[PRACTICE]

D5.9 HEALTH SERVICE REQUIREMENTS AND MODELS

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Summary Work Package 5

The objectives of WP5 are to develop, integrate and test a complete toolbox for first responders, decision makers and the public, including innovative components developed during the project to provide an improved and integrated preparedness and response to CBRN events. The tools will be organized in 6 categories,

1- Recommendations
2- Standards
3- Protocols / procedures
4- Equipment and systems (eventually simulated): hardware, software, with performances, Technology Readiness Levels (TRLs), validation/certification status
5- Simulated environment (with 3D databases)
6- Real equipment and system emulation capabilities.

These tools will fulfil functions as defined in WP3, organized in line with the ESRAB/Staccato taxonomy functions, completed and detailed when needed for PRACTICE. The toolbox should be considered as living system gathering “bricks” into an integrated solution to manage a CBRN crisis. It will include actual tools and equipment and ICT simulated environments including hardware and software. This will allow plugging and playing new components and guarantee their interoperability.

The toolbox will be developed and integrated in two steps:

- a V0 version integrating in an innovative way existing validated capabilities (fed from WP 2 and WP 3) i.e., tools, methods and procedures that will be put together into an information system, with specified standard interfaces

- a V1 version integrating innovative tools, methods and procedures and supporting future standards to improve interoperability and consistency without impeding the existing operational systems.

Developing V0 and new CBR tools for V1 will be an iterative process with all the stakeholders in the loop. Focus will be put on specifying simple interfaces for any supplier to describe and present its "bricks" in order to "index / reference" them in our PRACTICE Toolbox Information System. Any new tool that satisfies the "standards" interfaces should be easily added to build new solutions ("buildings").

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Contents

1. Executive Summary

This report, “D5.9 Health Service Requirements and Models”, is a deliverable associated to Work Package (WP) 5 “Toolbox Integration and Development” of the EU FP7 project “Preparedness and Resilience Against CBRN Terrorism using Integrated Concepts and Equipment” (PRACTICE). This WP is led by Astrium S.A.S. (AST).

The PRACTICE_HSS (Health Service Simulator) tools aim at demonstrating the support that Modeling & Simulation tools can provide to the Contingency Planning activities (see definition section, chapter 3 - crisis management - preparedness phase) with a specific focus on the Health Service facing a CBRN event.

In order to satisfy this objective the deliverable provides a description of the requirements of the Health Service and a definition of the models will be used to implement the PRACTICE_HSS tools.

More in details this report starts giving a high level description of the crisis context (with a particular focus on CBRN events) recognizing and describing different phases that commonly occur during a major event. It proceeds with an explanation of the main operational issues coming from the management of a crisis and a detail of those user needs that will be addressed. The following chapter refines these user needs in order to achieve a detailed and measurable set of user requirements: with this aim separate sections are dedicated to the requirements related to scenario, Health Services, inter-services interaction, reports, GUI and context. The report ends defining the key entities of the application domain, behaviors and procedures to be implemented. For this purpose, the models description is provided devoting different section to medical service, ambulance service, inter services interactions and casualties entities.

A specific section (in Chapter 3) briefly lists the relevant terms used in the report with twofold aim in giving a common view of the domain and explaining the meaning of some words reported into the text.

The user requirements and the models described in this report, will be the basis for the system requirements and design definition activities needed to implement the PRACTICE_HSS tools.

2. Introduction

This part of the PRACTICE toolbox, namely PRACTICE_HSS (Health Service Simulator) tools aims at demonstrating the support that Modeling & Simulation tools can provide to the Contingency Planning activities (see section 3 - Crisis Management - Preparedness phase) with a specific focus on the Health Service.

With this purpose, the objective of this document is to identify and define the requirements and the models of the Health Service facing a CBRN event. To that aim this deliverable provides a high level description of the:

- user needs: in order to develop a clear understanding of the problem to be addressed;
- user requirements: in order to define what the system should provide;
- models: in order to describe the key entities of the application domain, behaviours and procedures to be implemented in the system.

The user requirements and the models identified in this document will be the basis for software design and models implementation activities to be carried out in the next phases of the project.

3. Definitions, abbreviations and acronyms

Definition	Description
Crisis	An event involving major damage and injury to people and property of sufficient magnitude to create a temporary *imbalance* between the *large scale needs* of a community and the *availability of resources* able to provide the emergency care to address these needs.
Crisis Management	As previously defined by the five phases security cycle, the crisis management process involves four different phases: *threat assessment*: this phase comprises an analysis of the actor(s), their capabilities and possible target(s); *prevention*: the efforts in this phase attempt to prevent hazards from developing into disasters, or to reduce the effects of disasters when they occur; *preparedness*: in this phase emergency managers develop plans of action for when the disaster strikes; *Response*: this phase includes the mobilization of the necessary emergency services and first responders in the disaster area; *recovery*: the aim of this phase is to restore the affected area to its previous state.
Emergency Service/First Responder	Individuals and teams that are involved in activities which address the immediate and short-term effects of a CBRN emergency. This includes on-scene personnel from the police, fire brigades and health services acting to minimise the consequences of a CBRN-emergency. It also includes personnel in hospitals, crisis management institutions and those involved in detection, verification and warning.
Triage	It is a medical decision process used to arrange casualties in priority order to ensure the most effective use of limited medical resources and minimize morbidity and mortality. Triage is a continuous, ongoing process through the casualty care chain and should be utilized whenever casualties must be assigned priority for treatment, evacuation or decontamination.
Hot Zone	The hot zone is the area of chemical release. The area is determined to be contaminated with chemical agents (dry solid, liquid, or vapor). This determination is usually performed through the use of chemical monitoring devices. Individuals entering this area must be in a high level of protection at least until the agent is known, after which lower levels may be appropriate. MTFs located in this area typically cease operations, shelter in place, and do not receive patients.
Warm Zone	The warm zone is outside the hot zone. The level of contamination here is significantly lower than that found in the hot zone. Contamination in the warm zone is only that which is on the unprotected skin, clothing, and equipment of those entering from the hot zone. The warm zone is where decontamination occurs.
Cold Zone	Areas free of solid, liquid, and vapor contamination are in the cold zone. Before being allowed into the cold zone, individuals must go through decontamination and be determined contamination free; this

Definition	Description
	requirement applies not only to patients but also to medical workers and decontamination team members in protective ensemble. Individuals in the cold zone do not need to wear any type of protective equipment.
Decontamination	Decontamination is the process of removing or neutralizing hazardous substances from people, equipment, structures, and the environment. Early skin decontamination can often mean the difference between patient survival (or minimal injury) and death (or severe injury). Patient decontamination serves two primary purposes: (1) protecting the casualty by removing harmful agents from the skin, thus reducing the dose and severity of the agent's hazardous effects, and (2) protecting emergency responders, transport personnel, medical personnel, and other patients from secondary exposure. Casualty decontamination takes place at all levels of patient care, from the exposure site to the door of the medical treatment facility (MTF).
First Aid, Trauma Center Low/High Level	They represent three type of medical facility mainly different in the kind of treatment they are able to provide to the casualty. The *First Aid* is the provision of initial care; it generally consists of a series of simple and in some cases, potentially life-saving techniques performed with minimal equipment. The *Trauma Center Low Level* is an intermediate level of health care that includes diagnosis and treatment, performed in a hospital having specialized equipment and laboratory facilities. The *Trauma Center High Level* is a specialized, highly technical level of health care that includes diagnosis and treatment of disease and disability (through specialized intensive care units, advanced diagnostic support services, and highly specialized personnel).
Clean Treatment Area	The clean treatment area is part of the cold zone (located 30-60 meters upwind of the hot zone). The recently decontaminated patients are re-triaged in this area. The patient can be here treated definitively or transferred to another facility if needed.
Evacuation Matrix	If a casualty hosted in a medical facility (MF) needs a treatment that MF is not able to provide, that casualty must be evacuated towards an higher level MF. To manage those situations, in the contingency planning phase, for each MF involved in the plan, the "parent" MF towards which casualties will be evacuated (in case of need) must be defined. The evacuation matrix is the "tree" whose nodes are the MFs and whose "arcs" are the relationships among the MFs.
Personal Protective Equipment	The equipment provided to shield or isolate a person from the chemical, physical, and thermal hazards that can be encountered at a hazardous materials incident. Personal protective equipment includes both personal protective clothing and respiratory protection. Also called PPE.
Health Service	Includes both the Medical Service and the Ambulance Service

Abbreviation/ Acronym	Description
ABCDE	Airway, Breathing, Circulatory, Disability, Exposure
ALS	Advanced Life Support
BLS	Basic Life Support
CBRN	Chemical, Biological, Radiological and Nuclear
CTA	Clean Treatment Area
FA	First Aid
GCS	Glasgow Coma Scale
GUI	Graphical User Interface
HAZMAT	Hazardous Material
HSS	Health Service Simulation
MCS	Mass Casualty Situation
MF	Medical Facility
MS	Milestone
MTF	Medical Treatment Facility
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological and Chemical
PPE	Personal Protective Equipment
RR	Respiratory Rate
SBP	Systolic Blood Pressure
START	Simple Triage And Rapid Treatment
TCHL	Trauma Center High Level
TCLL	Trauma Center Low Level
ToD	Time of Death
TRTS	Triage Revised Trauma Score
WP	Work Package

4. User Needs

This chapter starts with a high level description of the crisis development (see section 3 - crisis). The focus will be on crisis caused by events with a definite beginning and causative factors that will not continue over indefinite periods.

The chapter will then present the main operational issues in the depicted context and will finally state those user needs that will be addressed.

4.1 Crisis context

4.1.1 Chaotic Phase

This phase is the period of disorganized confusion in the initial minutes to hours after a disaster strikes and is characterized by panic, fear and lack of leadership over those at the immediate scene and over the general population.

In urban settings the chaotic phase generally lasts less than 1 hour. The most critically injured/contaminated casualties are at great risk of death during this phase. The least severely injured/contaminated casualties generally walk themselves to the nearest hospital (overwhelming them and contaminating personnel and equipments).

4.1.2 Initial Response and Reorganization

This phase begins when professional first responders (see section 3 – first responder) arrive at the disaster scene to assume command and control and proceed to:

- needs assessment. This involves two major processes:
  - *situation analysis* is the collection of information about the extent and character of the disaster itself and the problems that have to be tackled (e.g estimating the number of casualties, recognizing signs and indicators of CBRN incidents etc);
  - *resource analysis* involves the collection of information about the resources needed to tackle the problems (considering specialist advice/resource requirements);
- decision on whether the disaster plan should be activated;
- establishment of a command centre that interacts with the central command authority.

The first responders typically include:

- *Firemen* with the responsibility to:
  - secure the area,
  - isolate the scene (“hot-zone” - see section 3 - hot zone) and establish different areas (triage, decontamination and clean treatment),
  - contain the hazardous material and
  - clear the area of dangers that could impede search and rescue operations.
- *Police* with the responsibility to:
  - control and restrict access to the incident scene,

- control movement of contaminated victims,
- maintain order among the first responders, casualties and volunteers and ensure the safety of victims and first responders and
- establish traffic cordon.

- *Pre-hospital emergency medical services* with the responsibility to evaluate the medical needs of the casualties and to provide first aid.

All responders must take appropriate measures to protect themselves before entering the contaminated area.

The sooner firm leadership and command authority is established at the scene and in hospitals, the smaller is the risk for further injury, damage and contamination.

4.1.3 Site Clearing

Once organization of the chaotic response is established, a thorough examination of the damage at the disaster scene must proceed and the plan for clearing debris and rescuing casualties is executed.

Generally the Firemen have the responsibility to secure the area in order to:

- prevent immediate dangers represented by, for instance, secondary structural collapse or second terrorist bomb detonated later (with the intent of killing first-line responders arriving at the scene to help);
- contain contaminant material/liquid;
- establish inner and outer cordon (hot/warm/cold zone - see section 3 for definitions)
- establish triage, decontamination and clean treatment areas (see section 3 for definitions);
- cordon off contaminated areas.

This emphasizes the importance of strict control of access to any disaster scene by the command authority, allowing only those personnel who are trained and have Personal Protective Equipment (respiratory protection, chemical protection suits) to enter the “hot zone”.

4.1.4 Search and Rescue

Once the disaster scene is reasonably secure, a search for casualties is undertaken.

Surviving casualties should immediately be assessed for the nature of their injuries and the urgency of treatment needs after being rescued from the disaster site, so-called triage.

4.1.5 Medical Care

The medical care of disaster victims begins at the first moment of rescue and extends for hours, days, weeks, or longer through all phases of definitive care and rehabilitation. This requires early and rapid rescue, evaluation, first care and decontamination if needed, and evacuation of casualties to hospital facilities.

The medical care phase can be split into phases as follows.

The initial phase of medical care begins at the incident location at the first moment of casualty-rescue and lasts until the casualty flow into the hospital has stopped.

The following activities are carried out during this phase:

- the first triage performed at the disaster scene (hot zone): this represents a highly abbreviated assessment to separate surviving victims with life-threatening problems that require immediate care from those with less severe problems requiring less urgent attention. In this phase, the priority for casualty decontamination is generally determined by the clinical priority for treatment. Initial medical care for instable red code casualties always take precedence over casualty decontamination; for the other casualties however, priority for decontamination will be influenced by the nature of the contaminating agent, and is further modified by the level of decontamination capability available.

- the immediate, initial care provided in a mass casualty scenario always occurs in the contaminated area (hot zone): it must be as little as necessary to evaluate and stabilize a patient in a matter of seconds so as to be able to quickly recognize that small minority who may require urgent attention.

- a second level of triage, a possible second level of decontamination and urgent stabilizing care: it is provided between the scene and the hospital in a safe area called warm zone located immediately outside the hot zone. Those casualties with non-urgent injuries can be monitored for any deterioration while first life-saving care is provided to casualties with critical injuries.

- the evacuation: this phase provided after various assessment and first care is essential to properly distribute the casualty load at the scene (after decontamination procedures) to as many different hospitals as possible, in accordance with the resources available at each hospital or in the area as a whole. This principle of casualty distribution prevents any one facility from being overwhelmed with such number of casualties that patients care capabilities are paralyzed.
  CBRN events impose additional constraints that should be considered when planning the casualty evacuation:
  - contamination of ambulances and vehicles may occur when transiting contaminated areas, and/or by the carriage of contaminated casualties;
  - casualties, medical attendants and crew must maintain appropriate levels of physical protection in the presence of CBRN hazards;
  - aside from the constraints imposed by the need for protection and contamination control, casualty transfer assets should be provided with an appropriate level of specialized medical equipment;
  - medical treatment facility (whether a small or large facility) entrances must be secured to maintain a contamination-free hospital environment;

  The orderly CBRN casualty distribution process can only be effective if all hospitals in any community are equally prepared for the unique demands of a mass casualty CBRN event.

An important concept in crisis management is that of surge capacity. This is the ability of an hospital to expand its resources to accommodate the large number of casualties in this settings that would otherwise overwhelm its capabilities under normal conditions. This involves increasing the number of available beds and patient care staff acutely, which generally requires discharge and transfer of existing patients elsewhere.

Once the casualty flow into the hospital has stopped, more time can be devoted to casualty care. All casualties can be more thoroughly re-evaluated. Available hospital resources can be inventoried and applied as necessary to casualty needs without the worry that they may be depleted by more incoming victims.

Casualties initially denied care due to the prohibitive nature of their conditions, who are still alive, can be reassessed for the possibility of initiating care based on their needs and available resources.

4.2 Critical Operational Issues

The main operational issue lies in the difficulty to have even a rough estimate of how the crisis management system will respond to the crisis and, as a consequence, in the impossibility to identify those key leverage points of change that enable the overall system to produce significant shift in its performance.

The main causes of the unpredictability of the response are:

- ✓ Decision making at service level

  Each organization involved in the management of an emergency is a complex structure made up of different tightly interacting entities and each one with specific responsibilities to be carried out mostly according to defined procedures. The overall response to the crisis will depend not only on the quantity and quality of the individual entities but also largely on how those entities cooperate in harmony with one another through the entire scenario, at national and at trans-national level.

  Focusing on the medical organization as a test case example, the increase of a single functional entity such as the number of beds will not necessarily grant a higher “casualty-hosting” capability of the medical service. Rather, the composite capability will improve if the sets of elements required to support the hospitalized patients (e.g. people, processes, hardware/software, equipment, other medical supplies etc) are balanced and coordinated to provide an effective and efficient casualty throughput and treatment within a well defined, scalable architecture (e.g. a hospital).

- ✓ Decision making at cross-service level:

  Although individual service organization may be quite effective, the system as a whole may experience a significant “failure to respond” due to a faulty or deficient inter-service interaction.

  The response of the whole system will be the result of the activities of different services (such as police, medical care, firefighting, decontamination team, etc) interacting vertically (i.e. with components of the same organization) and horizontally (i.e. with components of other organizations) and depending on and influencing each other.

  Again, in the health service example, an excellent Medical organization and a perfect Ambulance organization could lead to a non-excellent health service response in case of

lacking inter-service interaction (e.g. lots of casualties transported very fast to the wrong medical facility).

✓ Unpredictable factors:

Such complex system of strongly interrelated components, self-organizing and dynamic will have to operate in a complex environment where the situation evolution will be determined by predictable factors (e.g. responders behaving according to the agreed procedures) to a given extent and will be subject to unpredictable factors (e.g. crowd behavior, traffic gridlock, human behavior etc) otherwise. This is particularly important to consider during the preparation phase of a response to an unpredictable incident.

Referring once again to the Health Service, the current approach to medical planning is often based on resource requirements calculations. Often, the data used in requirements-based planning comes with a high degree of uncertainty.

For example, a medical planner must make assumptions on the number of casualties that will result from a conventional or non-conventional terrorist attack. Typically this is done by one of two methods:

- looking at and interpreting historical data;
- running computer simulations that rehearse preconceived scenarios.

In both cases, assumptions are made about how a particular scenario will unfold but rarely an operation develops exactly as planned.

✓ Procedures:

During an emergency an organization responds by performing specific tasks according to defined procedures. The most effective procedures need to be implemented correctly to provide the expected results. Several factors could lead the decision makers to fail in the application of these procedures. Some examples are:

- decision makers are forced to make important decisions under pressure and in a time critical context;
- in case of major disaster(s), international assistance may be necessary. However it is common that decision makers of different countries have implemented very different procedures from one another;
- even good procedures may not function if not adequately trained and exercised at national and international level.

4.3 Needs Statement

Referring to the crisis context depicted in section 4.1 and taking into account the focus of the PRACTICE project on preparedness and resilience to a CBRN crisis, the PRACTICE_HSS tools will be focused on providing decision support to health service contingency planners (i.e. in preparedness phase). As a consequence, the main “end users” of the system will be:

- Medical-Service Planning & Coordination level
- Ambulance-Service Planning & Coordination level

Despite the fact that most of the user requirements will come from the end-users mentioned above, it will be important to take into account the effects of inter-service interactions on the Health Service response (e.g. intervention delay).

The Health Service crisis manager needs support for:

- evaluating the effectiveness of the existing methodologies, doctrines/policies, procedures of operational units within the medical service and experimentation with new ones.

The case study chosen for the PRACTICE_HSS tools shall be focused on the evaluation of the following alternative procedures:

- *Triage*: support is needed for the evaluation of the effectiveness of different Triage policies.
- *Casualty regulation*: support is needed for the evaluation of the effectiveness of different casualty regulation policies.
- *Casualty evacuation*: support is needed for the evaluation of the effectiveness of different casualty evacuation policies.
- *Different evacuation matrix* (see section 3 for definition): different evacuation matrices could lead to a better distribution of casualties and a decreased average workload at the medical facilities.

Within the PRACTICE_HSS the focus shall be on the evaluation of the effects of different configuration of resources (e.g. varying number of personnel, vehicles and medical facilities, etc).

5. User Requirements

This chapter aims at refining the user needs presented in the previous chapter in order to achieve a detailed and measurable set of user requirements.

Separate sections are devoted to the requirements related to scenario, Health Services, Inter-services interaction, reports, GUI and context.

To each requirement a unique “code” and a progressive number has been associated. The “code” is an abbreviation of the domain the requirement refers to (e.g. “SC” stands for scenario, “HS” stands for Health Service, etc).

5.1 Case study

The case study will be focused on a chemical terrorist attack scenario. This specific scenario has been selected because of:

- the “finite” nature of the event (i.e. with a definite beginning and causative factors that will not continue over indefinite periods);
- the relative easiness of acquiring chemical agents (making this event quite possible);
- the evidence of the symptoms

compared to e.g. biological weapon whose effect may take days to become observable or severe.

An example of the situation where the tool is expected to provide decision support is the following:

- an event having international relevance will take place in a urban area;
- the health service crisis managers are tasked to make a contingency plan to face a possible terrorist attack with chemical weapons (i.e. an attack generating both trauma and contaminated casualties);
- as a consequence, the Health Service decision makers have to elaborate and evaluate the effectiveness of different alternatives (both in terms of resources and procedures) to face the above situation.

5.2 Health Service

The system shall support the user during the preparedness phase of the emergency management process. More in detail the system shall support the Health Service (HS) in:

- **HS-1**: contingency phase: evaluating the effectiveness of different procedures for: triage, casualty regulation, evacuation matrix.

5.2.1 Medical Service

Tasks

The system shall simulate the following tasks the medical service (MS) is in charge of:

At the accident location

- **MS-1**: secondary triage at the clean treatment area (CTA).
    - **MS-1A**: there shall be two forms of triage of casualties, one for normal operating conditions and one for mass casualty situations (MCS).
- **MS-2**: casualties stabilization and basic lifesaving treatment (Airway, Breathing, Circulation - ABC) in the clean treatment area.
- **MS-3**: casualty regulation i.e. to determine which hospitals will receive casualties in liaison with the ambulance service:
    - **MS-3A**: the casualty regulation process should be done according to casualties priorities.
    - **MS-3B**: the travel time (and the related casualty health status deterioration) and the effect of any temporary treatment provided at the medical facilities shall be taken into account when selecting the most suitable medical facility (MF).
    - **MS-3C**: the system shall allow the user to evaluate the effects of different casualty regulation policies.

At the hospital

- **MS-4**: personnel call-in: it shall be possible to simulate a runtime increase in the number of personnel resources (to simulate the effects of call-in procedures).

- **MS-5**: hospital triage: there shall be two forms of triage of casualties, one for normal operating conditions and one for mass casualty situations.
- **MS-6**: treatment plan: it shall be based on the estimated duration of each treatment as well as the available resources.
- **MS-7**: treatment: the effect of treatment on the casualty's health status shall be simulated.
    - **MS-7A**: the assigned resources will not be available to treat other casualties for a time period equal to the treatment duration.
- **MS-8**: casualties evacuation: the evacuation process for those casualties needing further treatment (with respect to the one the current medical facility is able to provide) shall be simulated.

Entities

Medical Facilities

- **MSR-1**: the system shall simulate the medical facilities.
    - **MSR-1A**: at least the following categories of medical facilities shall be represented: first aid (FA), trauma centre low level (TCLL) and trauma centre high level (TCHL) (see section 3 for definition).
    - **MSR-1B:** MFs belonging to different categories will differ mainly for the kind of treatment they are able to provide.
    - **MSR-1C**: the medical planner shall be able to assign a category to each medical facility and to arrange them in a hierarchy corresponding to the level of service each offers.
    - **MSR-1D**: each medical facility of a particular category shall have a "parent" medical facility belonging to the next higher category.

5.2.2 Ambulance Service

Tasks

The system shall simulate the following tasks the ambulance service is in charge of:

- **AS-2**: fast casualties assessment (at the accident location)

  The first assessment should be highly abbreviated (e.g. START protocol) to determine only those who need immediate treatment and those who don't.
    - **AS-2A**: there shall be two forms of triage of casualties, one for normal operating conditions and one for mass casualty situations.
- **AS-3**: casualty regulation (at the accident location)

  - **AS-3A**: establish and maintain a flow of information to receiving hospitals (e.g. actual available resources).
  - **AS-3B**: determine which hospital will receive each casualty in liaison with the medical service.
  - **AS-3C**: the system shall allow the user to evaluate the effects of different casualty regulation policies.
  - **AS-3D**: vehicles call-in: it shall be possible to simulate a runtime increase in the number of evacuation vehicles (to simulate the effects of call-in procedures).

- **AS-4**: casualty evacuation: it shall be possible to simulate the decision making process leading the ambulance commander to identify the most suitable vehicle able to take the casualty to the selected destination.
- **AS-5**: casualty transport: the system shall simulate the casualty transport time.

Entities

Evacuation vehicles

- **ASR-1**: the system shall simulate the evacuation vehicles.

  An evacuation vehicle is in charge of taking a casualty from his current location to the target destination.

  - **ASR-1A**: at least the following two categories of evacuation vehicles shall be represented.
    - Land
    - Air

- **ASR-2**: it shall be possible to define whether an evacuation vehicle should be used to carry out:
  - only forward evacuation (from the accident location to the medical facility);
  - only inter hospitals evacuation (from one hospital to his parent);
  - any kind of evacuation.

5.3 Inter Services Interactions

Medical vs Ambulance

- **IS-1**: The system shall implement the following procedures for casualty regulation (which casualty to what hospital):

- **IS-1A**: carried out by the medical service on the basis of the casualty treatment-needs and the hospitals capabilities information and interacting with the Ambulance service (e.g. to have a rough estimate of the transport time).
- **IS-1B**: carried out by the ambulance service without the support of the medical service casualty evaluation (e.g. on the basis of the hospitals hosting capability only).

- **IS-2**: The following non-health service tasks shall be simulated in terms of the impact they will have on the health service (both medical and ambulance) tasks:

Police vs Health Service

- **IS-2A**: grant access routes (will decrease the land evacuation vehicles transport time).
- **IS-2B**: establish traffic cordon and take care of non-injured people (will prevent entering to the limited access areas thus avoiding an increase in the number of injured/contaminated casualties).

Fire Brigade vs Health Service

- **IS-2C**: preliminary hazard estimation (e.g. will allow to identify the most effective personal protective equipment and decontamination procedure).
- **IS-2D**: secure area (will prevent an increase in the number of injured/contaminated casualties).

Decontamination vs Health Service

The system shall simulate the effects (e.g. at least a time delay) of the following decontamination tasks carried out both at the accident location and at the hospitals:

- **IS-2E**: establish a casualty decontamination station.
- **IS-2F**: carry out decontamination procedures.

5.4 Reports

5.4.1 Medical Service

- **RMS-1**: the system shall generate diagnostic reports which will assist the medical commander with evaluating the effectiveness of his plan.
- **RMS-2**: the diagnostic reports shall include at least:
  - **RMS-2A**: the number of casualties who died in the simulation, where and at what stage of their treatment.
  - **RMS-2B**: the number of dead that could be rescued given proper and timely treatment.

- **RMS-2C**: the distribution of the life expectancy of the casualties and classification in:
  - emergency casualty (< 30 minutes);
  - urgent casualty (between 30 minutes and 2 hours);
  - no urgent casualty (> 2 hours).
- **RMS-2D**: the workload of the different facilities.

5.4.2 Ambulance Service

- **RAS-1**: the system shall generate diagnostic reports which will assist the ambulance commander with evaluating the effectiveness of his plan.
- **RAS-2**: the diagnostic reports shall include at least:
  - **RAS-2A**: the number of evacuation requests not satisfied.
  - **RAS-2B**: the number of wrong evacuation (the medical facility where the casualty was taken to is not able to provide the treatment needed).
  - **RAS-2C**: the number of travels.
  - **RAS-2D**: the time elapsed from the first to the last evacuation.

5.5 Graphical User Interface

- **GUI-1**: the system shall display a map of the area involved in the scenario.
  - **GUI-1A:** it should be possible to interact with the map (zoom, pan, etc.)
- **GUI-2**: the system shall allow the user to configure a scenario:
  - **GUI-2A:** defining the elements (hospitals, events, etc.) that will take part in the scenario.
  - **GUI-2B:** deploying the elements previously defined on a map in order to create the scenario.
- **GUI-3**: the system shall display the results of the simulation.

5.6 Context

5.6.1 Environmental Conditions

- **EC-1:** the system shall simulate the effects of different weather conditions on the evacuation procedure (e.g. – rain could slow the land vehicle speed, wind could prevent the use of air vehicles etc).

5.6.2 Human Behaviour

- **HB-1**: the medical planner shall be able to assign to each event a value representing how many of the casualties generated by the event will be transported to medical facilities by local citizens or will reach the medical facilities by themselves.

5.6.3 Mass Behaviour

- **MB-1**: the system shall simulate the generation of additional casualties in case the crowd behaviour (due to panic) is not properly managed (e.g. by the police service).

5.6.4 Casualties

- **CA-1**: the system shall simulate the casualty health status evolution.
- **CA-2**: the system shall be able to define the expected spectrum of casualties associated with an event.

5.6.5 Traffic

- **TR-1**: the system shall be able to take into account the effects of traffic conditions on the travel time.
- **TR-2**: it shall be possible to simulate the effect of several types of traffic congestion (heavy/medium/small traffic load).

6. Models

The objective of this chapter is to describe the models of the application domain entities, behaviours and procedures to be implemented in the PRACTICE_HSS tools.

6.1 Medical Service

6.1.1 Triage Models

One of the following triage procedures can be used to assign a colour code to each casualty:

- TRTS (Triage Revised Trauma Score)

  The physiological variables represented by respiratory rate (RR), systolic blood pressure (SBP) and glasgow coma scale (GCS) will be computed starting from the ABCDE values. The range of these values will represent a specific score (namely TRTS).

  The colour codes correspondent to different TRTS scores are reported in the tables hereafter:

Table 6.1-1: TRTS score vs Colour code (conventional and MCS triage)

Colour Code	TRTS (conventional triage)	TRTS (MCS Triage)
Black	0	0-3
Red	1-10	4-10
Yellow	11	11
Green	12	12

- START

  The colour codes correspondent to different START (Simple Triage And Rapid Treatment) values will be computed starting from the ABCDE values. Moreover the red code casualties will be split into the following categories according to their time of death (ToD).

  - Instable: time of death <1h
  - Stable: time of death >1h

  Notes:

  - START triage may be applied only on accident location (not in CTA and not in a hospital).
  - Unlike TRTS, the START triage algorithm is the same for conventional and MCS situation.

  The final result of the conventional triage will be:

  - Instable red code
  - Stable red code
  - Yellow code
  - Green code
  - Black code

  No additional sorting will be possible within the same category (e.g. stable red code, instable red code etc).

Switch to MCS Triage

The conventional triage should be applied first. The triage shall switch from “conventional” to “MCS” any time the number of casualties that could not get resources exceeds a user-defined threshold.

The process to get the sorted list of MCS triaged casualties is the same as the one documented in section 6.1.1 i.e.:

- Instable red code
- Stable red code
- Yellow code
- Green code
- Black code

6.1.2 Plan Treatment

The following steps shall be simulated as representative of the treatment planning process:

- Conventional triage.
- Planning of the treatment based on the estimated duration of each treatment as well as the available resources.
- If the plan shows that the number of casualties that will not be able to get treatment in time exceeds the user defined threshold (e.g. 1 casualty):
    - the MCS triage shall be adopted;
    - the treatments shall be re-planned;
    - for those casualties that will not be able to receive treatment before they die an evacuation request shall be done.
- Each time a new casualty reaches the MF the procedure is started again.
- Treatments in progress cannot be interrupted.

6.1.3 Provide Treatment

At the accident location

The effect of life saving treatment on the casualties health status shall be simulated.

At the hospital

The effect of treatment on the casualties health status shall be simulated.

Starting from the casualty's treatment needed, the system shall assign the proper resources for the time interval specified in the treatment itself. The assigned resources will not be available to treat other casualties for a time period equal to the treatment duration.

6.1.4 Patient Flow

At the accident location

After an accident has occurred, the police has set the cordon and the fire brigade has secured the area, the Health Service activities can start.

The following procedures for casualty management are foreseen:

- the casualties are triaged on accident location (in the hot zone) using START procedure;
- depending on the casualty status, the casualty is either moved towards the decontamination area or to the CTA;
- in the CTA (in the cold area):
    - the casualties are triaged when entering the CTA using TRTS triage;
    - the casualties receive the first treatments in the CTA;
    - the casualties are triaged again (using TRTS).

The sorted list of casualties is ready for the regulation procedure to start.

The medical manager shall be able to select the policy to be implemented by the system among the following:

- *Policy 1*: saturate highest level MF first. The most seriously injured casualties should be sent to the highest level MF able to provide the treatment (the idea is to exploit to the maximum extent the best resources in the field taking the most urgent casualties to the MF able to provide the best treatment).
- *Policy 2*: saturate lowest level MF first. The most seriously injured casualties should be sent to the lowest level MF able to provide some treatment. Once got the treatment, the casualty will be evacuated towards the higher level MFs to continue the treatment (the idea is to provide as soon as possible some treatment to increase the time of death of the casualties without overwhelming the highest roles).

Once the most suitable destination MF has been selected, the evacuation procedure can start.

At the hospital

Two kinds of inter hospitals evacuation shall be foreseen:

- evacuation request for those casualties which (e.g. due to the MF overload or simply because the MF is not able to provide the treatment the casualty needs) couldn't be treated before their time of death;
- evacuation request for those casualties that will be treated but need to continue the treatment in another (higher level) MF.

The evacuation request shall be sent at the end of the treatment planning process.

6.1.5 Personnel Call-In

The system shall be able to model personnel call-in procedures through a set of call-in events.

For each call-in event the PRACTICE_HSS user shall be able to define:

- the amount of time after which the additional resources will be available;
- the number of additional resources that will be available.

6.1.6 Medical Facilities

Different categories of medical facilities shall be represented in terms of the following parameters:

- *Treatment effect*: the effect the treatment will have on the casualty health status evolution. It shall be possible to specify two different values:
    - an immediate reduction of the ABCDE parameters loss to simulate a non-definitive treatment
    - the change of the ABCDE parameters loss rate to simulate a definitive treatment
- *Treatment duration*: how long the treatment will last. In other words, the treatment will provide the “treatment effect” in the “treatment duration” amount of time.
- *Hosting capability*: the hosting capability of the MF. It represents the overall amount of resources available to the MF. Part of these resources will be locked at the start of a new treatment and will be unlocked at the end of the treatment itself.
- *Resources needed to provide the treatment*: the amount of resources that will be locked at the start of a new treatment and will be unlocked at the end of the treatment itself.
- *Parent medical facilities*: the medical facilities towards which casualties, needing further treatment, shall be evacuated. Each MF can have at least:
    - A “higher level” MF (toward which casualties needing further treatment shall be evacuated e.g. from a FA to a TCLL).
    - A “same level” MF (toward which casualty that can’t be treated due to lack of resources should be evacuated - Sideways evacuation).

  Note: higher level MF will be able to provide any kind of treatment a lower level MF is able to provide. As a matter of consequence it is possible to define a hierarchy composed of MF:
    - first aid (FA);
    - trauma center low level (TCLL);
    - trauma center high level (TCHL).

6.2 Ambulance Service

6.2.1 Casualty Regulation

At the accident location

- If there is *no medical manager,* the ambulance manager will be in charge of carrying out the casualty regulation procedure.

  The ambulance manager shall be able to select the policy to be implemented by the system among the following:

  - *Policy 1:* the most seriously injured casualties should be sent to the MF that he can reach first (nearest or shortest time of arrival) without taking into account its level. The idea is to provide as soon as possible some treatment to increase the time of death of the casualties.
  - *Policy 2*: the most seriously injured casualties should be sent to the nearest (either by distance or by time of arrival) highest level MF

  For each casualty, the ambulance manager shall:

  - Starting from the first priority casualty:
    1. Check if at least one evacuation vehicle is available.
    2. Check if the best (according to the selected doctrine) MF has residual hosting capacity:
       - If the MF has residual hosting capacity the ambulance manager will task the most suitable vehicle to carry out the evacuation and will inform the destination MF.
       - Otherwise, he will try with the next opportunity in the list.
    3. If no MF has residual hosting capability the casualty shall be brought anyway to the best (according to the doctrine) MF.
    4. If no vehicle at all is able to pick up the casualty:
       - the casualty stays at accident location till when new vehicles are available.
    5. The system shall repeat the procedure as soon as a new vehicle is available.

- If there is a *medical manager*:

  In this case the casualty regulation will be up to the medical manager.

  The ambulance manager shall satisfy the evacuation opportunity list according to the preferences provided by the medical manager.

  The preference expressed by the medical manager is a list of pairings (hospitals; time limit).

The ambulance manager shall try to distribute the casualties on all the medical facilities taking into account the time limits provided by the medical manager.

The ambulance manager shall try to evacuate casualties taking into account:

- the time limits computed from the casualty health status;
- the available vehicles;
- the weather and traffic conditions.

At the hospital

All of the evacuation requests will be sorted as follows:

- by triage code (i.e. red codes will have top priority),
- by the time of request (i.e. evacuation requests for casualties with the same triage code will be ranked by the time of evacuation request).

The evacuation requests for urgent casualties staying at the accident location will have top priority and only after all evacuations of urgent casualties from accident location have been performed the evacuation requests from the hospitals will be considered.

The ambulance manager shall try to evacuate casualties taking into account:

- the time limits computed from the casualty health status;
- the available vehicles;
- the weather and traffic conditions.

6.2.2 Casualty Evacuation

In order to implement the casualty evacuation, the system shall simulate the transport of casualties from the accident location to the selected destinations, taking into account:

- *Starting point*: the accident location where the casualty should be picked up.
- *Destination*: the medical facility will receive the casualty according to the result of casualty regulation.
- *Kind of vehicle* (air or land will have different cruise speed and different constraints).
- *Traffic conditions* (through a speed reduction factor).
- *Weather* (through a speed reduction factor).

The calculation of the time of transportation will be done assuming a uniform rectilinear motion between the starting point and the destination.

6.2.3 Vehicles Call-In

The system shall be able to model vehicles call-in procedures through a set of call-in events.

For each call-in event the PRACTICE_HSS user shall be able to define:

- The amount of time after which the additional vehicles will be available.
- The number of additional vehicles that will be available.
- For each vehicle, all of the attributes described in section 6.2.4.

6.2.4 Evacuation Vehicles

The evacuation vehicles shall be represented in terms of the following parameters:

- *Type*: surface or air vehicle.
- *Nominal speed*: the average speed of the vehicle.
- *Real speed*: the current speed of the vehicle, depending on the traffic and weather condition.
- *Home*: the place (e.g. medical facility or parking point) where a vehicle is based.
- *Treatment effect*: the effect the treatment will have on the casualty health status evolution.
    - Air vehicles always provide a treatment;
    - Surface vehicles will be divided into:
        - BLS evacuation vehicles: not able to provide treatment onboard.
        - ALS evacuation vehicles: able to provide treatment onboard.

  The treatment provided on-board will temporary reduce the parameters loss but will have no effect on the parameter loss rate.

  It will be possible to assume that the casualty will benefit of the treatment provided as soon as he is loaded on-board.

6.3 Inter Service Interactions

6.3.1 Health Service Interactions

The interactions between medical and ambulance services shall be simulated as follows:

- The medical service will provide the ambulance service with a sorted list of possible destinations (i.e. medical facilities) for each casualty. The ambulance service will be in charge of implementing the evacuation with the most suitable and safe evacuation vehicle.
- The ambulance service will provide the medical service with the estimated travel times:

- from the accident location to each hospital.
- from each hospital to its parent MFs (both parent and super-parent, specialty and sideway MF).

Such values will be used by the medical service to compute the evacuation time-limits.

6.3.2 Non Health Service vs Health Service Interactions

Police

- Task: grant access routes

  Till when an access route is established, the ambulances travel speed will depend on the traffic conditions. Once the access route is reserved, the ambulance travel speed will be the nominal one.

- Task: establish inner and outer cordons (hot/warm/cold zone)

  Till when the cordons are established the number of casualties will increase by a percentage settable by the user. Once the cordons are established the number of casualties will not increase anymore.

Fire Brigade

- Task: secure area

  Till when the area is not secured, the Health service can't access. The time devoted to secure the area shall be settable by the user.

- Task: secure area

  If the area is not secured there the number of casualties will raise by an amount (settable by the user).

6.4 Casualties

6.4.1 Casualty Model

The casualty health status will be modelled in terms of the initial value and evolution of the ABCDE parameters described in Table 6.4-1.

Different levels of seriousness of the injuries shall be simulated through different temporal evolution of the parameter. The casualty will die if even only one of the ABCDE parameters' values reaches the specific threshold.

Table 6.4-1 - Casualty parameters

Type	Parameter	Indicator
A	Airway	Ventilation
B	Breathing	Saturation
C	Circulatory	Volemia
D	Disability	Glasgow coma scale
E	Exposure	Damage: % body surface

6.4.2 Treatment Model

The effects of the treatment shall be simulated

- as an immediate increase of the parameter value (the loss rate is unchanged) if the treatment provided is not the definitive one.
- by setting the parameter loss rate to zero if the treatment provided is the definitive one.

7. Conclusions

In this document the user needs, the user requirements and the models to be implemented in order to simulate the Health Service application domain relevant entities, behaviours, procedures, interactions etc have been described.

The content of this deliverable will be used as input to the design and implementation activities related to the PRACTICE_HSS tools and the GIS-based GUI needed to easy configure and use the HS components.

8. Literature

Guidelines for First Response to a CBRN Incident, NATO Civil Emergency Planning Civil Protection Committee, 2008

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