Location Interoperability Services for Medical Emergency Operations during Disasters

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Abstract

The organizational structure that deals with the Response phase in disaster and risk management is based on a strong co-operation between several organizations, such as the police, fire departments, the local government and the health services[1] The size of the organization depends largely upon the scale of the disaster itself. Van Dijke 2003 identifies 31 processes, that concern information flows and coordination of forces, that are relevant in these cases.

This paper concentrates on the information process at the first aid in hospitals, which is part of 'somatic health care'. Research has been conducted on the information problems during emergency operations at first aid departments in Italy and The Netherlands. The results identify location information (location of patients, equipment, physicians and/or relatives, and so on) as a critical factor for improve quality and coordination of health services.

In most cases the location has to be determined indoors, where the most common global 3D positioning (based on GPS) is not available. It is still a challenge to obtain accurate positions indoors.

In general terms, one can distinguish between two broad classes of location technology: global (telecommunications) and local (WiFi, Bluetooth)

[1] Often called "Medical Aid during Accidents and Disasters". In the Netherlands there is a specific health organization involved in disaster management, called 'GHOR'.

network approaches, based on absolute (providing coordinates) or relative (providing speed and direction of movement) positioning. Currently, the most commonly used approaches for indoor positioning are based on WiFi and RFID.

This paper presents a system for indoor positioning and LBS to support hospital teams in emergency management. The paper discusses current information problems, investigates the required functionality of a system for hospital services, and the added value of indoor location technology.

1 Healthcare: Challenges for ICT

The health care industry is in the middle of a process that is often described as 'going from supply-based to demand-based services' Corrigan, 2004. In the supplied-based services, patient needs are 'matched' to the available services and the patient is required to adapt to the quality and level of services available. The demand-based services, in contracts, concentrates on the needs of the patient and adapts the services provided by a hospital to every particular case. The provision of demand-based services would imply higher requirements to the hospital organization; this is to say much more flexible and adaptive service organization. Such a demand-based organization can only be achieved with better coordination between providers of health services, better resource use, better personnel management and coordination, and an integrated information flow. Information Communication Technology (ICT), as in many other areas, plays a critical role in improving flexibility, quality and productivity in health industry and facilitates the shift towards demand-driven services.

Patient needs and quality of services increase in emergency situations. Large disaster, such as fire in a public building, a traffic accident, a plane or train crash, or an industry accident (explosion, leakage of heath-threatening chemicals, etc.), are characterized by:

- Large number of patients, which require mobilization of more hospital personal and equipment than usual;
- A large number of the same type of injuries (e.g. skin damages in fire, or breathing problems in gas leakage) that may require large amounts of the same medicines and specialists;
- Injuries that requite immediate and simultaneous high qualified treatment (e.g. surgery), which has usually limited capacity and is provided based on a long term schedule;
- Ambulances have to deliver several patients;

- Stress and panic situations, and very often bad estimates of the number of injured people and that need treatment;
- The critical need for real-time coordination and communication with police, fire brigade and the local authorities;
- The need for real-time communication and information to several media and the public.

These characteristics underline the need for a much better communication between medical institutions and other organizations involved in disaster management. At the same time, there is a need for a better organization within the hospitals concerning the deployment of specialists, availability of medical supplies, transportation, rooms and equipment. The services to be provided to the patients are necessarily demand-driven.

In this paper we argue that location technology through a process-oriented approach will increase the quality of the somatic health care process during disasters, by supporting the provision of relevant information and by helping coordination within health care and between organizations. LBS can play a very important task in order to facilitate a demand-driven approach to deliver the right information to the right person in order to deliver good care. The Dutch GHOR-organization GHOR, 2004 states that the integration of geographic information systems is essential to support health care services (see also Verhoef, 2001).

2 LBS Background

Location-based services (LBS) revolve around the ability to locate at any point in time the position of resources, people, vehicles and objects. People or objects can be located by a variety of means such as GPS location, telecom based location, indoor location systems such as RFID, Wi-Fi, bluetooth or radio tags. This location can be requested by a user, for instance to find a piece of equipment in the vicinity, or by a control facility, for instance to locate a nurse or a doctor within the hospital facilities.

All mobile applications are based on the ability to provide remote access to data sources from mobile devices. What distinguishes Location-based Services from a pure extensibility service (such as email access from a handset) is how critical location information is to the added value to the user. Services that add value by using the location component are called location-based services.

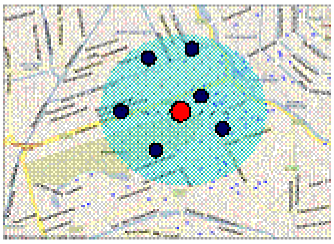
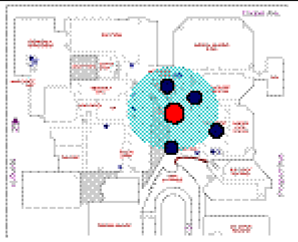
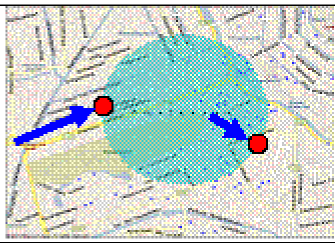
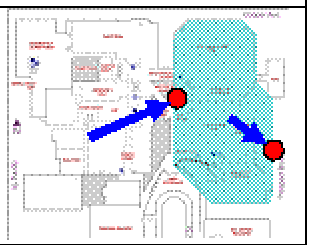
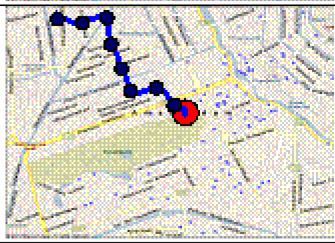
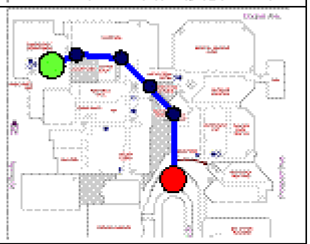
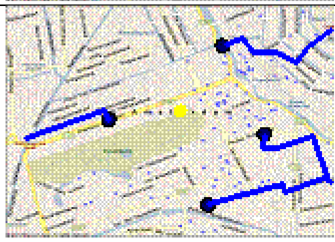
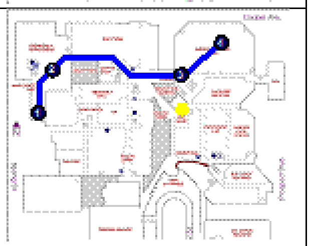
Proximity and position indicate services that detect information or objects in the proximity of a given point or the location of a user.		
Fencing refers to ability to identify areas or 'fences' that serve to detect special movements.		
Navigation provides instructions to navigate from and origin to a destination.		
Tracking refers to the ability of positioning an object in space and possibly monitoring its movements for analysis and management purposes.		

Table 1. Depending on **position** of the user and/or the position of the Point of interest, the LBS can be subdivided into four main types of location services

LBS are both horizontal (services suitable for consumers and business, such as route information) and vertical services (specific for type of business, such as field service engineer management). The importance of LBS is recognized by Open Geospatial Consortium (the formal Open GIS Consortium) and several standards regarding LBS are already either available (OpenGIS Location services) or under development.

OpenLS consider compulsory six core services, i.e. Gateway (related to obtaining position), Directory (access to user-specific information and or Points of Interest), Geocode (conversion from address to co-ordinates), Reverse Geocode (ability to convert co-ordinates to address), Route (commutation of route) and Presentation (presenting the requested information to the user, e.g. a map with the route). The services are intended for all classes of mobile devices. The request should contain the type of the user device (according to a list with well-known devices) and a number of parameters specifying the range and type of requested information.

Depending on the **type** of the information to be provided to the user, the services can be subdivided into the following groups:

1. **Information services**, which provide information about objects close to the user (in terms of distance, travel time or other). Examples are: locate my position, locate an address, check traffic conditions on the highway, etc.
2. **Interaction services**, which are based on the interaction between mobile users/objects and do not require a 'mobile internet' component or a content sources. Examples are: Where is my nearest colleague? Where is the specific device? Where is the closest emergency car to an accident?
3. **Mobility services that** support smart mobility and revolve around navigation capabilities. Examples are: How do I get from A to B? What is the quickest reroute to avoid this traffic jam?

3 Applications using LBS

A variety of applications utilizing location and location-based information are already operational.

In the US, emergency location services prescribe the possibility to locate a 911 call from a fixed and mobile phone, with the request to operators to disclose this information to emergency services. The accuracy requirements are the following: (1) for network-based solutions: 100 meters for 67% of calls, 300 meters for 95 percent of calls; (2) for handset-based solutions: 50 meters for 67% of calls, 150 meters for 95 percent of calls.

Alert Services may be enabled to notify wireless subscribers within a specific geographic location of emergency alerts. This may include such alerts as avalanche warnings, pending floods or accidents that interrupt cir-

culation. No legal or administrative requirements currently exist for Emergency Alert Services anywhere in the world.
Fleet and Asset Management services allow the tracking of location and status of specific service group users. Examples may include a supervisor of a delivery service who needs to know the location and status of employees, parents who need to know where their children are, or a natural park administrator that wants to know where the visitors to his park are. The service may be invoked by the managing entity, or the entity being managed, depending on the service being provided. Fleet Management may enable an enterprise or a public organization to track the location of vehicles (cars, trucks, etc.) and use location information to optimize services.

Asset management services may range from asset visualization (general reporting of position) to stolen vehicle location and geofencing (reporting of location when an asset leaves or enters a defined zone). The range of attributes for these services is wide.

For Fleet and Asset Management services, a distinction may be made between the manager of the fleet/assets in charge of tracking, and the entities being tracked (service group users, etc). The tracking service may make use of handsets with possible specialized functions (Web browsers, etc) to allow for tracking and specific methods for communicating with the managing entity. A managing entity would be able to access one or several managed entities' location and status information through a specified communication interface (Internet, Interactive Voice Response, Data service, etc). The managing entity would be able to access both real-time and recent location and status results of managed entities.

Mobiles in automobiles on freeways anonymously sampled to determine average velocity of vehicles. Congestion, average flow rates, vehicle occupancy and related traffic information can be gathered from a variety of sources including roadside telematic sensors, roadside assistance organizations and ad-hoc reports from individual drivers. In addition average link speeds can be computed through anonymous random sampling of MS locations. Depending on the capabilities of the location method, traffic behavior can only be determined if a vehicle location is sampled at least twice within a finite predetermined period. Traffic monitoring technology is at the basis of innovative road taxes schemes such as the proposed road pricing scheme currently under evaluation in the Netherlands. Location technology and on-board wireless connections are being considered as a means to exercise road taxes based on type of road, time of travel etc.

Location-Based Information services allow subscribers to access information for which the information is filtered and tailored based on the location of the requesting user. Service requests may be initiated on demand by subscribers, or automatically when triggering conditions are met. The purpose of the navigation application is to guide the handset user to his/her destination. The destination can be input to the terminal, which gives guidance how to reach the destination. The guidance information can be e.g. plain text, symbols with text information (e.g. turn + distance) or symbols on the map display. The instructions may also be given verbally to the users by using a voice call. This can be accomplished through carrying a GSM mobile phone that has location technology capabilities down to a few meters. Less granularity impedes the applicability of this functionality.

City Guides would enable the delivery of location specific information to city visitors or residents. Such information might consist of combinations of various services including historical site location, providing navigation directions between sites, facilitate finding the nearest restaurant, bank, airport, bus terminal, restroom facility, etc.

The main characteristic of this service category is that the network automatically broadcasts information to terminals in a certain geographical area. The information may be broadcast to all terminals in a given area, or only to members of specific group (such as members of a specific organization). The user may disable the functionality totally from the terminal or select only the information categories that the user is interested in.

An example of such a service may be localized advertising. For example, merchants could broadcast advertisements to passers-by based on location / demographic / psychographic information (for example 'today only, 30% off on blue jeans'). Similar services would include weather and traffic alerts Steenbruggen, 2004.

Mobile Yellow Pages services provide the user with the location of the nearest point of interest. The result of the query may be a list of service points fulfilling the criteria (e.g. Banks with ATM within walking distance). The information can be provided to the users in text format (e.g. bank name, address and telephone number) or in graphical format (map showing the location of the user and the bank).

4 Technology for LBS

The next step is to choose the right technology to perform the job. Figure 1 shows an overview of different location technologies and their related accuracy. Table 2. Location Systems and summery of their features (from Beinat, 200illustrates the major location systems currently available. Most of them find their application in health care, in particular the indoor systems.

Telecom based technology like Cell-ID and triangulation methods are useful for services that require an accuracy of 50 to 100 meters and are rather cheap and can be used both out- and indoor. For more accuracy outside however the Global Positioning System (GPS) can perform the job as it comes to outside services. For a more accurate solution location services based on wireless local area networks are suitable. These however are suitable for rather small areas. Radio Frequency Identification both active and passive (RFID) are suitable for accurate positioning within buildings. Ultra Wide Band (UWB) seems the right technology for all the services. Unfortunately UWB is not available yet. This will mainly depend on future technological developments, standardization, jurisdiction Steenbruggen et al, 2004 and it's acceptance by users.

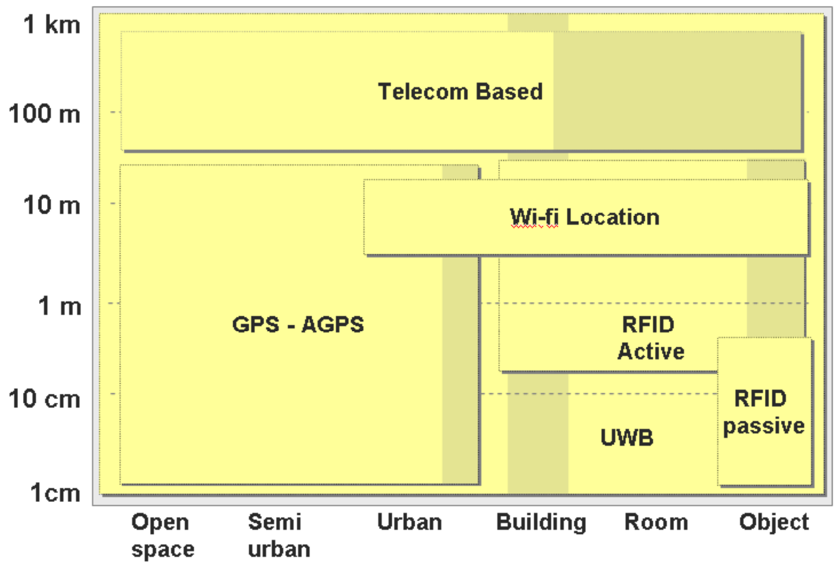


Fig. 1. Accuracy of different location technologies on a logarithmic scale

In order to facilitate processes that cover in- and outdoor activities, location technology needs to adapt to information systems that already exist or are being developed at this moment that will cover these processes. This will finally fulfill the need for, in our case, disaster management processes.

5 LBS for Health Care in Disaster Management

The services for health care in disaster management are much more demanding than most of the application described above. What is the added value of the use of location technology in solving problems during disasters?

Verhoef, 2001 describes the integration of GIS with systems used in control rooms. In this context he describes that integration of these systems will lead to information about the exact location of ambulances, travel times and distances between ambulances and incident locations, and the use of dynamic information like road blocks and such. The national Dutch GHOR organization describes the need for a system which is able to support the entire chain of health care during disasters. Although a lot of initiatives are taken at this moment in order to deploy this, a chain wide registration system is not developed and accepted yet GHOR, 2004. At this moment the Dutch Red Cross has taken the first steps in achieving this goal by developing a system where patients and relatives can be registered and followed trough the whole process of somatic health care Luyendijk and Schoof, 2004.

To Mennecke et al., 2004 it appeared that GIS can be used to extend the range of problems that can be solved using technology by allowing users to more efficiently complete problems that are more complex. A direct outcome of our interviews was the fact that information systems which will be used with the purpose to support processes during disasters have to resemble information systems which are used in the daily normal situations. Users said it is very hard to switch to other systems, which they do not use often and were they have to work under high pressure.

On the basis of interviews with people concerned with medical treatment, management and policy making during disasters the following requirements to a system can be formulated. The system has to be able to provide at any time:

- Patient position and health status. Registration systems can benefit form the use of location technology to know exactly which patient is where in the logistic process. On the basis of the collected and known medical information the nearest suitable hospital with enough resources can be found. When the location of the hospital is known, travel times can be calculated between the scene and the hospital or other health care facilities. This is important because some patients need specific care which can not be provided by every hospital or health care facility. Matching of location and medical information is very important in supporting these decisions.

- Position of health care personal. A clear overview of the entire scene during a disaster is important for management and logistics, and especially rescuers' safety. For health care purposes location of certain objects in the field is very important, for example: location of paramedics and other health care personnel, vehicles, areas of patients and specific areas of risks (chemical substances). Especially managers at the scene can benefit form this in order to have a clear overview of the whole situation at the scene.
- Routing for the first aid team. It is not usually hard to predict at what time and where exactly a critical situation will appear. An appropriate and fast routing to the accident, taking into account the actual situation in the surrounding areas, will save time and greatly support the work of the first aid teams. In some cases (e.g. accidents in metro, tunnels, large shopping centers), indoor routing will be required to avoid all kinds of obstacles and arrive quickly to victims.
- Information about the area affected. Another important requirement is information about the incident area for planning purposes. For managers it can be important to take decision on the basis of geographic information of the scene compounded with dynamic information collected in the field, such as the location of certain objects. With the help of maps displaying this information, managers can for instance decide where to deploy emergency teams or vehicles.
- Relevant information from different sources and information systems. To facilitate management processes it is very important to facilitate an infrastructure that will not only support health care managers but also managers from, for instance, the fire departments, the police and the public authorities. In the management team at the scene the combined information provided on a map can support the process of multidisciplinary decision making on the basis of geographic information combined with dynamic information collected by the resources on the field.
- Decision making. The system has to be fast, flexible and adaptable to any new coming information, suggesting partial or complete solutions for dispatching patients, delivering medicaments and managing emergency teams.

All these requirements show the need and added value of location information at the incident site. The next phase of a rescue operation takes place at the hospital or health care facilities. The case study below describes this next step and the use of location information within the first aid of a hospital.

6 Indoor Location for Emergency Services

Patient logistics play a very important role within health care facilities during disasters. Health care organizations, and the emergency departments of hospitals, are usually subject to an enormous level of stress that takes facilities and resources to the limit of their capacities. In these circumstances it is not always known were patient exactly are within the facility, if certain patient already left certain departments (such as research, intensive care or operating facilities) and have arrived at a ward for less intensive treatment. This is very important for management purposes, as a prerequisite to allocate resources efficiently. With this information, managers can monitor the status of their entire logistic chain all the time, anticipate and manage bottlenecks.

An example of this type of location system can be found in the figure below. This picture below (FIGURE 2) illustrates the emergency floor of a medium-large hospital in northern Italy (700 beds) that has implemented location information system within the emergency department.

In this implementation, tags are associated to important and scarce pieces of equipment. Nurses and doctors can locate a missing piece simply by locating the associated tag, which in this case is located with less than 2 meters accuracy. The same technology can be used to locate patients that are provided with a small tag, such as a bracelet. By connecting this information to the existing hospital information system, users can associate location and information related to the patient. Furthermore, since the location information becomes an element of the underlying information asset, a variety of analysis can be carried out based on this information and on the integration with ERP or CRM systems.

The system registers active users (such as a physician that carries a handheld system) and passive users (e.g. a piece of equipment). Active users can specify the degree to which their location can be disclosed, to who and when in respect of their privacy.

The service can also find a great number of uses in health services not directly linked to disaster management, from operations logistics to theft prevention, to warehouse maintenance and optimization.

In general, these systems are meant to provide services such as:

- Locate patients, doctors, specialists, nurses etc.
- Provide all kinds of routing: 1) to a patient, 2) with a patient to a particular first aid nest and 3) to other health care personnel in the area avoiding blocked stairs and inaccessible exits
- Locate other teams (or specialist) that are already in the building but in another section and establish communication with them

- Search for information on the internet (or particular server) e.g. how many and what type of people (old, young, children etc.) are in the building,
- Communication with the hospital or other managing the disaster centers.

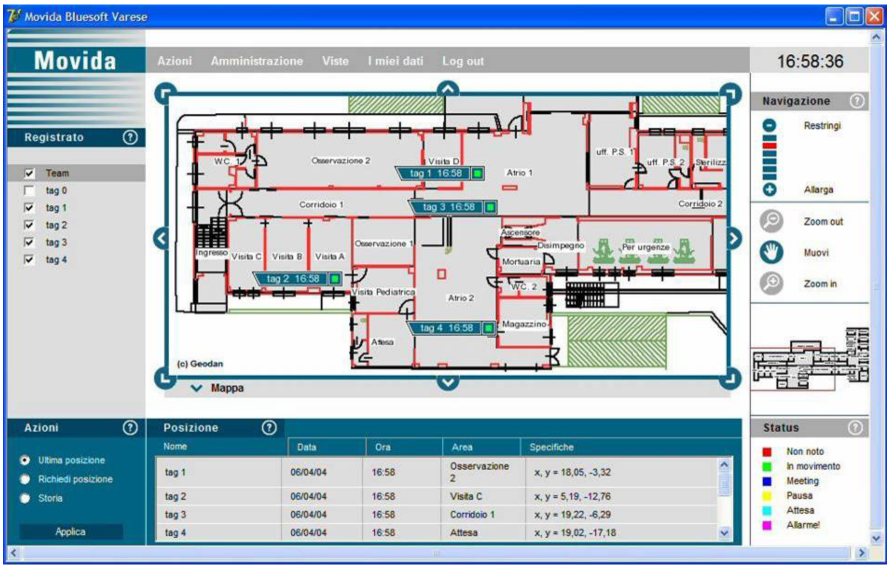


Fig. 2. Screenshot of an application showing the first aid-department of a medium-large hospital in northern Italy

7 System Architecture

The example above is developed on an Java platform[2]. The functionality revolves around three mayor layers:

- The application logic, built on Java and XML/GML, that contains all workflows of the application, and the integration interfaces towards other systems, such as CRM or ERP.
- The application toolbox, that contains service modules (such as web services) that perform specific task and provide basic services. They include:
  - Connector interfaces between legacy databases and the Java/XML platform;

[2] See Geodan Movida: www.geodan,com/movida.

- Messaging, such as SMS, email, voice, etc;
- Maps, portrayal, and spatial functions.
- Routing and Geocoding
- Push mechanism

• The location server. A broker system that connects to position information from indoor location systems while accounting for authentication, authorization and privacy. This component of the platform, in particular, ensures that any location system is made available and hides the complexity of location fixing from the user.

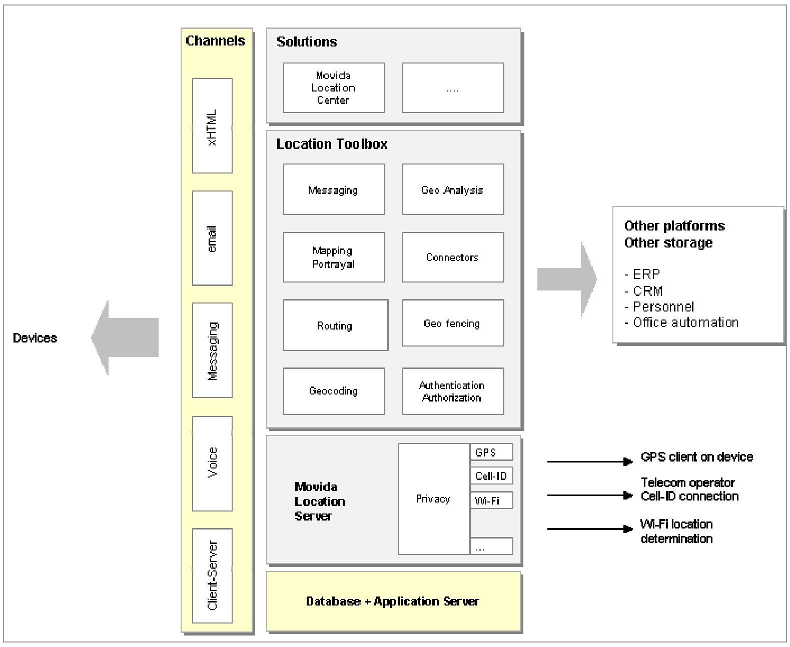


Fig. 3. Components of the indoor location solutions, and main functional blocks.

8 Discussion and Conclusions

An issue which is not addressed so far is the acceptance of users who will finally work with a system which can deliver both in- and outdoor location-based services. Because this is not the objective of this paper we will not describe this in to too much detail. The idea is to make use of the technology acceptance model as first described by Davis, 2004. The model will be applied to obtain a general understanding of how users will complete their tasks more efficiently and if it is to be expected that they will keep on using the system in the future. On the basis of the results policy makers can decide to implement and adapt the system.

Location system	**Object located**	**Operations**	**Coverage**	**Accuracy**	**Limitations**
GPS	GPS receiver	24 satellites broadcast their position. A receiver interpolates x,y,z	Outdoors, poor indoor availability	<1 m .. 20 m	Battery consumption, warm-up time, indoor coverage
A-GPS	A-GPS receiver	GPS signal is processed by receiver and support network - such as UMTS - for higher sensitivity and lower consumption	Outdoors and some indoor environments	1 m .. 20 m	Battery consumption, indoor coverage
Cell-ID, various versions	Mobile phone or SIM based tag	The location is approximated by the position of the connected base station. Sector shape and time advantage can be used to increase accuracy	Network coverage	50 m .. > 1 Km	Accuracy
Telecom based triangulation (e.g. UTOA)	Mobile phone or SIM based tag	Triangulates distance from base stations to estimate position	Network coverage	20 m… 200 m	Accuracy, devices
Wi-Fi passive devices	Wi-Fi device (laptop, handheld) or Wi-Fi tag	Distance from several hot spots is used to triangulate a precise position based on time difference	Coverage of location receivers	2-4 m	Infrastructure calibration, environmental sensitivity
Wi-Fi active devices	Wi-fi device with computation capabilities	The signal intensity model of the environment is used to estimate the position of the device	Wi-Fi network coverage	2-4 m	System calibration, environmental sensitivity
RFID passive tags	Passive tags	The tag is activated by a transmitter/reader field and sends an ID back	Proximity of the receiver, from a few centimeters to a few meters	Na	Proximity detection only
RFID active tags	Active tags	The position of a broadcasting tag is detected by entering in the range of a receiver	Receivers coverage	Rooms, corridors, etc.	Calibration, accuracy

UWB systems	Active tags	Detects distance through travel time on UWB and filters out multipath	Receivers coverage	15 cm	Price
Image systems	Object Pattern	Detects object pattern from camera image	Visible area for the camera	Small areas	Image noise
Hybrid RFID-Infrared	Active tags	The position of a broadcasting tag is detected by entering in the range of a receiver. Infrared signals – blocked by walls or obstacles - are used to increase location resolution	Receivers coverage	Rooms, corridors, etc.	Infrastructure costs, accuracy
Ultrasound	Active tags	The position of a broadcasting tag is detected by entering in the range of a receiver	Receivers coverage. Blocked by walls.	Rooms, corridors, etc.	Infrastructure costs, accuracy, tags

Table 2. Location Systems and summery of their features (from Beinat, 200)

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