Implementation of an Advanced Spatial Technological System for Emergency Situations

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Key words: GIS routing, GPS fleet navigation, GSM telemedicine, traffic management and e-communication.

SUMMARY

This paper describes the combination of new technology along with the collaboration of several authorities and organizations, for the development of an advanced technological system for emergency situations. The coordination of all parties directly or indirectly involved, consists a crucial parameter for the fast and effective confrontation of trauma incidents ranging from massive risk events to single cases.

The system developed was based on Geographical Information Systems (GIS), Global Positioning System (GPS) and wireless technologies, to improve pre-hospital treatment by optimizing Emergency Vehicle (EV) fleet route guidance, thus reducing the overall time needed to transfer patients to the appropriate trauma centre. Furthermore, on-vehicle equipment simulating the operation of classical traffic management systems ensures EV traffic pre-emption, while at the same time a cellular based (GSM) telemedicine system transfers patients' key medical data from the ambulances to trauma center.

The system was successfully tested for a three month time period, covering the greater Patras area in Western Greece. Over the recorded cases, a significant time reduction was noted, showing that new technology can improve pre-hospital treatment in a rapidly changing heath care system. The key innovation concepts required minimal infrastructure interference that relied on: 1) computerized navigation algorithms for routing the ambulances from and to the accident location, 2) transfer of visual and sound data from the ambulance and continuous telemedical communication between the dispatch center and the ambulance.

The system was developed within the framework of a EU funded multidisciplinary research project (INNACT – RWG, Action 3.1, 2002-03) that involved the collaboration of researchers at the University Hospital, the Architectural Engineering Department and the Electrical and Computer Engineering Department of Patras University as well as a private consulting firm (ATMEL). The end users of the project are the National Center for Emergency Response (NCER), the Fire and the Police Departments.

The project's objective for coordinating hospital departments involved with the treatment of trauma patients, with non-hospital departments and high technology services, was fulfilled within the effort towards the deployment of the above-mentioned integrated system.

1. INTRODUCTION

The key components of the system developed include:

a) An Emergency-Vehicle (EV) fleet equipped with a GPS-based management system encompassing a cellular (GPRS) module for transmitting the EV's location to a trauma/ dispatch center.
b) An innovative cellular-based (GSM) telemedicine system for transferring key medical data from patients in ambulances to trauma-centers in hospitals.
c) A decentralized traffic management system for EV traffic pre-emption.
d) An innovative GIS-based system for pinpointing the optimum routes for the EVs to the accident's location and back to the hospital.
e) An on-going lecturing-program for offering up-to-date training to EMS-personnel.

2. SYSTEM DESIGN

2.1 Mapping Issues

For the projects needs the following mapping issues had to be be dealt with:

- City of Patras and greater area Geographic Information System (GIS) maps.
- The Global Positioning System (GPS) collection system.

2.1.1 Geographic Information System (GIS)

Geographical Information Systems (GIS) can effectively link spatial and descriptive information and display it on a map or a computer monitor. The research team developed an innovative GIS-based system for EVs optimum route guidance. The GIS system was based on Arc-Info ESRI software using Map Objects 2.2 and Net Engine 1.2 products. A specific application code was developed for displaying and monitoring EV routing data. Additional features had to be added to the dataset in order to accomplish the digital infrastructure coverage:

- Digital road network of the entire study area
- Satellite images (IKONOS, resolution 1m.)
- Digital cadastral and town planning maps
- Traffic management data.

All the above geographic data were transformed into the Hellenic Geodetic Reference System (EGSA '87) and the necessary corrections were performed. The altitude information of 4,800 axial junctions included in the cadastral maps was also added to the digital infrastructure data. The road network model structured included 12317 edges and 7051 junctions. The final outcome was the development of a GIS system, relying on the following data layers:

- The entire road network, containing information on speed limits, direction of travel, traffic signals, and other important traffic parameters (figure 1).
- EV GPS data (figure 2).

- References of the accident location according to the data received by the trauma/dispatch center.
- Best possible route guidance from the EV's location to the accident location (figure 3).
- Best possible route guidance from the accident site to the University Hospital trauma center (figure 4).
- Updating and expanding the system by introducing new traffic data.

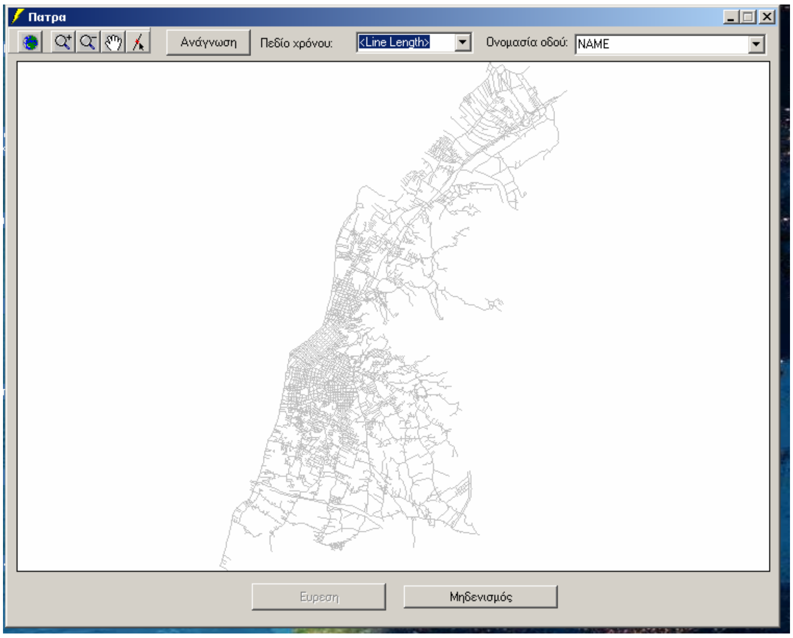

Fig 1. Road network display

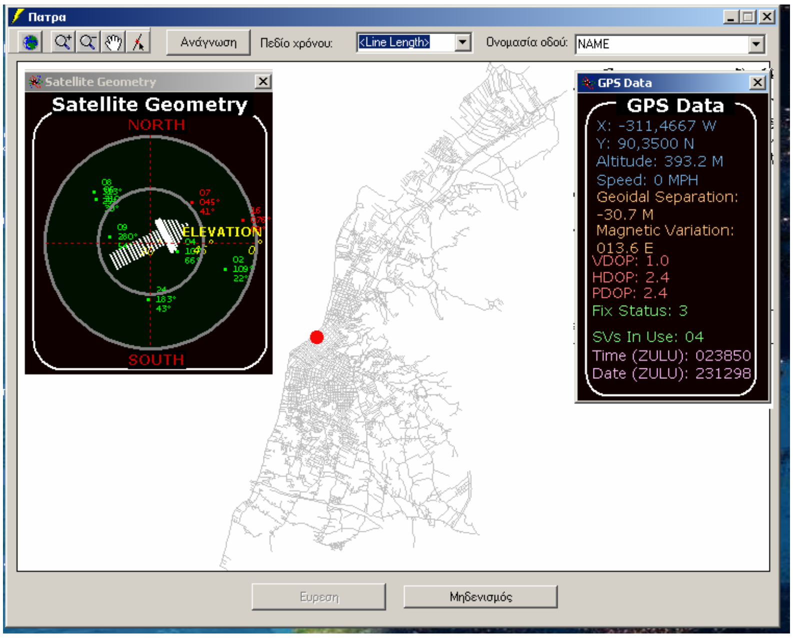

Fig 2. EVs location, according to data received by the GPS

2.1.2 Global Positioning System (GPS)

GPS is a world range system, developed by the USA Department of Defense and is based on an array of 24 satellites at an altitude of 11.000 nautical miles with a rotation period around the earth 12 hours on six orbital levels, as well as on their ground stations. This satellite constellation accomplishes at any period of time, a universal and under any weather conditions, location and navigation of an unlimited number of users. GPS accuracy is affected by a number of complex factors. Estimated error is calculated by the GPS unit and logged from its data stream by the Host PC used during data collection. Furthermore, the GPS provides accurate velocity data, which can be used to get an idea of the +/- position relative to time (i.e. distance traveled in a given time).

Each EV emits its position to the data reception center, which is acquired through the GPS system installed, together with other necessary data, such as the EV identity number. These data are received from the data center and are displayed on special software. This software is compatible with the transmission system in the EV and allows the proper and immediate reception of data. The EV's position is displayed on the detailed map of greater Patras area with an obvious light signal. This signal is updated as soon as allowed by the combination of the position update rate from the GPS and the transmission speed of the signal.

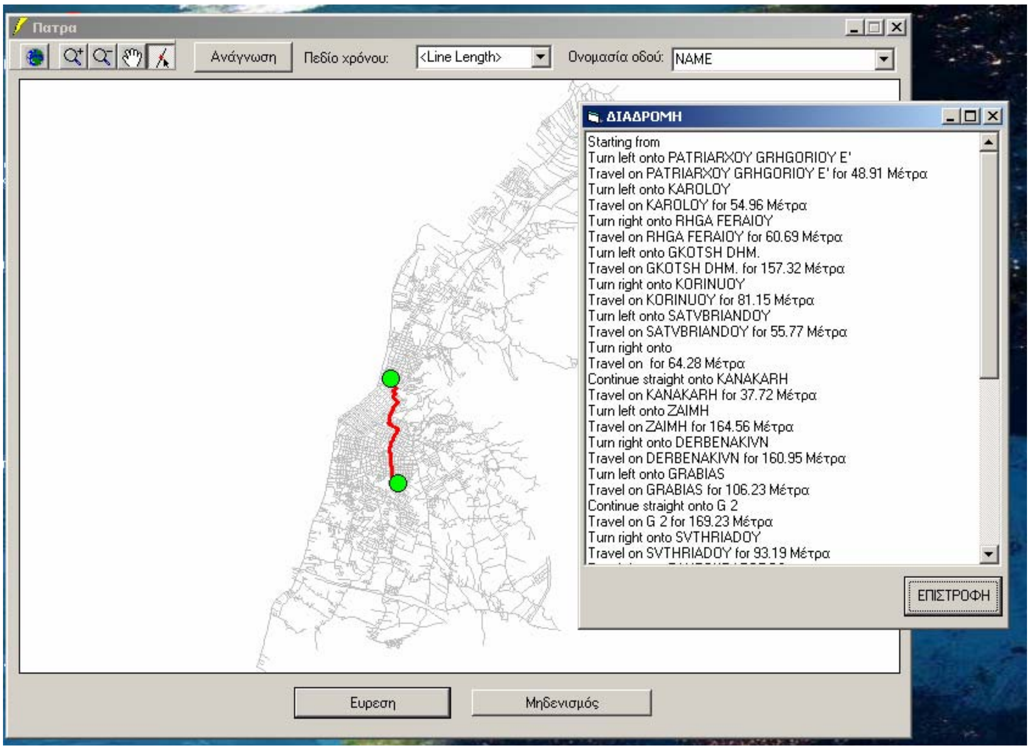

Fig 3. Best possible route guidance from the EV to the accident's location

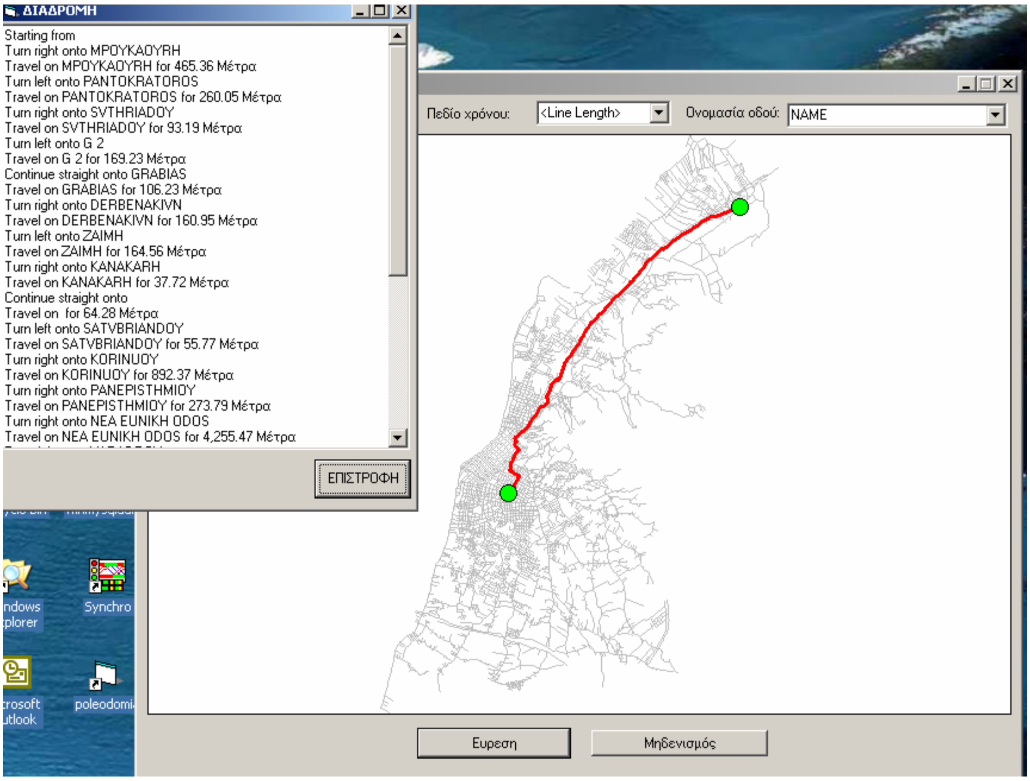

Fig 4. Best possible route guidance from the accident to the trauma center

2.2. Emergency Vehicles Priority System at Signaled Junctions

Preemption provides priority treatment by interrupting the normal cycling of a traffic signal in favor of an emergency vehicle. This assists emergency personnel in safe and timely arrival at incidents and back to the trauma center.

The city of Patras, and many other Greek cities, don't use centralized traffic signal control system. Therefore, the project team designed and applied an Original Equipment Manufacturer (OEM) solution so that EV's approach is detected by the traffic signal sufficiently in advance of its arrival. This is because the signal has to cycle through any necessary timing intervals and arrive at the desired signal display before the emergency vehicle is at the intersection. The range setting of preemption equipment is therefore critical for proper operation. A vehicle equipped with a preemption emitter can capture its Position, Velocity, and Time (PVT) data with a Global Positioning System (GPS) receiver unit.

Based on this solution, an open architecture system was designed and applied, where the EVs location was wirelessly transmitted (UHF Modem) to the signaled junction by the use of a micro-controller, in order to give the appropriate priorities. The mobile unit was placed on the EVs and the immobile part on selected traffic lights. A decentralized control system is shown in figure 5.

The central processing unit was receiving data through a serial port RS232 from the EVs and these data transferred, were received by the GPS receptor. After processing the vehicle's location data, an encoded RF signal (433.92MHz) was transmitted, containing information about the location and type of the vehicle received by the corresponding RF receptor. Accordingly the proper signals were sent to the traffic regulator for the amendment of the signaling schedule taking into consideration the safety times, so that the ambulance priority can be granted. Moreover, the software offered the possibility to classify the priority with regard to the vehicle type as well as to the direction at which it moves.

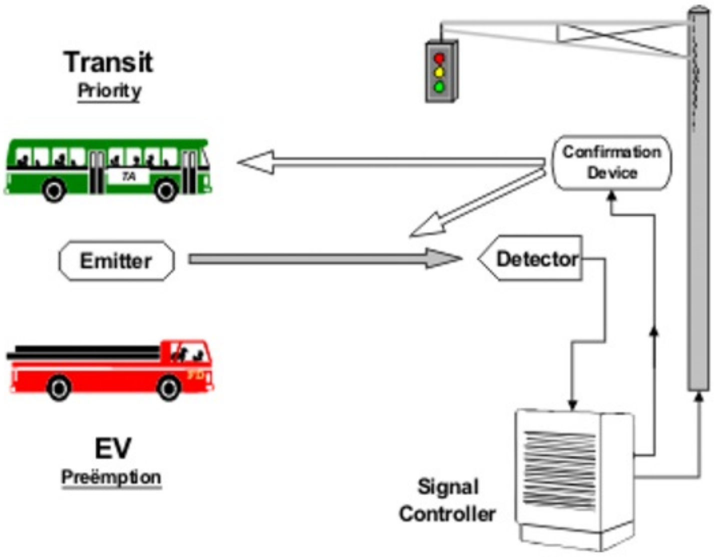

Fig 5.Vehicle detection and signal control in traffic lights.

2.3 Wireless Telemedicine System on EVs

For the acquisition of data related to the patient's condition inside the ambulances, as well as for their wireless transmission to the data reception center, a defibrillator device was selected which can also register and transmit to the trauma center a wide range of vital signs such as:

- 12 lead ECG and automatic diagnostic operation
- Blood Oxygen Saturation (SpO2)
- Heart Rate (HR)
- Non-Invasive Blood Pressure
- Temperature

The defibrillator equipped with a GSM modem, transferred the data collected to the trauma center, by using a modem connected to the mobile telephone network and a mobile telephone SIM card. The reception and storage of the signals sent were carried out using specific pc software, which allowed:

- The filing of the incidents received.
- The easy search for incidents.
- The implementation of measurements in order to better evaluates the data.
- The time and quality monitoring of all incidents – actions – alarms during the transportation of a patient.

With this information, doctors can perform the evaluation of patient's condition in a short time, providing the paramedics advices for improved pre-hospital care (figures 6a & b)

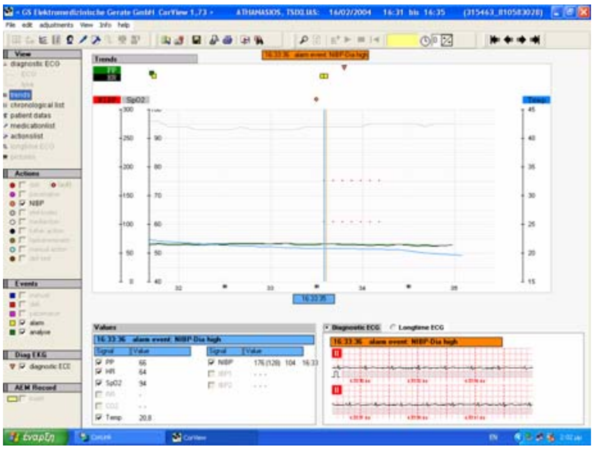

Fig 6a. Timetable showing alarm events

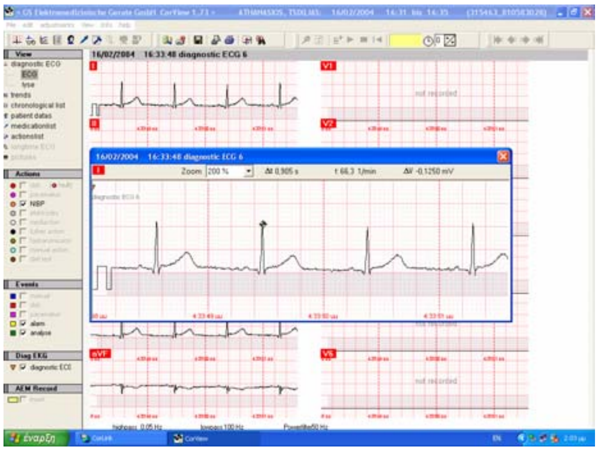

Fig 6b. Measuring on an ECG strip

2.3.1 System Web Camera

A small web camera was installed in each EV that participated in the study (figure 7). This allowed a constant reception of image and sound from the ambulance, enabling thus an ongoing monitoring of the patient. With the patient's data and image received, doctors from the trauma center can provide instructions to paramedics, while the patient is still on its way to the hospital. An experimental Wi-Fi network was used to send data. A significant advantage was the fact that this camera was mobile and could be taken outside the ambulance to get pictures from the accident scene, providing the trauma center with a more global view of the injury severity and the accident's conditions.

Fig 7. EV equipment

2.4 Human Resources

The project's human resources consisted of two main groups:
1) The medical group, including eight physicians participating in the project who were trained to use the technological systems, as well as to evaluate the incoming data 24-hours/ day on three 8hour shifts. This group was supervised by five physicians of different specialties who were available on a 24-hour basis to back up the rest of the medical group and help tackle complex medical problems.
2) The technical group staffed the signal reception centre on a 24-hour basis in order to resolve any technical problems that could arise as well as to supervise the effective operation of the whole system.
In addition, the crews of the mobile units that participated in the project also trained to technologic innovations of their vehicles' equipment, being in continuous contact with the technical and medical groups.

2.5 Trauma Centre Operation

The trauma/dispatch centre, located at the Emergency Department of Rion University Hospital, has been the centre of reception, management and evaluation of signals – data. The centre consisted of two workstations equipped with 3 PC monitors, each one displaying exclusively (figure 8):

- The digital map of greater Patras area, the current location of the EVs as well as the accident's location.
- Still images and video transmitted from the wireless cameras installed in the EV cabin, allowing the monitoring of the patient's condition and the control of the crew's actions.
- Continuous monitoring, recording and managing patient's vital signs, displayed in the form of diagrams.

Fig 8. Data Receptor at the Trauma Centre

3. RESULTS - CONCLUSIONS

The entire system developed within the research project, had effectively operated (figure 9). The coordination and collaboration of the multidisciplinary team, participating in the project has been successful, while the training of the medical, paramedical and technical staff rendered the participants surprisingly capable of effectively using the above novel technologies.

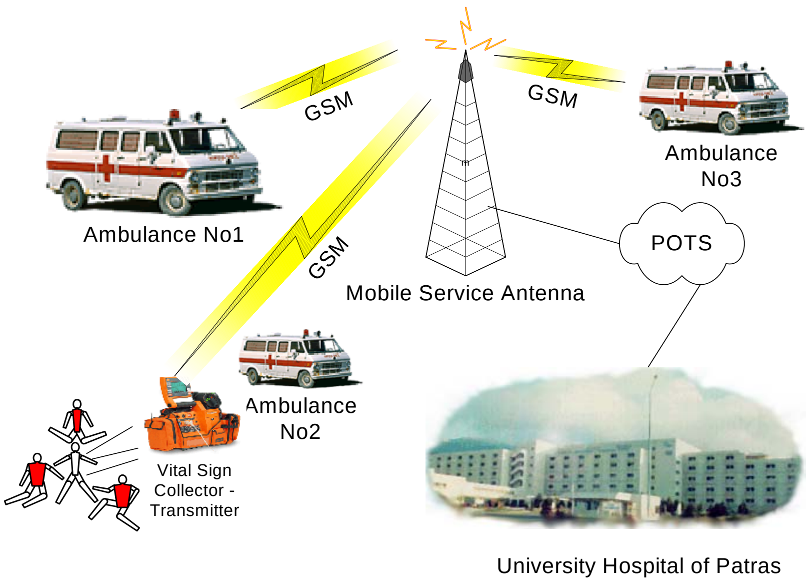

Fig 9. Overall architecture of the system developed.

During the three-month study period, 56 transportations were examined before the implementation of the project, serving as controls and 45 after the implementation of the project, with properly equipped ambulances. The causes of the emergency transportations are summarized in Table 1. The majority were trauma cases, followed by acute medical or cardio logical incidences.

NATURE OF INCIDENTS	**BEFORE REGULATIONS**	**AFTER REGULATIONS**
MULTIPLE INJURIE (CAR ACCIDENTS etc)	32	28
PATHLOGY AND REGULAR INCIDENTS	16	11
CARDIOLOGICAL INCIDENTS	8	6
TOTAL	*56*	*45*

Table 1. Nature of incidents studied

3.1 Transportation Time Reduction

Reduction of pre-hospital transportation time represented the main criterion of success in our study. Table 2 depicts the time required for transportation before and after the implementation and operation of the system in the different groups that were examined. A significant reduction in was found when the total time required for the transportation in the 56 controls was compared with the 45 cases after the implementation of the system (p=0,000002). When the subgroups with and without the use of sirens and lights were analyzed, still a significant reduction in the transportation time was found after the implementation of the project (p=0,000002 and p=0,03 respectively). A significant difference was also noted in the groups not using sirens and lights, independently of the traffic load at the time period that was examined. There was no difference in the groups using sirens and lights, before and after the implementation of the project, however the numbers in these last groups were too small to result to statistical conclusions.

TRANSPORTATION TIME	**STAGE I**	**STAGE II**	**p**
Total time	12,36 min n=56	10,21 min n=45	0,000002
Total time without using sirens and lights	12,34 min n=48	10,20 min n=40	0,000002
Total time using sirens and lights	12,07 min n=8	9,40 min n=5	0,03
In the time period 07:00-19:00 without using sirens and lights	12,40 min n=31	10,36 min n=22	0,0005
In the time period 07:00-19:00 using sirens and lights	12,00 min n=3	9,00 min n=3	0,13
In the time period 19:00-07:00 without using sirens and lights	11,51 min n=17	9,53 min n=18	0,007
In the time period 19:00-07:00 using sirens and lights	12,30 min n=5	9,36 min n=2	0,09

Table 2. Transportation time.

3.2 Coordination of the parties involved

An incident, either a simple one such as a car accident or a complicated one, such as a massive destruction, requires the collaboration of several authorities and organizations, such as police, the army, the port police, the fire department and the NCER. The coordination of all parties directly or indirectly involved consists a crucial parameter for the fast and effective confrontation of the trauma incident.

The implementation of the system developed within the presented project, rendered the dispatch centre as the significant junction that offered the possibility to notify and coordinate all these parties, so that their mobilization is fast, effective and efficient.

ACKNOWLEDGMENTS

To accomplish the aforementioned goals, the multidisciplinary research group collaborated under the auspices of the Regional Health & Welfare System (RHWS) of Western Greece. The group consisted of the three Departments of Rion University Hospital:

- University Department of Surgery,
- University Department of Orthopaedics and
- Emergency Department.

Three University Laboratories of Patras University:

- Laboratory of Town Planning, Department of Architectural Engineering,
- Laboratory of Automatism and Robotics, Department of Electrical Engineering and Computer Science and
- Laboratory of Wireless Communications, Department of Electrical Engineering and Computer Science.

The rest entities of the group were the following:

- The National Center for Emergency Response (NCER) and
- ATMEL Company (Private participation)

The research group also collaborated with several state, public and private entities (Ministry for the Environment, Physical Planning and Public Works, Hellenic Police Force, Fire Service, Region of Western Greece, RHWS of Western Greece, Patras' Municipality, Intracom) that we would like to thank cordially.

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She participated in scientific committees of the Technical Chamber of Greece (1986-88) and the Hellenic Mapping and Cadastral Organization –HEMCO (1987+), in 16 Funded Research Projects (1988+) and in 7 seminars as instructor. Since 2000 she is also Visiting Assistant Professor, in the School of Architecture, University of Patras. She has published 36 papers on Cadastre, GIS/LIS, Photogrammetry and Remote Sensing in Greek or International Magazines and Congress Proceedings.

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