western area is mainly farmland, and the poorer communities live in mud and straw huts, a number of which disintegrate and crumble in the event of flooding.

During the 2015 earthquakes, it was primarily the older buildings which collapsed completely, many of them built with clay bricks or stone, and lacking sufficient vertical and horizontal beams. These dwellings are also most likely to have been inhabited by the poor. Reinforced concrete homes sustained much better, though in the areas closest to the epicenter many of these also collapsed or cracked beyond repair. The damage pattern of the earthquake is as following:

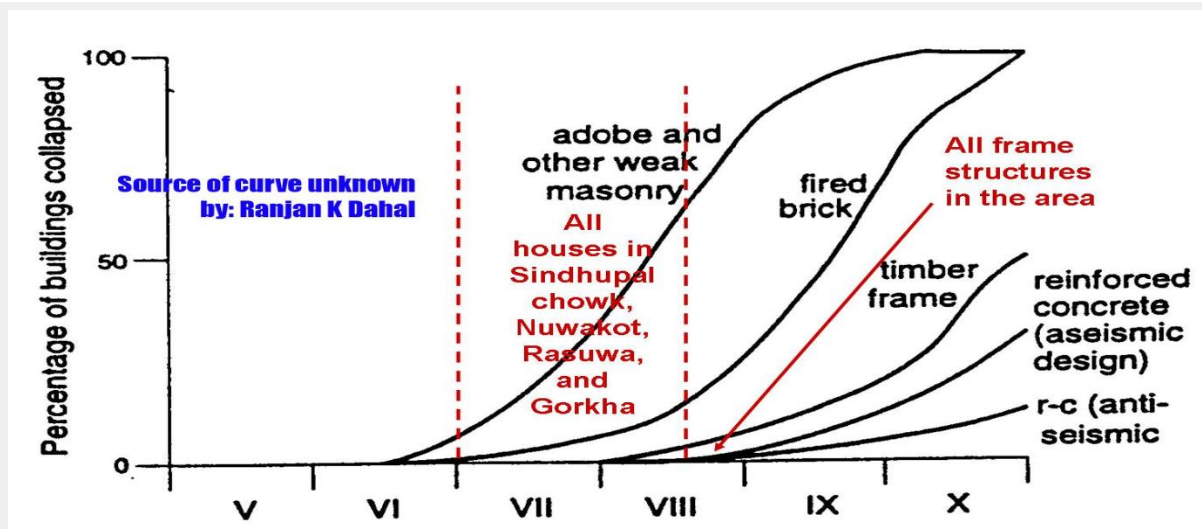


Figure 1

A preliminary estimate indicates that more than 80% of homes in the 14 most affected districts were severely damaged, creating huge mounds of rubble and debris impeding life-saving operations and access to affected areas. More than 25 hospitals and more than 900 smaller facilities, predominantly village health posts which supply basic medicines and other routine services in remote communities outside the Kathmandu valley, were completely or partially damaged in the earthquake. Since the 25 April disaster, nearly 2 million people have been displaced because their homes have been destroyed or the fear that their homes may not be safe enough to reside in. Many are still living in open fields in tents.

Data collected from advanced GPS stations have revealed that the death toll could have been far higher. These stations track tiny shifts in ground position, at a rate of five measurements every second. The seismic waves travelling underground were a lower frequency than expected, causing the ground to vibrate more gently. Prof Jean-Philippe Avouac, University of Cambridge says that "this earthquake didn't generate a lot of high frequency waves, which would have been devastating for the small buildings in Kathmandu. They could withstand the earthquake because of the characteristics of the 'pulse' - and its relative smoothness."

The Post-Disaster Needs Assessment (PDNA) carried out by the government estimates that $6.7 billion will be needed for reconstruction and rehabilitation. The government has already set up a National Reconstruction Fund of $2 billion for post-earthquake reconstruction and rehabilitation works.

7. Problems Associated with the Great Earthquake

The response work was highly criticized as it was not prompt and well organized. A key complaint was of a slow and inadequate relief effort, which failed to reach in due time to many of the affected people of remote, rural and hilly areas. It was mainly due to the lack of a strong road network and transport resources, especially helicopters, and a serious bottleneck at the airport. Major delays were also caused by bureaucratic procedures and even bitter mutual accusations - both in public and private—over who was to blame and who should be in control of resources.

Thousands of people in the affected districts still lack even the most rudimentary shelters and even those who have received tarps are suffering. The monsoon season has begun and the affected people are in a difficult situation. Tarps and tents will not be able to withstand the monsoon downpour. While local governments have been working day and night to provide relief supplies to people in the affected districts, they have found it very difficult to procure adequate supplies from the center.

Now, the monsoon has already started which will not only expose households living in temporary or transitional shelter to extreme weather, cold and increased diseases, but also to further collapses of houses damaged during the earthquake. Every year several dozen houses will collapse due to landslides and floods in heavy rains, and this year the situation is much worse as the earthquake has triggered the mountains causing numerous cracks. Landslides and rains will aggravate the condition of roads, adding to the logistical challenges.

8. International Cooperation and Disputes

On 26 April 2015, the Government of Nepal declared an emergency in the worst affected districts and made a request for international humanitarian support. For any government, it would be difficult to cope alone with such a huge disaster. Therefore, international assistance is pertinent for response and rehabilitation efforts for victims and the rebuilding of structures. It is more difficult in Nepal due to some of its inaccessible landscape and difficult terrain. Unfortunately, it risks adding a man-made calamity to a devastating natural disaster. During the course of search and rescue efforts, an American helicopter crashed near the Nepal-China border resulting in the sad demise of five American soldiers, two Nepali soldiers and five disaster victims.

Actually, relations between the Nepal government and the international community were not conducive for some time right after the earthquake. However, it did improve as time passed. There was the problem of mutual trust. Actually, the donor communities didn't fully trust the government; questioning its ability to deliver services while the government wasn't happy because the donor communities wanted to spend the assistance money through their agents. On the other hand the Nepalese government wants any assistance to be collected into the Prime Minister Relief Aid Fund and then channel to the affected areas. In other words, the government wants to adopt one door policy.

Earthquake victims have repeatedly complained that the rice distributed in relief was "substandard and inedible". The rice was distributed in various districts by the World Food Program (WFP) through Nepal Red Cross Society (NRCS).

9. Set Back to the Development Process

This mega disaster will have a long-term effect on Nepal's economy and development efforts for several years. The agriculture, industry, tourism and service sectors have been badly affected. This is a major set-back. It will take many years to revive. If the government will be efficient, effective and honest then the recovery will be fast. If not, it will take a long time and will pass through the similar situation as Haiti has faced since its own earthquake in 2010. This is high time for Nepal to learn a lesson from Haiti while Nepal must not repeat the mistakes done by the Haitian government after the 10 January 2010 earthquake.

10. Generous Aid Pledges Delight Nepal

There was a donor community meeting on 25 June 2015 in Kathmandu, Nepal. The highest-profile international donor conference ever held in the country amassed more than 300 delegates from 56 nations, development partners and the donor community. In a major boost to Nepal's reconstruction and recovery efforts, development partners and the donor community have pledged $4.4 billion in aid during the International Conference on Nepal's Reconstruction (2015). This has come as a huge relief to the reconstruction and recovery bid and brought cheers to the government. As a matter of fact, this amount has been beyond the expectation of the government.

11. Formation of Reconstruction Authority Through An Ordinance

An Ordinance on 'Reconstruction of the Structures Damaged by Earthquake -2015′ has been promulgated to carry out post-earthquake reconstruction works. According to the ordinance, an 11-member Reconstruction Authority would be formed under the chairmanship of Prime Minister, including four ministers picked by PM, a chief executive officer, Vice-chairperson of the National Planning Commission, Chief Secretary and three experts having 15 years of experience in related field after completing post-graduate degree in infrastructure engineering, law, economics, management, economic or social development as members. The tenure of the authority will be five years and the government can either extend its term by a year if the tasks of reconstruction remained incomplete or assign any other body for the same. The CEO can recommend chairman to appoint secretary of the authority from among government officers. Laws related to acquiring and registering land, public procurement and Environment Impact Assessment will not be applicable in the quake-hit areas to accomplish the task of reconstruction rapidly.

A separate 11-member Development Assistance Coordination and Facilitation Committee will be formed with a CEO at helm and include national and international development partners and civil society representatives.

Reconstruction Authority's salient tasks

- To determine total loss due to earthquakes
- To acquire necessary land following legal procedures
- To order authority concerned to remove physical structures after providing compensation to owners
- To coordinate with different bodies for effective implementation of reconstruction work
- To order owners to remove their damaged structures or to remove them at their cost.

The authority would direct the concerned ministries to accomplish necessary work of reconstruction providing them with necessary budget from a separate fund created for reconstruction work.

12. Challenges, Gaps and Lessons Learnt

It is still early to assess the total impact of the 2015 Nepal Earthquake. There were psychosocial consequences of that devastating earthquake disaster. The nightmare and traumatic situation caused by the disaster upon many people **particularly among the children and adolescents** are still there and may remain for a prolonged time.

The following challenges and gaps were identified after the earthquake:

12.1 Search and Rescue (SAR) works carried out by the security personnel of Nepal and foreigners was commendable. But it was slow and inadequate while they failed to reach in due time in the remote, rural and hilly areas and it was not well-organized. Of course, sometimes it was compounded by the lack of equipment, road network, transport, and well-trained skilled human resources.

12.2 Delay and serious lapse in damage and need assessment was felt almost all the time. Due to this although there was high number of international SAR team they could not contribute considerably as expected. Hence, the productivity of the international teams was not in compatible with the heavy investment upon them.

12.3 Emergency warehouses, prepositioning of relief materials with proper inventory were also lacking.

12.4 Debris management was found as one of the big problem basically because of the lack of debris management equipment, tools and techniques.

12.5 Accurate and proper communication between District Emergency Center (DEOC) and Central Emergency Operation Centre (EOC) was not effective.

12.6 Identification Cards to the affected of ID cards to affected families for systematic relief distribution.

12.7 Although the response phase was over some International Search and Rescue Teams remained unnecessarily for a prolonged time causing burden to the concerned government budget.

12.8 Most of the personnel from international organizations worked in tourist visa which is actually illegal.

12.9 In addition to the identified 82 open spaces, more open spaces are required.

12.10 A weak database and an absence of modern technology were other bottlenecks for poor response in Nepal.

What are the lessons? –

Critical areas of concern of the Nepal Earthquake can be summarized as following:

a) Lack of awareness as well as coordination among disaster management stakeholders;

b) Inadequate attention to structural mitigation measures in the engineering education syllabus;

c) Weak law enforcement and monitoring of building codes and town planning;

d) No licensing system for engineers and masons;

e) Absence of earthquake resistant features in non-engineered construction in sub-urban and rural areas;

f) Lack of training for professionals in earthquake resistant construction practices; and

g) Lack of adequate preparedness and response capacity among various stakeholder groups.

The biggest lesson Nepal learnt from this earthquake is that the threat of earthquakes will never end while Nepal is in seismically very active zone. The best way to be safe from earthquake hazards is to build earthquake resistant infrastructures. There should be no COMPROMISE in building earthquake resistant infrastructures. Hence, this is high time to Build Back Better (BBB).

All most all casualties were due to the collapsed infrastructures. Another lesson we learnt is that if similar high intensity earthquake in the U.S.A., Japan or other equally developed nations do not lead to enormous loss and damage to human lives and physical properties as the infrastructures in these countries are earthquake resistant. This emphasizes the need for strict compliance of town planning bye-laws and building codes in Nepal.

It has been realized that in the past the government did not paid due attention to Disaster Risk Reduction (DRR). DRR has not been a priority for the government. The government was found too weak in preparedness at all levels. Inadequate legal instruments and poor implementation of existing legislations have also been identified as a factor for losses and damages. The government was never serious in DRR. **Not only the government, but also the NGO and INGOs were entangled with mounds of paper work (preparation of reports etc.) and discussions (seminars, workshops, interactions, meetings, visits etc.). Overall, less emphasis was given to actual hardware considerations. Resource constraints and managerial weaknesses were and are still there.**

13. Way Forward and Recommendations

Nepal faces an enormous challenge from major disasters like the devastating earthquake of 25 April 2015. Therefore, long-term and sustainable efforts are required to address the problems of earthquake hazards in Nepal. Although disaster management and risk reduction may be considered expensive in the light of competing demands for resources in a developing country like Nepal, this is high time for the government to invest on considerable activity and resources into preparing for and responding to familiar and unexpected emergencies and disasters before the human and economic consequences of inaction are extensive, unmanageable and more expensive. This paper suggests some basic principles and guidelines to reduce the impact of the potential future earthquake disaster not only in Nepal but also for other earthquake prone countries as well. Following are the basic and fundamentals for earthquake management in Nepal and beyond:

13.1 Construction of earthquake resistant infrastructures;

13.2 Selective seismic strengthening and retrofitting of existing priority structures and lifeline structures – a priority list for structural safety audit, seismic strengthening and retrofitting is required;

13.3 Effective implementation of Building Code and other legislations;

13.4 Mass awareness and preparedness;

13.5 Capacity development through education, training, research & development (R&D), documentation and information sharing;

13.6 Effective and efficient response during and after emergency.

The above basics are necessary to reduce the impact of earthquakes in the short-term as well as in the medium and long-term. They recognize the enormous challenge in improving seismic safety because of the inadequate numbers of trained and qualified civil engineers, structural engineers, architects and masons proficient in earthquake-resistant design and construction of structures. They also recognize the need for imparting training in earthquake-resistant design and construction to faculty members in professional courses and for creating mass awareness on earthquake and other disaster risk reduction features in non-engineered construction in earthquake prone areas.

14. Conclusions

As the impacts will forever affect landscape, people, society, and livelihoods in Nepal – there is no choice but to adapt to disasters. Living not only with earthquakes, but also with many other disasters in daily life is the destiny of Nepalese people. Yet, the Nepalese and their neighbors and friends all over the globe, have to reconcile themselves to the fact that tens of kilometers beneath where they live, the Indian and Eurasian plates will continue their tussle again and again. In that journey, they must build on the fundamental strengths they possess—social capital and community resilience. Despite a weak government and post-conflict political instability, the presence of community-based institutions at sub-national levels maintain a social cohesion and play a constructive role in managing services like drinking water, electricity, forest, and even developing infrastructure such as trail bridges. As the Nepalese move forward, they must allow competing visions, strategies, institutional cultures, resources, and perspectives to be expressed and articulated as democratic deliberation. The fact is that tremendous challenges lie ahead for the government, semi-government, and private organizations to collectively work towards addressing the urgent needs of the nation and its people who have been severely affected by this natural calamity.

Of course, the government of Nepal should be at the forefront of any effort to rebuild Nepal responsibly and prepare the country for future earthquakes. To rebuild Nepal, the government should call on experts inside and outside the country to engage in interdisciplinary collaboration. Non-governmental organizations, the private sector, experts, intellectuals and the media can contribute in the rebuilding and disaster-preparation efforts and working collaboratively and effectively. To successfully rebuild Nepal, the government will surely need a huge amount of funds.

* * *

Biographies

The author, **Meen B. Poudyal Chhetri** earned his Post Doctorate in Disaster Management Policy from the Queensland University of Technology (QUT), Brisbane, Australia. He also holds Ph. D., Master's and Bachelor's degree in Economics and International Law. Currently, Prof. Chhetri is the President of Nepal Center for Disaster Management (NCDM) and Chairman of The International Emergency Management Society (TIEMS)'s paper Review Committee. He is the Adjunct Professor at the Queensland University of Technology, Brisbane, Australia since 1 March 2009. He served as the Director of the Department of Disaster Management of the Government of Nepal from 2001 to 2003. In 2004 He worked as the Deputy Regional Administrator in Hetauda, Nepal. From 1995 to 1996, he was the Chief District Officer and Chairman of District Disaster Relief Committee in Dhading district of Nepal. Prof. Chhetri also held positions of Under Secretary, Investigation Officer and Special Officer in various government agencies of Nepal including the Commission for the Investigation of Abuse of Authority, Ministry of Home Affairs, Ministry of Finance, Ministry of Agriculture and Ministry of Education. Prof. Chhetri is the author of two books and a number of research articles that are published in national and international journals. Prof. Chhetri awarded with

AEI Australia Alumni Excellence Awards 2014 by the Government of Australia on 20 January 2014. On 13 October 2014, he is awarded with "DPNet Award" by the Government of Nepal. He is also decorated with several national medals and awards in recognition to this contribution for the development of the nation.

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Simulation of Primary Service Degradations for Crisis Management Operations

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1. INTRODUCTION

Critical Infrastructure Protection (CIP) is a concept that relates the preparedness and the response to severe incidents involving critical infrastructures of all countries. Events such as 9/11, Katrina, and others, showed that considering infrastructures separately was not sufficient to prepare for and respond to large disasters in an effective manner that prioritizes overall societal impact over individual infrastructure states. When a specific perturbation, such as an earthquake, hits a system of Critical Infrastructures (CI), the “primary effects” or "No-CI related Consequences" of the damages produced by the event can be expressed in terms of the number and the economic value of the collapsed buildings, and the number of casualties or the economic losses related to the disruption of a given production. In addition, there might be “secondary effects or “CI related Consequences” connected to the degradation of CI services (e.g., electricity, water, gas) that can be exacerbated by cascading effects. In general, No-CI Consequences are limited to the area affected by the natural events whereas the area to which CI-related Consequences refer to can be much larger than the area affected by these natural events. A typical example of this situation is the 2003 Italian blackout where the large CI-related Consequences caused by an extended and prolonged electrical blackout were triggered by the collapse of a high tension pylon that produced a very small No-CI Consequences blackout. Prediction and a rapid assessment of both types of consequences in a critical scenario can be a major breakthrough for increasing preparedness and mitigation actions. To this end, a major goal could be represented by a correct prediction of the course of events, starting from the prediction of the occurrence of natural hazards and their strengths to the resulting effects that they will produce due to a reduction in supplied services and the consequences they have on relevant areas of societal life. The realization of a similar object, cast in the form of a Decision Support System (DSS), is one of the objectives of the EU FP7 CIPRNet project. The designed DSS implementing the above mentioned risk assessment workflow, can be used to both predict the extent of the expected crisis used to "weigh" the efficacy of the proposed mitigation and to predict the subsequent healing actions, therefore being a valuable tool for supporting emergency managers, such as CI operators, Civil Protection and fire brigades. Whether No-CI related Consequences can be evaluated on the basis of the damages, the transformation of them into CI related Consequences is much more complex and requires the introduction of a further term, which we indicate as "impact". Impact identifies the resulting effects of damages on the services produced by the CI (e.g., the damage of an electric distribution substation that produces an electric outage in a city area for a given period of time as well as disruptions in the telecommunication network). After creating the complete assessment of the impact, one can evaluate the CI related Consequences by transforming impact into well-being societal variation. The proposed DSS advances the state of the art by including in a unique framework, the prediction of natural hazards and the estimation of their effects on CI and societal life.

In Rosato et al. (2015), we showed how the DSS is able to estimate the consequences for the citizens due to the degradation of technological services. To this aim, we defined a Service Access Wealth Index (SAWI) based on consumption data of Italian residents and we related the possible loss of electricity service in specific parcel areas to the well-being of citizens of different age groups. In the present paper, we show how the predicted degradation of services can be used to propagate the dependencies among a power grid, a SCADA system and a water distribution network to quantify the reduction of primary services delivered by a hospital. The DSS uses an interdependency simulator to model and simulate the dependencies among the different CI domains and primary services. In particular, the work presented here illustrates how the proposed approach faces some of the main challenges that need to be considered in modeling and simulation of CI related urban crisis scenario i.e.: i) data gathering; ii) data homogenization; and iii) simulation of large models. A major contribution of this work is that the data from the electrical system infrastructure is obtained directly from the utility company database. The simulation scenario is established automatically from data mined from this database and the weather prediction layer.

This paper is structured as follows. Section 2 describes related work in the area. Section 3 presents the main functionalities of the DSS required to implement the risk assessment workflow. Section 4 focuses on the DSS impact and consequence analysis modules and present the procedure that allows to propagate the predicted damages in the considered CI in terms of short time scale impact and effects on the delivery of primary services and to define possible mitigation strategies of the crisis. Section 5 presents a case study where we apply our methodology to estimate the consequences to hospitals in an area of Rome due to disruptions occurring in the electric-telecommunication system and water distribution system. Finally, Section 6 draws some conclusions and ideas for future work.

2. RELATED WORK

This section discusses related work on DSS for the estimation of primary effects of natural hazards, models for impact assessment, and approaches for evaluating the CI related consequences, i.e., the effects on the operability of primary services due to the loss of CI services.

Kamissoko et al. (2013) developed a DSS that estimates the vulnerability of infrastructure networks taking into account interdependency phenomena. Their DSS models network dependencies through graph theory and is able to infer vulnerable areas, critical components and the most threatened stakes (e.g., a firm, a habitation, a government institution) by specifying the probability of a natural hazard and the state of the system. The European UrbanFlood (2012) was aimed at developing an Early Warning System (EWS) for the prediction of flooding in near real time. The system was validated in the context of dike performance in an urban environment and uses a sensor monitoring network to assess the condition and likelihood of failures. The system employs flooding specific modules, including dike breach evolution and flood-spreading models. In the context of the European Earth observation program, Copernicus (2010), a European Flood Awareness System (EFAS) was developed to produce European overviews on ongoing and forecasted floods to support the EU Mechanism for Civil Protection. The Italian national project SIT_MEW (2010) focused on the implementation of an EWS, to predict potential impact of seismic events on structures and buildings immediately following an earthquake. These previously proposed DSS, however, do not take into account the interplay of environmental forecasts and interdependency phenomena of CI.

Regarding the latter, Ouyang (2014) has reviewed all the research in modeling and simulation of interdependencies of CI according to six branches: (i) empirical; (ii) agent based; (iii) system dynamics based; (iv) economic based; (v) network based; and (vi) other approaches based on High Level Architecture (HLA) and Petri-net techniques. Our DSS employs network-based approaches, which models the performance of each network through topological properties of the network such as the connectivity loss, the number of normal or failed physical components, the duration of components unavailability, and the number of customers served or affected. Other network based approaches include De Porcellinis et al. (2008) who tested mitigation and healing strategies modelling of an electrical network with a DC power flow solution, and finding the relationship between an Internet Quality of Service (QoS) index and its effect on the QoS of the electrical network. They used a data packet model to model the Internet communication layer.

Our DSS is interacting with the real-time, time-domain simulator, i2Sim, developed by Martí (2008, 2014), which solves the interdependencies among CI in a system, and determines the optimal allocation of resources for all CI in terms of a global system objective (e.g., save human lives). i2Sim has been applied in several real cases including the campus of the University of British Columbia (UBC), the downtown area of the city Vancouver, and the Guadeloupe Island. i2Sim's conceptual and solution framework is very general and can accommodate for non-linear relationships among systems of dissimilar nature, thus it is able to model a small city with many different interdependent infrastructures.

3. OVERVIEW ON THE CIPRNet DECISION SUPPORT SYSTEM

The CIPRNet DSS can be logically represented in terms of five functional components (Bi), which leverage on a large database containing GIS data of CI elements, assets, geographical, social, and economical information of the area under control. These are:

- **Monitoring of natural phenomena (B1)**: This functional block acquires geoseismic, meteorological forecasts and now-casting data, and other sensor field data when available.
- **Prediction of natural disasters and events detection (B2)**: This block, based on information of B1, predicts, within an estimated temporal horizon, the strength of a limited set of natural phenomena occurring in the specified area.
- **Prediction of Physical Harm Scenarios (B3)**: This block evaluates the probability that each CI component, located in a certain area, can suffer a certain amount of damage if hit by the predicted natural events with a certain strength. The association "event strength-damage" of a physical component c_i of the *x*-th CI by a threat manifestation T_j is performed by considering the intrinsic vulnerability of c_i w.r.t. the intensity of T_j (output of B2). The outcome is a set of affected CI physical components with the extent of the estimated physical damages called *Physical Harm Scenario* (PHS) defined as:

$$PHS = (c^{\intercal}, d^{\intercal}) \qquad (1)$$

where $c^{\intercal} = (c_1^{s_1}, \ldots, c_R^{sR})$ is the set of CI components belonging to the infrastructure s_i that, at time t=0, are expected to receive an over-threshold probability to be damaged; $d^{\intercal} = (d_1^{s_1}, \ldots, d_R^{sR})$ is the set of the extent of estimated damages for each CI component; R is the number of possible damaged components; $s_i \in \{1, \ldots, U\}$ and U is the total number of CI considered.

- **Estimation of Impact and Consequences (B4)**: This block estimates the impact that the PHS may produce on the services delivered by the CI and the resulting consequences for society. Based on the PHS and models to propagate damages of the physical components across different CI, the DSS is able to produce an *Impact Vector* I(t), which contains the set of QoS functions Q(t) associated with each CI. The generic Impact Vector estimated over time T of the crisis is defined as:

$$I(t) = (\Delta Q(T)^{T}) \quad (2)$$

where: $\Delta Q(T) = (\Delta Q_1^{v_1}(T), \ldots, \Delta Q_L^{vL}(T))$ is the set of the QoS variations of the CI over the time T; L is the number of services considered and $v_i \in \{1, \ldots, U\}$. In Section 4.2, we define the Consequence Vector $C(t)$ that contains the consequences due to the reduction of CI services by introducing the concept of wealth of primary services.

- **Support of efficient strategies to cope with crisis scenarios (B5)**: This block provides crisis managers with a decision list of actions in those cases where the DSS can provide further information needed to support a crisis solution.

In the next Section, we focus on B4 by first recalling our approach to estimate the Impact Vector in a power grid and then present our metric to assess the related consequences on the primary services due to the degradation of power services.

4. CRITICAL INFRASTRUCTURE RELATED CONSEQUENCES

4.1. Estimation of Impact

Starting from the predicted damages of CI physical components, B4 first computes the reduction of QoS of the dependent networks and then the related consequences for the delivery of primary services. To take into account the different time scales of the dependency mechanisms, the Impact evaluation module executes two consecutive procedures called Pre-Impact Assessment and Comprehensive Impact Assessment respectively.

In the Pre-Impact Assessment, strongly coupled infrastructures such as the electrical and the telecommunication networks are considered. Their strong coupling activates dependency mechanisms holding in the short time scale (from a few minutes up to one hour). The outcome of this procedure is the expected outage duration of the electrical distribution substations. In the Comprehensive Impact Assessment, dependencies among all the infrastructures (e.g., power grid with water distribution) that present a larger latency are analyzed. During very short times scales, such CI could be considered as “decoupled” from the previously cited infrastructures, in a sort of adiabatic approximation. This procedure takes as an input the expected outage duration of the distribution substations of the considered scenario calculated in the Pre-Impact assessment block and propagates to other CI.

4.1.1 Pre-Impact Assessment

The estimation of impact is performed through a network based procedure developed by Tofani et al. (2015) that takes into account the interdependency mechanisms existing among a power grid and its SCADA system. This approach is based on the real properties of the electrical distribution grid of Rome consisting of several High Voltage (HV) Primary Substations (PS) and Medium Voltage (MV) Secondary Substations (SS) that are connected to PS through backbones (consisting of two semi-backbone or SB) according to a serial configuration. Each SS can satisfy the electrical demand of a district approximately composed of 100 households. The interdependency phenomena between the two CI stand as the electrical SS supply energy to specific Telecom devices, called Base Transceiver Stations (BTS) that in turn ensure tele-control capability to the electrical grid. In addition, the BTS installed in each mobile antenna, requires energy to function, which is provided through the electric SS. Considering their strong interdependency, damages occurring in the electrical SS and/or the BTS, can cause disruptions that hold in the short time scale (from a few minutes up to some hours) leaving people without power and mobile communication services. Based on the interdependency information regarding the two systems and the PHS (periodically estimated by the DSS B3) including the possible damaged electrical SS and Telecom BTS, the impact estimation procedure emulates the restoration procedure of the electrical operator to infer the possible evolution of the electric grid in the medium term. In particular, the procedure identifies those SS that, because of the loss of tele-control capability, require manual intervention and those that can be reconnected via the electric SCADA system. Then, considering the average time required by the emergency teams (that are limited in number) to reach specific electric SS and reconnect the related users (e.g., using UPS), the procedure estimates the Impact Vector I(t) in terms of the electric power profiles that are generated by each specific SS. It is clear that, according to the sequence of manual actions executed by the emergency teams, there might be different impact outcomes. Some SS can supply several households w.r.t. other ones, or the reactivation of some SS are necessary for other restoration and/or can enable some actions to be performed more rapidly. Let K be the number of available emergency teams and M be the number of electric SS to be reconnected. We define the ordered sequence $O_l = (SS_1^l, SS_2^l, \ldots, SS_M^l)$ of SS that are reconnected by the *l*-th emergency team with $l \in \{0,1,\ldots,K\}$. Thus, depending on the sequences O_l implemented to cope with a crisis, the DSS estimates the related consequences for the delivery of primary services as their functionality is influenced by the availability of services delivered by CI.

4.1.2 Comprehensive Impact Assessment

In the Comprehensive Impact Assessment procedure, all dependencies from the electrical and telecommunication domains are considered in order to have a complete assessment of the considered crisis scenario. An i2Sim model is constructed and executed to simulate the dependencies among the different domains. Figure 1 shows the full process of converting the data from the DSS DB (storing CI dependency data coming from different sources and format) into the i2Sim DB, constructing the i2Sim model and delivering it to i2Sim engine for interdependency simulation. The i2Sim Database Integration tables (i2Sim DB tables) represent a common data formalism that stores and homogenizes data of different CI networks. The i2Sim DB tables are read by the i2Sim model builder, which in turn, creates a model that can be simulated using the i2Sim engine. The SS Power Profiles are treated as scenarios and run with the i2Sim model file. Each profile is converted into an input file in XML format, which the i2Sim engine reads, analyzes and processes. The final results are then stored into output files also in XML format. i2Sim runs multiple scenarios in real time based on the changing inputs that the scenario profile provides. Therefore, two types of output files are generated. The first file is an accumulation of all time steps throughout the total simulation runtime. This output file represents the QoS of all entities considered in the scenario (e.g., hospitals, water pumps, electricity). The second file is a profile of each individual time step, allowing the user to assess the situation at any moment. Based on the given objective of the problem, the i2Sim output files detail the impact of distributing resources to one infrastructure over another, thus observing the consequence of each action.

i2Sim considers the dependencies among CI through its Human Readable Table (HRT). The HRT table homogenizes the different data sources and correlates the resources and factors that will affect the production of a given system unit (e.g., factory, hospital, substation). The input vectors (columns of the table) are linearly independent eigenvectors, allowing elements of different nature to affect the operating level of the system unit under linear or nonlinear relationships. Based on the level of these inputs, i2Sim computes the operating level of that unit and provides an output based on the limiting physical, structural, or operational actions. For example, in a hospital unit, the inputs could be electricity, water, number of injured people, number of doctors and nurses, stress level of the personnel, and the output is the number of patients treated by the unit. If there was a scarcity in water from the water pumping station that fed the hospital, the number of patients treated would be limited based on the amount of water fed to the hospital.

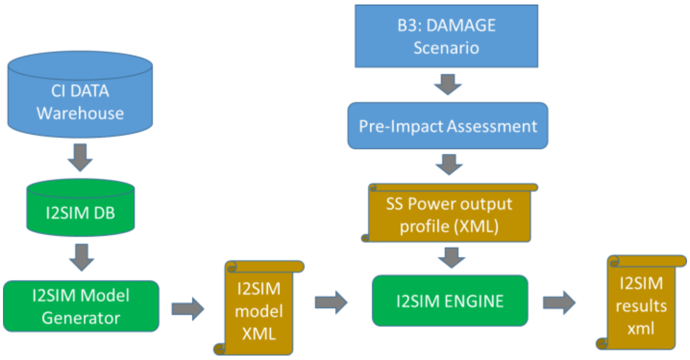

Figure 5 Comprehensive Impact Assessment data flow.

4.2 Estimation of Consequences

In order to define the significance of the impact produced by the disruption or destruction of one (or more) CI, the European Council Directive 2008/114/EC (see European Commission, 2008) proposes that such effects should be assessed in terms of cross-cutting criteria. These include: (i) Casualty criterion assessing the potential number of fatalities or injuries; (ii) Economic effects criterion assessing the significance of economic loss and/or degradation of products or services including the potential environmental effects; and (iii) Public effects criterion in terms of the impact on public confidence, physical suffering and disruption of daily life including the loss of essential services.

Based on the latter, we summarized in a unique list of criteria, a number of domains that express the criteria above mentioned whose well-being reduction could be estimated both in the No-CI and in the CI-related Consequence analysis. We defined four criteria (called CA Criteria) as the following:

- **CA Citizens Criterion.** It relates to population, to citizens and encompasses the reduction of well-being to the most vulnerable population layers (e.g., elderly people, children).
- **CA Primary Service Criterion.** It relates to the primary services that affect the wealth and the well-being of the population (i.e., hospitals, schools, public offices, and public transportation).
- **CA Economy Criterion.** It relates with the economic losses that depend, in turn, on the integrity and the lack of production hours/days due to services outages. (i.e., primary, secondary and tertiary sectors).
- **CA Environment Criterion.** It relates to the environmental damages that can be produced by disruptions (e.g., landslides, flooding etc.) but also by secondary effects (e.g., pollution, leakages from plants) on specific assets (i.e., forests, protected areas, sea and shores, basins).

The DSS provides an estimate of the No-CI and CI related consequences performed according to the previously defined criteria, in the time interval predicted for the crisis. In particular, the impact estimation module will result in the prediction of the loss or reduction to the QoS of one or several CI services. This is provided in the form of a vector $Q_i(t)$ for each service i coming from the damage of CI physical components. On the basis of this data, the consequence estimation module generates the related consequences in terms of wealth variations of each criterion. Such quantities are provided as a Consequence Vector C(t) defined in the following:

$$C(t) = \{C^{cit}(t), C^{ser}(t), C^{eco}(t), C^{env}(t)\} \quad (3)$$

where $C^{cit}(t)$, $C^{ser}(t)$, $C^{eco}(t)$, and $C^{env}(t)$ represent the consequences for citizens, primary services, the economy and the environment respectively, predicted over time *t*. In this paper, we limit our analysis to the evaluation of the consequences on primary services. To this aim, in the next Section, we define a metric that evaluates the level or *wealth* of primary services based on the variation of specific CI technological services.

4.2.3 Wealth Index of Primary Services

Limiting our analysis to the wealth of primary services delivered by hospitals, let us define the wealth $\boldsymbol{W(t, h_j)^{ser}}$ of the **CA Primary Service Criterion** related to hospital h_j as a function of the available technological services k that are required by the hospital to deliver its service:

$$W^{ser}(t, h_j) = M(h_j) f_{h_j}[Q_1(t), \ldots, Q_N(t)] \quad (4)$$

where:

- N is the number of the technological services, which contribute to the delivery of the primary service of hospital h_j.
- $M(h_j)$ is the maximum number of patients healed that can be delivered by hospital h_j.
- $Q_k(t)$, with $k \div 1, N$ and $0 \leq Q_k(t) \leq 1$ measures the QoS of service k over time where $Q_k(t) = 1$ represents the full availability of service k and $Q_k(t) = 0$ the unavailability of service k.
- $f_{h_j}[Q_1(t), \ldots, Q_N(t)]$ with $0 \leq f_{h_j}(\cdot) \leq 1$ relates the QoS of the N technological services service to the availability of hospital h_j to deliver $M(h_j)$ healed patients per hour.

4.2.4 Consequence Vector

In the following, we define the consequence $C^{ser}(T, h_j)$ as the wealth variation of hospital h_j associated with the variation of the QoS of the technological services k over the time duration T of the crisis. Let us first define the maximum wealth $W_0^{ser}(h_j)$ during time T with full availability of services k:

$$W_0^{ser}(h_j) = M(h_j) \quad (5)$$

We can now define the $C^{ser}(T, e_j)$ as the difference between the maximum wealth $W_0^{ser}(e_j)$ and the effective wealth integrated on time duration T normalized w.r.t. $W_0^{ser}(h_j)$ as follows:

$$C^{ser}(t, h_j) = \frac{W_0^{ser}(h_j) - M(h_j)\int_0^T f_{h_j}[Q_1(t), \ldots, Q_N(t)]\,dt}{W_0^{ser}(h_j)} \quad (6)$$

Considering a generic hospital that requires N=3 technological services (i.e., electricity, water and telecommunication), we have:

$$W_0^{ser} = W_0^{ser}(h_j) \qquad (7)$$

$$C^{ser}(T) = \frac{W_0^{ser} - W_0^{ser}\int_0^T f[Q_1(t),\dots,Q_3(t)]dt}{W_0^{ser}} \qquad (8)$$

The resulting consequence $C^{ser}(T)$ is a number varying between 0 and 1 (with 0 indicating no consequences and 1 severe consequences) expressing the possible variation of wealth of a hospital over time T of the crisis due to the degradation of the electricity, water and telecommunication service.

5. CASE STUDY

A real case study is shown in Figure 2 where we represent an area of Rome consisting of:

- A section of the electric distribution grid with 9 electrical PS (PS_1 – PS_9) and 164 electrical SS (SS_1 – SS_{164}) serving specific census parcels, where the orange circles denote the remotely controlled SS.
- A Telecommunication network with 6 BTS providing tele-control capability to specific SS.
- A water distribution network with 3 pumping stations.
- 3 hospitals.

The Telecom BTS are supplied power by the electric SS. There are also three water stations that are supplied by the electric SS, which in turn provide water to three hospitals. Hospitals receive electricity from one (or more) electric SS and water from the pumping stations. The hospitals cover the needs of citizens according to the areas shown in Figure 3. Six main assumptions are made in the case study: (i) the PHS built on weather forecasts estimates a disconnection of SS_3, SS_{84} and SS_{124}; (ii) only one emergency team is available for the electric operator to reach and reconnect the isolated SS; (iii) no power backup is available to the BTS, pumping stations and hospitals; (iv) the moving time required by the emergency team to reach the electric SS is negligible; (v) one hour is the average time to perform a manual intervention in any SS of the district of Rome and (vi) the average time to perform tele-control operations (e.g., opening or closure of breakers) is negligible.

Considering such assumptions and the properties of the electrical grid, the impact estimation procedure described in Section 4.1 suggests the following subsequent events:

- At time t_1=0, SS_3 and SS_{84} and SS_{124} are disconnected;
- At time $t_2 \approx 0$, all electric SS in SB_{01}, SB_{19} and SB_{11} will automatically disconnect (due to the failure of SS_3, SS_{84} and SS_{124}).

At this stage, only some electric SS are reactivated:

- SS_1 through the direct connection to PS_1
- SS_{81} through the direct connection to PS_2

- SS_{120} and SS_{121} are reconnected through tele-control because BTS_6 is working
- SS_4 - SS_{27} are not reconnected through tele-control because BTS_7 is not working due to the disconnection of SS_{124} which in turn causes the disconnection of SS_{123}
- SS_{126}, SS_{127}, SS_{125} are not reconnected through the closure of the normally open switch connecting SB_6 and SB_{19} as SS_{60} receive tele-control through BTS_{07}, which in turn, is not working.
- SS_{123} and SS_{122} are not working due to the disconnection of SS_{124}.

Considering that some electric SS cannot be reconnected through tele-control actions, a manual intervention to be performed by the emergency team is planned via the impact estimation module. In addition, considering that there is only one emergency team, a choice about which manual intervention to be implemented first should be made by the electric operator. In Figure 3, we report the Impact Vector I(t) in terms of QoS reduction related to the following sequences: $O_1 = \{SS_{84}, SS_3, SS_{124},\}$, $O_1^* = \{SS_{124}, SS_3, SS_{84}\}$.

Considering O_1, the following events are generated:

i. SS_{84} is reactivated manually in about one hour;

ii. SS_{82} - SS_{85} are now supplied;

iii. SS_3 is reactivated manually in about one hour;

iv. SS_2 is now supplied;

v. SS_{124} is reactivated manually in about one hour;

vi. SS_{123} and SS_{122} are now supplied with the effect that BTS_7 provides tele-control capability;

vii. SS_4 - SS_{27} are reactivated through tele-control operations (due to the reactivation of BTS_7) with the effect that WS_3 is working;

viii. SS_{126}, SS_{127}, SS_{125} are reconnected to SS_{60} through tele-control operations.

Considering O_1^*, the following events are generated:

i. SS_{124} is reactivated manually in about one hour;

ii. SS_{123} and SS_{122} are now supplied with the effect that BTS_7 provides tele-control capability.

iii. SS_4 - SS_{27} are reactivated through tele-control operations (due to the reactivation of BTS_7) with the effect that WS_3 is working;

iv. SS_{126}, SS_{127}, SS_{125} are reconnected to SS_{60} through tele-control operations;

v. SS_3 is reactivated manually in about one hour;

vi. SS_2 is now supplied;

vii. SS_{84} is reactivated manually in about one hour;

viii. SS_{82} - SS_{85} are now supplied.

Based on the Impact Vector I(t) produced by the Impact Estimation module for the two sequences, the related consequences $C^{ser}(T)$ are estimated as the wealth variation of the hospital (see eq. 8) delivered over the time duration T = 4h of the crisis. Because only SS_1, SS_2, SS_7, SS_{89}, SS_{90}, SS_{135},

SS_{140} and SS_{141} are feeding electricity into the water station or directly the hospital, the following discussion will focus on these SS and all CIs connected to them.

Two scenarios are created based on the provided power profiles shown in Figure 4. In Scenario 1, both SS_2 and SS_7 are down for 2 hours. After 2 hours, only SS_2 is reactivated. Because both SS_2 and SS_7 feed H_3, although SS_2 is operating at full capacity after 2 hours, the hospital cannot operate due to the limitation from SS_7 being disconnected, as SS_7 supplies water to the hospital. After 3 hours, when SS_7 is reactivated, the water facility is restored and the hospital can operate at its full capacity.

In Scenario 2, SS_7 is reactivated after 1 hour, but SS_2 is reactivated after 2 hours. Therefore, after 1 hour, H_3 cannot operate, because it is limited by the electricity supplied by SS_2. Only after SS_2 is reactivated after 2 hours, H3 can operate at full capacity.

Figure 5 shows the resulting consequences $C^{ser}(T)$ in terms of operability of the hospital. These results show that only H_3 is impacted by failures and interdependency phenomena. In addition, results show that, in order to have H_3 operate at its full capacity, one cannot focus on single factors but the whole system's interdependencies need to be considered. In this case in particular, both SS_2 and SS_7 must be reactivated for the hospital to begin working at full capacity as H_3 is dependent on electricity from both SS_2 and SS_7.

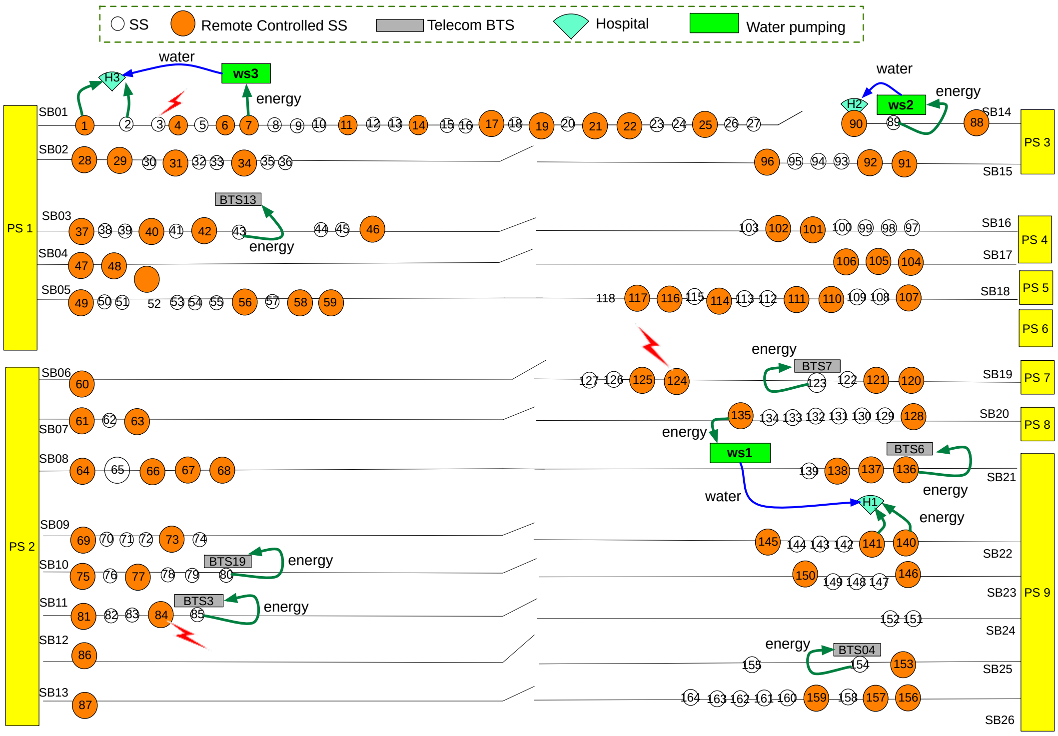

Figure 6: Case study: Representation of the resources exchanged among the different CIs.

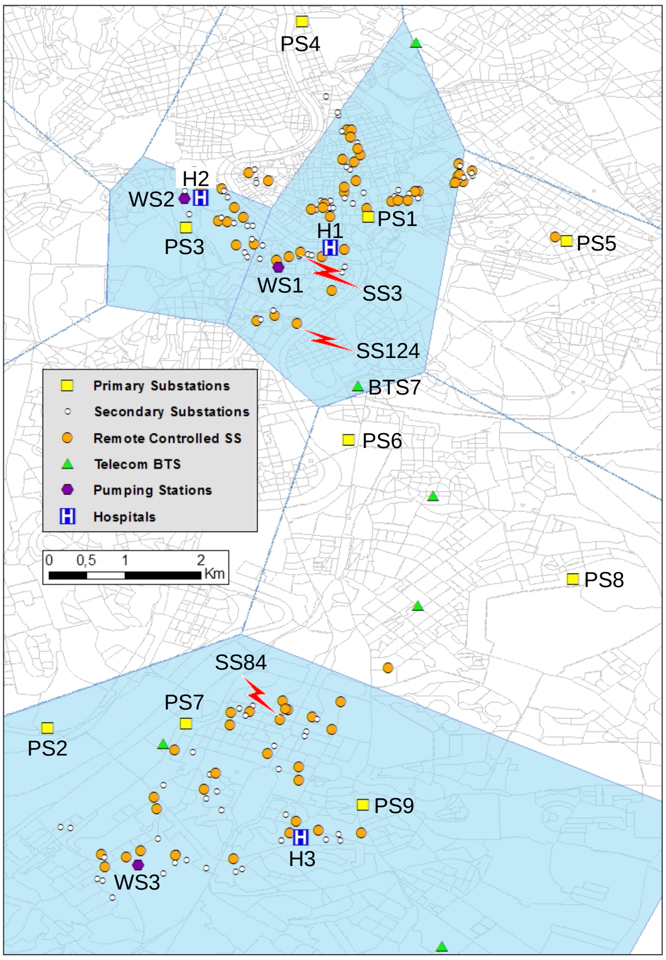

Figure 3. Case study: GIS representation.

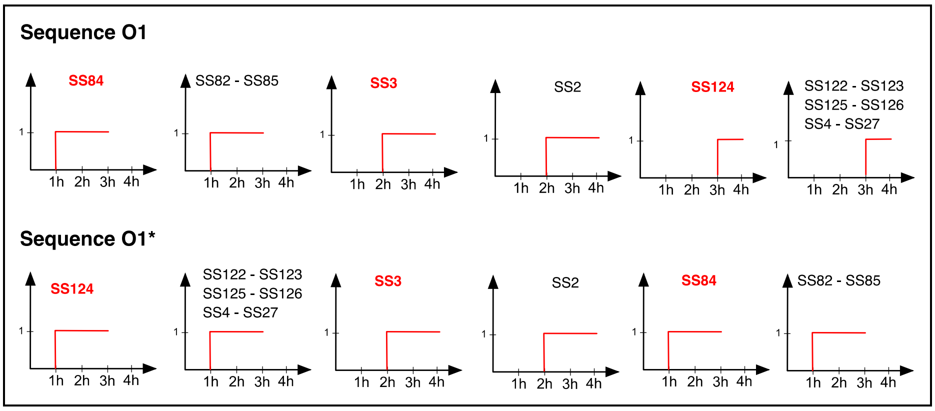

Figure 4. Case study: Power profiles of the SS.

6. CONCLUSIONS

The proposed Decision Support System (DSS) employs modeling and simulation techniques based on weather forecasts and interdependency properties of the electrical and telecommunication grid to estimate the reduction of primary services delivered by hospitals affected by electric and telecom outages in a city area. The case study shows how the DSS may be able to suggest actions to decision makers that would not be considered by the individual contingency plans of the separate infrastructures (which usually do not include interdependencies with the other infrastructures). Future work will focus on the extension of the approach to consider additional primary services (e.g., public transportation).

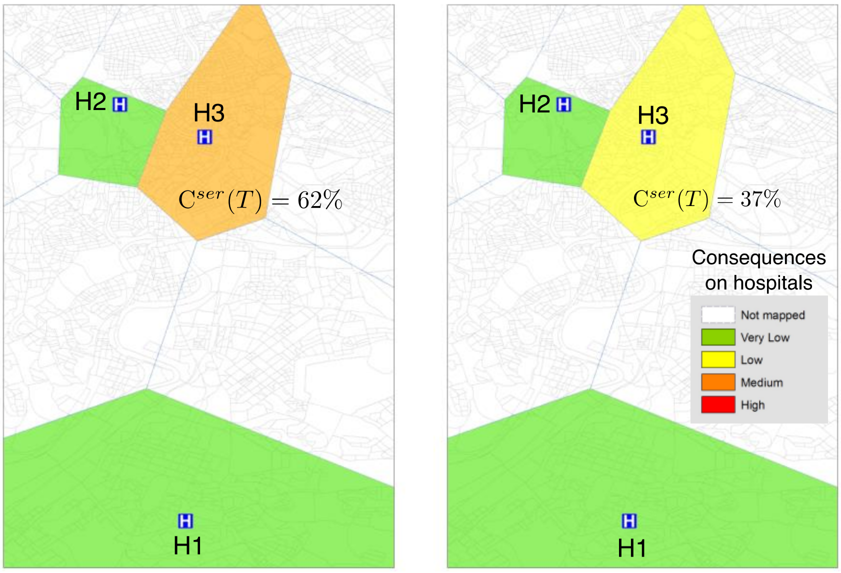

Figure 5. Case study: Consequences on three hospitals.

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Analysis of fatalities originated by burning of agricultural and forestry residues in Portugal

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ABSTRACT

Forest fires are a major problem that occur in Portugal every year during the summer months and usually get major coverage by the media. The burning of agricultural and forestry residues tend to have less impact in the media but they often result in large fires and fire related accidents. These ancient practices, a part of rural heritage, in some cases result in fatal accidents. This is a growing problem and has not received much attention from the authorities.

This paper describes some of these accidents, chosen from a large set of cases that have been inventoried and studied in the last years by the Centre for Forest Fire Studies of ADAI. An historical analysis is done based on data collected in Portugal for each one of the identified fatal accidents related to these residues burning. We studied in detail four cases that resulted in fatalities, reporting the victims' characterization and the circumstances of the accident.

In the place of each accident the topography, meteorology, vegetation, fire behaviour, the situation of wildland urban interface and the conditions in which the burnings were made are characterized. The victims were characterized according to their profession or current occupation, age and gender.

This paper aims to contribute to a better understanding on these situations and to aid in the mitigation, or prevention of such accidents in order to minimize it occurrence in the future.

KEYWORDS:

Wildfires, rural fires, burnings, burn victims, risk

1. INTRODUCTION

Wildfires are one of the most devastating natural hazards in Portugal having large impacts on the economy, environment and society [1]. Natural caused wildfires have always been part of the ecosystems of the Mediterranean region and are responsible for significant changes in the landscape [2] however the actual figures of the burnt area currently verified in Portugal have high a percentage of anthropogenic causes.

Portugalhas a temperate climate with Mediterranean influence, characterized by hot and dry summers, and rainy winters. The topography in Portugal, especially in the centre and north, is very sloppy and the typical vegetation is adapted to dryness and have pyrofitcharacteristics. These natural conditions make Portugal very susceptible to wildfires, and this susceptibility has been increasing in recent decades due to natural, demographic and socioeconomic changes [3]. The population in rural areas decreased and theaverage age has increased as a result of the exodus of young people to the cities. Rural and forest properties are typically small, mostly in the centre and north of Portugal, and are frequently managed by people over 65 year’s old. Areas previously dedicated to agriculture were gradually converted to forested areas frequently improperly managed and other areas were abandoned accumulating natural vegetation and becoming uncultivated areas of scrubland with high fuel loads [4].

Currently, approximately 98% of the fires occurred in Portugal result from anthropogenic factors [5], and only 2% have natural causes [6]. Accidental or negligent use of fire are frequently associated to the common practice of burning slash or other agricultural and forest residues which are burnt in fires aiming its destruction, from now on mentioned as “agroforestry burns”. Additionally, in order to renovate the grazing lands, there is an ancestral practice of making small prescribed fires that frequently get out of control. Several fatalities are known as having been originated by agroforestry burns however only recently this cause was analysed separately from other fatalities related to wildfires and therefore only recently accurate data are available [7]. One of the most exhaustivestudies analysing fatalities related to agroforestry burns was carried out by the Association for the Development of Industrial Aerodynamics (ADAI) which collected, investigated and reported the accidents involving fatal events related to wildfires in the years of 2003 [8], 2005 [9] and Rosa [2012]. The present work aims to improve the understanding of the social and cultural aspects related to some of the known fatalities originated by agroforestry burns in Portugal between 1988 and 2015.

This study focused on the accidents that occurred in Continental Portugal where the probability of having such accidents is higher.

2. METHODOLOGY

The survey of the fatalities originated by agroforestry burnsthat occurred in Portugal was carried out by a review of the news reported on the internet, national and local radio stations, newspapers and TVs, and by a review of the existing literature on this them from which we highlight the books referenced as [8] and [9]. In the scopeof this survey several Portuguese civil protection and rescue services, as well as criminal investigation and law enforcement authorities were invited to give information related to three issues: 1) the number of fires which have killed people since 1988, referencing the place, the date, the circumstances and the number of victims; 2) the number of fires held annually since 1980; and 3) the number of agroforestry burnsthat escaped to control triggering a wildfire event.

The gathering and compilation of the data allowed an analysis aiming at the spatial characterization of the occurrences that was performed using the ArcGIS 10.2 software.

Finally, some of the most impactful events were selected for a more detailed analysis addressing the following issues: type of vegetation, fire behaviour, topography, weather, characterization of wildland-urban interface (WUI) area, characterization of the victims and circumstances in which these accidents occurred. Interviews to firefighters involved in the events, to the victims' relatives and to the neighbours of the victims were conducted. People involved in the accidents such as family or friends or who had hastened to the local immediately after the accident were invited to describe the scenario and the situation lived. All the data, evidences and witness testimonials were compiled and analysed in order to have the accidents descriptions as accurate and complete as possible.

3. RESULTS AND DISCUSSION

The CEIF team investigated in the last 30 years most of the fatal accidents related to forest fires in Portugal and in some other countries. Inseparable from these accidents are the cases of deadly victims caused by burning of agricultural and forestry residue also related to forest fire management. The data collected on these cases are presented in two books entitled *Cercados pelo Fogo Vol. I and II*. In these books a very precise description of the facts, environment and victims was made.

The collection of data on cases of fatalities in agricultural and forestry residues was done through several stages. As it is not common practice that a single agency collects this type of data a general enquiry to several governmental authorities was made but it did not get many responses. Then a more direct approach to other sources like local Fire Brigades, CEIF team, students, National Republican Guard (GNR), National Authority of Civil Protection agents, national and regional newspapers, radios and television was made.

The Mainland of Portugal have a total of 445 Fire Brigades who were contacted by mail, email, or phone to answer a small questioner with 3 questions. Only 33 of them answer the questioner (7.4%) of the Fire Brigades. Nature and Environmental Protection Service of the GNR report 8 deadly cases from 2008 to 2011. This department was created in 2007 and for the motive the cases previously 2008 aren't report by this service. Despite the cases reported by this service the data wasn't completed and in the most part of this recorded the gender or the age of the victim's wasn't completed. The national and regional televisions, radios and newspapers reported eight more deadly victims in the years of 2011 and 2012, 2014 and in the first trimester of 2015.

3.1. Distribution of accidents

The several information sources consulted reported 39 fatal cases originated by agroforestry burns since 1988 to March 2015. 31 of the 39 cases surveyed occurred after 2005. As previously mentioned, in 2005, the accidents originated by agroforestry burns started to be classified separately and therefore the information about accidents occurred before this year may not have been found.

In figure 1 the geographic dispersion of the fatal accidents occurred in Portugal between 1988 and March 2015 is presented. It is possible to verify the larger concentration of cases occurred in the North and Centre of Portugal compared with the south regions.

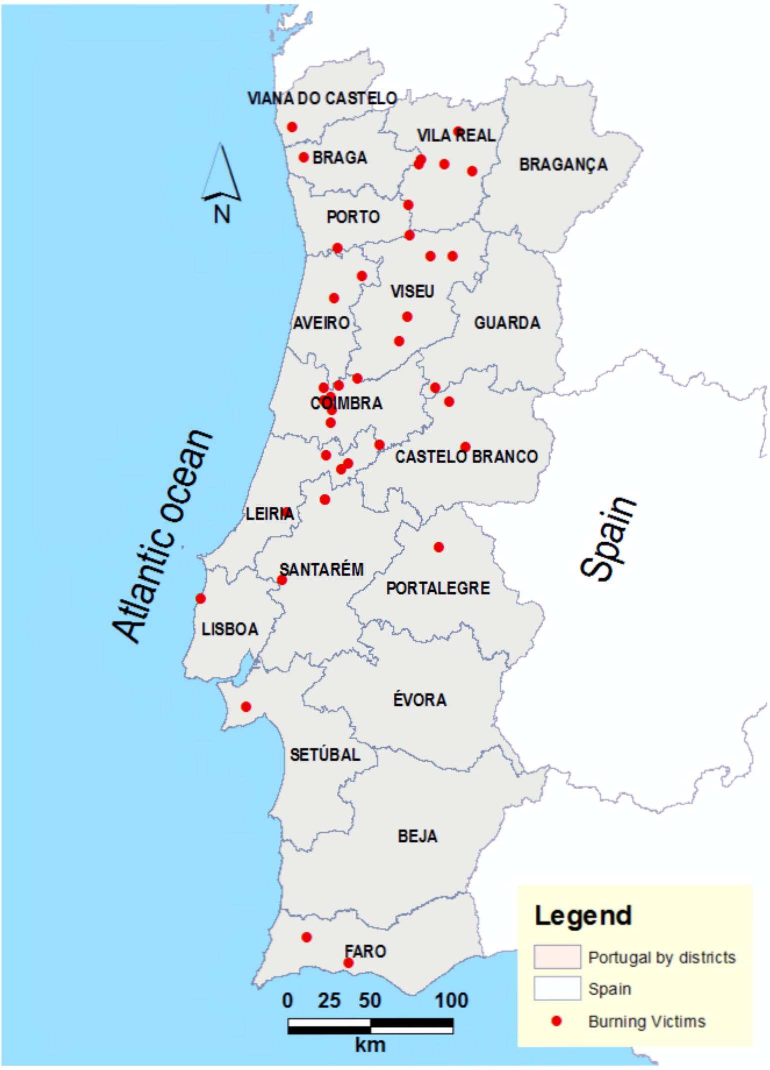

Figure 1 – Spatial distribution of the victims of rural burns in Portugal from 1988 to 2015.

In figure 2 it is possible to see that Coimbra, Leiria, Vila Real and Viseu are the districts with more fatalities originated by agroforestry burns. However all districts with the exception of Bragança, Évora and Beja have at least one fatal accident reported in the period mentioned before (1988-2015).

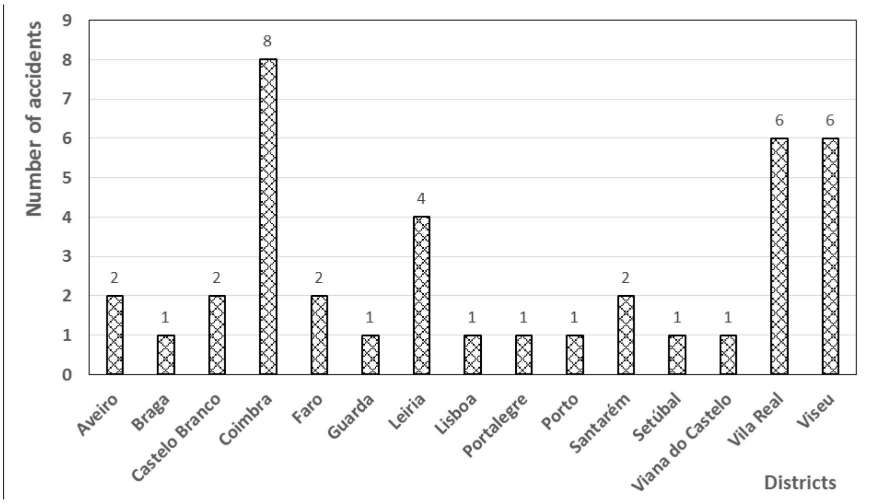

Figure 2 - Distribution of the victims for district in the period from 1988 to 2015.

The first case reported in this study occurred in 1988. During 14 years period we did not have any reported case of burn victims linked to rural fires or burning of agricultural of forestry residues. In the period between 2005 and 2014, the most dramatic years are those of 2005, 2007, 2010 and 2012 when the larger number of cases were reported (figure 3). In the first trimester of 2015 two fatal accidents originated by agroforestry burns have already occurred in the month of March. The average of deadly victims by year is 3.0 but this value was duplicated in 2010 and 2012.

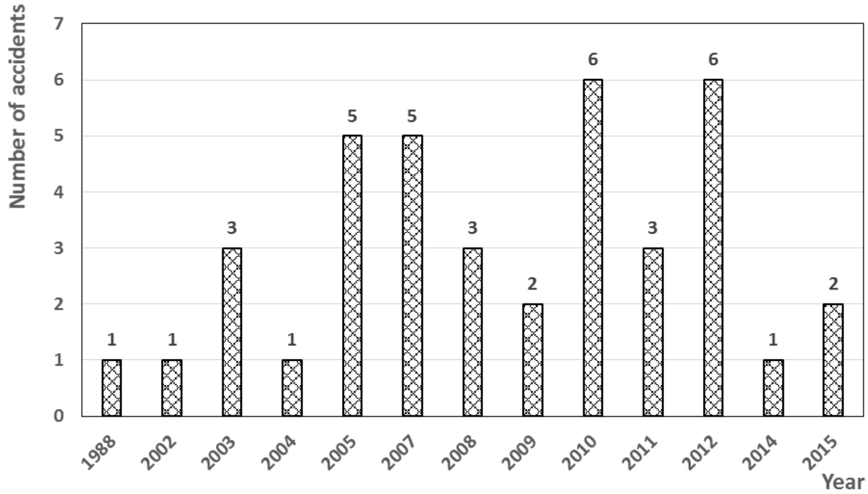

Figure 3 - Distribution of victims by year

The months that reported more deadly victims are March and October with 7 case each (figure 4). In Portugal usually the higher temperature and lower relative humidity values are registered in July, August and September and the number of victims is lower than in the other periods of the year because people tend to make less burs in the summer period. Contrarily to what could be expected, this type of accidents frequently occur during the first trimester of the year which is coincident to the later winter season in Portugal. The existence of a period when the burning is not allowed (from May 15th to September 15th) and a period when the burning is allowed (rest of the year) may cause the wrong sensation that making agroforestry burns out of the critical period has reduced risks and that people can use the fire without the convenient safety procedures.

Most part of these people did not realize how the conditions changed in the last decades. For one side the physical shape is not the same as some years ago but we can seethat some burns are made in a way that requires a great physical capability. On the other side, with the rural exodus and the accumulation of fuels in uncultivated areasthat have been noticed in Portugal in the last decades, the probability of a burning haywire to a uncontrolled fire increased dramatically.

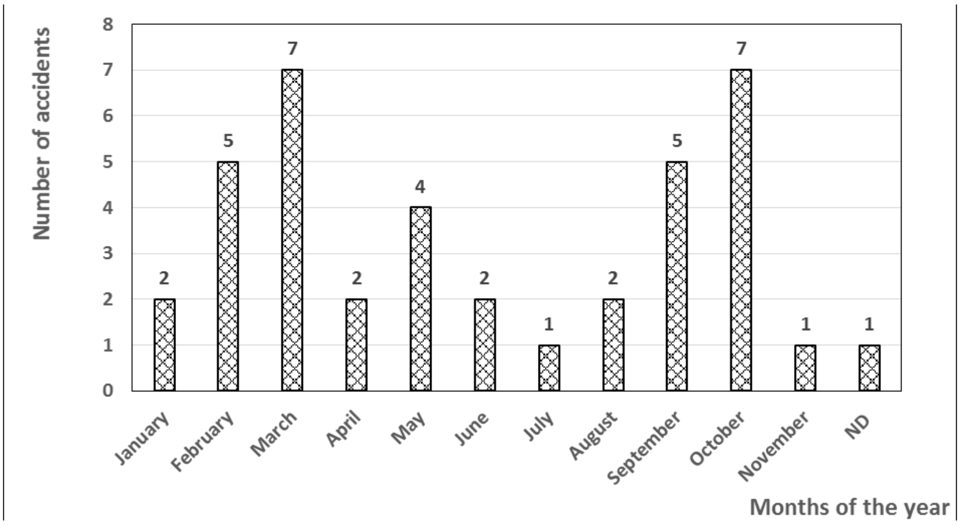

Figure 4 - Distribution of the victims by months

The distribution of victims by gender and age is shown in figure 5where it is possible to seethat males with 75 to 80 years old is the most representativeclass among the groups of victims. The average age of the victims was 75.0. As previously mentioned, the population in rural areas is aging and the subsistence farming is mostly developed by elder people who naturally have lower endurance to manage a fire or to escape froma dangerous situation. On the other side culturally in Portugal agroforestry burns are commonly handled by menwith a percentage of 61.53% of the fatalcases reported.

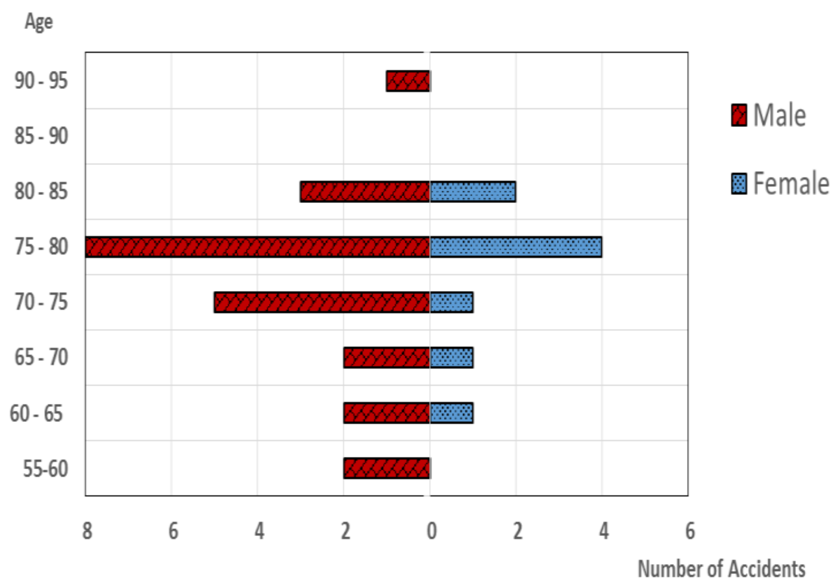

Figure 5 - Distribution by gender

Most part of the fatalcases are registeredoutside the critical period of wildfires (figure6)74.35% of the reported cases against the 25.64% during the critical period. In Portugal this period is usually in late spring and summer and isdefined by law to be from the 15 of May to 15 of September (Law number 17/2009 of 14 of January).

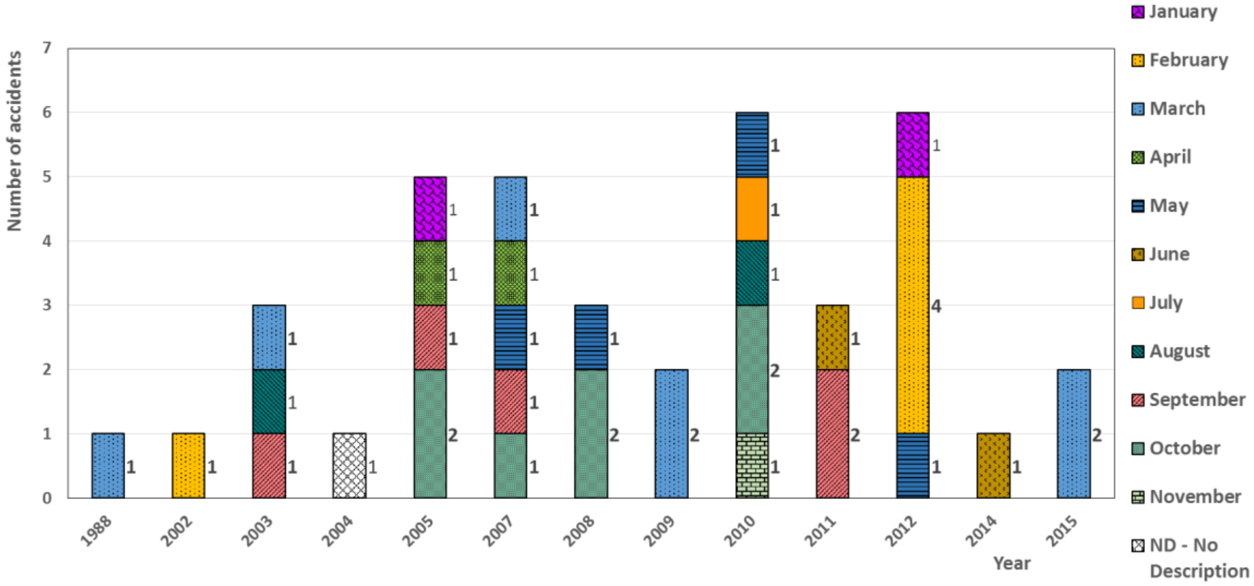

Figure 6 - Distribution of the number of victims by year and month.

3.2. Description and analysis of some case studies

Among the 39 cases reported involving deaths originated by agroforestry burns, we choose four cases to make a more detailed analysis. The main motivation to choose these cases was the difference in the patterns between them. The first case that occurred in the Vasco Esteves de Baixo shows an unusual strength of a 78 years old man who climbed a very steep slope with the intention to extinguish the fire he started. The second case occurred in Loureiro de Silgueiros and involved a 77 years old man with a recurrent record in more than 25 years of being advised by the authorities for putting fires. The third case occurred in Cabaços and the victim was an 82 years old woman in a terrain she had near to her house, this accident occurred in an area of WUI. The last case we chose occurred in São Martinho do Bispo. The victim was a 78 years old woman who died in her back yard without any contact with the flames.

3.2.1. Case study of Vasco Esteves de Baixo

On February 20th of 2002 in Vasco Esteves de Baixo, Alvoco da Serra, municipality of Seia, district of Guarda occurred a wildfire as consequence of an agroforestry burn that caused the death of a 78 years old man. The victim was retired and owner of the terrain. In this day his wife was with him working in the field. The landscape in the mountain is characterized by steep slopes and the cultivated parcels are very small and all the pieces of flat terrain are occupied with agriculture. It is typical in such cases that the person who starts the fire tries to extinguish it by any means to avoid problems with his neighbours.

The Fire Brigade of Loriga received an alert of a wildfire in Maceiras and immediately moved to the scene 4 operational vehicles. The fighting started in the head of the fire near to the ridge (figure 7 a) in contradiction of the protocol as at this point the fuel was lower and the intensity of fire was also lower. The fire was extinguished from the head to the bottom of the valley by the flanks, when the brigade arrived at the bottom they saw one elderly woman crying and saying that her husband had climbed the slope alone to extinguish the fire with an hand tool.

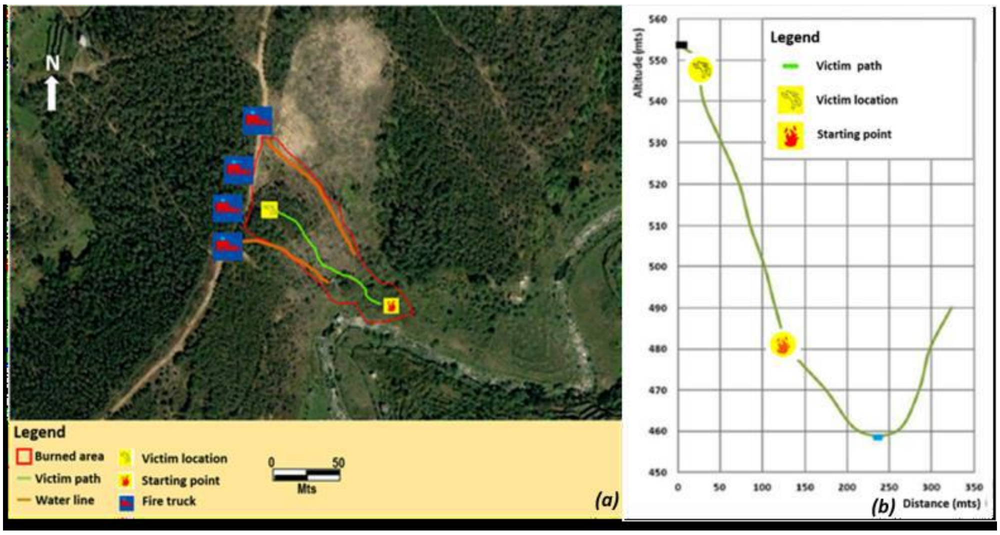

Figure 7 (a) Description of Vasco Esteves de Baixo events (b) victim path

Then the Brigade climbed once again the slope and found an elderly men dead 5 meters from the road near the ridge. The elderly had severe burns in the face, thorax and arms.

To analyse the slope of the area and the difficulty of progression of victim, we built up a topographic profile shown in figure 7b. In this way we can see that the slope of the path taken by the victim was around 36 ° (approximately 73%) which allows us to draw some conclusions regarding the mobility of the septuagenarian and the fire behaviour in such situations.

This accident occurred according to the military map nº 234 in an altitude it varies between 470 and 560m and in a South exposure, receiving greater radiation causinga lower moisture content of the fuel. In this case we had aneruptive fire behaviour phenomenonthat isresponsible for numerous accidents both in Portugal and abroad.

In this day the meteorological parameters for the district of Guarda was 4.1ºC of temperature, 39.9% of relative humidity and the wind speed was 17.5 km/h with gusts of 50.4 km/h. There was no precipitation during the 12 days prior to the accident. The Drought Code Index (DC) in the day was 92.73 that isconsidered as moderate.The fuelcoveron the accident site was a maritime pine stands aged between 15 and 20 years and shrubs with about 1.5m in height (figure 8).

Figure 8 - Fuel cover in the area where the accident occurred

3.2.2. Case study of Loureiro de Silgueiros

On September 14th of 2012 in Loureiro de Silgueiros, municipality and district of Viseu, a rural fire as consequence of an agroforestry burn that caused the death of a 77 years old man occurred. The victim was retired and owner of the terrain. In this day he decided to burn residues of agriculture alone around the 3:00pm. The

Volunteer Fire Brigade of Viseu received an alert to a wildfire in Loureiro de Silgueiros around 3:45pm and immediately moved to the scene one operational vehicle with 5 elements (figure 9).

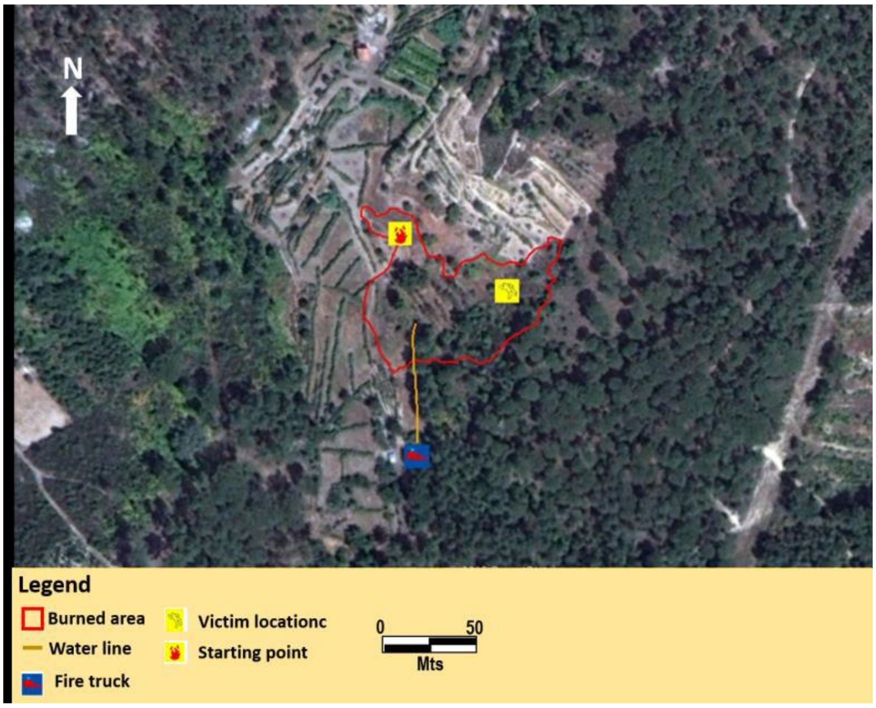

Figure 9 - Description of Loureiro de Silgueiros events

The helicopter and the air team from the National Guard (GNR) were already fighting at the scene. During the operations teams from Volunteers Fire Brigade of Nelas, Cabanas de Viriato and Viseu Municipal arrived.

The vehicle of the volunteers of Viseu started the fighting by the right flank with awater lineofproximally125mof hose. The elderly started burned small portions of grass and controlled them with a hand tool. According a neighbour the septuagenarian had problems a few yearsbeforewith thistype of practices and he wasreferenced bythe authorities. During the process the septuagenarian let the fire to outbreak and go to a small stand of juvenile *Eucalyptus globulus Labill*nearby.

Atthe end offightingoperations the Fires Brigades at the scenereturnedto the vehicles and prepared to leave the site. Itisusualwhenthe burned areas are smallthat the leadersof the operationsmake an inspection by foot with other element, to checkif the fire iscompletelyextinguished. Inthis inspection, the team leader of the volunteers of Viseu found a body with the legsand the feet burned (figure10a). Immediately the authorities were called to the local to identifythe victim and initiate the procedures to remove the body to the medical coroner (figure 10b).

Figure 10 - a) Detail of the location of the victim (b) Municipal Fire Viseu await the arrival of the health delegate to certify the death. (Source: (a) CEIF / ADAI, (b) Correio da Manhã edition 15-Sep-2011)

This accident occurred according to the military map nº 199 in a flat slope with small differences of altitude and whita South exposure, receiving greater radiation as well.In this day the meteorological parameters for the district of Viseuwas 33ºC of temperature,50% of relative humidity and 15.2 km/h wind speedwith gusts of 54 km/h. Theprior 13days before the accident don’t register any rainfall the last record of rainfall was in September firstwith 21.4mm in that day.The September of2011 was a month extremely dry. The DCin the day was 343.02that isconsidered as extremely high.

The fuels are initially herbaceous (figure 11a) and after the outbreak are a mix of juvenile *Eucalyptus globulus Labill*and*some Quercus suber* (figure 11b).

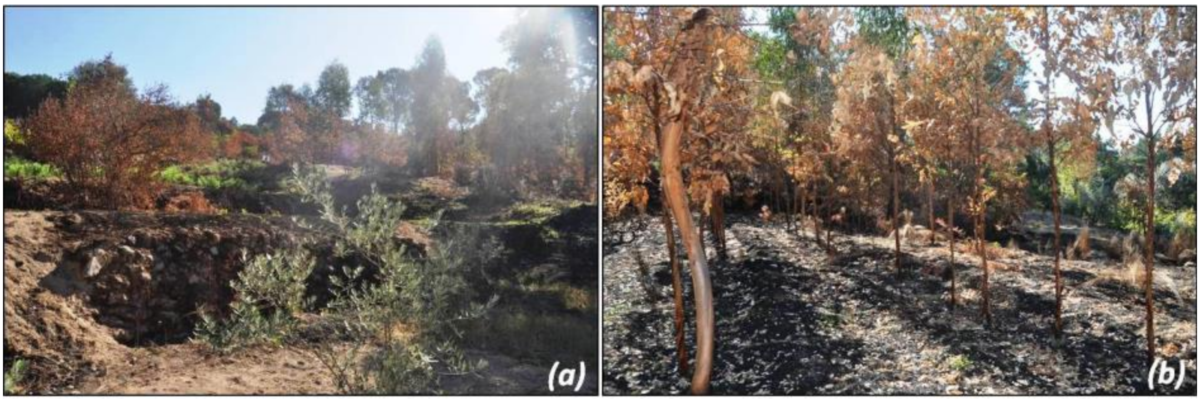

Figure 11 - Fuel cover in the area where the accident occurred

3.2.3. Case study of Cabaços

On February 22th of 2012 in Cabaços, municipality of Moimenta da Beira, district of Viseu a rural fire as consequence of a burn of *Quercus suber L* leaves occurred causing the death of an 82 years old woman. The victim was retired and owner of the terrain where it happened. The victim who had mobility difficulties because she had a prosthesis in a leg decided, against the will of her daughter to go alone to collect the leaves of *Quercus* near her house (figure 12 a) with the intention to burn them (figure 12 b).

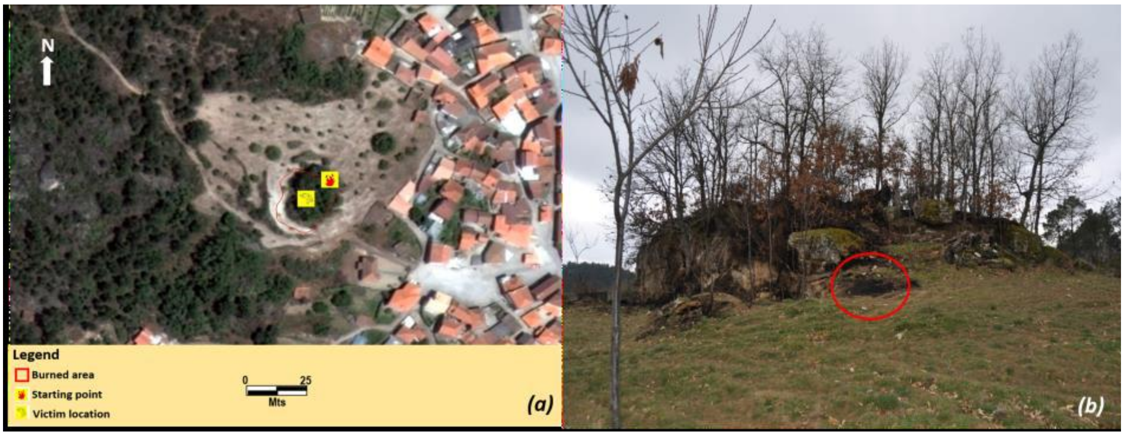

Figure 12 – (a) Detail of the area of Cabaços accident (b) view of the starting point area

At 12h30pm, her son in law called the Moimenta da Beira Fire Brigade to report an accident with her mother in law, and asked for a fire truck and an ambulance to Cabaços. The area where the accident occurred is characterized by a typical WUI layout in the border of urban constructions surrounded by agriculture parcels. The burned area had approximately 800 m2 and was located near a wall of stones with few *Quercus suber L* on its top (figure 12 b). According to the victim's son-in law the elderly woman had gone early in the morning alone to the propriety to collect the leaves started a fire and lost the control of the flames that progressed to the upper part of the ground.

When the firefighters arrived theyfound the victim sitting back in a small step on top of the stones with the bodycharred. When the CEIF team visitedthe placeon March17thof 2012, few days after, the tools (figure 13 a) used bythe elderly woman as well as some pieces of burned clothing (figure 13 b)were still visible.

The body of the elderly woman was transported to the Coroner Officer at São Teotónio Hospital in Viseu. Her daughter also residentin Cabaços had warned hermother on several occasionsof the danger of fires inthis time of the year, especiallywithout rainfall.

Figure 13 - (a) Tool used by the elderly woman (b) pieces of burned clothing

This accident occurred according to the military map nº 148 in a flat slope whit a South(S) exposure. In this day the meteorological parameters registered at Vila RealMeteorological

Station was 13.3ºC of temperature, (the lower temperature since 1932registered in Vila Real Meteorological Station), 49%relative humidity and 2.9 km/h wind speed blowing from the West (W) quadrant. The February of 2012was an extremely dry month, the DC in the day was 93.51 that is considered as moderate. The fuel dryness state, exposure, shape and slope will have contributed to a rapid spread of the fire after the outbreak and to change their behaviour.

3.2.4. Case study of São Martinho do Bispo

The last case study, occurred on June 28th of 2014 in São Martinho do Bispo, municipality and district of Coimbra and caused the death of a 71 years old woman. The victim was retired and owner of the terrain where it happened. The victim who had mobility difficulties because she had been surgically intervened to the heart.

At 5h07pm the District Command active for a rural fire in São Martinho do Bispo (figure 14 a) three crews and three operational vehicle's. The vehicle of the Volunteers Fire Brigade of Coimbra takes about 9 minutes from the headquarters to the scene. Upon arrival at the scene the leader performs a visual recognition and informs the Distract Command the human and material means present in the local was sufficient and assumed the command of operations, until the arrival of the senior element of Municipality Fire Brigade. When the crew of the volunteers Fire Brigade of Coimbra arrived, only a very small portion of grass burn whit a grey smoke, nothing serious for the Portuguese Fire Brigades used to large fires.

Immediately the small fires were extinguished. As usual, if the burned areas are small the leaders of the operations make an inspection by foot with other element, in this case a female element of the Volunteers Fire Brigade of Coimbra found a body face down without any burnings (figure 14 b) behind a small elevation of land.

The crew of the Volunteers of Coimbra starts immediately the *Basic Life Support* protocol while the leader request to the local differentiated medical support. The differentiated medical support arrived very fast with a medicalized ambulance and a special vehicle of emergency with a doctor on-board. After the manoeuvres of resuscitation the medic at the local confirm the death of the elderly on site. The body of the elderly woman stay at the local until the National Police arrived to the local and initiated the protocol to remove the body from the place to the coroner located in the Medicine Legal in Coimbra.

According to her daughter the victim had been surgically intervened to the heart 15 days before the accident. The victim had been seen by neighbours in themorning to gather mounds of agricultural residues apparently to burn. During this bonfires cleaning actions results shorts spot fires projections (2-5 m) which started the fire in the lands of neighbours. The place where the victim die as shown in figure 13 is a yard, perfectly bonded by the urban area.

Figure 14 – (a) Detail of the area of the location of the victim (b) Detail of position of the victim

This accident occurred according to the military map nº 241 in a flat slope whit a northwest (NW) exposure. In this day the meteorological parameters for the district of Coimbra was 18.2ºC of temperature, 45% of relative humidity, 12.3.2 km/h wind speedand 10mm of rainfall.The DC in the day was 179.38that is considered high.

The fuels are very high herbaceous with 1.5 to 2 m in average (figure 15) nearby her home.

Figure 15 – Fuel complex existing in the area of accident of São Martinho do Bispo

4. CONCLUSIONS

Wildfires that are one of the most devastating hazards in Portugalare quite often originated by negligent practices associated to the use of fire, namely impropermanagement of burningof agricultural and forestry residues. Since during the months from Mayto Septemberthat areconsidered as critical period of wildfiresagroforestry burnsare not allowedmost fatalities occur out of this period.

The average age of the victims is around 75 years and correspond mostly to individuals of male genderwho usually make more agroforestry burns. As mentioned before the agriculture of subsistence is mainly developed by elder people that always have been handling fire in agroforestry burns.

Most fatal accidents analysed occurred in the North and centre of Portugal, which coincides with the regions where the probability of wildfire is statistically higherdue to the combination of high values of vegetation load, roughtopography and periodsof high temperature and low relative humidity. Frequently the accidents occurred during days with high values of fire risk indexes like DC when the burns should be avoided. The typical elder people involved in the accidents to not have access to this information that is commonly available on the internet with which they are not able to deal. This information isavailable in physical supportsduring the fire critical season when the burns are not allowed. We suggest the prohibition of burnings during the days with higher fire risk and the availability of this information in accessible spots or by other means like telephone numbers dedicated to give information. Moreover an extra-effort of education on the topic of wildfires should be provided to this group of people.

As a recommendation to mitigate the fire risk, the landowners should beinstil to better manage theirareas to avoid fire spread. On the other side, the larger burnings or burnings in high fire risk areas should require an authorization by the civilprotection authoritiesand should be supported by firefighters or equivalent agents.

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