UNDERSAFE Report Summary

Project ID: 286176
Funded under: FP7-SME
Country: Poland

Final Report Summary - UNDERSAFE (Wireless intelligent system for environmental evaluation, safety monitoring and guidance for recreational and Ecotourism underground activities)

Executive Summary:
Undersafe is a system which will provide constant, round-the-clock monitoring of environmental and other conditions in underground sites open for recreational and tourist purposes. The UnderSafe system is based on wireless technologies. The objective is to develop a safety system which will detect and provide early warning about a number of conditions that can pose a danger to those underground attractions. It will be based on low cost and low consumption communication technology, which offers robust conditions in front of electromagnetic disturbances. The basic system will include AP modules (access points) located in the upper limits of the walls. Visitors will wear specifically designed nodes, which will communicate with AP modules.
The system will include the following characteristics and capabilities: i) Only power wire is needed, in order to power supply to AP modules; ii) Low maintenance cost; iii) Low cost; iv) Robustness: IP compliant for hazardous ambient; v) specialized static nodes for vibration sensing and landslide detection vii) mobile nodes.

Project Context and Objectives:
Tourism is a key sector of the European economy, generating more than 5% of the EU GPD1 (Gross Domestic Product). Within tourist sector, tourist Underground activities are gaining social relevance; year after year are appearing more attractions of this type. Nowadays there are 3,614 underground tourist attractions worldwide. Of them, more than half (1,724) are placed in Europe2 - with Germany, Austria, Italy, Spain and France as the main players - and it is predicted an increase of 24 per year, envisioning a number of 1,820 underground tourist places in Europe by 2014. The economical and social impact of these activities is significant3: as average, the number of visitors it is estimated by 15,000 per year, and each attraction has an average staff of 5 workers per place – with a total of 8,620 employees in Europe - being many of them SMEs and other type of institutions. Usually (especially in Europe) these activities, despite the number of non expert visitors, are poorly regulated or completely deregulated. In Europe only Germany, UK, France and Switzerland have specific safety normative for these activities, meanwhile the rest of countries are based on current professional mining normative interpretation. Safety nowadays is provided by underground expert professionals whom proceed to regular inspections and by basic safety some infrastructures. But even with these measures still some potential dangers (personal and environmental) are always present and cannot be totally avoided due to its nature:The technical objectives of the project were aimed to the development of a technical system for continuous environmental risk monitoring, specifically focused on Touristic underground activities. The system consists of scecialized wireless nodes using RFiD and Zig Bee technology. The main aim of the system is to monitor of the environment and the visitors position with the possibility to trigger automatic warning alerts by the system to facilitate the environmental diagnosis in a continuous way.
Environmental risks: Attractive underground points are visited by a high number of visitors and gradually more and more people are interested on such attractions. This is a favorable point because visitors' contribution helps to their maintenance, but is also dangerous for their ecosystem: these environments without human intervention are naturally

protected due to its closed nature, but human impact implies a modification of its natural environment - mostly caves - which modifies it and put their natural ecosystem at risk (temperature, humidity, light, sound...).
Personal risks: Underground tourist activities are, of course, carried out in safe placements previously verified by professionals. Most of the security measures are based on basic safety infrastructures and equipment such as indicated paths, rock netting, handrails or a simple helmet, even in huge galleries. Nevertheless, risks are still present due to its nature: people lost occur and gas exposure, lack of air, rock falling and terrain movement are still considerable risks due to its unpredictability. Logically and fortunately, injuries and fatalities on such activities are not comparable to professional industrial mining (although not inexistent, including rock fallings injuries and even deaths in some cases, and owners can talk about anecdotes with involvement of specific visitors, such as children or aged people). To proceed to a complete study of incidents that happens in such places without dead results is difficult due to that have not an individual identification code and fall within 'tourist accidents'. But at same time, the number of attractions and visitors is astonishing and increasing, and includes all ages of visitors. In such situation due to unpredictable underground characteristics (permanent terrain movements, erosion, humidity, etc...) still a potential personal danger is highly present. Nowadays there is a void in the EU normative related to this issue which is surprising. In some way (we expect this is not the case), seems as society is waiting to the accident to happen to raise potential dangers to public awareness and to act accordingly.
For professional mining, there are a number of technological safety systems available in the market, but these ones are out of the scope of the needs for tourist underground activities in terms of requirements and costs.
Therefore, as agreed with SME partners, there is a clear Need for a new technological product system for safety and environmental continuous monitoring of tourist underground attractions. So, the aim of the UnderSafe project is to provide underground attractions with a novel and specifically tailored monitoring system, easy to use and maintain, for continuous and automatic monitoring of safety and environmental conditions for tourist underground attractions.

The technical and scientific objectives of this project are aimed to the development of a technical system for continuous environmental risk monitoring, specifically focused on Tourist Underground activities.
Technology related objectives:
- the system platform is based on RFiD UHF Gen 2 technology nad Zig Bee technology as a communication network for sensors with AP module
Wireless nodes development:
- Static nodes: the basic static nodes (AP modules) have the function to act as beacon and repeaters for communication, but also it will measure ambient parameters: temperature, humidity, light, pressure and noise. In addition, specialized Static nodes will add specialized measurements such as gas (O, CO and CO2).
- Specialized ground affordable ground vibration measuring static nodes: vibration sensor nodes are developed. These ones are based on microphones inserted in depth in the stone; it will be able to detect distant vibrations (at least 50 meters distant, but it is expected to reach more than 90m) by means of a sensor placed at 20cm deep in the stone. Used for rock falling detection.
- A new sectional landslide laser based node will include landslide detection. The sensor principle is on intermittent laser as emitters and photo electronics as receivers, able to detect precise ceiling and walls landslides measurement of 1 cm precision at any direction.

Intelligent control system: graphical and friendly Personal Computer centralized monitor software will harvest the whole environment information and place it on top of a graphical representation. After processing, it will proceed to automatic monitoring, raising specific alerts when needed. It will include:
- User positions and movement detection: movement or lack of it when it is supposed to be present, forbidden zone position, distance to assigned visiting group and guider.
- Positive gas detection.
- Landslide detection: ceiling and wall landslide detection based on laser emitters and where and when it has happened.
- Ground vibration intensity detection (location and vibration signature): registered noise is classified by means of signal

decomposition and artificial intelligence classification.
- People fall and stress based on their movement.
- People's movement registering and statistics.
- Environmental data and recommendations in terms of number of visitors, humidity and temperature, based on attraction structure, period of the year, previous results, etc...

Social objectives:
- To increase to new levels the safety of tourist underground activities (benefit to users and owners) by means of a complement to the existing tourist mining official normative in countries it exists this specific normative, or professional mining in others.
- To increase SME partners benefit and prestige with a novel product and State of the Art technologies.
- To decrease environmental damage in natural caves, detecting as soon as possible and avoiding major unrecoverable deterioration in time.

The Scientific Objective of the UnderSafe system is three folds:
- Wireless underground monitoring and intelligent system: by means of Artificial Intelligence tools and wireless system specifically developed for underground applications, a new expert system processing tool is developed, with capabilities for dangerous situations analysis and action in terms of personnel and environmental characteristics, providing recommendations in order to solve risky situations.
- Development of new low cost landslide detection for underground tourist attraction: the high costs and precision of current professional detectors are not affordable by underground tourist attractions. So a new simpler and cheaper, but accurate enough, sensor based on laser emitters – not triangulation – is developed
- Rock falling by means of ground vibrations: by means of stone vibrations processing, a novel rock falling detection is developed by means of sound vibration signal processing. By means of local digital signal processing, ground vibrations are properly analyzed and classified.

Project Results:
According to the DoW document at the beginning of the project survey was prepared and send to potential endusers. In order to obtain feed-back from underground touristic mines and caves a survey has been sent to more than 800 underground activities, mainly mines and natural caves but also wine caves, war bunkers and others. The survey has been designed to be short and easy to answer, with four differentiated parts:
1. Identification data. This part was only addressed to obtain complementary data to contact the activity (reference person, confirmation mail and phone number...), we also include a question to know if they are interested to receive news about the project. In this sense it could be interesting to define a policy to inform people interested in the UnderSafe project advances.
2. Activity data. This part consists of 33 questions about the main features of the underground cavity and installations. Most these questions have limited answers that facilitate a statistic analysis of the acquired data.
3. Evaluation of the UnderSafe Project objectives. This part is devoted to the evaluation of UnderSafe Project goals. It is very useful for determining the main demands of the potential market concerning monitoring activities.
4. Finally a free text box allows people to give us some complementary information not took into account by our survey.
To make the survey we chose "Google Docs Spread Sheet", this online application is very easy to use and enable us to do on-line surveys which can be easily answered through a web link. This application allows doing reiterative sending of the survey by e-mail. The survey has been sent using the first language of the asked person when it was possible (English, German, Spanish, Catalan, Italian, Polish, French, Portuguese and Estonian).

General analysis of the survey results:
Mines and tourist caves that have answered the survey are characterized by:
- Most activities have a length between 501 and 1000 m (29% n = 12) and 251-500 m (24% n = 10). Only 7% n = 2 are

formed by a gallery activities of less than 100 meters long.
- The maximum depth at which most of the activities arrive is less than 50 meters (49% n = 18), followed by 51-100 (24% n=10) meters and 101-150 meters (24% n = 10). Only two activities reach up to more than 201 meters in depth.
- There are 16 (38%) activities that receive between 5.001 and 20.000 annual visitors, 9 (21%) activities between 20.001 and 75.000 visitors, and 7 (17%) activities with more than 75.000 visitors.
- Maximum number of visitors that can visit an activity at the same time is of less than 50 in 36% n = 15 activities and between 51 and 100 visitors in 31% (n = 13).

Reasons for limiting the number of visitors who can visit the activity at the same time are diverse, highlighting the following:
- Capacity and geometrical characteristics of the mine or cave.
- For the number of available guides.
- For reasons of environmental protection and ecological parameters.
- For reasons of safety.

The interpretation of the answers indicates that in Europe, each country applies different types of regulations for these underground touristic activities. This seems to confirm that there isn't any country that has specific rules for these activities. The existence of a European regulation is required; it should specifically regulate, in an integrated set, ecological and environmental issues, administrative, historical, safety in underground activities, safety of workers and tourists, ... This should be standardized at European level legislation to apply to underground tourstic atractions.
- Eight activities that have indicated they have been involved in an accident. These activities have commented:
- An activity has indicated that they have had 2 accidents of tourists that failed to the floor walking through galleries and stairs. Specifically, an accident happened in a gallery and the other in the stairs of access to the activity, which had 300 steps.
- Three activities have indicated that they have been involved in several accidents due to falls of tourists to the ground, all at the ground level, from slips on wet ground. One of the three activities indicated that they had 3 accidents of this type, whereas the other activity has not specified the quantity.
- Other activity has commented that they have had several accidents in which groups of tourists were lost and the rescue team had to go to get them out.
- Other activity has indicated that they have had 10 accidents because of storm, the light switches off sometimes.
- An activity indicates that they have had one accident but they do not comment anything.
- Finally, an eighth activity indicates that they have suffered an accident due to falling rocks.
- The lowest score given by the activities at the 9 points specified in Part 3 of the survey concerning the aspects that are to be developed in the project Undersafe, was 2.6 and 2.7 for the following points: "People tracking" and "Control of environmental parameters: noise and vibrations" with 2.6, and "Video monitoring" and "Rock and other elements falling detection" with 2.7.
- The highest score has been 3.4 to "Providing wireless communication with a guide" and "Control of environmental parameters (temperature and dampness)". The next highest score has been 3.2 points to "Environmental parameters control (Gas and ventilation)".

UnderSafe System
The basic unit in the proposed solution is the AP module. This is a special access device designed for the needs and requirements of the Undersafe project. It would be controlled by a low-power ARM processor; the equipment will include: a long distance RFID reader module, a ZigBee communication module, the module battery backup, an emergency lighting and an internal intercom speaker.
Communication will take place via an Ethernet cable (capacity of 1 Gb). In situations where it is not possible, communications will take place via the Wi-Fi module, which is an integral part of the device. The advantage of this solution is the possibility to plug in some system in the form of additional IP cameras in order to further illustrate the

underground situation.

The AP module was constructed in such a way to:
• Act as an automatic beacon and repeater for communication. AP modules is able to recompose its net in order to avoid failures when some AP module has fallen. To assure this functionality the use of Ethernet cable/Wi-Fi for through-mine communications in combination with the ZigBee standard to get in touch with sensors and the RFID technology for location and personnel tracking purposes was used.
• Use passive distance RFID tags to make possible the monitoring of the visitor position inside facilities. The combination of mobile passive long distance detection RFID tags (860 MHz) enable the Real Time Location System (RTLS) based on a second generation chip, find the location (at section level) where every single visitor is located.
• In case of power failure, the AP module is able to switch to battery backup. With the aim of maintaining the power supply, an AP module contains a LiOn battery or Litium non-rechargeable and lead-acid rechargeable batteries
• Every specialized sensors is able to transmit information through an attached AP. Via the AP module net the sensors send information reached by using ZigBee-based communication.
• A basic sound sensor for soil sound detection was used for underground vibrations sensing.
• The slow movement sensor will be firmly placed on sensible situations where movements may appear. The purpose of such sensor is to detect slight movements (as short as 1 cm) and to advice of such movements automatically and in an economic and affordable way for touristic attractions.

System Topology

The system topology is presented on the Fig. 1 Annex 1

• All AP modules are equipped with Ethernet Switch 1000Base-T
• All AP modules are connected vie UTP cable, creating expanded Ethernet network in 1000Base-T standard.
• Tourists, who are in range of AP module are identified by detection of passive RFID tags
• All AP modules are equipped in WiFi Access Point, with range covering whole touristic path
• Guider is equipped with smartphone with Android system and UnderSafe application, which by the WiFi connection allows to view of tourists group
• Broken UTP cable can be replaced with automatic WiFi connection between two AP Modules
• Sensors (temperature, landslide etc) are connected to the AP modules via ZigBee network
• Network created by the AP modules is connected to the server in one spot, where software Undersafe is installed.

Mobile RFiD tags

The long distance RFID reader will be reading passive tags distinguishing between visitors and maintenance personnel (guiders and employers). According to the results obtained from the testing of different tags type and location there was decided that:
• The RFID tag is located in the plastic card on the neck lanyard.
• Lanyard is also equipped with RFID tags stitched inside
• Lanyard with RFID tag should be wear on the neck and shouldn’t be covered.

Under the influence of a radio emission, tags send the response which constituted a unique digital code which is the basis of the process of analysis and distinction of the object.
• In combination with AP modules, they make possible the monitoring of the visitor position inside facilities.
• Detection of the distance from the guide

As a mobile nodes for the guiders there are application for smartphones available. In combination with AP modules,

they will make possible the monitoring of the tourist guide position inside facilities. To receive underground environment updated information, as:

• Communication voice and text with monitoring center any time.
• Out of range advertises indicating that some of the members are “out of group’s range” from the tourist guide or are reaching some non-authorized zones.
• Status of alert detections at any time.
• In case of emergency, information about the nearest exit.

ZigBee in the UnderSafe project is used to transmit data from the remote sensors to the main device called AP Module. Gas (CO, CO2, O), temperature and humidity are the measured parameters. It is required for real time monitoring of the underground environment and react in an appropriate way if needed. There is no need to utilize the entire ZigBee stack in this application.

One independent ZigBee network is associated with each AP Module, and is responsible for measuring mentioned parameters within the range of wireless modules around AP. The network is consisted of one coordinator and sensors as end devices. The number of end devices depends on the number of separated sensors. It is possible to handle sending parameters of temperature and humidity by one ZigBee module, if both sensors are integrated or are placed in the one device (case). It is also possible to use two ZB modules in the case of separated sensors. A block diagram of the sensor system is shown in the Figure 2 Annex 1.

Figure 2: Overall place of ZigBee sensor system in the project

ZigBee Coordinator is connected to the AP Module by a wired serial port. Sensors could be powered from a battery or a grid, but data transmission is made wirelessly. Usually, in the underground attractions power from grid is available in most places, because of an existing infrastructure. For the sake of neccessity of a wiring modification, data transmission is not recommended to be made by wire, a wireless modules are included.

As mentioned earlier, ZigBee Coordinator is connected to AP Module by serial port. Microcontroller on the AP board is a supervisor to the coordinator. It issues commands to the ZigBee main module. A block diagram is shown in the Figure 3 Annex 1.

Figure 3: Block diagram of the sensor system

According to the ZigBee protocol, network cannot be set up without coordinator. Before forming or joining a network all radio modules are obliged to:

• initialize hardware abstraction layer (power up peripherals, initialize ADC, start and calibrate clocks),
• initialize utilized peripherals (LEDs, buttons, interfaces),
• set up a serial interface to communicate with AP Module (only coordinator),
• set up sensor which is on board,
• turn on interrupts.

ZigBee coordinator is connected to AP Module by a serial link. An appropriate protocol needs to be prepared in order to make the commands understandable for both sides: AP Module and coordinator. Communication between the devices assumes to accept simple commands from AP Module, and send responses, for instance with measured parameters. A part of the AP Module board responsible for connecting ZigBee Coordinator module is shown in the Figure 4 Annex 1.

Figure 4: ZigBee part on the AP Module board

The location system

The location system is used by the UnderSafe system to show the current location of all visitors that are provided by

an RFID tag. Different kinds of tags will be provided (for example, one type for general visitors, another for workers, and so on) so different kind of problems may be covered by the alarm system regarding the different kinds of personnel that will be along the mine's facilities. But in general the location system itself will be the same for any kind of person.

The principle of operation of the location system is as follows: every AP module comprises two antennas called "11" and "22" and determines the boundary of the zones, as shown in the Fiigure 5 Annex 1.
Fig. 5: Location system principle

Each antenna can be attached to a single zone so consequently each AP module, provided by a maximum of N antennas, can be attached to N zones, being N minor or equal to 8. An antenna is a kind of flag of walking direction. According to the Fig. 5 Annex 1., a man detected by any "11" antenna is moving forward (right), elsewhere he is detected by antenna "22" – tag is moving back (left). All of wrong detections are filtered by low layers of the system.
Fig. 6: Calculation of the number of persons within a zone.

In order to get the total number of persons that are within a given zone, the system calculates the addition of any person who has entered the zone and subtracts the number of persons that has left the zone. For example, imagine the situation shown in Fig. 6 Annex 1, with antenna "11" of AP module 1 attached to the Zone, antenna "22" of the same AP module attached to a different zone, antenna "22" of AP module 2 attached to Zone and antenna "11" of AP module 2 attached to a different zone. To calculate the number of people who is inside the Zone in a given moment, the system retrieves the last number of persons within this zone and adds to this number the number of persons detected by AP module 1 antenna "11" and AP module 2 antenna "22", and subtracts the number of persons detected by AP module 1 antenna "22" and AP module 2 antenna "11".

The system will periodically (e.g. every 2 minutes) launch a process which explores the net of nodes trying to discover situations where the core (bigger set of persons of the group placed at the same zone or set of persons of the group in the same zone than the guider) of a group remains in a different Zone than other members of the group, while this zone is not a neighbor of the core group zone. If these members remain isolated (on a different and not neighbor zone than the core of the group's zone) for a given number of periods (e.g. 3 instances of the process) a warning alarm will be triggered.

Wireless system.

The main purpose for WiFi connection in Undersafe system is wireless WiFi network for Guider nodes (Smartphones). It is achieved by the WiFi1 module, located on the right side of the AP Module mainboard. During normal system operation WiFi1 is enabled and guiders can use Undersafe application on theirs smartphones.
The WiFi connection is also used in Undersafe system for emergency connection between two AP Modules, when UTP cable is broken. When that situation occurs, UTP connection is automatically replaced with WiFi connection, using WiFi2 module. This situation is shown on the Figure 7 Annex 1.
Figure 7 - emergency WiFi connection

Ground vibration sensors.

The final ground vibration sensor hardware has been developed in two hardware versions. The first version designed had been tested in Les Coves del Toll, as is explained in Deliverable D3.6 "Soil Vibration Signatures and Technology Selection on Sensors", after those tests, those circuits have been improved and have designed the second version. The second version had been designed in order to perform some tests in Les Mines de Sal in Cardona, near Barcelona, to acquire more signals and check the detection of rock falling. This version was described in this deliverable together with the processor and other modules developed.

In those tests, each chosen technology had specific conditioning electronics developed, according to their impedance, polarization, noise, etc...characteristics. After these first tests, we concluded that some sensors were discarded because the result weren't the expected and others, specifically piezoelectric, electret and geophone were chosen. Therefore, we have focused on developing electronic circuit for these three sensors.

However, being that the geophone and the electret have similar operation and the signal can be processed in the same way, only two conditioning electronics has been adopted: one piezoelectric and one for geophone plus electret. The piezoelectric one has adaptation for high output impedance on piezoelectric, and it has been adapted thanks to an input Mos-Fet type.

Laser sensors.

Our idea was to develop the simple optical sensor, which could be able to detect the movement between walls (or any surfaces). There are a lot of professional and rich sensors on the market, but for UNDERSAFE purposes we don't need to meet all requirements related with explosion hazard in active mines. Laser system consist of:

• Transmitter, which emit a laser beam
• Receiver, which detect laser beam

Laser beam can be used in different ways:
• Measure the distance between transmitter and receiver
• Measure if laser beam hit on receiver

The first way is more precise, but electronic circuits are more complicated. It is necessary to use the microcontrollers on both sides to modulate and then compute the time and phase of received signal.
The second way, that we chose, is very simple and cheap. We need only to detect the presence of laser beam on a photodiode. Some disadvantage in this solutions is, that sensor can't detect movement along the axis of laser beam, but this case will be very rare. To avoid the situation, when two observed surfaces will move along the axis of laser beam, we put several breams. All transmitters can be located in one case (called transmitter), and each receiver has its own case. The arrangement of transmitters and receivers is shown in the Figure 8 Annex 1:
Figure 8 - sensor scheme

All nodes are wireless connected to AP Module, using ZigBee transmission. The basics of operation are showed in the Figure 9 Annex 1.
Figure 9 - flow chart

At the beginning all nodes are registered in AP Module and set to sleep mode. Transmitter (TX) is equipped with real time clock, which is used to wake up it and make the measure. After wake up, transmitter sends via ZigBee to AP Module information about new measurement. AP Module starts to wait for measurement results. Then, Transmitter make a short impulse of laser beams to all receivers. Each receiver is weak up by received laser beam and then it sends via ZigBee to AP Module information about received laser beam. If AP Module receive acknowledgement from all receivers until end of time of wait, the result of measurement is positive. If any receiver not response, the result is negative.
The time between each measurements is stored in Transmitter and can be set from AP Module.

The prototype developed within the task consists of a vandal proof casing, a mechanical calibration and stabilizing structure, a ZigBee module for a wireless transmission, an electronic circuit and receiving or transmitting element.

At present, the transmitter contains two lasers positioned at 180° to each other, receivers contain the verified before photodiode SFH203, which has the best ability to detect laser beam. Two Darlington transistors are used to condition the output signal.

Case design for all system elements.

The casing has to be minimum IP 65 for dust and water, impact, temperature. Also mobile nodes needs to be ergonomically designed for human use.
Based on D1.1 (System specification, part 2: Requirement analysis) there are three main devices to develop during this project, which are equipped with dedicated cases:
• AP Module case (D1.1 -> 2.2.1 AP Module)
• Ground vibration sensor case (D1.1 -> 2.2.2.1 Vibration sensor)
• Laser sensor case (D1.1 -> 2.2.2.2 Landslide sensor)

This report show the projects of all above cases, using to achieve commissioning and tests for this devices.

AP module
• IP65 class
• Wall mounting type
• Connector for network cable (230V + UTP) Ř18mm
• Mounting board for AP Module mainboard and RFID module
• Material: painted steel
• PE connections to ground
• Ball joint for RFID antennas

Schemes of the AP module case were shown in Annex 1

Ground vibration sensor case
• IP65 class
• Wall mounting
• Steel material for EMC shield

Schemes of the ground vibration sensor case were shown in Annex 1

Laser sensor case
• IP65 class
• Transparent case for proper laser beam propagation
• Adjustable laser mounting
• Wall mounting

Schemes of the laser sensor case were shown in Annex 1

UnderSafe System Software.

The UnderSafe software was initially conceived as a desktop application but after recommendations of ARTHAUS SME partner and further analysis, it was considered to improve design by migrating the software system to the more modern and appropriated web paradigm. This led to the software architecture depicted in Figure 10 Annex 1.
Fig. 10: Final architecture of the UnderSafe system.

The main reasons for this change on the back technology are based on the following benefits that this approach provides:
- No need for specific installations of any local application as the only strong requirement for application clients (users) is to have a compatible web browser (as, for example, standard versions of Chrome, Firefox and Internet Explorer, which in fact are the most popular ones today).
- Cross-platform compatibility. Avoidance of OS dependencies.
- Application accessible anywhere and anytime, even by using a smartphone.
- More suitable for low-end computers.

Dealing with this new architectural approach implied a modification of the initial set of chosen technologies and platforms. The main sets of technologies that have made possible the current version are the following ones:
• Microsoft .NET
• HTML5
• SQL Server 2008 R2
• Drools Expert
• OpenLayers
• Apache CXF
• Android
UnderSafe application is a data processing engine which is always listening for incoming messages sent by the set of distributed AP modules and sensors (hardware system). Software detects a set of events that could be triggered by any AP module such as a movement of a RFID tag from one zone to another, a failure of a specific AP module or the latest measurement performed by an individual sensor.
Incoming data is processed as depicted in Fig. 3. Once the main application has received an update from the net of nodes and after registering changes, if any, into the database, WebSockets technology is used to automatically update the map view (avoiding an annoying page refresh) to show live data to any client. Retrieved information is received by the page's JavaScript code and processed by the OpenLayers library which is responsible for almost all map related tasks.
Simultaneously, updates are also sent to the UnderSafe expert system. The expert system, formally named ExSysUndersafe, is responsible for maintaining a status of the whole facilities in order to apply the rule set that responsible personnel must have previously defined. This task is usually performed by the use of a spreadsheet for a better understanding by non IT experts on the alarm activation conditions relying behind (a typical Office Excel or LibreOffice Calc document), but other formats such as DRL (Drools Rules Language) are also supported.
Fig. 11: Processing path of the AP modules data.

The expert system
In artificial intelligence, an expert system is a computer system that emulates the decision-making ability of a human expert. Expert systems are designated to solve complex problems by reasoning about knowledge like an expert, and not by following the procedure of a traditional developer as is the case in conventional programming.
An expert system has a unique structure, different from traditional programs. It is divided into two parts, a static one, and independent of the expert system: the inference engine, and a variable one that it is updated periodically, based on current situation: the knowledge base. When the expert system is running, the engine proceeds to a reasoning based on the rules and using the knowledge base in a human-like manner.

ExSysUndersafe - the UnderSafe expert system, is built over the Drools Expert (a well-known and full-proven general purpose rules engine). This module is currently prepared to deal with the following set of variables applied into rules that the administrator is able to easily modify on his own initiative if needed in a relatively easy manner.
Table 1 Annex 1

Web services technology has been chosen for ExSysUndersafe module connection with the main application.

A Web service is a software function provided at a network address over the web or the cloud: The W3C defines a "Web service" as "a software system designed to support interoperable machine-to-machine interaction over a network". It has an interface described in a machine-processable format (specifically Web Services Description Language, known by the acronym WSDL). Other systems interact with the Web service in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards.

The uses of a Web service has advantages as separates clearly the different functionalities in different software modules, which allows modifications on each separate module in a transparent manner – if communication protocols are well respected.
By using the Apache CXF framework, two methods have been defined:
ExSysUndersafe: setting rules
Decision tables are a precise and compact way of representing conditional logic. Drools supports managing rules in standard spreadsheet formats. Supported formats are Excel (XLS) and CSV, which means that a wide variety of programs (such as Microsoft Excel and OpenOffice.org Calc) can be utilized, and more relevant, non IT expert may understand it and manage it. Very briefly speaking. In Drools decision tables are a way to generate rules driven from data entered into a spreadsheet, by following the procedure of: rules excel sheet automatic translation into DRL (Drools Rules Language).
There are two types of regular areas defining data that is used for generating a DRL file. One, marked by a cell labeled RuleSet, defines all DRL items except rules. The other one may occur repeatedly and is to the right and below a cell which contents begin with RuleTable. These areas represent the actual decision tables, each area resulting in a set of rules of similar structure.
All Rule Tables begin with a cell containing "RuleTable", optionally followed by a string within the same cell. The string is used as the initial part of the name for all rules derived from this Rule Table, with the row number appended for distinction . All other cells defining rules of this Rule Table are on the inferior and right part of the cell.
The next row defines the column type, with each column resulting in a part of the condition or the consequence, or providing some rule attribute, the rule name or a comment. The table below shows which column headers are available. Note that each attribute column may be used at most once. For a column header, either uses the keyword or any other word beginning with the letter given in the "Initial" column of these tables. Table 2 Annex 1

As first configuration step, constraints related to a closed set of parameters should be set. This basic set of constraints can be found into the Undersafe_raised RuleTable, but going one step further, a trained user will be able to define additional RuleTables which will in turn allow a higher degree of interaction between rules. For example, user could define an additional RuleTable to deal with the results of the actions activated by Undersafe_raised RuleTable rules which means that the activation of a rule within the RuleTable could act as part of the conditional activation of a given rule of the new user-defined RuleTable.
The basic set of constraints included into the Undersafe_raised RuleTable is shown in the Table 3 Annex 1

Location-based alarm processing
A monitoring system that deals with people may look incomplete without a fully-functional and real-time alarms system. This chapter is focused on a particular kind of real-time alarm that concerns a singular problem with individuals that may have any situation that, even is not concerning the whole facilities and do not usually pose a danger for others, must equally be taken into account as can become the source of future problems or unexpected situations.
Thus, this chapter talks about the absence of movement for a long time problem, especially regarding visitors which are provided by an RFID tag and about the excess of distance from a group guider, dealing with situations where people

remain isolated from its group.

Absence of movement detection

Detecting absence of movement is about detecting the difference between the last time the tag's position has been updated and the current moment. If this difference is above a given threshold an alarm must be triggered.

Alarms triggered by this system will always be considered a warning more than emergency, so false positives (e.g. a tag that has fallen on the ground which poses no real danger) are possible. However, true positives, even probably happening not so frequently, when happen, are vital enough. So has to be taken into account.

The given threshold will be empirically set based on the specific deployment on each touristic underground attraction. It is not possible to set a general threshold so the time threshold to consider absence of movement, dealing with zones instead of specific position, depends heavily on the zone's size, on the distribution of AP modules and on other deployment and mine-specific constraints.

Maximum distance from group exceeded

Another important situation based on the location of visitors is the relative distance between group guiders and the members of the guided group. In normal conditions, the group of visitors around the mine should remain together most of the time. Divisions (a part of the group being in a zone while the rest of the group is in an adjoining section) may take place and probably be normal for short periods of time, but when this situation is present for a longer time than this expected "normal", it should be indicative of a problem.

Neighborhood of zones is understood within the context of the UnderSafe system as a pair of zones connected by the same AP module. The system periodically launch a process which explores the net of nodes trying to discover situations where group guiders remain in a different zone that specific group members during a time period above a given time value threshold.

Looking at Fig.12 Annex 1 (actual application part of screen of UnderSafe software system), points with same color represent members of the same group. Then, we have two different groups around the mine: blue group and brown group. The situation of the blue group doesn't pose an alarm so they are separated in two neighbor zones (Zone 2 and Zone 3). The situation of the brown group is different and it truly corresponds to a warning situation so three members has been left behind the core of the group (which contains group guiders), this is in Zone 3.

Fig. 12: Separation from guider example situation.

Graphical interaction interface: maps

When dealing with a map-based application a simple, interactive and comfortable user experience becomes of high importance. For the interface design the principles of simplicity, clearness, robustness and clarity (avoiding excess of information) have been followed.

In order to provide the best possible solution OpenLayers library has been used. OpenLayers library is a JavaScript code package that allows advanced map management in a web environment. It is completely free and open source and allows setting a SVG map as base layer.

Fig. 13: OpenLayers and UnderSafe technology, working together.

Scalable Vector Graphics (SVG) is a family of specifications of an XML-based file format for two-dimensional vector graphics. The SVG specification is an open standard that has been under development by the World Wide Web Consortium (W3C) since 1999. All major modern browsers –including Mozilla Firefox, Internet Explorer 9, Google Chrome, Opera, and Safari- have at least some degree of support for SVG and can render the markup directly.

The main advantage of using a vector format is that images are not defined at pixel-level but at "feature" level. This way, the SVG 1.1 specification defines 14 functional areas of features as paths, basic shapes (as circles, ellipses and rectangles), text and color. Consequently, this format allows zooming in and out without loss of quality. This combined

with OpenLayers and integrated into the UnderSafe environment results in a very attractive, user-oriented and intuitive map interface (see Fig. 13 Annex 1).
As you may notice by looking at the image below (Fig. 14 Annex 1), even with the maximum zoom level pixels are not noticeable. Also, it's important that the code-behind allows us to interact with the dimensions of the base layer (the map) without a direct modification of the data layer (e.g. the "TAGS: 0" text shown in the image above). It results in a very satisfactory result that really fits the objective behind the UnderSafe project: to have a very suitable for any kind of user final product, even the less-experienced in computer matters. Also allows displacement and zoom in a friendly and intuitive manner.
Fig. 14: SVG format and OpenLayers allow an interactive and powerful result where pixels cannot be noticed even with the maximum zoom level.

Database development
The UnderSafe system, in order to provide long time persistence and assure a high level of accuracy, availability, usability and resilience, and also with the objective of offering integrated and high end software that uses the Microsoft DBMS: SQLServer (v2008 R2).

SQL Server has been selected for its ease of use and low maintenance requirements. Since many people are familiar with Microsoft products, using the visual interface of SQL server is not as intimidating as other programs. With UnderSafe we will be offering a full Microsoft solution so the Microsoft solution center availability (24 hours per day, seven days per week) has also been taken into account. To offer a secure and reliable system is of main relevance for a system such as UnderSafe.

Login screen and roles policy
In computer security, a login or logon refers to the credentials required to obtain access to a computer system or other restricted area. Logging in or on and signing in or on is the process by which individual access to a computer system is controlled by identifying and authenticating the user through his credentials.
Undersafe application login process is done by entering a unique username and password. These credentials are also used to retrieve the role of the user which determines the set of available functionalities. Non-available (or forbidden) functionalities will be neither visible nor available.
This interface, and in turn the entire UnderSafe UI (user interface) has been developed always having in mind a simple, unified and clear design that assures it is easy to use and friendly (Fig. 15 Annex 1).
Once the entered user credentials have been validated, system retrieves its available set of functionalities based on the roles policy. Roles policy in the UnderSafe context work as a four layers structure (Fig. 16 Annex 1).

- First layer is formed by all user entities. A user entity is the representation of every person provided with valid credentials. Every user could be provided with zero, one or more roles.
- A role is the entity that allows users to perform a set of functionalities and is contained in the second layer. For example, "Root" role could gather all functionalities (functionalities represent the third layer). Assigning this role to a specific user will allow this user to perform, consequently, all activities. Furthermore, not all roles must be so permissive. Another role, called "Basic", could just gather functionalities related with the map view. A user attached by this role, and to none else, will be only allowed to view and use map view functionalities.
Fig. 15: UnderSafe login screen.

By default, a user is not attached to any role, so initially the set of available functionalities for a user with no roles is empty. Other particular case is when a user has two different roles providing the same functionality, which will imply the user being allowed to perform such functionality with no side effects.

- The fourth layer is constituted by modules gathering functionalities. These modules can be activated or deactivated

directly from the database. Deactivate a module directly implies all contained functionalities to become not available.
Fig. 16: Four layers at charge of the roles policy.

Entities of each layer can be completely managed by users. These means that allowed users could create new users, new roles, attach them to the desired functionalities and activate or deactivate the desired roles.
Fig. 17: Available functionalities depending on the role policy.

UnderSafe system interface
In the UnderSafe interface there are some parts that can be easily differentiated (Fig. 18 Annex 1):
Fig. 18: UnderSafe main interface schema.

1. User bar showing a welcome message with the name and surname of the logged user, a link to the input box with an indication of the non-read input messages and a logout button.
2. Main menu bar its content is fully dependant of the logged user's roles. Though this bar user can access to the full set of available functionalities.
3. Options menu dependent of the selected functionality. It will only be visible in functionalities that take profit of it.
4. Text string that shows the position of the selected functionality into the web's tree.
5. Main part of the selected functionality showing almost all of the information.
6. Notifications panel, which will show the list of current alarms and notifications.

These parts are common in all functionalities despite not all of them are always available.

Management views
The basic set of management views offers a unified and friendly environment allowing the user to perform, in an easy manner, most of the functionalities that the whole system offers. A management view consist on a list view, which allows to examine the complete list of items of such type, an edit view, where the user is able to modify the list of parameters of a given type of item and an add view, where the user is able to add new items of such type.
List view is usually the first (base) screen a user will see when he tries to perform an operation related to an entities set. However, direct access to the add view through the main menu bar is also available. In the list view (e.g. Fig. 21):

- By clicking on the bin icon in the "Delete" column a confirmation pop-up related to the respective clicked row's item will appear. After its acceptance, this item will be fully deleted.
- By clicking in the "Edit" button ("Edit" column), user accesses the edit functionality (e.g. Fig. 22 of the clicked button's row which allows the modification of the corresponding user attributes. Update button will confirm the "edit item" operation.
- By clicking in the "Add new item" button, user accesses the add functionality which allows to add new items (e.g. Fig. 23). This view is quite similar to the edit's view but with empty fields by default. Add button will confirm the "add item" operation.

Underlined columns can be ordered by a given column field by clicking on the column's title in the headers row.

Sometimes, when there are an important number of items to be listed, paging controls will appear in the bottom of the table. But, other cases, as in views such as Alarm management related views, has been considered that a long list of all alarms will be preferable as it will allow a faster management.
It is also mandatory to explain that, always that a modification initiated by a user is committed in the database, a notification in the right-top corner of the screen will confirm it has been properly performed. It will look as follows:
Fig. 19: Message confirming a database commit.

Users

This option set gathers functionalities related to the users management and to the communications system. First, second and third functionalities are represented by standard management views: the first one related to the user profile, the second allowing a user to perform management tasks on other user's information while the last is related to the management of roles. There are also two more functionality sets.

The first of the two remaining contains a general chat which can be used for multi user live communications, and a log to retrieve and check for old live communications. The last option allows sending, receiving and consulting private text messages that can be sent between specific users.

The following three subchapters will just show the appearance of the first three functionalities. The last two subchapter will be referred to the pair of communication functionalities (chat and private text messages), and will contain a more detailed explanation.

Profile is a simple typical update view, showing the logged user information and allowing a partial edition of it such as image, name and surname, password (to let this field empty means not pretending to modify it), contact number and personal identifier. This functionality doesn't have special constraints or particularities so they both absolutely fit the general management view description..

Fig. 20: Profile screen.

Users management - User management functionality fit the management view explanation..

Fig. 21: Users list view.

Fig. 22: Users edit view.

Fig. 23: Users add view.

Roles management - Roles management functionality fit the management view explanation..

Fig. 24: Roles list view (up) and Roles edit view (bottom)

Live Chat

The basis of the real-time communication system is sustained on a live chat (Fig. 25 Annex 1) where different logged users can share live text messages. It has been developed by using the newest HTML5 WebSockets standard. Its interface is simple: a friendly conversation field, a text box as text input method and a button with a simple shortcut.

In the last alpha release deliverable we stated the following:

This functionality will be expanded in beta version to provide additional options, being the most essential of them total database support and, additionally, persistent private messages.

The current version of the chat functionality allows retrieving old conversations based on a given time interval the user must provide. This functionality is based on AJAX technology, not requiring a complete post-back of the current page so it will be easy and comfortable to iterate, retrieve and look for specific conversations of different time intervals of the past. This functionality looks as the following Fig. 26 Annex 1 depicts.

Fig. 25: Live chat.

Fig. 26: Live chat log, configuration screen.

And, after the entrance of the desired set of dates (or leaving fields empty, which means we desire to retrieve the full set of chat messages), the next screen will be shown in Figure 27 Annex 1:

Fig. 27: Live chat log, view screen.

The configure button will allow the user to get back to the previous configuration screen.

Text messages

Text messages functionality contains three options which allow user to prepare and send a new private text message, to retrieve a list of already sent private text messages and to show the list of received text messages. The three functionalities, as can be seen in the image next to this text, can be accessed from the Text messages option inside the users menu.

The New functionality, as could be seen in the image below (Fig. 28 Annex 1), allows to create a new private message which is represented by a subject, the message itself and a list of receivers who will receive the message which is being prepared. After pressing the Send button the message will be validated and sent.

The Inbox functionality (Fig. 29 Annex 1) is shown by a screen with two main grids showing, the first one, the list of messages that have not been viewed yet while the second one shows the list of stored text messages that have already been viewed, but not deleted yet. The body of each message is not shown in neither of the two grids as it is needed to access the detail of a given message to view it, operation that is performed by clicking the letter envelope icon of a specific message (Fig. 30 Annex 1).

The Sent functionality is almost equal that the Inbox functionality but with a single grid. It also allows to click on the same letter envelope to view a given message's details, such as the receivers list or the text (the body of the message) itself (Fig. 31 Annex 1).

Fig. 28: New private text message functionality.

Fig. 29: Text messages inbox.

Fig. 30: Received message detail.

Fig. 31: Sent message detail.

Around the received and not viewed yet text messages there is also an always visible panel showing their number in order to advise and notify to the logged user of new (received) message (Fig. 32 Annex 1). It also acts as a link to the Inbox functionality.

Fig. 32: New received messages notification.

Alarms

This option set gathers functionalities related to the alarms management and characterization. It also involves how alarms are shown to the user in the left-side notifications panel. All these options can be found under the Alarms tab in the main menu bar, being the following ones:

- Alarms management: Allows viewing and interacting with the different alarms, and access a log to retrieve the old ones (Fig. 33 Annex 1).
- Alarm status management: Management of the alarm status set such as "Raised" and "Solved".
- Alarm types management: Management of the alarm types set such as "Danger" and "Warning".
- Alarm codes management: Management of the alarm codes such as "MIN_TEMP" or "SMOKE_DET".

Alarms management

Alarms management basic-list view looks as a standard management view screen (Fig. 34 Annex 1). It shows information about the alarm type based on a colors legend (red-danger, yellow-warning and blue-others), code with brief description, alarm status, source location, date and time when it has been raised and, if solved, also this moment's date and time and an additional description (the text that can be added in the ExSysUndersafe spreadsheet ACTION's column).

Edit view (Fig. 35 Annex 1) allows user to modify all parameters of an alarm but its raised and solved dates, which are considered a structural parameter and an important value for historical record retrieval purposed based on the global

watch which cannot not be altered.
Alarms will only disappear from the alarm's view when a user deletes it, which in turn means that at this point alarms will be marked as old and used only for historical retrieval purposes (log view).
Alarms can also be manually added to the system. This functionality (add) is represented by an interface almost equally than the edit view but with the complete set of fields fulfilled with a default or empty value.
Fig. 33: Alarms log configuration screen to retrieve alarms based on a time interval.
Fig. 34: Alarms list view.
Fig. 35: Alarms edit view.

Alarm status management
It allows alarm status management strictly based on the standard management view behavior. Edit and add views are almost equals but add view beginning with empty / by default fulfilled fields.
Fig. 36: Alarms status list view
Fig. 37: Alarms statuses edit view.

Alarm types management
It looks similar to alarm status management. It allows alarm types management strictly based on the standard management views behavior. Edit and add views are almost equals but add view beginning with empty / by default fulfilled fields.
Fig. 38: Alarms types list view.
Fig. 39: Alarms types edit view.

Alarm codes management
Alarm codes (Fig. 40 and 41 Annex 1) are the values that identify a specific type of abnormal situation. They should be coincident with the codes entered by the user in the ExSysUndersafe spreadsheet in order to be properly processed by the system.
Moreover, alarm codes can be attached to specific roles. To attach an alarm code to a role means that alarms with this code will only be notified to users provided by at least one of these roles. By default, alarm codes are not attached to any role which in turn means that will be notified to all users.

Notifications panel
Notifications panel shows alerts that, based on the user's roles and on the alarm code's roles attachment, must be notified to the current logged user. This works near to real time by using a page method every 10 seconds without any action by the user.
Alarms appear grouped by its type. First group, (red header) gathers all dangerous alarms. The second groups (yellow header) contains all warning alarms. Finally the last group gathers all other alarms (e.g. environmental alarms or recommendations, green header).
For each alarms groups, first sentence say how many alarms of this group are being notified to the current user. It follows up a brief description of each alarm is shown including the alarm code and zone of occurrence. Finally, a link to the alarm's view functionality is provided.
Fig. 40: Alarms codes list view.
Fig. 41: Alarms codes add view.

Maps
Here is where all map-related functionalities are gathered together. The current functionalities set is compound of three functionalities: i) floors management and ii) zones management and map view. First and second functionalities are management views while the third is one of the most important functionalities of the whole application which In turn should finally gather most of the information of the entire attraction's facilities.

Floors management

Floor management options allow the user to manage all floor-related parameters. Floor images must be in SVG (vectorial) format as they need to be processed by the OpenLayers framework. Most image software allows converting from any image format to SVG.

Fig. 42: Floors list view.

Fig. 43: Floors add view.

Zones management

Zones management options allow the user to manage all zone-related parameters. Moreover, it allows interactive definition of zones based on defining polygon's vertex directly over the selected floor's map.

A particular attribute of a zone is the "Exit?" attribute. An exit zone is a zone that, when reached by a specific tag, removes it from the system's memory.

Fig. 44: Zones list view.

Fig. 45: Zones add view.

Zones edit and definition functionalities allow defining zones directly selecting perimeter polygon's vertexes over the floor's map. This definition operation is also compatible with zoom in and zooms out. When the selected area is properly surrounding the zone being defined a double-click will close the shape. Finally, if user decides that the resulting shape isn't accurate enough, starting a new one will completely remove the previous one. Currently defined zones will appear painted in orange color while the currently under definition zone will appear in red (Fig. 45 Annex 1).

Other parameters that can be edited or modified in the zone add and edit functionalities are the zone's floor, zone's code, zone's description and zone's "is exit" attribute.

Map view

Map view will become the hearth of the UnderSafe software. By looking at it, a user should get in touch with all what is happening around the touristic attraction's facilities. It has been designed having simplicity in mind, always taking into account users not familiarized with computers (avoiding excess of information interface).

The map, as explained in the section devoted to the graphical interface, allows to interactively zoom in, zoom out, move the map to any direction directly by using the mouse or by using the on-screen buttons. Also, the map allows to show up or hide data based on a layered architecture.

The layers of the location system are the background layer, which cannot be hidden and remains in the background showing the base map of the floor, the zones layer, which shows the yellow shapes representing the set of zones, a layer devoted to show the total number of visitors that are within each zone, an RFID tags label which shows the tag of each visitor located at a every zone or, if known, the registered name of the person and finally a sensors tag showing the last measurements retrieved by sensors.

Fig. 46: Map view (I).

In this view, options menu is available and used to select a floor from the floors database, which will in turn update the map's view.

Fig. 47: Map view (II).

In this version a full screen option has also been added (Fig. 48 Annex 1).

Fig. 48: Map view, full screen.

AP modules

AP modules are the core of the UnderSafe net. Distributed around the mine's facilities and provided by WiFi

connectivity, they are at charge of transmitting all data between all devices and the central computer.
The AP Modules option contains the functionality of the management of the devices itself. Active attribute is continuously updated when AP modules send data frames to demonstrate its availability. The pair of antennas that each AP Module is provided with are mapped though both 'Zone 11' and 'Zone 22' fields each one associated to different zones (one "coming" zone and one "going" zone). More details on AP module and zones definition may be found in respective AP hardware deliverables. There is also the IP address, which uniquely identify each AP Module and allows an easy identification of it though the net, and the "Power" field, which gives useful information about the power status of the device which can be grid, battery or battery low (Fig. 49 Annex 1).
Fig. 49: AP Modules list view.
Fig. 50: AP Modules edit view.

Sensors
A sensor (also called a detector) is a converter that measures a physical quantity and converts it into a signal which can be read by an observer or by an (today mostly electronic) instrument. A thermocouple converts temperature to an output voltage which can be read by a voltmeter. For accuracy, most sensors are calibrated against known standards. Detectors may be placed freely inside facilities and allows easy and automatic connection with AP modules (which gathers all information to be sent to central system) by means of ZigBee technology.
The UnderSafe system is well-prepared to deal with a complete set of sensors which in turn will define the status of the whole mine's facilities at a given moment. But, through the following management interface, additional types can be added:

Sensor types management
This view looks like a standard management view. All different types of sensors are classified and introduced into system. The following image shows the complete set of sensors that the system is initially prepared to deal with (see Figure 51 Annex 1).
Fig. 51: Sensor types management (I).
Fig. 52: Sensor types management (II).

There is also the edit / add view, which in turn looks as on the Figure 53 Annex 1:
Fig. 53: Sensor types edit view.

Sensors management
Sensors management functionality also looks as a standard management view as on the Figure 54 Annex 1.
Fig. 54: Sensor list view.

This time the user is in charge of setting the active field. Value field will contain the last retrieved measurement of the given sensor.
Fig. 55: Sensor edit view.

Personnel
This option contains all functionalities related to the personnel (people distributed around the mine – not related with system users) management. In this case these ones are three: personnel management itself, person types management and groups management.

Personnel management
Personnel management looks like a standard management view and gathers the available information of each known person around the mine's facilities.
Fig. 56: Personnel list view.

Fig. 57: Personnel edit view.

Person types - This functionality allows users to manage person types see Figure 58 and 59 Annex 1.
Fig. 58: Person types list view.
Fig. 59: Person types edit view.

Groups
Groups functionality allows users to manage groups of people that are planned to visit or working in the mine's facilities. It is also based in the standard management interface but with a number of particularities required by clients. Basic table show groups information. This information is shown based on the following fields:
- Group code,
- Start and end date and time and comments (e.g. group formed mostly by old people or by kids).
- There is also a "select" field which allows user to select a specific group. Once a group is selected, an extra table will appear at the bottom of the first table, under the "Persons in the group" text label. This second table contains information of the persons in the group. It shows information of each person's type (e.g. "Visitor" or "Guider"), name, surname and NIF.
Both, group direct attributes and included personnel could be modified in the edit view. But, at first, let's talk about the add view:
Add view allows to create a new group by entering its basic information. This information is the same explained above, not including the group members. Group members will be added later, after group creation, by editing it and adding its members.
Edit view has two different tabs that are accessible from the options menu. The first one is the "General" tab, which is equivalent to the add view and allows to modify the group's parameters. The other tab is named "Persons" and allows adding and removing persons from the group.
Fig. 60: Groups list view.
Fig. 61: Groups add view.
Fig. 62: Groups edit view (I).
Fig. 63: Groups edit view (II).

Charts
This functionality, not present in the previous alpha version of the application, allows the user to plot data based on a selection. Based on a configuration screen, user is able to choose data from sensors and from section's population and plot it to correlate, analyse or simply display it in a comfortable format for an adequate human understanding. This functionality, as others, is based on AJAX technology and supports plotting without an explicit and entire page post-back so different selections of data, plots and posterior modifications could be comfortably and quickly made by the user.

The configuration screen (Figures 64 and 65 Annex 1) looks as the following Figure 64 depicts. It allows to choose data based on a three filter strategy. The first filter allows the user to select whether he prefer to plot data based on a specific zone or based on a specific source. It the user selects to plot data based on a specific zone, the first filter level (first drop down box) will be automatically updated to contain the complete list of zones that are defined in its corresponding functionality. By selecting a specific zone on the first level, the second level filter (second drop down box) will be updated to show the complete list of data that could be plotted based on the already chosen zone. By pressing the Add button the corresponding selection will be added to the list of data to be plotted.
If the user selects to filter by source, the first level filter will allow the user to select between two simple options: to filter by sensor data or to filter by population data. If the user selects the first option, the second level filter will be fulfilled with the entire list of sensors that are distributed around the cave. If the user selects the second option (filter by persons), the second level filter will be fulfilled with the list of data related with the population of the different zones of the cave.

The user will also chose to plot data based on a specific interval of time by using the Start and End fields.
Fig. 64: Charts, configuration screen (I).
Fig. 65: Charts, configuration screen (II).

When user clicks the Generate button the plot will be generated (Fig. 66 Annex 1).
Fig. 66: Charts, plot screen.

If different types of sensing data are selected different Y-axis will be added in the left side of the plot. Also, population data will be referenced in a Y-axis in the right-hand side of the chart. The bottom axis (X-axis) will always be attached to the moment when the chosen data has been produced.

The chart allows zooming and panning directly by using the mouse (Fig. 67 Annex 1).
Fig. 67: Charts, zooming and panning.

The SmartPhone application
A SmartPhone application (or mobile app) is a software application designed to run on smartphones, tablet computers and other mobile devices. They are usually available through application distribution platform such as Google Play. Usually, they are downloaded from the platform to a target device, such as an Android phone. The usage of mobile apps has become increasingly prevalent across mobile phone users. Researchers found that usage of mobile applications strongly correlates with user context and depends on user's location and time of the day.
Developing application software for mobile devices requires considering the constraints of these devices. Mobile devices run on battery and have less powerful processors than personal computers. Developers also have to consider a lengthy array of screen sizes, hardware specifications and configurations because of intense competition in mobile software and changes within each of the platforms. Mobile application development requires use of specialized integrated development environments made. Mobile applications are first tested within the development environment using emulators and later subjected to field testing. Emulators provide an inexpensive way to test applications on mobile phones to which developers may not have physical access.

Motivation and purpose
Web paradigm typically allows standardized access from standard web browsers, including browsers specifically tailored to work as mobile applications within the context of a smart device (mainly, smartphones and tablets). By using this method, the main UnderSafe application could be accessed through any device simply provided with a web browser. However, it also has some limitations:
- As the main web interface of the UnderSafe application has been developed having typical desktop screen sizes in mind, the visualization and management though a reduced screen is not optimal.
- Despite the fact that all used technologies have been used based on its compatibility on mobile web browsers, its management could not be as comfortable as its desktop equivalent (due to the reduced precision of tactile interfaces managed by fingers, among other factors).
- The desktop-based version of the application could not provide support to real-time notifications such as raised alarms as the person in charge will probably not remain 24/7 in front of the system's screen.

Consequently, a complementary and specifically tailored mobile application has been developed in order to deal with this specific needs. The intention of this mobile application is to be an interesting complement to the main application, providing specifically tailored support to 24/7 monitoring and urgent alarm reception, but it NOT pretends to be a substitute of the main desktop application, which will still remain necessary to perform, in a more comfortable way, almost all configuration and daily tasks.

UnderSafe mobile app: Android OS as chosen platform

UnderSafe mobile application has been developed for Android devices. Android has been chosen as main and primary development platform instead of others such as iOS, Blackberry, Symbian of Windows.

Fig. 63: Smartphone web traffic by OS.

The application

UnderSafe application, as is explained above, supports comfortable reception of alarms raised on the main system near to real time, also providing access to the typical interface without the use of an external web browser.

The first time we get into the application the login screen will appear. As the application does not know where the main application server is located, the first thing that must be done is to access the settings screen and provide it with valid setup. At least, a valid host and port for either internet or local end-point must be provided.

If we try to log into the application without having fulfilled the necessary settings we will receive a notification “toast” remembering that this process cannot be forgotten. Other settings that can be configured by using this settings screen are whether the application should be continuously polling the main server in order to retrieve new alarms or not, the interval between polling requests, activation and deactivation of vibration in notifications and the ring-tone that sounds when notifications are generated.

After fulfil all necessary and configure desired settings, we are ready to get back to the main screen (by pressing the left-arrow Android standard button) and log in. After connecting to the main server and checking that we provided valid credentials, the system will grant us access to the web view screen.

Fig. 69: Web view.

As could be seen in the image depicted above, it allows traditional access to the entire application. The only general adaptation is that it provide unified login in order to facilitate full access to the device owner anywhere and at any time.

Fig.70: How GCM works.

Fig. 71: Alarms on mobile device.

Continuous polling: The mobile application will be regularly polling the main server application. The time interval between polls can be set by the user between a fixed set of values. This option has, as main advantage, that will run even when a complete and opened Internet connection is not available as, for example, inside a mine’s facilities. However, it has to be taken into account that it requires more work for both the main server and the mobile device, which can have direct consequences in, for example, battery duration. When this mode is activated, a grey version of the application logo will be set in the top bar of device’s screen and as an on-going notification that will be depicted when the top bar is unfolded.

Polling mode could be forced by activating the corresponding option in the settings menu or automatically turned on when GCM is detected as unavailable and connectivity with the central server by using local end point settings exists. Central system will be regularly sending keep alive messages to every registered device. Not receiving keep alive messages during a specific amount of time will be understood as the GCM system has become inoperative. Thus, a connectivity test to the main server will be performed and, if possible, continuous polling will be activated.

Through one way or another, application can register an alarm reception. By clicking the notification the application will guide us towards the notifications screen. This screen will display information about all registered alarms (not just the notified one despite it will be highlighted). Accessing this screen from the main application (by using the top-right corner icon) will also send a request to retrieve pending alarms from the central system when using GCM, so we are sure we are seen all the pendings alarms. Once in the main notifications screen, alarms could be removed from the mobile application by drag an alarm to the left or right side of the screen.

Potential Impact:

Tourism is a key sector of the European economy, generating more than 5% of the EU GPD (Gross Domestic Product). Within tourist sector, tourist Underground activities are gaining social relevance; year after year are appearing more attractions of this type. Nowadays there are 3,614 underground tourist attractions worldwide. Of them, more than half (1,724) are placed in Europe - with Germany, Austria, Italy, Spain and France as the main players – and it is predicted an increase of 24 per year, envisioning a number of 1,820 underground tourist places in Europe by 2014.

The economic and social impact of these activities is significant: as average, the number of visitors it is estimated by 15,000 per year, and each attraction has an average staff of 5 workers per place – with a total of 8,620 employees in Europe - being many of them SMEs and other type of institutions. Usually (especially in Europe) these activities, despite the number of non-expert visitors, are poorly regulated or completely deregulated. In Europe only Germany, UK, France and Switzerland have specific safety normative for these activities, meanwhile the rest of countries are based on current professional mining normative interpretation.

Safety nowadays is provided by underground expert professionals whom proceed to regular inspections and by basic safety some infrastructures. But even with these measures still some potential dangers (personal and environmental) are always present and cannot be totally avoided due to its nature:

Environmental risks: Attractive underground points are visited by a high number of visitors and gradually more and more people are interested on such attractions. This is a favorable point because visitors' contribution helps to their maintenance, but is also dangerous for their ecosystem: these environments without human intervention are naturally protected due to its closed nature, but human impact implies a modification of its natural environment - mostly caves - which modifies it and put their natural ecosystem at risk (temperature, humidity, light, sound...).

Personal risks: Underground tourist activities are, of course, carried out in safe placements previously verified by professionals. Most of the security measures are based on basic safety infrastructures and equipment such as indicated paths, rock netting, handrails or a simple helmet, even in huge galleries. Nevertheless, risks are still present due to its nature: people lost occur and gas exposure, lack of air, rock falling and terrain movement are still considerable risks due to its unpredictability.

Logically and fortunately, injuries and fatalities on such activities are not comparable to professional industrial mining. To proceed to a complete study of incidents that happens in such places without dead results is difficult due to that have not an individual identification code and fall within 'tourist accidents'. But at same time, the number of attractions and visitors is astonishing and increasing, and includes all ages of visitors. In such situation due to unpredictable underground characteristics (permanent terrain movements, erosion, humidity, etc...) still a potential personal danger is highly present.

Nowadays there is a void in the EU normative related to this issue which is surprising and. In some way (we expect this is not the case), seems as society is waiting to the accident to happen to raise potential dangers to public awareness and to act accordingly. For professional mining, there are a number of technological safety systems available in the market, but these ones are out of the scope of the needs for tourist underground activities in terms of requirements and costs.

Economic impact

The development of UnderSafe means the creation of a new product into the market which will be jointly exploited by all partners through a new specifically created brand and its royalties distribution coming from the commercialization of the product. Furthermore, SME partners will have access to state of the art technologies, which can lead to future products with same or similar technologies, meanwhile end users will benefit from the use of the UnderSafe product. Each SME member expects to become one of the initial players in the supply chain capable of offering the proposed technology. They are also keen to sell the technology to other companies within the EU, thus spreading it as rapidly and widely as possible..

The UnderSafe project will serve as a platform for best practices in the area of underground tourist attractions risk and environmental management, contributing to raising technological standards for the sector across Europe. The result will be a wireless system for risk management and microclimate environmental protection and project dissemination plans

will standardize UnderSafe technology throughout the EU which fits perfectly well within the current procedures running in actual tourist mining sites (see for example the Australian document “Walhalla Long Tunnel Extended Tourism Mine Management Plan”, June 2010, which is a typical procedures document and indicates the different risks that can appear in such tunnels, and procedures for its control). A reflection of Undersafe’s contribution to improved H&S standards will be the formulation of a proposal for a safety normative in the underground tourist/recreational environments, which will constitute a deliverable within the
Project. Additionally, the future broader use of UnderSafe by industry and business will further expand the ability of the underground attractions owners by means of training materials developed by SMEs, facilitating professional development to keep up with changes in industrial technology. The technology will also provide collaborative opportunities and the ability to share knowledge between users within the sector. Raising of standards is of particular importance to accession countries. Success or failure of new member states in adapting to EU standards will have an important impact on the quality of life in the New Member states. By facilitating a consolidated effort, the UnderSafe project will contribute to ensuring the cohesion and the uniformity of standard among all EU countries.

UNDERSAFE will obtain a number of outcomes that will be planned for its use and exploitation. These ones include:
1. The whole UNDERSAFE system, including hardware for the given purpose and control software related.
2. Underground Wireless Platform, based on multi-hop linear communication specifically designed for underground activities, can be used by third parties developments.
3. Sound Based Ground Sensor: this development has clear interest for other infrastructures, such as tunnels or drills monitoring, among others.
4. Landslide Laser based sensor: similar sensors in the market are currently extremely expensive due to their accuracy and purpose (deformations measurement, zone parameterization, etc...). This sensor, due to its limited focus (to measure small displacements only) is clearly the first in the market with this effectiveness / cost relationship, so it can be a new future product for tunnels and possibly professional mining industry.
5. Intelligent central unit: The central control unit will include new embedded algorithms and expert knowledge, such as Artificial Intelligence, mathematical algorithms, procedures and interfaces, which can be licensed to future products.

The UNDERSAFE technology has important benefits for the monitoring of mines and show caves in order to become safe for visitors and employers. This technology aims to be friendly and an easy-to-use system; with permanent monitoring of the environment and the visitor position; detection of landslide, positive gas, ground vibration intensity and other environmental data. The cost of the monitoring system is moderate. All this technology has been tested and scientifically validated.
In addition to the development of this technology, it is necessary to report this system and its advantages to support its implementation in the various underground activities. For this purpose, we use different mechanisms: the project website, project partners website, mailings, newspapers, television programs, and technical publications.
In addition, the research activity of the UNDERSAFE project represents an opportunity to advance in different fields of science and technology. Diffusion of the research advances is carried out by peer-reviewed publications, presentations at scientific conferences, project website and project partners website.
The project will provide social benefits as increased safety levels of tourists visiting an underground touristic mine or a show cave. To share these benefits with the society we use the project website, project partners website and media tools, such as newspapers and TV. The following Table shows the UNDERGROUND communication strategy for each target audience.
To effectively reach each of the target groups, the correct choice of dissemination tools is of paramount importance. The UndeSrafe consortium is aware that the world of communications is moving at a fast pace, and an effective communication strategy for communicating research to different target audiences can no longer rely on the traditional channels alone. To this end, a broad spectrum of channels has been considered to ensure a well-balanced communication mix.
In the context of tools and channels for reaching industry, commercial, technical, financial and industrial publications,

media broadcasts, trade fairs and seminars are all useful channels for informing industry of the latest advances in the field. Another important channel, especially among SMEs, is face-to-face communication with industrial end-users and manufacturers.
However, the effectiveness of social media tools such as YouTube, Facebook or twitter and other professional forums such as existing focus groups in “Linked-in” can also be exploited, as increasingly SMEs and business professionals are participating in professional virtual networks and social media.
For many years TV has been a popular medium for communicating science to the public, with newspapers, magazines and radio also playing a major role in informing the public and raising awareness. As more and more science-based articles are made available online, the Internet is becoming a reference for those members of the public that want to access information and learn facts on innovation and research. The usefulness of social media tools is also highly relevant in the case of the general public, with such sites as YouTube (and especially EU-tubes broadcasting EU-related contents) and Twitter offering enormous potential to engage with young people, students, and early stage researchers.
The typical communication channels for scientific innovation are mainly peer-reviewed publications and scientific conferences. Specialist websites are increasingly becoming more widely accepted among the scientific community.

Project Website

This site, http://www.undersafe.eu/about_project.html, offers generic information about the project, aims, partners, a member’s area and a contact address. The website contains a public and a private section. The public section gives information about the project, its objectives, and its project partners. All project partners have also created links to the UNDERSAFE website in their company websites that can be opened from the main web. The contact data of partners is indicated with the address, and telephone and fax numbers. The private section is accessed with a login and password and it is destined to the members of the project.
In the annex section, annex I, different websites with information of the UNDERSAFE Project are included.

UNDERSAFE News (website)
Other websites have been used to disseminate relevant non-confidential results, interviews with staff of the SMEs, short articles from the research team, etc. One of these webs is the blog Speleominas, http://speleominas.blogspot.com It is a blog devoted to mining heritage, history of mining and mining museums. It is also dedicated to the "caving mining" and exploring abandoned mines. In this sense, it puts attention to the risks that abandoned mines imply.

Mailings
In order to obtain feed-back from underground touristic mines and caves, a survey has been sent to the business stakeholders of more than 800 underground activities, mainly mines and natural caves but also wine caves, war bunkers and others. The survey has been designed to be short and easy to answer. It was structured in four parts:
1. Identification data. This part was addressed to obtain complementary data to contact the activity (reference person, confirmation mail and phone number...), we also included a question to know if they were interested on receiving news about the project.
2. Activity data. This part consists of 33 questions about the main features of the underground cavity and installations. Most of these questions have limited answers that facilitate a statistic analysis of the acquired data.
3. Evaluation of the UNDERSAFE Project objectives. This part is devoted to the evaluation of the UNDERSAFE Project goals. It is very useful for determining the main demands of the potential market concerning monitoring activities.
4. Finally a free text box allows people to give us some complementary information not taken into account by our survey. To make the survey we chose “Google Docs Spread Sheet”. This online application is very easy to use and enabled us to do on-line surveys which can be easily answered through a web link. This application allows doing reiterative sending of the survey by e-mail. The survey has been sent using the first language of the interviewed person when it was possible (English, German, Spanish, Catalan, Italian, Polish, French, Portuguese and Estonian). We

have recorded 58 responses.

Participation in Scientific Conferences

Dissemination of the project at conferences, that is oral presentations and posters, were planned to participate in activities from the different fields of research involved in the project.

We hereby briefly detail the conferences where we participated:

International Congress on Scientific Research in Show Caves. The conference took place in September 2012 in Slovenia. It is a congress focused on scientific research in show caves. This was a good opportunity to contact with other researchers and managers of important show caves of different countries. In the annex we include the abstract sent to this conference.

XIII Congreso Internacional sobre Patrimonio Geológico y Minero. This symposium took place in September 2012 in Manresa (Catalonia, Spain). It is organized by the Spanish Society for the Defense of the Geological and mining Heritage (SEDPGYM). One of the topics of this symposium was safety in mine-museums and show caves. Here we contributed with two presentations. The first one, entitled “Safety legislation for touristic mines and caves in the European Union”, presented the main results of the study of the normative framework regarding safety in touristic mines and caves of the European Union (EU). The second one, entitled “Market research for automated safety parameters control in touristic underground activities through communication and information technologies” presented the most relevant results of the study conducted on touristic underground activities of the European Union. Both presentations are included in annex II.

IV Congreso Español sobre Cuevas turísticas, Cuevatour 2012. This conference was held in Palencia, Spain, in October 2012. It is dedicated to professionals and students related to geology, biology, environmental sciences, tourism, management and representatives of caves, and general public interested in this subject. Here we presented the communication: “Market research for monitoring safety parameters of touristic caves” (Estudio de mercado para el monitoreo de parámetros de seguridad de cuevas turísticas). This presentation is also included in annex II.

2nd International Conference on Sustainable Tourism and Cultural Heritage. This conference will took place in June 2013 in Brasov, Romania. Here we will present a communication entitled “Development of an integrated monitoring system for touristic mines and caves”.

XIV Congreso Internacional sobre Patrimonio Geológico y Minero. This conference will be held in September 2013 in Asturias, Spain. Here we will contribute with one communication entitled "Geographical information system of European tourist mines and caves and marketing plan of the Undersafe project". This symposium is organized by the Spanish Society for the Defense of the Geological and mining Heritage (SEDPGYM). The abstract to be sent is included in annex II.

Moreover, the Undersafe Project has been included within the 12 outstanding projects to be presented at the SME conference under the Irish EU presidency (http://eurosme2013.eu/). This conference will take place in Dublin on 11-12 June 2013 under the auspices of the Irish EU presidency. It will take a closer look at what it takes to be a thriving entrepreneur in the 21st century, how small companies can compete effectively in an increasingly globalized world, and how they can gain maximum benefit from existing and future private and public support mechanisms. The event will spotlight Horizon 2020, the EU’s upcoming Framework Programme for Research and Innovation.

Participation in Trade Fairs

Leaflets about the Undersafe Project were distributed among visitors.

Dissemination at general public press, on the web and in social media

There were prepared several publications in public press and reportage which was transmitted by TV 3 Catalonian TV and now it is available on the YouTube.

List of Websites:

www.undersafe.eu

Project Coordinator; Innowacja Polska Sp. z o.o.
ul.Lublanska 34, 31-476 Cracow, Poland
tel. (12) 627 77 56

Related information

Result In Brief	Safer below-ground tourism
Documents and Publications	final1-annex1.pdf

Contact

Monika Bańdura, (Head of Scientific&Technical Department)
Tel.: +48 12 627 77 61
Fax: +48 12 627 77 56
E-mail

Subjects

Industrial Manufacture

Last updated on 2014-11-13
Retrieved on 2017-10-08

Permalink: http://cordis.europa.eu/result/rcn/149392_en.html