FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

Education of Emergency Personnel for the Adoption of an Electronic Triage Tag Framework

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Magister der Sozial- und Wirtschaftswissenschaften

im Rahmen des Studiums

Informatikmanagement

eingereicht von

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an der
Fakultät für Informatik der Technischen Universität Wien

Betreuung
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Wien, 21.03.2011

(Unterschrift Verfasser/in) (Unterschrift Betreuer/in)

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Education of Emergency Personnel for the Adoption of an Electronic Triage Tag Framework

DIPLOMA THESIS

for the obtainment of the academic degrees

Master of Science

within the academic study

Computer Science Management

submitted by

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matriculation number 0425106

at the
Faculty of Informatics at the of The Vienna University of Technology

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Vienna, 21st March 2011 ______________________ ______________________

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Vienna, 21st March 2011 --

Edin Srndic

Acknowledgement

“Seek knowledge even in China.” (Prophet Muhammad)

First of all I want to thank Got for supporting and guiding me every day, for my wonderful family and all the material and nonmaterial blessings. Particularly I want to thank:

- My supervisor Ao.Univ.Prof. Dipl.-Ing. Mag.rer.nat. Dr.techn. Rudolf Freund for his helpful advice.
- My parents Hazim and Zevkija for their caring support during years of study and my whole life.
- Everyone who helped me to finish this diploma thesis especially my one and only fiancée Aida, my favorite sister Edina and my best friend Volkan.

Abstract

Training and education have long been accepted as integrant to disaster readiness, but many currently taught practices are neither evidence-based nor standardized. The need for effective disaster training of emergency personnel at all levels has been designated by the disaster response community as a high priority. Triage is a process during emergency care which aims at maximizing the provided care in a situation where the available resources are limited by diagnosing injuries and categorizing patients into groups to determine the priority for treatment and transport. The electronic triage tag framework increases the quality and amount of medical care for patients in such situations and increases the efficiency of the entire triage process. This thesis evaluates the main characteristics and differences of a conventional triage system and an electronic triage system, utilizing RFID tags and a client/server approach based on wireless communication. Information gathering is performed by the mobile triage devices with integrated RFID reader. Adoption of mobile computing technology can potentially improve information access, enhance workflow, and promote evidence-based practice to make informed and effective decisions in the triage process. Handheld computers or personal digital assistants (PDAs) offer portable and unobtrusive access to clinical data and relevant information at the point of care. The education of emergency personnel during the changeover from the conventional triage system to the electronic triage system using mobile triage devices is the central part of this thesis.

Kurzfassung

Schulung und Ausbildung sind seit Langem wesentlicher Bestandteil der Katastrophenbereitschaft, allerdings sind viele Lehrmethoden weder evidenzbasiert noch standardisiert. Der Bedarf einer effektiven Katastrophenausbildung für Notfallpersonal auf allen Ebenen wurde von der Katastrophenschutzgemeinde mit hoher Priorität ausgewiesen. Triage ist ein Prozess während der Notfallversorgung, bei der die vorhandenen Ressourcen begrenzt sind und rasch in oftmals unübersichtlichen Situationen optimale Hilfestellungen zu erbringen sind. Durch Triage soll diese Notfallversorgung deutlich effizienter gestaltet werden, indem Verletzungen diagnostiziert und die Patienten in Gruppen kategorisiert werden, um die Priorität für Behandlung und Transport zu bestimmen und klar darzustellen. Diese Arbeit evaluiert die Kernanforderungen und leitet daraus ein elektronisches Triage Tag System ab, das RFID Tags und einen Client/Server Ansatz basierend auf drahtloser Kommunikation verwendet. Informationen werden durch die mobilen Triage Geräte mit integriertem RFID Lesegerät erfasst. Die Einführung mobiler Informationstechnologie kann den Informationszugang verbessern, die Ablauforganisation optimieren und evidenzbasierte Methoden fördern damit fundierte und effective Entscheidungen im Triageprozess gemacht warden können. Handheld Computer bzw. Personal Digital Assistant (PDA) bieten tragbaren und unauffälligen Zugang zu klinisch relevanter Information an Ort und Stelle der Katastrophe. Die Ausbildung von Notfallpersonal während der Umstellung von konventionellen Triage System auf das Elektronische Triage System mit den Mobilen Triage Geräten ist der Kern dieser Arbeit.

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1 Introduction

The need for effective disaster training of emergency personnel and healthcare workers at all levels is widely recognized. However, one of the highest priorities identified by the disaster response community is to develop standards and guidelines for education and training in the multi-disciplinary health response.

Differences among emergency personnel such as educational backgrounds, prior training, abilities and work experience are significant challenges for the standardization of disaster training and education. First it is necessary to define training requirements for each job description what requires adequate modification of educational content. Second it is essential that emergency personnel are equipped not only with knowledge but specific technical skills and decision-making abilities. This type of flexible training is provided by the competency based approach.

In recent years competency based approaches to training have been widely implemented and have gained acceptance in medical education although the application of competency based education for training healthcare workers in disaster is a relatively new concept. While competency statements for public health workers and various hospital staff in emergency preparedness have been previously outlined, there are important differences in the derivation methods, degree of inclusiveness in development processes, level of detail and the definition of the term competency. In this diploma thesis there is a set of competencies described with specific measurable objectives derived using evidence-based consensus building techniques that addresses the training of all healthcare workers in disaster response.

Providing training content from a single set of competencies offers both theoretical and practical advantages over utilization of distinct competency sets for each type of healthcare worker being trained. Emergency personnel require training to develop the fundamental knowledge and skills to function independently but also to act in part of a coordinated response effort. Competencies and terminal objectives are designed to emphasize higher levels of learning such as synthesis and performance, rather than strictly knowledge acquisition. Each terminal objective was constructed so that performance may be readily tested or evaluated and it can be easily mapped to the most appropriate target audience.

There are different training needs from front-line physicians for example for critical event leadership compared to the training needs from community-based practitioners. Hence, while competencies apply to all healthcare workers, certain terminal objectives like decontamination skills which are essential for first receivers would be unlikely required for healthcare administrators.

The competencies and accompanying objectives may serve as a paradigm for healthcare worker disaster training and education. This diploma thesis offers the opportunity for greater standardization in training and evaluation by facilitating a uniform approach to derivation of objectives, content and evaluation.

The application of IT embedded in medical care influences the future outlook of the medical sector in a positive way. Better access to information, more efficient data exchange, increased data processing capabilities allowing real-time and on-line diagnostics, simulation of results and stimulation of distributed decision-making processes are all results that are opening up new opportunities in the practice of medicine.

Many medical fields such as diagnose, treatment and patient care benefited from the application of IT-infrastructure. Better performing medical instrumentation, more efficient diagnostic systems, improved medical components and IT technology ranging from complex architectures to small monitoring devices are directly benefiting the medical sector. The goal of this thesis is to bring these benefits to the field of emergency care. The next chapter provides a short overview about this thesis.

1.1 Overview

Triage is a process during emergency care which aims at maximizing the provided care in a situation where the available resources are insufficient for medical treatment of all patients. One of the goals of triage is to diagnose critical injuries requiring lifesaving treatment in the shortest possible time. To this end patients are categorized into groups to determine their priority for treatment and transport to definitive care facilities.

The word “Triage” is derived from the French word “trier”, meaning to sort out. The French military were the first to use it in the Napoleonic Wars in the 18th century, when victims were classified and sorted according to the urgency of their conditions with the intention to determine the medical treatment priorities.

The purpose of the military was to provide care to the casualties, so that the soldiers could return as soon as possible to the front. Therefore combat Triage was directed by the adage: “the best for the most with the least by the fewest”. This meant that critical casualties requiring extensive resources received delayed medical care. Triage described the first-aid treatment of battle casualties in collection stations at the front before their evacuation to hospitals located behind the lines. [EdSr11]

The major objective of military triage is to sort who can be returned to the front immediately, who needs treatment before returning to duty and who will not be able to return to active duty. This takes place in geographically dispersed areas by personnel with varying levels of expertise. The military experience has useful application for civilians working in disaster situations. Triage in disaster situations and emergency departments must be conducted with the purpose of doing the greatest good for the largest number of people. While military and civil triage have the same goals they use different methods and processes. [HuJe03]

Triage is a procedure used by emergency personnel to distribute the limited medical resources to the injured people in a mass casualty situation. Thereby emergency personnel attach Triage Tags to the injured people. Triage tags are used to

- Classify the degree of the injury and determine the transport order of injured people to the hospitals
- Store and provide information about the casualty incident to publish to special facilities or to use for decision making like medical resource procurements.

Although the usage of triage tags and paperless digital system is growing, the current state of documentation of triage activities remains poor making research in the actual performance of triage difficult [VaGr03]. Up to now triage is operated manually with conventional paper triage tags, radiophones and check lists. This leads to failure (Chapter 1.5.1), inaccuracy and delay in information transmission when the state and the scale of the casualty incident should be published to involved facilities or used for decision making. Patient information must be collected manually and written down on the conventional Triage Tag. Information from the conventional tags can be stored electronically for statistical and analytical work resulting in a media break. This media break can lead to failures and wrong information caused by human errors like typing, read or operating errors.

The priority of emergency personnel is to treat the injured people efficiently because after a civilian disaster it may be appropriate to use the insufficient resources for those most likely to survive.

To aid the emergency personnel in the triage process and to avoid some of the drawbacks of conventional triage tags in this diploma thesis we propose a triage system using RFID tags (silicon chips with IDs, radio frequency functions and some additional logic and memory) which are attached to the conventional paper triage tags. RFID readers supply power to the RFID tags (passive) through radio frequency communication and read/write information from/on the tag. The RFID tags recommended in our diploma thesis are passive and have 1 kb of rewritable memory. [EdSr11]

Emergency personnel use mobile devices equipped with an RFID reader. Mobile devices are used for the collection of patient information and identification of the injured person by the unique ID of each RFID tag. The RFID tag is embedded to the conventional triage tag.

The main differences which evolve by applying an electronic triage system using RFID tags compared to paper triage are:

a) The information of the injured person can be stored on the RFID tag because of the rewritable memory of the RFID tags.

b) Mobile devices combined with wireless communication allow collecting the needed information of injured people quickly via the network. Input method using mobile devices allow less error prone read/write features. Input rate is improved by automating the information of the emergency personnel and reducing the information which must be input in the early phase of triage to the injury level and the hospital.

This RFID triage system addresses important challenges for ubiquitous computing. These challenges are:

- Availability:
  The emergency personnel must be able to input information about the patient anytime in the triage process, even when the network is not reachable.
- Confidentiality:
  The electronic triage system must ensure that patient information is accessible only authorized emergency personnel providing information security.
- Low Latency:
  The information about injured people must be quickly collected and viewed by the control center.
- Input Rate:
  The time to input the patient information must be optimized to a minimum.
- Data Integrity:
  The information of injured people should not be lost or changed after being acquired. In this context consistency and accuracy of the stored patient information must be provided by the system. [EdSr11]

In this diploma thesis we outline a solution for these challenges by analyzing the workflow and optimizing the network usage by following approaches:

- Availability is assured by the storage of the information of the injured people on the RFID tag and using it as local buffer.

- Confidentiality is assured by the security measures applied to the electronic triage system on different layers.
- Latency is lowered by defining minimum wireless communication areas in the paths of the triage workflow.
- Input rate is improved by using mobile devices allowing easier input methods and automating information storage.
- Integrity is assured by mechanisms in the middleware being responsible that patient information is consistent, updated constantly and provided for the control center. [EdSr11]

This chapter gave a short introduction about education of emergency personnel in disaster situation and triage in general. In the following sections of chapter 1 the field of application of triage is specified. In chapter 2 the motivations of an electronic triage system are described. Chapter 3 contains the competencies and responsibilities of emergency personnel. Related work in chapter 4 presents similar projects to this diploma thesis and the. In chapter 5 the education of emergency personnel using competency based approach is described. Chapter 6 contains barriers of the adoption of an electronic triage system. Finally chapter 7 concludes this master thesis.

1.2 Conventional Triage

Today triage is used to organize the medical care available during disasters and mass casualty situations, and in emergency departments and urgent care centers.

Triage in health care facilities, triage on the battlefield and triage at the disaster site differs in both requirements and functions from each other although sharing the same purpose.

a) Triage in Emergency Departments (ED)

Emergency Department (ED) use of triage systems began in the early 1960s, when the demand for emergency services outpaced available emergency resources. Emergency department space, equipment, and personnel were not adequate to handle the explosive increase in the number of emergency department visits. [IsMo07]

As the use of EDs increased and the waiting times became longer, the triage process evolved as a way of effectively separating patients requiring immediate medical attention from those who could wait.

The primary goals of an effective ED triage system are to:

- Quickly identify those patients with emergent, life-threatening conditions

- Regulate the flow of patients through the ED
- Provide direction to visitors and other health care professionals [VaGr03]

An efficient triage system increases the quality of patient care delivered, shortens the length of a patient's stay, and decreases patient waiting time by combining immediate assessment and interventions.

EDs in the United States generally use a 3-level system, although 5-level systems are gaining acceptance as they prove themselves to be more reliable. Countries, such as Canada, Spain, the United Kingdom, and Australia, have already adopted 5-level systems for ED use. The Emergency Severity Index ranges the patients into 5 groups from level 1 (most urgent) to level 5 (least urgent) on the basis of acuity and resource needs and uses the number of resources a patient needs. The Manchester Triage Scale, used widely in Great Britain, uses algorithms based on the patient's chief complaint to determine the triage level. The Canadian Triage and Acuity Scale (CTAS) uses an extensive list of clinical descriptors to place patients in one of 5 triage levels. Each level has an associated time required for physician assessment, with all level 1 patients needing to be treated immediately. These methods have good, but not excellent reliability, making it unclear whether these are incorrect systems, whether those using them are not up to the task, or whether nonmedical criteria are influencing some decisions. [IsMo07]

b) Military (Battlefield) Triage

Military physicians were the first to implement formal systems of triage to determine treatment priorities for wounded soldiers. Military triage has several distinctive features. The triage officers and treating professionals are typically members of a military service, and the patients are usually also military personnel. As military personnel, these health care professionals and patients may have obligations, allegiances, and expectations that are not shared by other health care professionals or by the general public. For example, military personnel typically give up certain rights and liberties and assume an obligation to obey their superior officers' orders. Military personnel may also be willing to accept life-threatening assignments according to, in part, the expectation that they will receive optimal medical care if they are injured in the line of duty. Furthermore, in addition to the internal medical objective to act in the patient's best interest, external objectives related to accomplishing a strategic or military mission may influence military triage systems. These systems may, for example, define which patients they may treat, such as combatants and civilians injured by their actions, and whom they may not, typically all other civilians. [IsMo07]

Triage decisions must often be modified when casualties are being transported from an "unsecure location". In a military setting, this may occur during the evacuation of casualties from a combat zone where the transport vehicle may represent a very attractive target for enemy attack. In paramilitary situations (e.g., postwar), civil unrest, looting and lawlessness can develop and patient transport vehicles may become targeted for theft, hijacking or destruction. When moving multiple patients from such an area, time can be critical for ensuring the safety of the vehicle and transport personnel.

In military firefight situations, medical care for the injured soldier begins at the scene with treatment administered by other soldiers trained in “combat lifesaving”. Specialized medics are available to provide care for the North Atlantic Treaty Organization (NATO) combat units. Transport of battle casualties to the next level of care by personnel without medical training is referred as casualty evacuation (CASEEVAC). [WiGr07] An example of this is the transport of a patient by a combat helicopter returning from the battlefield. A medical evacuation (MEDEVAC) occurs when patients are transported in a medically configured helicopter, by trained medical personnel, with varying levels of resources at the associated medical treatment facilities (MTFs). [WiGr07]

There are five “levels of care” recognized by NATO for the management of battle casualties. [WiGr07] In the NATO system, the lowest level of support and treatment occurs at level I and the highest is level V. An increase in the level of care corresponds with expanded availability of resources in the NATO system. Surgical services are available at the different levels. These include are rudimentary medical treatment facilities (MTFs), known as Battalion Aid Stations (BAS) or Shock and Trauma Platoons (STP), U.S. Army Forward Surgical Team (FST), the U.S. Air Force Mobile Field Surgical Team (MFST), U.S. Navy Casualty Receiving Treatment Ships (CRTS) and the U.S. Marine Corps Forward Resuscitative Surgical System (FRSS). [WiGr07]

c) Triage in Disaster Situations

The goal of triage in disaster situations is to quickly move from patient to patient and rapidly assess and classify the injured in terms of urgency and necessity of care. In addition triage may involve providing some basic life saving or stabilizing measures, but it is not meant to be the time at which definitive care is provided. Another difference between triage in a disaster situation and triage in a hospital setting is that the time to definitive care is unknown in a disaster situation.

A medical disaster creates demands that overwhelm the capacity of the local health care system; at least some demands cannot be satisfied. Therefore triage is used to determine who will receive treatment immediately or delayed and who will not receive treatment. Depending on the expected number of casualties and the severity of their injuries, the geographic area involved, and the expected arrival time of additional resources, criteria used for triage after natural or manmade disasters may vary. Hence, to come to the optimal disaster triage decisions, triage officers also need accurate information about the cause and extent of the disaster, as well as the location, capabilities, and functional status of nearby health care facilities. Moreover they need rapid patient assessment skills and knowledge of triage systems.

Triage in a disaster situation is only one part of an overall organizational approach that requires preplanning. Probably the most important goal of triage is to diagnose critical injuries requiring lifesaving treatment in the shortest possible time. For this purpose patients are categorized into groups to determine their priority for treatment and transport to definitive care facilities. A variety of formats have been used, most of them have three to five categories. [EdSr11]

1.2.1 Triage Workflow

In the following section the workflow of triage operated by emergency personnel will be described as well as the challenges for ubiquitous computing in the context of an electronic triage system. Triage is a practical application that requires urgent and continuous improvement since we are facing massive casualty incidents.

Current triage is done in the following sequence without using an electronic triage system by the emergency personnel (Figure 1-1). [InSo08]

a) *Arrival*: Emergency personnel arriving first to the incident site establish a first-aid area, which is a safe place for first-aid near the incident area. Besides they establish a control center, which is the command center for the triage.

b) *Primary triage*: Once the incident site is secured the emergency personnel enter the incident site and the primary triage by identifying the injury level in about 30 seconds. They attach the triage tags to the injured people representing the injury level.

   During primary triage the emergency personnel try to write as much as possible from the following information to the tag:

- Time of input
- Name and category (doctor, emergency medical technician) of the emergency personnel
- Age of the injured person
- Sex of the injured person
- Injury level

c) *Collection*: Injured people are moved to the first-aid area.

d) *Secondary triage*: In the first-aid area the injured people get a medical treatment. Besides that the secondary triage is performed by collecting following information if possible and writing the information down on the triage tag.

- Name of the injured person
- Phone number
- Address
- Updated information from the first triage

e) *Hospital determination*: Before the patient leaves the first-aid area the target hospital must be determined. This information is written down on the triage tag and a carbon copy of the triage tag is left to the emergency personnel of the control center.

f) *Transport*: When a transport vehicle arrives at the first-aid area the injured people are transported to the selected hospital. In the ambulances additional information about the patient is written on the triage tags.

g) *Return to disaster site*: Emergency personnel being in the hospital and collecting information of the transported injured people. The transport vehicles return from the hospital to the incident site again and repeat the transportation of the injured people to the hospital. On returning the transport vehicle delivers the carbon copy of the triage tag from the hospital to the control center.

h) *Update information at control center*: In the control center the information of the carbon copies of the triage tags are collected and reported to the search and rescue teams. This information is used, e.g., for decision making. [InSo08]

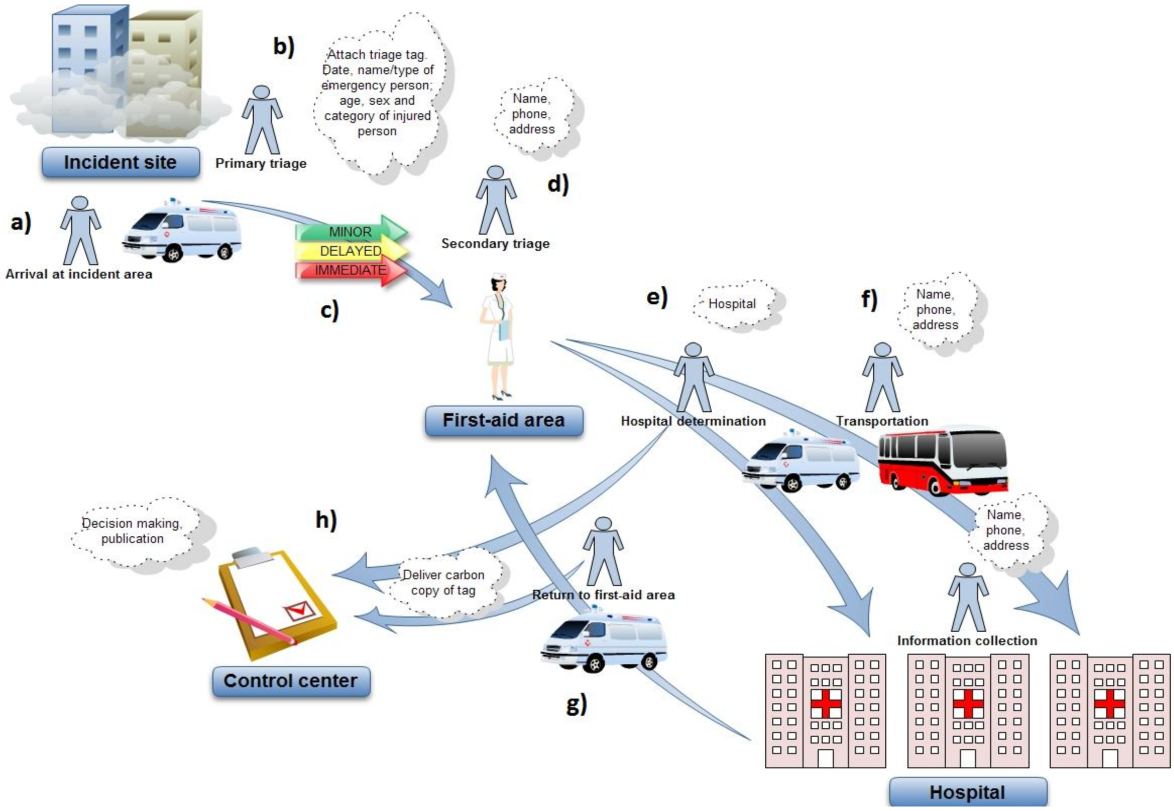

Figure 1-1: Workflow in triage [InSo08]

By using a wireless network combined with the RFID technology for the electronic triage media breaks can be avoided because input information can be collected through the network, even if emergency personnel do not directly or indirectly give a triage tag to the person who is responsible for collecting the information. But, this stands on the assumption that information once acquired can be reached in a destination in the network for a long time. This assumption does not always hold in ubiquitous computing. Therefore data integrity and low latency in the semi-reachable network remains one of the challenges in ubiquitous computing.

The approach of this diploma thesis is the storage of patient information on the RFID tag to improve availability, while most of the RFID applications in the literature store only the ID on the RFID tag referencing patient information. However, the requirements in surroundings of insufficient network infrastructure are also discussed in mobile and ad hoc networks with a requirement for quick deployment. [EdSr11]

1.2.2 Priority of Patient Injuries

The World Medical Association has recommended that clinicians categorize disaster victims with a general approach that has been adopted worldwide in some form and which involves the following triage criteria: [IsMo07]

a) Priority 1 (“immediate) – red triage tag
Those who can be saved but whose lives are in immediate danger, requiring treatment immediately or within a few hours

b) Priority 2 (“delayed”) – yellow triage tag
Those whose lives are not in immediate danger but who need urgent but not immediate medical care

c) Priority 3 (“minimal”) – green triage tag
Those requiring only minor treatment

d) No Priority (“expectant”) – black triage tag
Those whose condition exceeds the available therapeutic resources, who have severe injuries such as irradiation or burns to such an extent, and degree that they cannot be saved in the specific circumstances of time and place, or complex surgical cases that oblige the physician to make a choice between them and other patients

e) No specific triage tag
Those who are psychologically traumatized and might need reassurance or sedation if acutely disturbed (no specific triage tag)

Health care providers are coordinated into teams capable of delivering medical care immediately after a disaster situation. The goal of these teams is to stabilize the condition of patients in the field and then facilitate their transport to local hospitals or predestinated evacuation sites.

Dead or expected to die patients (black) and minimally injured victims (walking wounded, green) are identified. Those considered requiring immediate (red) or delayed care (yellow) are further evaluated like outlined in Figure 1-2 [ScKo96]. Patients with at least a 50 percent probability of survival if treated receive care. All victims are periodically reevaluated. Once their condition has been stabilized, patients are evacuated to nearby hospitals or casualty-collection points.

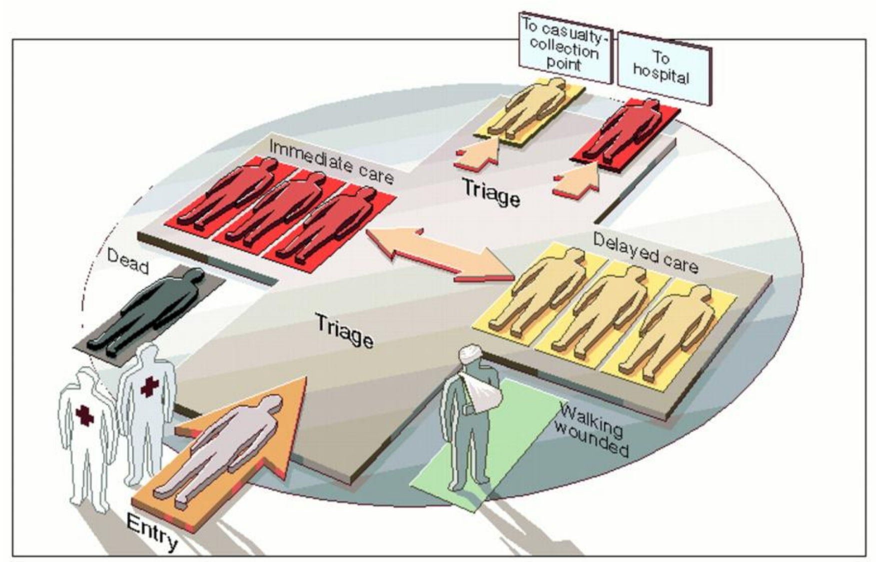

Figure 1-2: Operations of a Disaster-Medical-Aid Center

These activities which rely on making a rapid assessment (taking less than a minute) of every patient, determining which injury categories the patient should be in are standardized in different schemes. One of them is the START System. [EdSr11]

- The START System

Many experts agree that the START (simple triage and rapid treatment) system using the assessment of respirations, perfusion, and mental status is the best strategy [DeDr02]. This system supports the emergency personnel deciding which patients should be transported immediately, which can wait, and which patients are "unsalvageable".

Color coding schemes are generally used to identify the severity of injury and the category of treatment or evacuation into which the patient should be included. Although the use of color triage tags has been described, another practical option is to write the color code on the forehead of the patient with a marker for instance. It is important that all the participating people in patient care and evacuation understand and use the same color scheme.

Color	Priority	Description
Red	1	May survive if given immediate simple life saving measures
Yellow	2	Should survive if given care within a few hours
Green	3	Walking wounded: minor injuries that do not require rapid care
Black	4	Deceased or severely injured patients unlikely to survive

Table 1-1: Severity of injury

Injured patients are placed in one of the four color groups listed in Table 1-1 depending on the severity of their injuries [DeDr02].

All patients who can walk are asked to leave the immediate scene and they are initially categorized with the minimal priority (green triage tag). Afterwards the triage nurse moves quickly to individual patients, assessing respiration, circulation status, and mental status.

Patients who can walk are identified first and receive first-aid measures only. Afterwards the triage nurse moves quickly to individual patients, assessing respiration, circulation status, and mental status according to the algorithm shown in Figure 1-3 [ScKo96]. Patients considered to need immediate care (red) are assessed and treated before those whose care can be delayed (yellow). [EdSr11]

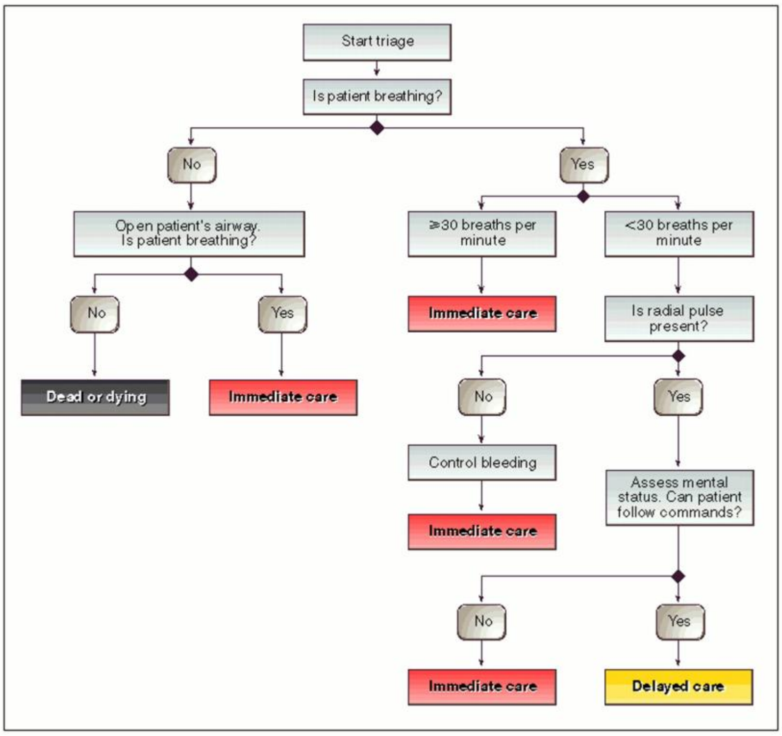

Figure 1-3: The Modified Simple Triage and Rapid Treatment System

1.2.3 Triage Tag Examples and Restrictions

The identification of victims is an ever-present problem that occurs with multiple-patient incidents. After the victims are initially assessed, it is essential that they are identified as whether they require immediate care or whether they can wait for care. A variety of triage tags have been developed across the world to provide this identification. [HoBu07]

The triage tag should be easy to write on, weatherproof and it should be able to be secured directly to the victim, not to the clothing of the victim. Moreover it should store some information about the patient, at a minimum, name, age, gender, injuries, medical problems, field interventions, hospital destination, transportation agency, emergency medical service unit number, and of course the triage category. Space for some other information or checklists should be provided according to the requirements of the emergency care system of each individual facility, community or country.

Above all the triage tag must be easy to understand and easy to use while writing and reading patient information. Otherwise the tag will remain just a colorful decoration on the victim. [EdSr11]

Within the scope of the research of this diploma thesis we investigated the following 4 types of triage tags:

a) Smart Tag

The Smart Tag (Figure 1-4) has unique folded design which means that effective triage is quick and simple, but most importantly it allows casualties to be re-triaged without having to replace the tag. It has been adopted as the standard triage tag for the states New York, Connecticut, Philadelphia, Boston and Nevada. [EdSr11]

Figure 1-4: Smart Tag (by courtesy of [TsAs09])

b) METTAG (Medical Emergency Triage Tag)

The most common triage tag is the METTAG (Figure 1-5), which uses a combination of colors (black, red, yellow, green), priorities (0, I, II, III), and icons (cross/dagger, rabbit, turtle, ambulance crossed out) all on the same tag. The colors immediately identify the priority and urgency of the victim’s situation. The dagger means the victim is dead; the rabbit means hospital care is urgently needed; the turtle indicates no urgency but hospital care needed; and the crossed-out ambulance means only first aid and no hospital care is needed. [EdSr11]

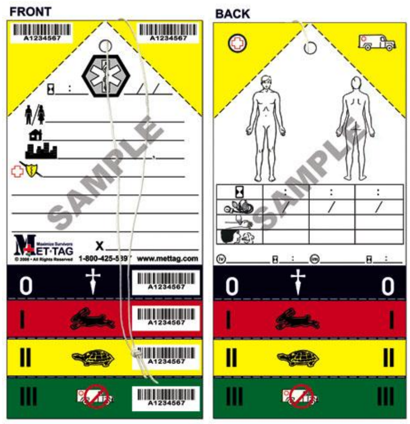

Figure 1-5: METTAG (by courtesy of [MeMa09])

c) New Jersey Disaster Triage Tag

The New Jersey Department of Health developed a new and unique triage tag to address the current and future needs of the disaster scene management. The New Jersey Disaster Triage Tag (Figure 1-6) is designed to make up for some of the shortcomings of the METTAG. It is two-sided, has basic three components (Tear Off Sections, Main Body, Peel-off Stickers) and includes the START scheme. [EdSr11]

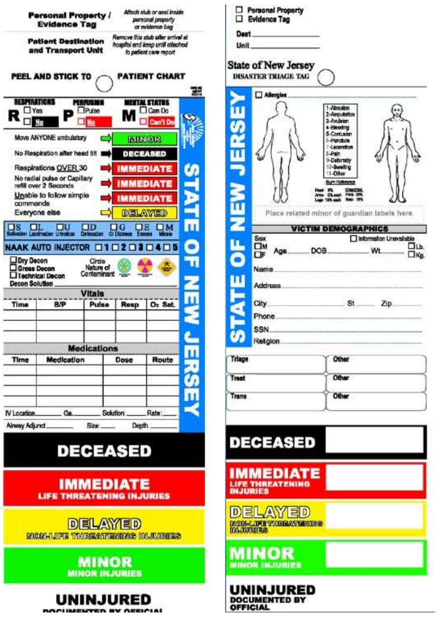

Figure 1-6: New Jersey Disaster Tag (by courtesy of [StOf09])

d) All Risk Triage Tag

The All Risk Triage Tag (Figure 1-7) is manufactured by Disaster Management Systems (DMS) is the standard tag of several states including Florida and California. It has adapted START triage, mass decontamination procedures, patient care criteria and evidence tagging into a simple and effective tool. The information stored on the All Risk Triage Tag is the basic information for the implementation of the prototype of this diploma thesis. [EdSr11]

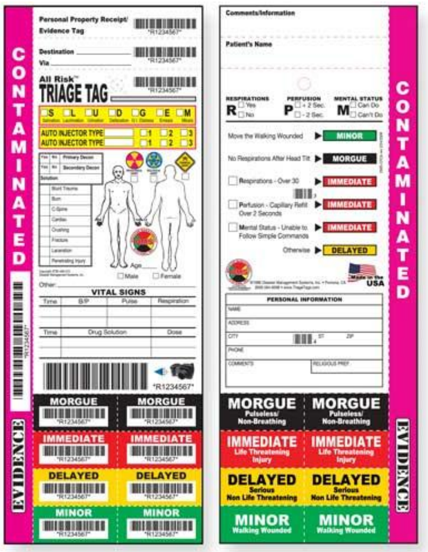

Figure 1-7: All Risk Triage Tag (by courtesy of [DiMa09])

Restrictions of the Conventional Triage Tag

Most medical facilities use conventional paper triage tags. Some of them use bar codes to provide a unique identification for the patients' information; nevertheless the conventional tags have many limitations.

- The space for recording medical data or additional information about the patient is limited (e.g., if the emergency person writes down long comments about the patient the space on the conventional triage tag might be insufficient)
- The "tear off" format of tags only allows unidirectional changes in victim condition (change for the worse)
- The tags can be corrupted, destroyed or lost which means that patient information is lost partially or entirely
- The tags might contain unreadable handwriting resulting from the stress situation for the emergency personnel
- The manual count of the injured people (e.g., deceased) is prone to human error
- Media breaks caused by the manual transmission of patient information from the conventional tag to electronic documentation is a source of error
- The tags do not discriminate between victims categorized under the same color
- The tags inefficiently monitor and locate victims
- The tags are static and disconnected information storages without any real-time information about the victim [EdSr11]

2 Electronic Triage System

The current state of documentation of triage activities remains poor, while the usage of triage tags and paperless digital system is growing.[VaGr03] This makes the research in the actual performance of triage difficult because only the documented results of triage decisions can be evaluated with correctness. Research on electronic triage is marginal, while most studies in this field cover the triage in EDs and not the triage in disaster situations.

This diploma thesis compares our proposed electronic triage tag to the conventional triage tag and outlines that the electronic triage tag can be adopted more efficiently. All required information is prepared and stored electronically. Thus the information can be forwarded to a central unit (e.g., a mobile control center). A chip (rather a transponder) upgrades the conventional triage tag. Data is read and written by a read/write device which is connected to the central unit via a wireless connection.

The electronic triage tag is not a static and disconnected information repository. Real-time information about patients and their status is critical to the overall management of field medical care by the command center. Because of the known and limited availability of resources (such as on-scene providers, ambulance locations, and area hospital capacities) medical command must coordinate timely information on the number of casualties and their needs. Moreover real-time information is critical to determine the appropriate patient destination, depending on the type of injuries and the capabilities of the receiving facilities.

The sequential interdependence described above highlights the importance of information transfer in a disaster scenario. Actions in the field, such as triage, transport and treatment of victims, finally impact hospital resources and capabilities. On the other side real-time information on hospital and health care resources has an important impact on disaster response management and field care of victims. Still this information is mostly not available and is hampered by the lack of a global communication and information system at the disaster scene. [EdSr11]

2.1 Characteristics of the Electronic Triage

The complex work processes and communication patterns exhibited in emergency medicine may be effectively managed through the use of information technology. These tools must be evaluated within the work environment to understand their effects on work flow, information flow, and patient safety. The usage of electronic and conventional triage systems is growing, but the research in this field is not adequate.

The results of studies and researches like [LeFr06], [DoBu07] and [BlBu05] show that electronic triage has positive effects. Efficient work and communication processes are essential for the management of time-critical activities in the ED and in a disaster situation. Information technologies are being developed and integrated into the triage workflow to meet these demands; however, few studies have quantified their impact on work processes and clinical outcomes.

Study of the impact of effects of computerized triage on nurse work behavior outlines that triage times did not change significantly after the CTA (computerized triage application) was introduced. Patient chief complaint, age, acuity score and nurse experience did not impact triage times. After CTA implementation the number of tasks each triage nurse performed and the average duration of interruptions decreased significantly. [LeFr06]

Study of comparing a novel computer triage program with standard triage tries to determine the agreement between a computer decision tool and memory-based triage. There was significant discrepancy by emergency personnel using memory-based triage when compared with a computer tool. The results of the study show a considerable down-triaging of patients without using the computerized tool. Triage decision support tools can mitigate this drift, which has administrative implications for the triage workflow. [BlBu05].

The electronic triage system is designed to assist those performing triage by displaying the modifiers for each complaint that define the criteria for each triage level. These systems are not intended to replace clinical judgment and should not be permitted to promote total dependence. The goal is to develop trustworthy systems that permit and even encourage overrides when indicated by clinical judgment. Moreover, these clinical overrides can be used to adjust the source reference used to develop the system. The principles of iterative feedback, clinical efficiency, end-user sensibility and implementer flexibility have ensured success of such computer information systems. [DoBu07]

The main advantages of an electronic triage system compared to a conventional triage system are:

- Mobile triage devices (Chapter 1.6) combined with wireless communication allow collecting the needed information of injured people via the network by sending the information to a central server.
- Input method using mobile triage devices allow less error prone read/write features compared to handwriting
- Input rate is improved by automating the information of the emergency personnel and hospital addresses
- Real-time access to the patient information which is critical to the overall management of field medical care is provided by the wireless data transmission and the storage of the information on a central unit [EdSr11]

The main disadvantages are:

- There is a strong dependence on the IT infrastructure. Wireless network might not be available or can crash anytime and mobile triage devices are at risk to become defective by hardware errors.
- The acceptance of the electronic triage system by emergency personnel cannot be assured. Gathering patient information might be less intuitive or slower than with the conventional triage tags. These uncertainties about the acceptance and prosperity of the electronic triage system can be reduced through the results of studies or field trials. [EdSr11]

The requirements for the electronic triage system must ensure that critical information collected in the field is communicated to receiving personnel quickly and accurately. All patients and emergency personnel must be registered and identifiable. The electronic triage system must ensure that patients and emergency personnel are accounted for at all times without over reliance on manual, error prone, processes. The collected information relevant to situational management and decision support must be integrated into a central unit and available over a single application for the command center. In case of system or network failure the electronic triage system must have contingency capabilities. [EdSr11]

2.2 Workflow in the Electronic Triage System

By applying the RFID technology into the triage workflow the triage system implicates the change that instead of writing and collecting the conventional paper tags, emergency personnel read the information of each injured person from the RFID tag, input the information of each injured person to the mobile triage device and then write it on the RFID tag.

Figure 2-1 demonstrates the workflow in the RFID Triage System with electronic triage tags and mobile triage devices using the wireless communication. [InSo08]

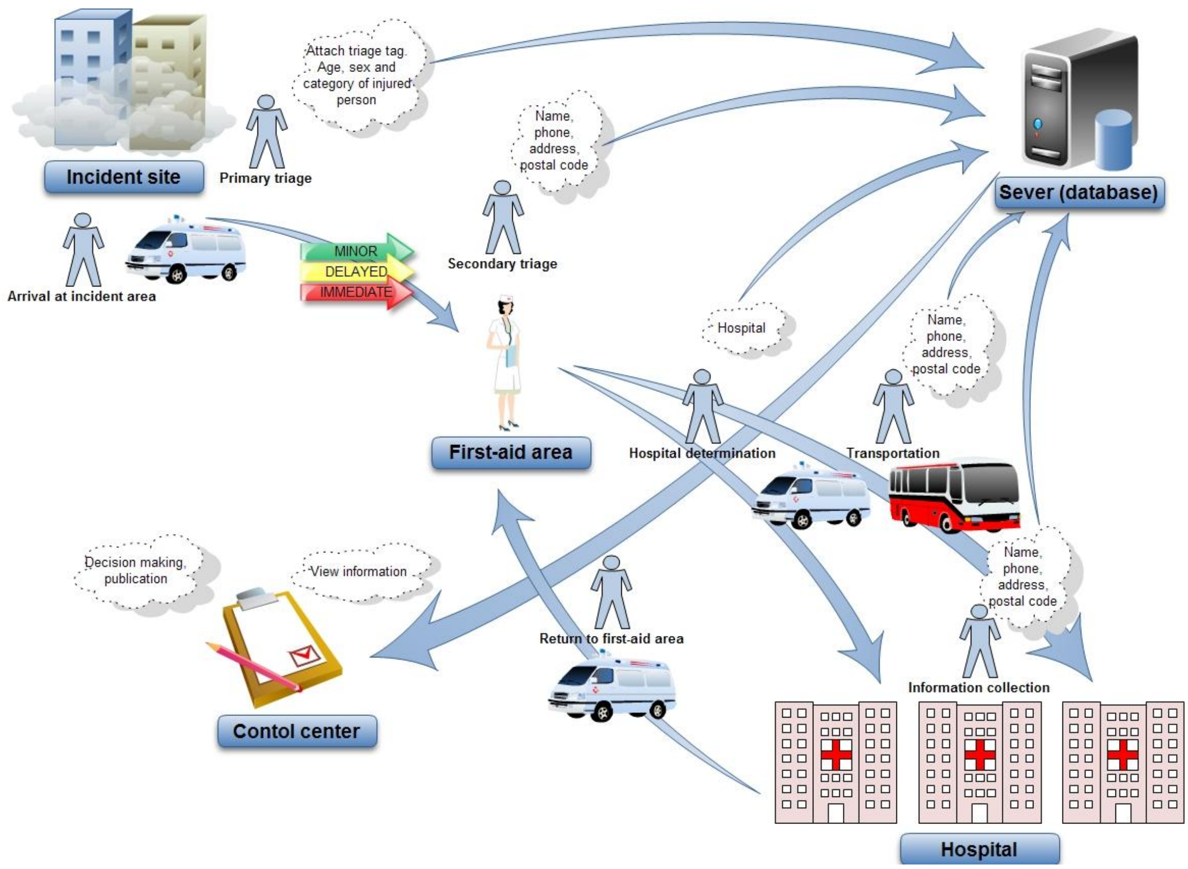

Figure 2-1: Workflow in RFID Triage System [InSo08]

In the following section the usage of the electronic triage system by emergency personnel in different stages of triage will be described.

The emergency person being responsible for primary triage inputs the information of each injured person by the mobile triage device which writes it on the RFID tag. At the same time the emergency person attaches the triage tag with the RFID tag to the injured cuts the triage tag off to the right color. In the background the mobile triage device sends the information of the injured person, written to the RFID tag, to the server as soon as the wireless network is available.

The emergency person being responsible for secondary triage reads the information of each injured person from the RFID tag through the mobile triage device and changes or adds the information to the RFID tag by interviewing the injured person.

The emergency person being responsible for hospital determination selects the hospital to which the injured person must be transported by the mobile triage device and writes the information to the RFID tag.

The emergency person being in an ambulance/transport vehicle or in a hospital has the same duties like the emergency person being responsible for secondary triage with the difference that he/she has not the mobile triage device but a notebook PC with keyboard and mouse and an RFID reader. Except that the emergency person can record the time needed to carry the injured person to the hospital.

The emergency person in the control center can browse the patient information. The information is stored on the server and can be visualized by using web browser software for instance. Then the emergency person can inform different facilities like the emergency control center in the municipality or the search and rescue teams. The information of the injured people is stored on the server providing the information to the control center terminal for instance through HTTP protocol. [InSo08]

The following sequence diagram shows the information flow and the connection between the emergency personnel and the server with the information database (Figure 2-2). [EdSr11]

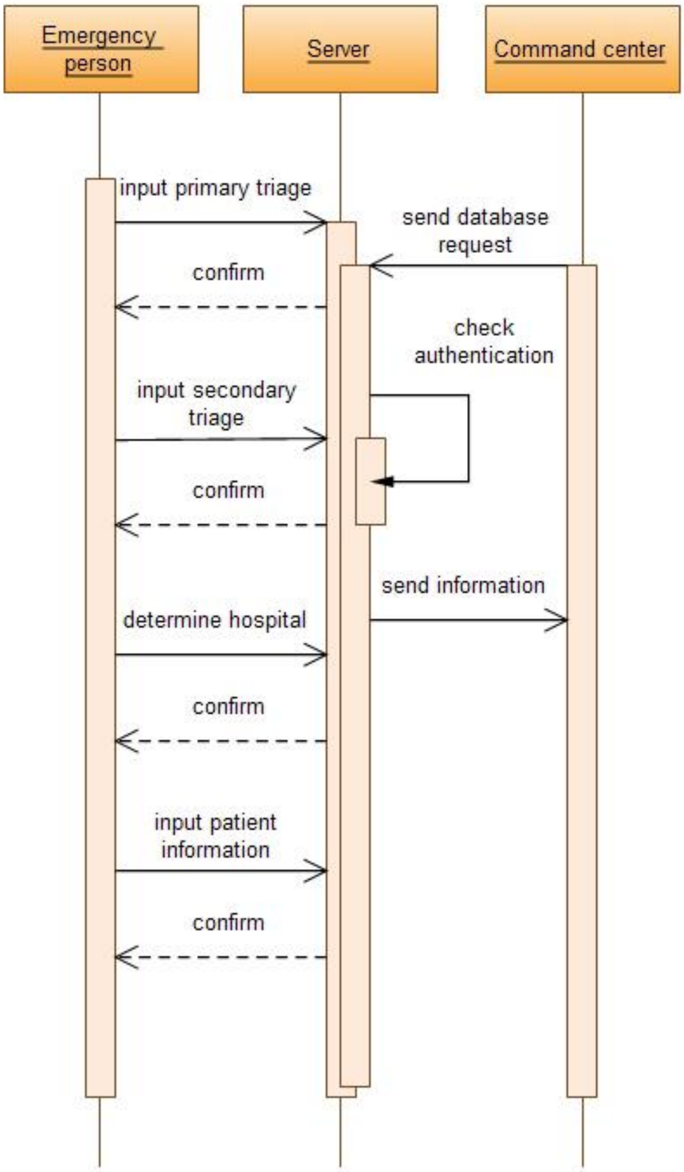

Figure 2-2: Information flow between emergency personnel and server

2.3 System Requirements

Several technical requirements of the electronic triage system can be identified as important challenges for pervasive computing arise regarding the paths through which the information of injured people is collected:

- Confidentiality:

  Patient information is stored on the RFID tag and on the central unit. This information must be accessible only to authorized emergency personnel. Thereby the electronic triage system ensures information security. Accuracy of the stored data must be provided by the system through security measures applied to the different layers of the electronic triage system. [EdSr11]

- Input Rate:

  The time is a critical factor in the early stage of triage. Hence, the input time of the patient information must be optimized to a minimum. Input rate is improved by the mobile devices using less error prone input read/write methods and automating information storage like the emergency personnel information.

  The network status must not influence the input rate, this is assured by storing the patient information primary on the RFID tag and in the case of an available wireless connection the information is sent asynchronously to the central unit. [EdSr11]

- Availability

  Emergency personnel must be able to use the system properly. Especially, input operations of the information of a patient must be available anytime in the triage, even when the network is not reachable. This is assured by the storing the patient information on the RFID tag and using it as local buffer. Emergency personnel can read or write data by referring the RFID data already which has already been written so far. The input device pushes the new data to the queue that is sent to the destination independent of the user's operation, as well as writing to the RFID tag. [EdSr11]

- Low Latency:

  Input information of the early stages of triage must be collected quickly and viewed from the control center. Latency is lowered by defining minimum wireless communication areas in the paths of the triage workflow. [EdSr11]

3 Emergency Personnel

Training and education of emergency personnel have long been accepted as integral to disaster readiness, but many currently taught practices are neither evidence-based nor standardized. [HsTh06] There is a need for effective evidence-based disaster training of healthcare staff at all levels. Thus we define certain educational competencies for the preparedness and response to a disaster situation relevant to each emergency person.

3.1 Competences for Disaster Training

The below-mentioned competencies may be applied to related, but distinct target groups within the field of emergency personnel. These groups may include, but are not limited to first receiver physicians, first receiver nurses, other first receiver staff, critical event leadership, non-first receiver physicians, nurses, technical support staff and administration.

a) Recognition of potential critical events and implementation of initial actions

   Critical events are any situations which threaten to disrupt the ability of an organization to maintain continuity of operations. They include, but are not limited to disasters and emerging infectious diseases. The ability of emergency personnel to recognize a critical event and to know what to do is an essential component of appropriate disaster response. They especially must know who should be notified and how a disaster plan is activated. In order to minimize the damage of the critical event it is important to provide early event recognition and early response mobilization. Moreover emergency personnel should recognize triggers that precipitate reporting to the appropriate personnel.

b) Application of critical event management principles

   For the successful management of all critical events in a facility the emergency personnel should understand the essential elements of an effective preparation and response including the appropriate actions to be performed.

c) Demonstration of critical event safety principles

   The ability to protect themselves during a disaster event is a critical response component for emergency personnel. Thus they will protect the facility and its resources. This embraces elements of self and scene safety, security issues related to potentially large numbers of victims and contamination, as well as other risks or threats.

d) Understanding the institutional emergency operations plan

Familiarity with the institutional emergency operations plan is essential for individuals working within the institution in order to support and implement an effective, coordinated course of action during any critical event.

e) Demonstration of effective critical event communications

One basic element of a successful critical event response is communication. Emergency personnel need to recognize how poor communication can undermine response effectiveness and learn effective critical event communication skills.

f) Understanding the incident command system and the role in it

An essential requirement of effective critical event response is the successful integration of internal and external participants. To achieve this there is a recognizable and unified command and control structure necessary.

g) Demonstration of the knowledge and skills needed to fulfill the role during a critical event

Emergency personnel responding to a critical event require specific knowledge and skills. These encompass triage, personal protection, decontamination, and treatment and technical skills. Injury pattern recognition and syndrome recognition that suggests the use of particular agents is essential to correct response as well as experience with electronic devices for the usage of the mobile triage device.

3.2 Responsibilities in a Disaster Situation

This section discusses the use cases of the electronic triage system giving an rough overview of the use cases of an emergency person in figure 3-1 shows a rough overview for an emergency person in the RFID triage system. [EdSr11]

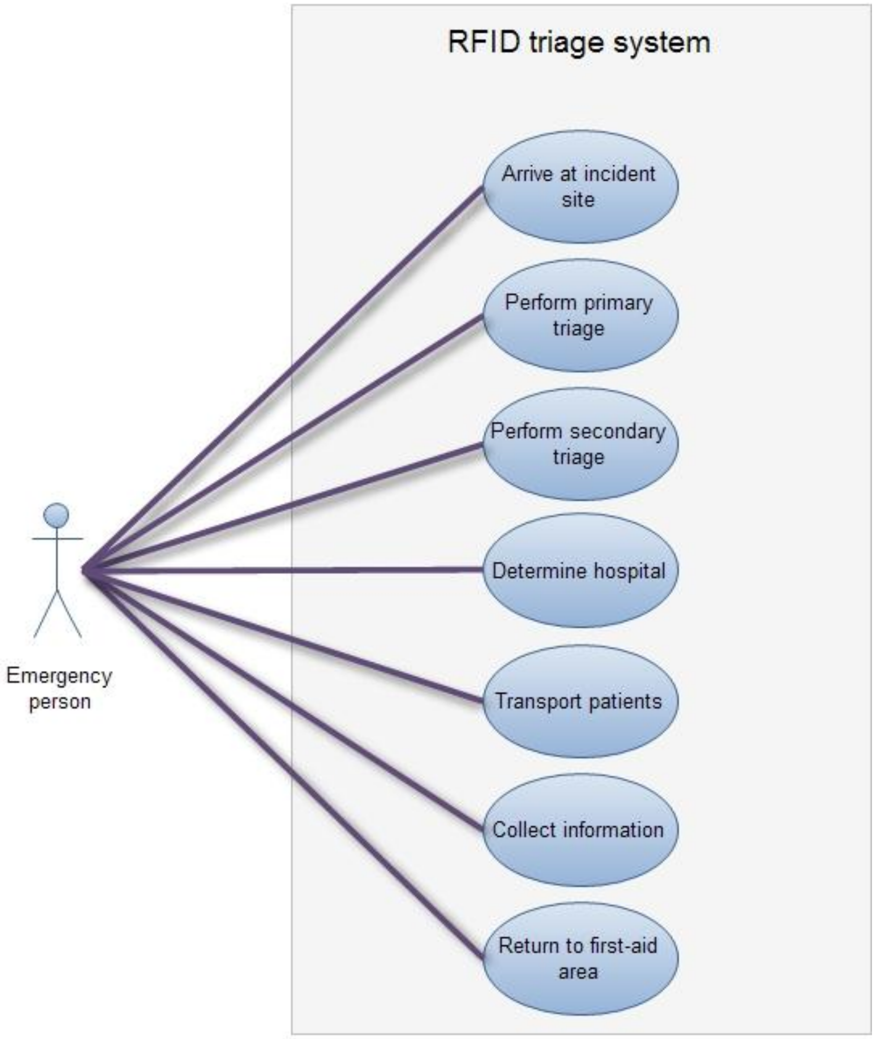

Figure 3-1: Rough overview of the use cases for an emergency person

In Table 3-1 the use cases of the RFID triage system are described and demonstrated in Figure 3-2: [EdSr11]

ID	Use Case Name	Primary Actor	Brief Description
1	Arrive at incident site	Primary triage person (the actors are derived from the superior actor "Emergency person")	Emergency personnel responsible for the primary triage arrive at the incident site. They start scanning the incident site for injured people.
2	Establish first-aid area	First-aid nurse	Close to the incident site, but on a safe place, the first-aid area is established. Patients are moved from the incident site to the first aid area after the primary triage is performed. After the hospital determination transportation personnel move the patients from the first-aid area to the hospitals.
3	Establish control center	Director of operations	Close to the incident site, but on a safe place, the control center is established. The director of operation can browse the patient information stored on the server. The director of operation can inform different facilities like the emergency control center in the municipality or the search and rescue teams. The responsibility of the director of operations is to establish wireless network at the incident site, the first-aid area and the control center.
4	Attach triage tag	Primary triage person	Primary triage person attaches the triage tag (including the RFID tag) to the injured person and identify the injury level in about 30 seconds.
5	Input primary triage information	Primary triage person	The primary triage person inputs the primary triage information (age, sex, injury category) with the mobile triage device and writes the information to the triage tag and tears of the appropriate color of the injury level. In the background the mobile triage device sends the information of the injured person, written to the RFID tag, to the server as soon as the wireless network is available.
6	Move patients to first-aid area	Transportation person	Triaged patients with the attached triage tag are brought to the first-aid area by

			transportation personnel. Emergency personnel can perform first-aid in the ambulance.
7	Medicate patients	First-aid nurse	Patients arriving at the first-aid by the transportation personnel get a medical treatment. The nurse performs first-aid to the injured person in the first-aid area.
8	Input secondary triage	Secondary triage person	The secondary triage person reads the information of each patient from the RFID tag through the mobile triage device and adds or changes information by interviewing the injured person. Afterwards the emergency person writes the information to the RFID tag with the mobile triage device and saves the information. If wireless network is available the mobile triage device sends the information to the server.
9	Determine hospital	Hospital determination person	Before the patient leaves the first-aid area the target hospital must be determined. The hospital determination person decides which patient is brought to which hospital.
10	Input hospital	Hospital determination person	After determining the target hospital the hospital determination person inputs the address (postal code) of the hospital into the mobile triage device and saves the information to the RFID tag. If wireless network is available the mobile triage device sends the information to the server.
11	Move patients to hospital	Transportation person	After the hospital has been determined the transportation person moves the injured person to the hospital by the ambulance. Emergency personnel can record the time needed to carry the injured person to the ambulance. Changed or added information is stored on the RFID tag and sent to the server as soon as mobile network is available.

12	Input patient information	Transportation person & hospital nurse	Emergency personnel in ambulance and hospital input or change information of the injured person with the ambulance terminal and hospital terminal and save the information to the RFID tag and send the information as soon as mobile network is available. The transportation person and the hospital nurse use notebook PC combined with an RFID reader for the input of patient information.
13	Return to first-aid area	Transportation person	After moving the injured person to the hospital the transport vehicles return from the hospital to the first-aid area again and repeat the transportation of the injured people to the hospital.
14	Read information of injured people	Director of operations	The information of the injured people is collected on the server in the database of injured people. The director of operation can read this information by using for instance browser software.
15	Coordinate triage	Director of operations	After reading the information of the injured people the director of operations can make decisions how to proceed with the triage activities. This information is stored on the server and can be visualized by using web browser software for instance. Then the emergency person can inform different facilities like the emergency control center in the municipality or the search and rescue teams.
16	Public information	Director of operations	The collected information about injured people can be published or forwarded to particular facilities.

Table 3-1: Use cases of the RFID triage system

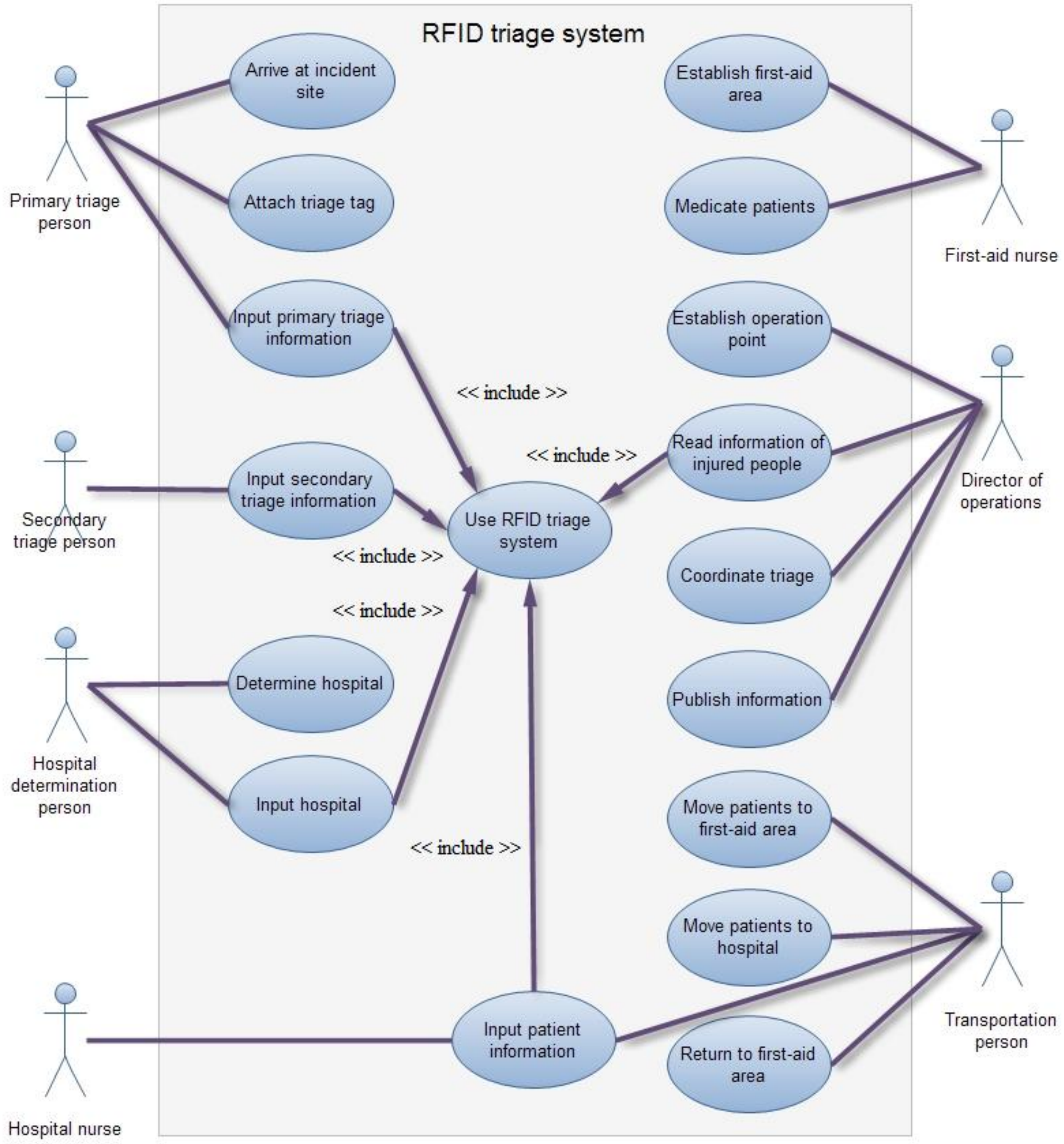

Figure 3-2: Use case diagram of the RFID triage system

The actors using the electronic triage system add or change patient information by the mobile triage device or the terminals. Only the director of operation in the command center obtains the information by read access to coordinate the triage. [EdSr11]

3.3 Actors in the Electronic Triage System

The coordination of the field management consists of predefined processes operated by certain actors (Figure 4-4):

- Primary triage person:
  After arriving at the incident site the primary triage person starts scanning the incident site for injured people, inputs patient information (age, sex, injury category) by the mobile triage device and writes it on the RFID tag and finally attaches the triage tag with the RFID tag to the injured person.

- Secondary triage person:
  In the first-aid area the secondary triage person reads the information of each patient from the RFID tag through the mobile triage device and changes or adds the information (name, phone, address) to the RFID tag by interviewing the injured person.

- Hospital determination person:
  The hospital determination person is responsible for the selection of the hospital to which the patient must be transported. This information is written to the RFID tag by the mobile triage device.

- First-aid nurse:
  The first-aid nurse is responsible for the medication of the patients arriving in the first-aid area.

- Transportation person:
  The transportation personnel move the patient from the incident site to the first-aid area and afterwards from the first-aid area to the hospital and return to the incident site or the first-aid area again. Emergency personnel in the ambulance can change or add patient information and write it to the RFID tag. Except that they record the time needed to transport the injured person to the hospital.

- Hospital nurse:
  The hospital nurse can add or change patient information using the electronic triage system.

- Director of operations
  The director of operations can browse the patient information stored on the server and can be visualized by using web browser software for instance. He/she can

inform different facilities like the emergency control center and coordinate the search and rescue teams.

3.4 Collaboration of Emergency Personnel

The following sequence diagram shows the collaboration of the emergency personnel and the standard treatment of an injured person using UML version 2 (Figure 3-3). [EdSr11]

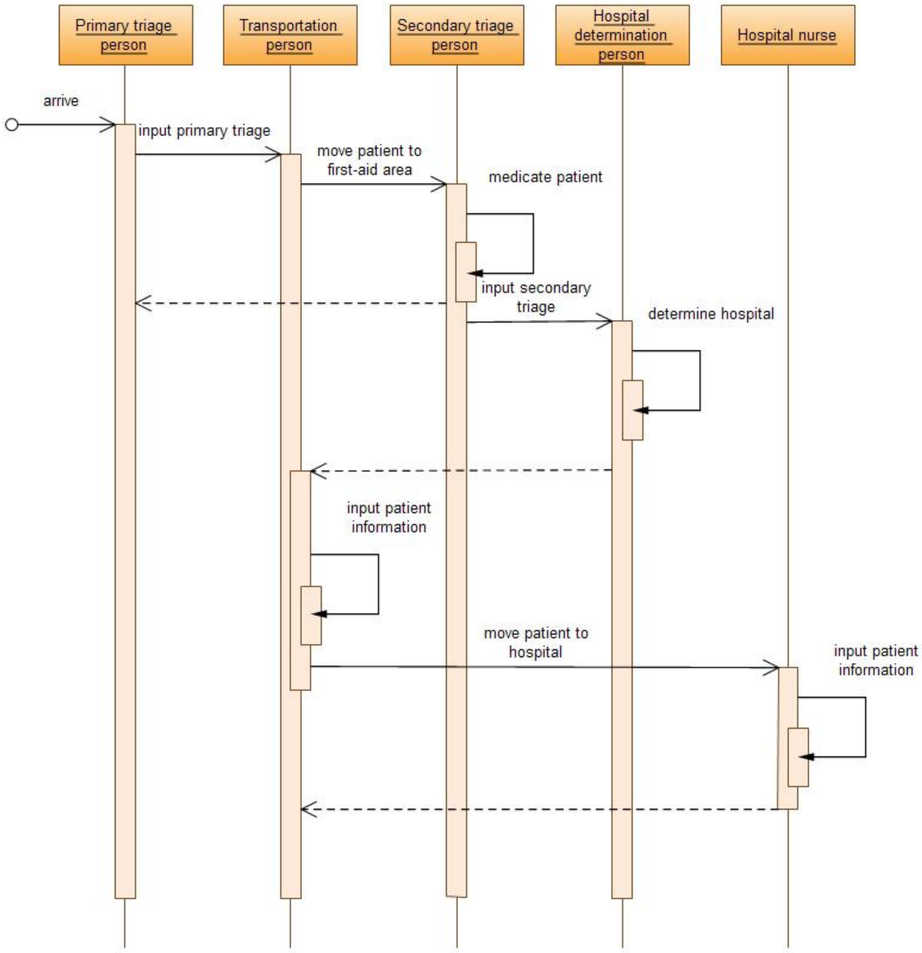

Figure 3-3: Sequence diagram visualizing emergency treatment

4 Related Work

This section provides an overview of thematically relevant work for the electronic triage system and the education of emergency personnel. Related studies are mentioned to provide an overview of the existing literature of the research which is remaining poor in the field of electronic triage. Some mentioned projects are implementing the electronic triage tag with a similar technology and presenting the advantages and disadvantages of this solution.

4.1 Studies and Research

The research in the field of electronic triage systems and the education of emergency personnel for the adoption of this system is poor; nevertheless there are studies relevant for this diploma thesis.

The objective of the study “Disaster plan education: how we made and tested a video” [DuGr96] is to describe the making and testing of a 40 minute video to educate staff about a hospitals disaster plan. The goals of the video were to educate all hospital staff on how the plan worked, and to make it interesting and enjoyable to watch. A disaster scene was created away from the hospital, portraying two cars crashed into a bus queue. The disaster scene was used to explain and demonstrate disaster triage. Casualties were then followed through the hospital from the accident and emergency department to the wards. Thus each department's role was portrayed, including radiography, pharmacy, laboratories, and so on. The text for the video was adapted from the written plan. This was then voiced over scenes or the author was filmed during demonstrations, such as performing triage. On completion the video was shown in the hospital auditorium twice daily for two weeks to ensure several convenient viewing opportunities for all staff. To evaluate information recall after viewing the video, we compared a group of 20 staff who saw the video with a group of 20 staff who had read the plan, using a multiple choice questionnaire (MCQ). Nine of the subjects had otherwise been exposed to the information in the plan before their tests. Subjects were ward nurses and paramedical staff matched into pairs and then each pair split randomly into either group. The MCQ test was applied immediately after seeing the video or reading the plan. The MCQ was designed by an independent examiner and consisted of 25 questions on the plan, each with four options one being correct. Wrong answers scored zero marks. Statistical analysis of MCQ results was done using the Mann-Whitney U test. At the end of the two week viewing period over 500 staff had voluntarily seen the video. Those who viewed the video included the vast majority of those who would be involved in a disaster response. The hospital employs a total of about 1200 staff. Those who did not see the video were mainly employees such as gardeners, mechanics, recreation staff, and so on, and would not be directly involved in any response. The test group who had seen the video scored a mean of 72%/ (range 6-92%), which was significantly better (P <001) than the test group who had read the plan, who scored a mean of 45% (range 40-64%). Reading the plan took an average of 40 minutes; the video is 42 minutes long. [DuGr96]

The study “The effect of training on nurse agreement using an electronic triage system” [DoBu07] describes the inter-rater agreement and manual overrides of nurses using a CTAS-compliant (Canadian Triage and Acuity Scale), web-based triage tool (eTRIAGE) for 2 different intensities of staff training. This prospective study was conducted in an urban tertiary care ED. In phase 1, eTRIAGE was deployed after a 3-hour training course for 24 triage nurses who were asked to share this knowledge during regular triage shifts with colleagues who had not received training (n = 77). In phase 2, a targeted group of 8 triage nurses underwent further training with eTRIAGE. In each phase, patients were assessed first by the duty triage nurse and then by a blinded independent study nurse, both using eTRIAGE. Inter-rater agreement was calculated using kappa (weighted κ) statistics. In phase 1, 569 patients were enrolled with 513 (90.2%) complete records; 577 patients were enrolled in phase 2 with 555 (96.2%) complete records. Inter-rater agreement during phase 1 was moderate (weighted $\kappa = 0.55$; 95% confidence interval (CI) 0.49–0.62); agreement improved in phase 2 (weighted $\kappa = 0.65$; 95% CI 0.60–0.70). Manual overrides of eTRIAGE scores were infrequent (approximately 10%) during both periods. [DoBu07] Agreement between study nurses and duty triage nurses, both using eTRIAGE, was moderate to good, with a trend toward improvement with additional training. Triage overrides were infrequent. Continued attempts to refine the triage process and training appear warranted. [DoBu07]

The purpose of study “The Australasian Triage Scale: Examining Emergency Department Nurses’ Performance Using Computer and Paper Scenarios” [CoLe04] is to examine emergency nurses’ performance using triage scenarios characterized by type of patient population (adult versus pediatric) and mode of delivery (paper versus computer). A combination of paper-based (script alone) and computer-based (script plus still photographs) triage scenarios were used. Of the 28 scenarios used, half were written and half were computer based. Within each subgroup, there were 7 adult and 7 pediatric scenarios. Participants were asked to allocate an Australasian Triage Scale category for each triage scenario. One hundred sixty-seven participants completed a total of 2,349 adult scenarios, and 161 participants completed 2,265 pediatric scenarios. Sixty-one percent of the triage decisions made by the nurses were “expected” triage decisions, 18% were “undertriage” decisions, and 21% were “overtriage” decisions. Nurse triage allocation decisions for the scenarios containing still photographs delivered by computer demonstrated a higher average agreement percentage of 66.2% compared with the average agreement percentage of 55.4% using paper-based (text-only) scenarios. [CoLe04] The mode of delivery appeared to have an effect on the nurses’ triage performance. It is unclear whether the use of simple still photographs used in the computer mode of delivery resulted in a higher incidence of expected triage decisions and, thus, improved performance. The use of cues such as photographs and video footage to enhance the fidelity of triage scenarios may be useful not only for the education of triage nurses but also the conduct of research into triage decision-making. [CoLe04]

The objective of the study “Comparison of Mass Casualty Incident Triage Acuity Status Accuracy by Traditional Paper Method, Electronic Tag, and Provider PDA Algorithm” [BuLy07] was the evaluation of the accuracy of triage using an embedded algorithm in a wireless electronic system compared to traditional methods of triage. The Wireless Internet Information System for Medical Response in Disasters (WIISARD) [BuLy07] project uses wireless technologies, including 802.11, mesh-networking, instantaneous data transfer and geo location to coordinate patient tracking and care from field to hospitals. The conducted comparative trial during a multi-casualty incident (MCI) drill comparing the Wireless Internet Information System for Medical Response in Disasters (WIISARD) system to traditional paper tracking of casualties. There were two parallel response teams, both of which consisted of professional emergency responders. The control using the traditional paper technology and the experimental using the WIISARD wireless system, both receiving 50 identical matched patients. The WIISARD group could perform automated triage using a personal digital assistant (PDA) or they could perform manual triage using an electronic triage tag (iTag). The “Gold Standard” for the patient triage status was determined a priori and written into patient scenarios that should have led to the appropriate triage status (Immediate, Delayed, Walking Wounded, Morgue) with strict application of the START (Simple Triage and Rapid Assessment) triage algorithm. There were three groups analyzed: Control-manual, WIISARD-PDA, and WIISARD-iTag. They were able to retrieve 76% of scenarios for the control group and 92% of scenarios for the WIISARD group, 17 scenarios using the PDA, 28 scenarios using the manual entry into the iTag. The control manual group had 73.7% accuracy when compared to the gold standard. The WIISARD-PDA group had 72.2% accuracy and the WIISARD-iTag group had a 67.8% accuracy when compared to the gold standard ($p = 0.09$) which shows that there was no significant difference in accuracy between the 3 methods of triage acuity determination in this MCI drill. [BuLy07]

The objectives of the study “Data collection on patients in emergency departments in Canada” [RoBo06] were to determine the use of electronic patient data in Canadian EDs, the accessibility of provincial data on ED visits, and to identify the data elements and current methods of ED information system (EDIS) data collection nationally. Surveys were conducted of the following 3 groups:

a) All ED directors of Canadian hospitals located in communities of >10 000 people
b) All electronic EDIS vendors

c) Representatives from the ministries of health from 13 provincial and territorial jurisdictions who had knowledge of ED data collection.

The results of the study were the following: Of the 243 ED directors contacted, 158 completed the survey (65% response rate) and 39% of those reported using an electronic EDIS. All 11 EDIS vendor representatives responded. Most of the vendors provide a similar package of basic EDIS options, with add-on features. All 13 provincial or territorial government representatives completed the survey. Nine (69%) provinces and territories collect ED data; however the source of this information varies. Five provinces and territories collect triage data, and 3 have a comprehensive, jurisdiction-wide, population-based ED database. 39% of EDs in larger Canadian communities track patients using electronic methods. A variety of EDIS vendor options are available and used in Canada. [RoBo06] The wide variation in methods and in data collected presents serious barriers to meaningful comparison of ED services across the country. The majority of information regarding ED overcrowding in Canada is anecdotal, when the collection of this critical health information is so variable. According to [FoBo06] there is an urgent need to place the collection of ED information on the provincial and national agenda and to ensure that the collection of this information consistent, comprehensive and mandatory. [RoBo06]

4.1 Realized Projects

The article [FrLe05] describes an integrated software–hardware system (MASCAL) designed to enhance management of resources at a hospital during a mass casualty situation. MASCAL uses active 802.11b asset tags to track patients, equipment and staff during the response to a disaster. The system integrates tag position information with data from personnel databases, medical information systems, registration applications and the US Navy's TACMEDCS triage application in a custom visual disaster management environment [FrLe05].

The main difference between the MASCAL project and my diploma is that MASCAL seeks to facilitate the resource allocation decisions, avoid patient flow bottlenecks and maximize system capacity and throughput at military and civilian hospitals, and the electronic triage system of my diploma thesis work is applied at the disaster area. Nevertheless the fundamental architecture of the MASCAL project will be relevant for my diploma thesis. Besides that the MASCAL project uses passive RFID tags for the storage of patient information.

Most localities and facilities applying the triage system use conventional paper triage tags. Some of these tags have bar codes to provide a unique identification for an injured person. The article [LePa05] ascertains the limitations of the conventional tag and describes the design and development of an electronic triage tag. The “tear off” format of tags only allows unidirectional changes in patient condition (worsening). The tags are not weather resistant, and are hence easily marred or destroyed [LePa05]. The focus of the article [LePa05] is on the design of an Intelligent Triage Tag (ITT) developed as part of the Wireless Internet Information System for Medical Response in Disasters project (WIISARD) using 802.11 (WiFi) wireless-based technologies to coordinate and enhance care of mass casualties.

The Advanced Health and Disaster Aid Network (AID-N) project designs a hardware and software architecture of the electronic triage system. The decentralized electronic triage and sensing system uses low power, electronic triage sensors to monitor the vital signs of patients and provide location tracking capabilities [MaGa06]. This article identifies the limitations of the conventional paper triage tag. Paper tags inefficiently monitor and locate patients, have limited visual feedback and do not aid in locating a particular patient in a sea of patients with the same triage color tags. When a commander needs to tally the number of patients triaged under a certain color, the manual count is prone to human error. Finally, paper tags do not distinguish between patients categorized under the same color. Two patients categorized as critical (red) have the same priority, even if one patient’s vital signs designate him to be much worse than the other [MaGa06].

The conventional tag is static and disconnected information repository. Real-time information about the injured persons and their status is significant for the management of the field work. Medical command must coordinate timely information on the number of casualties and their needs with the known availability of resources, such as on-scene providers, ambulance locations, and area hospital capacities. Real-time information is also critical to determining the appropriate patient destination, depending on the type of injuries and the capabilities of the receiving facilities [LePa05].

5 Education

Education and training being a part of good disaster triage planning have a fundamental importance. Emergency personnel should be familiar with the simple basics of a disaster plan and the novelties and usage of the electronic triage system, such as where to find equipment, how to use it. In many hospitals there is a lack of staff training for major incidents, most of them not giving any specific training, even to their Incident medical officers, key persons in a disaster response. [JaFi90]

There research and publications remain poor in the field of the methods how to convey a hospitals disaster plan to hospital staff. In the following section we will mention different possibilities of education for the emergency personnel.

5.1 Educational Objectives for Triage

The triage educational objectives address emergency medical assessment in addition to triage systems. Emergency personnel who acquire these skills will understand the operation of triage systems and how casualty classification is performed in response to a catastrophic event. Furthermore, emergency personnel will be able to perform critical medical assessment and immediate treatment with the training proposed for emergency medical procedures. [PsHe06]

- Describe the START stage system.

- Demonstrate the ability to properly classify casualties into the proper triage category.

- Conduct a physical exam that assesses cardio respiratory status, extent of head and neck injuries, and complete physical examination including neurological assessment.

- Must be certified in Basic Life Support (BLS), Core and Basic Disaster Life Support (C/BDLS), Advanced Cardiac Life Support (ACLS), and Advanced Disaster Life Support (ADLS).

- Describe the psychological effects of terrorism.

- Accurately select and identify criteria that would allow the application of a tourniquet and describe the proper application of such.

- Recognize signs and symptoms of acute shock.

- Demonstrate ability to use adjunctive airway support including the Laryngeal Mask Airway (LMA).

- Based on appropriate assessment, emergency personnel must properly record the information on the casualty and describe reasons for doing so.

- Be able to place an appropriate I.V.

- Be able to monitor fluid status.

- Be able to perform an emergency tracheotomy.

- Must complete a minimum four-week anesthesia rotation.

- Must complete a minimum two-week emergency medicine rotation with the goal of achieving minimal competence in airway assessment and management. [PsHe06]

5.2 Methods of Education

Disaster practices have long been recognized as having great value in training and education. Practices are often missed by individual staff, are not seen in their entirety by most participants, and occur infrequently. Therefore practices cannot be relied upon as the only educational tool in most hospitals, and other educational methods should be used.

In this section we describe conventional methods as well as innovative approaches for the education of hospital staff.

5.2.1 Competency-based approach

Certain competencies of emergency personnel for disaster training were defined in chapter 3.1. Since disaster training must integrate multi-disciplinary training with different levels of training, the competency approach can serve as a valuable starting point. These competencies can form the basis for standardized training and unify the disciplines and skill levels involved. Thus we define testable terminal objectives for each competency using similar processes covering requisite knowledge, attitudes and skills, shown in table 5-1, 5-2, 5-3, 5-4, 5-5, 5-6 and 5-7. [HsTh06]

Competency 1: Recognition of potential critical events and implementation of initial actions

#	Terminal Object	Given...	To be successful...
1-1	Recognition	…scenarios that may be encountered in the course of normal professional duties, the participant should be able to identify all potential critical events and their event type.	…the participant must correctly identify all potential critical events among a list of scenarios.
1-2	Notification	…a potential critical event scenario, the participant should be able to identify the appropriate authorities to be notified, recognize the appropriate notification steps and identify the key information to be reported.	…the participant must correctly identify the appropriate notification steps, information to be reported and correct reporting authority.
1-3	Protection	…a description of a specific potential critical event, the participant should be able to list the immediate actions needed to protect personal, environmental and public safety.	…the participant must correctly identify standard safety precautions as well as additional precautions that may be needed for potential chemical, biological and radiological events.
1-4	Mobilization	…a specific critical event scenario, the participant should be able to make recommendations for emergency response needs prior to disaster plan activation (mobilization).	…the participant must correctly identify standard safety precautions as well as additional precautions that may be needed for potential chemical, biological and radiological events.
1-5	Synthesis	…a simulated workplace scenario, the participant will apply knowledge of potential critical event recognition and immediate response needs to perform the appropriate notification, safety and mitigation actions for that event.	…the participant must identify the specialized personnel and equipment that may be needed for the type of event and the preparation steps required for mobilization.

Table 5-1: Competency 1 - Recognition of potential critical events and implementation of initial actions

Competency 2: Application of critical event management principles

#	Terminal Object	Given...	To be successful...
2-1	Management	…a list of disaster terms and management activities, the participant will be able to identify the phases of critical event management and match the activities to the appropriate phase.	…the participant must be able to correctly recognize the phases from among a list of disaster terms and match the activities to the correct phase.
2-2	Preparedness	…a critical event scenario, the participant will be able to apply their knowledge of disaster preparedness to identify the key components of preparedness and recognize appropriate preparedness activities.	…the participant must be able to correctly identify the components of disaster preparedness, and select the appropriate preparedness activities for each preparedness component.
2-3	Response	…a critical event scenario, the participant will be able to apply their knowledge of disaster response to identify the key components of response and recognize appropriate response activities.	…the participant must be able to correctly recognize the components of disaster response and select the appropriate activities for each response component.
2-4	Recovery	…a critical event scenario, the participant will be able to apply their knowledge of disaster recovery to identify the key components of recovery and recognize appropriate recovery activities.	…the participant must be able to correctly recognize the components of disaster recovery and select the appropriate activities for each recovery component.

Table 5-2: Competency 2 - Application of critical event management principles

Competency 3: Demonstration of critical event safety principles

#	Terminal Object	Given...	To be successful...
3-1	Safety	…a critical event scenario, the participant should be able to demonstrate knowledge of critical safety principles by identifying safety threats and appropriate actions.	…the participant must be able to correctly identify appropriate responses to safety threats.
3-2	Security	…a critical event scenario, the participant should be able to demonstrate knowledge of security principles by identifying security threats and appropriate actions.	…the participant must be able to correctly identify appropriate responses to security threats.

Table 5-3: Competency 3 - Demonstration of critical event safety principles

Competency 4: Understanding the institutional emergency operations plan

#	Terminal Object	Given...	To be successful...
4-1	Purpose	The participant should be able to identify the purpose and components of an EOP in critical event response.	…the participant must be able to correctly identify the purposes of the EOP and its components.
4-2	Components	an institutional scenario, the participant will be able to apply knowledge of critical event planning to outline an institutional EOP.	…the participant must be able to identify the necessary EOP components and functions for the scenario presented.

Table 5-4: Competency 4 - Understanding the institutional emergency operations plan

Competency 5: Demonstration of effective critical event communications

#	Terminal Object	Given...	To be successful...
5-1	Communication Overview	…a critical event scenario, the participant should be able to apply knowledge of communications to fulfill basic communication needs including identification of appropriate timing, content, recipients, and modalities.	…the participant must correctly identify the appropriate communication steps, information to be reported, correct reporting authority, and alternative modalities.
5-2	Communication Implementation	…an institutional scenario, the participant should be able apply knowledge of communications to outline a communications plan.	…the participant must outline the complex communication needs for a critical event.

Table 5-5: Competency 5 - Demonstration of effective critical event communications

Competency 6: Understanding the incident command system and the role in it

#	Terminal Object	Given...	To be successful...
6-1	ICS Overview	…a critical event scenario, the participant will be able to recognize their role in the incident command system and identify the corresponding responsibilities and limits of their authority.	…the participant should be able to identify ICS defined individual tasks and scope of responsibility.
6-2	ICS Implementation	…a simulated incident command scenario, the participant should be able to apply knowledge of the incident command system to outline a command structure and interpret incoming information to make appropriate command decisions.	…the participant should be able to correctly identify lines of authority, recognize data needs and select appropriate command decisions.

Table 5-6: Competency 6 - Understanding the incident command system and the role in it

Competency 7: Demonstration of the knowledge and skills needed to fulfill the role during a critical event

#	Terminal Object	Given...	To be successful...
7-1	Triage Skills	…an institutional scenario and descriptions of mock victims, the participant will be able to apply knowledge and skills concerning disaster triage systems to rapidly assign victims to appropriate triage categories.	…the participant must recognize the appropriate triage system and correctly assign triage levels to all victims within a given timeframe.
7-2	PPE Skills	…a critical event scenario and descriptions of mock victims in a simulation, the participant will be able apply knowledge and skills concerning personal protective equipment (PPE) to successfully select, don, and monitor the appropriate level of PPE.	…the participant must recognize levels of PPE as well as correctly choose and simulate utilization of the appropriate level of protection.
7-3	Decontamination Skills	…a critical event scenario, the participant will be able to apply knowledge and skills regarding decontamination to select, demonstrate, and monitor the correct method(s) of decontamination.	…the participant must correctly identify the decontamination level as well as select and demonstrate appropriate decontamination techniques.
7-4	Diagnosis/ Treatment	…a description of a patient presentation in a critical event scenario, the participant will be able to apply knowledge and skills regarding critical event diagnosis and treatment to identify critical event related syndromes and causative agents and select the appropriate treatment(s).	…the participant must correctly diagnose the presented clinical syndrome, identify the causative agent and select the appropriate treatment(s).

Table 5-7: Competency 7 - Demonstration of the knowledge and skills needed to fulfill the role during a critical event

5.2.2 Educational Video

The study [DuGr96] shows that the use of a video has advantages over reading a written plan. These advantages are:

a) A video allows staff actually to see items of equipment such as mobile triage device and triage tags being used, and to see where equipment is stored, how to don protective equipment, etc;

b) A video may give staff an insight into what it would be like to be faced with mass casualties;

c) A video is convenient; it can be viewed by groups or individuals and it requires little preparation;

d) A video being viewed is easy to supervise; in contrast, giving staff a plan to read does not mean they will read it or even part of it.

A video can prove an efficient, convenient, and enjoyable way for emergency personnel to learn about the novelties and usage of the electronic triage system. It is recommendable for medical facilities facing the challenge of disaster plan education, and having access to basic equipment and expertise, to make an educational video. In this video there should be disaster scene created and a disaster triage simulated using the electronic triage system. These facilities could share and copy parts of an educational video which are not specific to their plan, such as a crash scene and triage, then adding scenes specific to their own plan.

5.3 Difficulties in Education

Disasters and major accidents are rare and available reports do not permit analysis and comparison of results, thus making evaluation of the training methodology difficult or impossible. When a mass casualty incident happens, it is an understandable temptation to state that “some casualties were so badly injured so they could not be saved”. To analyze the response/performance in a major accident or disaster might appear a delicate process, and there has been a reluctance to criticize people who did their best in a difficult situation. On the other hand, whenever such analyses have been performed, they have illustrated that many things could and should have been done differently. [StLe05]

Training in disaster medicine is different from training in most other fields of medicine because in other areas there is usually sufficient “clinical material” in the form of patients that can be used for training under qualified supervision. This does not exist in disaster medicine, where major accidents and disasters are rare events. Disasters are difficult and stressful situations requiring maximal effort from all involved, and are not training opportunities. Thus, training in disaster medicine must be based on simulated situations, employing a wide array of mock casualties, simulators and educational tools. This puts very high demands on the quality of training.

Unfortunately, many such training programs put a major emphasis on the dramatic and spectacular – blue lights, sirens, dramatically painted and screaming mock casualties. When medical staff is inserted into the chaos, they may learn how to behave on a scene, to communicate and find their role in collaboration with staff from other agencies. However, the medical aspects of their performance – decision making, triage, patient management – are often not put to the test.

The key element in disaster medicine is decision-making: from decisions at the command level to triage and management decisions in the individual patient (19, 20). If, during training, the decision maker is unable to see the consequences of his or her decisions, the value of the training will be very limited. A central challenge in disaster training is therefore to measure and illustrate the consequences of the trainee’s decisions and actions. It is as possible as it is necessary, but it requires considerable effort on the part of the trainer. [StLe05]

5.4 Implementation and Testing

Prototype mobile triage devices should be implemented with 2 test environment settings:

- First: Utilize the mobile triage devices in a controlled mock event with simulated clinical patient scenarios to be entered into the mobile triage device by technical staff.

- Second: Distribute the mobile triage devices to actual first responders as a part of a large scale MCI (mass casualty incident) drill with 100 actors simulating victims of a terrorist disaster incident.

5.4.1 Functionality Test Implementation

First test environment is designed to evaluate the functionality of the mobile triage device and under a mock event simulated by technical staff. In this test environment, 20-30 patient scenarios are created and attached to triage tags. Technical staff establishes an mesh network in an outdoor setting of approximately 200 yards in diameter and the tags are distributed throughout this area. Staff utilized the mobile triage device to enter patient data under the triage screen with acuity status determined automatically by the START triage algorithm. The patient scenarios are evaluated by physicians unaware of the mobile triage who determine acuity status based on their own assessment of the scenario. Data obtained with the mobile triage device can be compared with the actual number of victim scenarios as well as the physician evaluation.

Patient scenarios should be successfully logged by the individuals operating the mobile triage device. Acuity status (Immediate, Delayed, Minor and Dead) should be in agreement between the mobile triage device and conventional triage.

5.4.2 Field Drill Implementation

Second test environment is designed as an operational field test of the mobile triage device as a part of the electronic triage system in a large scale MCI (mass casualty incident) involving a simulated terrorist chemical and blast injury disaster. This large scale drill should involve about 100 actors simulating victims, over 20 responding law, fire and EMS (emergency medical service) agencies, and hundreds of first responders, scene managers, and incident commanders. About 15-20 mobile devices were deployed to initial EMS and fire personnel responsible for triaging, treating and determining disposition of the simulated victims on scene. Responders should have little or no training with the device, but technical staff should be on scene to provide support.

The average time for the first responder to initiate and complete the mobile triage screen should be 30-40 seconds. All patient data logged must be automatically transmitted to an active central database that allows simultaneous access and display of patient logs. [KiCh06]

6 Adoption and Barriers

6.1 Benefits of handheld computers in health care

A systematic review shows that the adoption rate of handheld computers by physicians is at its highest yet with 46% of US internal medicine physicians and 75% of residents using them daily. [HaDe07] Physicians report that use of handheld computers references results in safer patient care. Clinical and library staff using handheld devices in a clinical setting concluded that the devices provide enough relevant and quickly accessible information to influence clinical decisions and improve patient safety. [HaDe07] Handheld computer-based decision support systems improved antibiotic prescribing in critical care. Nursing students using a handheld computer-based drug reference calculated medication dosages with greater accuracy and speed than students using textbooks. [HaDe07]

A frequently asked question is which of the increasing number of PDAs should be used. Various medical and lay publications review benefits and disadvantages of the different hardware platforms and operating systems. Functionality is the first important question that needs to be addressed before purchasing a handheld device. If the PDA is meant to replace a paper planner, the memory requirements are significantly less than if it is to be used as a clinical reference. Memory is an important point to consider because many medical resources require a large amount of memory. The recent introduction of external memory sources (e.g., memory card, memory stick) has added to the diversity of choice. [FiSt03]

6.1.1 Errors reduction

Handheld computers with customized software have been used for research data collection. A study compared the accuracy of electronic data collection with a paper questionnaire. They found that successful implementation depends on proper training of the respondent in the handling of the electronic instrument. Except that they found that the total time for the data collection on a handheld device and downloading to a personal computer was 23% faster than hand recording and generated 58% fewer errors. [LaSm00]

6.1.2 Education

Electronic data collection is becoming increasingly important to manage information in the medical education environment. Handheld devices have been used for the evaluation of training for medical personnel, to help monitor their clinical experience, and to ensure that they benefiting from the provided teaching. Because a large amount of information needs to be collected, many institutions use an electronic method for data collection. Handheld computers have been found to be a practical and feasible way to identify gaps in the education of emergency personnel and experience so that action can be taken to address them. Because it is possible for them to take the handheld computer into settings where they come into contact with patients, reporting of contacts is maximized. One advantage is that additional software can be added, providing reference material that can be accessed during clinical training. [BaSg00]

6.1.3 Cost saving

An important factor that may affect the integration of handheld devices into the medical setting is cost. Costs, which tend to vary depending on the package, include the software, the server, upgrades to the hospital’s network, the handheld units themselves, and support. One may assume that cost return will occur through decreasing charting time, fewer errors, and more time left for patient care, but so far a comparison of costs before and after integration of mobile technology has not been done. [JoKe01]

6.1.4 Time saving

A number of studies describe procedure logging in different areas of medicine with handheld devices. The mean number of procedures, encounters and follow-ups performed per resident using a handheld device was compared with a historical control group. It was concluded that the overall time savings in using a resident procedure database may result in a transition to a handheld computer-based procedure log. Logged procedures can be sent to a central database and analyzed for residency management. [LaLo01] A study report shows that a handheld procedure log has achieved high reliability and data integrity, low data entry workload and rapid feedback for residents and the program director concerning the residents’ procedural experience. This approach was associated with very low cost, training overhead or complexity. [NiDa01]

6.1.5 Clinical impact

Handheld devices are described to evaluate teaching interactions. A clinical teaching evaluation form was transferred into a PDA format. Preliminary feedback indicates that entering evaluation data has prompted participants to improve and change their teaching profile. A randomized controlled trial demonstrated comparability of the hand-held computer method to the paper-and-pencil method in obtaining survey information. [McAn99]

6.2 Barriers to handheld computer adoption

There are several concerns about documenting clinical experience via handheld computer, such as inaccurate data entry, the potential to lose data, patient privacy, incomplete trainee participation, technical difficulties with software installation, and the need to provide additional training and support for users unfamiliar with the technology.

The size and mobility that make handheld computers attractive to busy clinicians also create barriers to their widespread adoption and general utility. Many physicians find them small and difficult to use. Even residents with handheld computers experience had difficulty performing text entry tasks on such devices. Although a prototype point of care system for handheld computers can be generally helpful for checking medical orders at the bedside, it might not display an adequate amount of information on one screen. Physicians and health care organizations are concerned about reliability and security of handheld computers. Organizations are also concerned about their ability to provide training, hardware and software IT support, and an appropriate infrastructure. [HaDe07]

7 Conclusion

Effective decisions at the point of care can be achieved by adoption of mobile computing technology improving information access, enhancing workflow and promoting evidence based practice. Portable access to clinical data and relevant information at the point of care is provided by mobile triage devices or handheld computers and PDAs in general.

The level of use of PDAs in health care providers' practice is high and it is expected to rise rapidly in the future. PDAs are useful in access of patient data, areas of documentation but there are major barriers to adoption identified as usability, security concerns, and lack of technical and organizational support.

Emergency personnel have the possibility to enhance and improve their clinical practice. Nevertheless it is necessary to increase the acceptance and wide use of PDAs in healthcare by designing better PDA hardware and software applications, providing more institutional support, integrating PDA technology seamless with hospital information systems and ensuring adequate security measures.

Disasters are stressful situations requiring maximal effort from all involved. They are not training opportunities. Therefore training in disaster medicine must be based on simulated situations, employing a wide array of mock casualties, simulators and educational tools.

It is necessary to define training requirements for each job description what requires adequate modification of educational content. Except that it is essential that emergency personnel are equipped not only with knowledge but specific technical skills and decision-making abilities. This type of flexible training is provided by the competency based approach.

Competency based approaches to training have been widely implemented and have gained acceptance in medical education although the application of competency based education for training healthcare workers in disaster is a relatively new concept. While competency statements for public health workers and various hospital staff in emergency preparedness have been previously outlined, there are important differences in the derivation methods, degree of inclusiveness in development processes, level of detail and the definition of the term competency.

We described a set of competencies with specific measurable objectives derived using evidence-based consensus building techniques that addresses the training of all healthcare workers in disaster response.

Providing training content from a single set of competencies offers both theoretical and practical advantages over utilization of distinct competency sets for each type of health-care worker being trained. Emergency personnel require training to develop the fundamental knowledge and skills to function independently but also to act in part of a coordinated response effort.

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