SPATIAL DECISION SUPPORT SYSTEM: A CONCEPT FOR SUCCESS IN EMERGENCY MANAGEMENT ON THE MOTORWAYS?

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Abstract

This paper will present an approach to the problems of emergency management on motorways with the use of a Spatial Decision Support System (SDSS). The acceptable data management costs by using existing spatial data stored in GIS, like generation of new data with various spatial functions and transparency for all emergency services, give such an approach an advantage in relation to the classical operational methods used. The SDSS uses GIS in conjunction with other decision models and could be a powerful tool for the coordination of all participants in the decision-making process during emergency situations, and to give them a more cooperative surrounding. Therefore, herein, for the purposes of the emergency management on motorways the main idea is to provide support in organisation by combining GIS with decision models to make an operative spatial decision support system concept.

Introduction

The state motorway systems due to the permanent exposure to the risky events i.e. accidents should be especially concerned. For example, Europe has an average of 1.7 million of car accidents per year assisted by emergency services, which includes the medical emergency service. The straight consequences of car accidents are higher costs of health insurance systems, and national economies are burdened with less productivity and bigger range of material goods damage. In order to maximise road safety and efficacy of emergency support, Europe initiated several projects to increase safety on the roads such as E-Merge, eSafety and eCall. Concerning its efficiency eSafety system and eCall could be of the special interest. For example, *e*Safety Support is a European Commission funded project assisting the *e*Safety initiative in its goal of reducing the number of fatal road accidents in Europe (eSafety; 2005). The project's main tasks are to stimulate and monitor the activities, progress and results generated by the *e*Safety initiative. It offers assistance to the *e*Safety Forum and its Working Groups, keeps all stakeholders up-to-date on *e*Safety progress and findings, and promotes the benefits of Intelligent Vehicle Safety Systems to the general public (esafetysupport, 2006).

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The data from the document "European Road Safety Action Programme" (11) point to the fact that the motorway accidents make 5% of the total number of accidents, but the level of mortality in the motorway accidents is over 9% of the total number of injured people including the pedestrians that are unfortunately the most endangered population. The very interesting information is that the motorways in EU are only 0.9% of the total length of the paved roads, but on contrary, in the last years the annual average number of dead persons in the accidents on the motorways in EU is 2.500.
Figure 1 shows lowering trend of the fatalities on the EU roads as well as set objective to reduce a number of the fatalities for 50% by 2010.

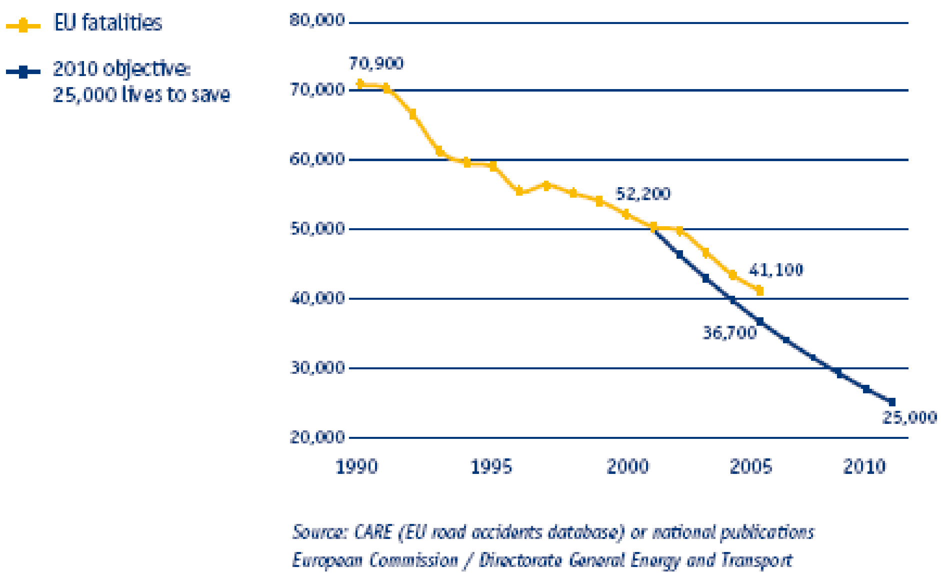

Figure 1: Lowering trend of the fatalities on the EU roads

Acceptance of eCall technology means that European countries have to improve their Public Safety Answering Point (PSAP) by the end of 2007. The whole emergency management system should be also improved with necessary ICT tools that enable quick and reliable response to the car accidents and fully utilize the advantages of eCall technology. Regarding the promotion of eCall at national level the Commission strongly recommends that the Member States set up national platforms for promoting eCall (5). They should have participation from relevant ministries including the authorities responsible for emergency services, as well as private industry and service providers (Buzolic J., Mladineo N., Knezic S.; 2002).

The Commission strongly urges the national and regional governments to act and to invest in the necessary emergency care infrastructure for eCall, with the view to launch the full pan-European service in 2009. Considering the total impact of eCall estimated by the SEiSS study, the annual accident cost savings are estimated to be up to 22 billion € and the annual congestion cost savings up to 4 billion €, which brings the total annual benefits up to 26 billion €. Compared to these benefits, the investments needed are relatively small, 150 € per vehicle and up to 50,000 € to upgrade a PSAP (13). On the basis of this initial investment per PSAP, and adding the costs for training their staff and to ensure adequate language support, it brings the annual total costs up to 4,550 million € in EU 25, including the in-vehicle systems.

Accepting the international agreements and protocols, as well as hosting numerous tourists during summer, Croatia faces the need for establishment unique Enhanced Emergency Call

Services. European citizens in distress situations are able to call the “112” and get through to the emergency services in all Member States. Thus, anyone traveling within the Union has to remember only one number and this guarantees a quicker and more efficient intervention.

In November 2004. Croatian Parliament accepted Protection and Rescue Law. The introduction of the new Law states that: "In accordance with 112 European Convention, Republic of Croatia, like European Union members, will introduce free phone number 112". Until the new Law was accepted, like in the most European countries, emergency services in Croatia were disassembled such as: police (telephone no. 92), fire brigades (telephone no. 93), medical emergency service (telephone no. 94) and National Maritime Search and Rescue Centre (telephone no. 9155). The new law recommends an introduction of the new Centre 112 as Public Safety Answering Points (PSAP) services, which would efficiently pull together and coordinate all emergency services. Organization of "Centers 112" demands very complex intervention within information and telecommunication systems in order to achieve high technological services level, increase efficiency of first aid and, generally, interventions in diverse emergencies and catastrophes. Experiences of the United States and European countries will definitely help the process of system conceptualization in Croatia, even though, the progress in information and telecommunication technology is so fast, that all the countries have the same challenge how to utilize all possibilities of technological progress.

A particular challenge for the rescue system in Croatia is recently built motorway Zagreb-Split (officially marked as A1) a part of which, named “Bosiljevo-Dugopolje”, is isolated regarding urban centres (cities), thus making an approach of the emergency services very difficult considering responding time. In order to make emergency services to function properly on the Zagreb-Split motorway, a specific approach for emergency system development on the motorway based on both E112 concept and functional support of "Spatial Decision Support System" (SDSS) is proposed.

Building SDSS for emergency management on motorways

Decision process is a generic process that can be applied on any kind of organized set of activities in order to meet objectives. Generally, there is no unique model of decision process, because it includes numerous variables, different kinds of decisions (strategic, tactical, and operational), as well as different decision makers.

Generally, use of that knowledge and experience in the development of a “Decision Support System” (DSS) for enhanced emergency call services logically leads to the implementation of a system that will support all decision levels (Mladineo, N., Knezic, S., Jajac, N.; 2005). The organization of that system is generally hierarchic; at each level decisions are made in accordance with the authority. Decision character is different at some levels and depends on the system organization; decision range at lower levels is in accordance with previously made strategic decisions.

Conceptualized DSS for tactical and operational level is divided in a number of segments (modules) that will be additionally built in the further phases. Basic module is GIS (Geographical Information System), for all levels of DSS, that comprise information sub-systems about spatial and other data and serves the other modules with data and information. GIS module is divided in several thematic layers with basic information about settlements, road network, topographic data, location about police and fire departments, emergency services and hospitals, etc (Mladineo, N., Knezic, S., 2005).

For "Center 112" level conceptual scheme of DSS is different, because this level supports activities of particular services (police, fire brigades, ambulance, etc.) as can be seen on Figure 2.

For the different emergency situations the simulations have been performed for the following items: availability of the emergency vehicles, velocity of the intervention as well as scope of the intervention in the 20 minutes time outside of urban areas, such as motorway (Mladineo, N., Knezic, S., Jajac, N.; 2006). Functional organization of the 112 Centre is conceptualized taking into account political and administrative borders, such as counties. Each 112 Centre is usually in charge for only one county thus making the coordination difficult during the rescue operation on the motorway A1, because its southern part is situated in five counties.

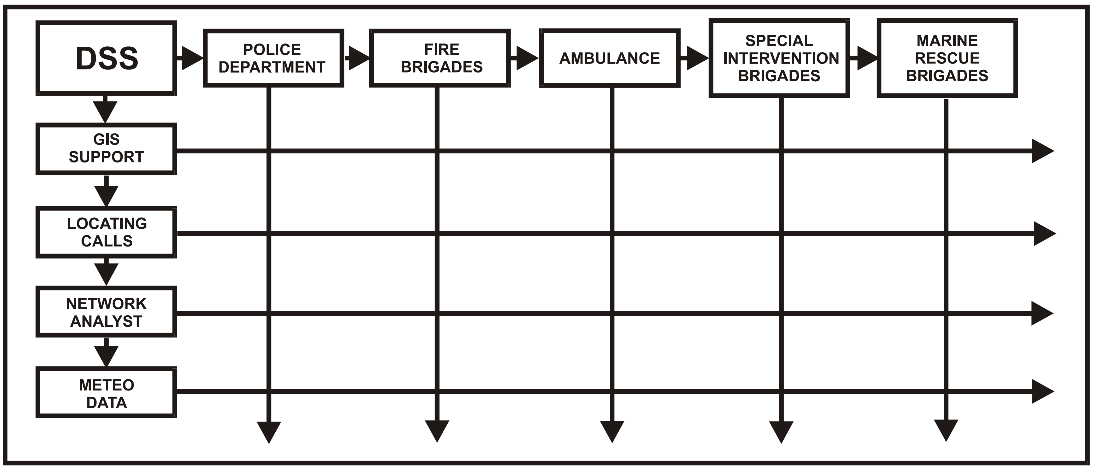

Figure 2: Conceptual framework for DSS development for “Enhanced Emergency Call Services (Centre 112)” level

Aiming at improvement of an efficacy of the rescue operation on the A1, precisely on the segment from Bosiljevo to Dugopolje, an inter-agency model is conceptualised. Therefore, an efficient coordination between counties’ 112 Centres is established. Since the major problem is spatial processing, namely determination of the accident spot, the selection of the nearest available resources for the rescue operation, as well as determination of the fastest intervention pathway "Spatial Decision Support System" (SDSS) concept is used with the dominant role of GIS.

Reviewing the literature it may be found that Jankowski et al. (1997) discuss the involvement of many stakeholders in solving spatial decision problems. They present SDSS for groups called Group Choice. Additionally, Jankowski et al. (2001) present a new prototype of SDSS emphasizing the need for the improvement of the typically limited role of maps as support tool, to move toward the use of maps as a source of structuring in multiple criteria spatial decision-making.

For the solving problems on the motorway, the first step in a development of the SDSS was an establishment of GIS support for a relatively large area (313 km of the motorway) as well as significant number of available emergency services’ units on the motorway (police, emergency medical care, fire brigades, special services) that access the motorway via local roads. Approach to the motorway is limited to the 20 official toll (entrances/exits) distributed equally each 10 to 30 km. Isolation of the motorway from the urban centres and thus from the most important resources for the emergency actions rises a question of meeting the usual responding times. This means that assumptions for the rescue system with the responding time within 20 minutes should be analysed on both whole and part of the motorway A1.Using GIS and other GIS-based tools the scope of the emergency services action is visualised. Centres of the areas are base stations and scope is defined by using 10 to 20 kilometres of the road network.

Since both medical emergency unit and fire brigades have additional stations, the three separate layouts (Figure 3 – police, Figure 4 – medical emergency unit and Figure 5 – fire brigades) were made showing that medical emergency unit has the best mobility. Fire brigades have also good mobility because they have three stations located on the motorway near major tunnels.

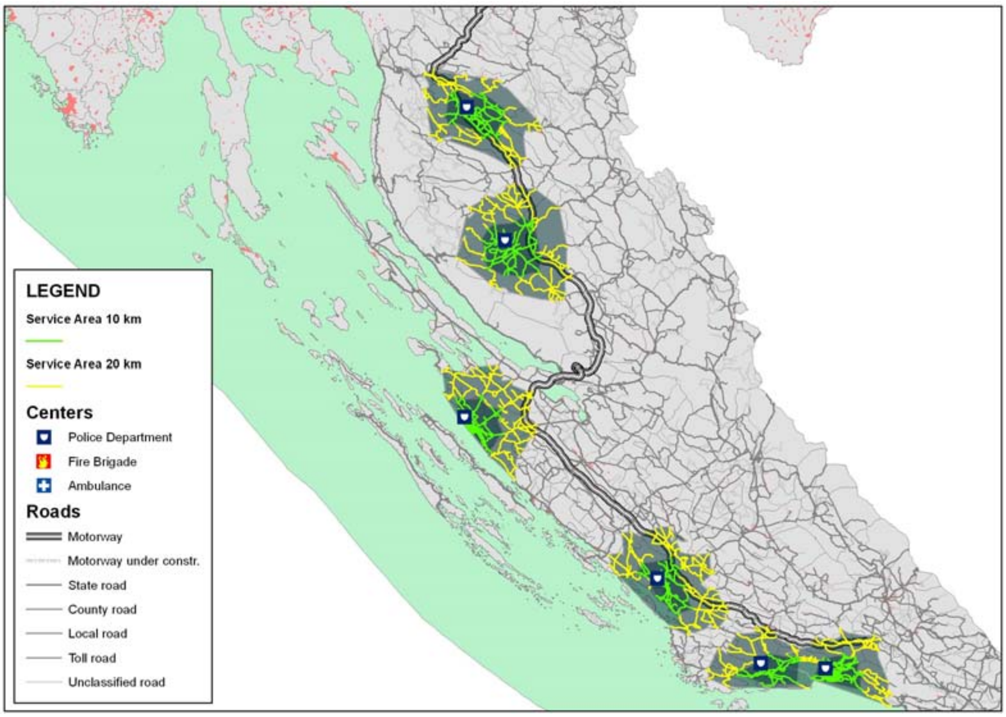

Figure 3: Service area (10 and 20 km) for police vehicles

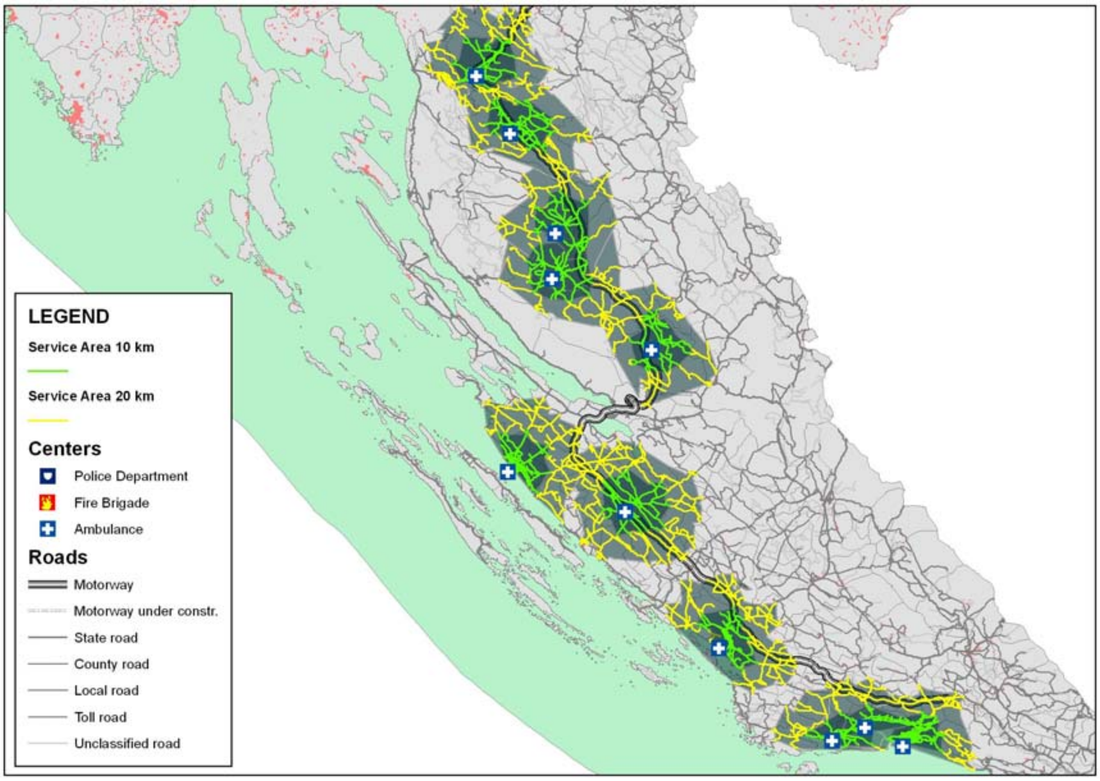

Figure 4: Service area (10 and 20 km) for medical emergency units

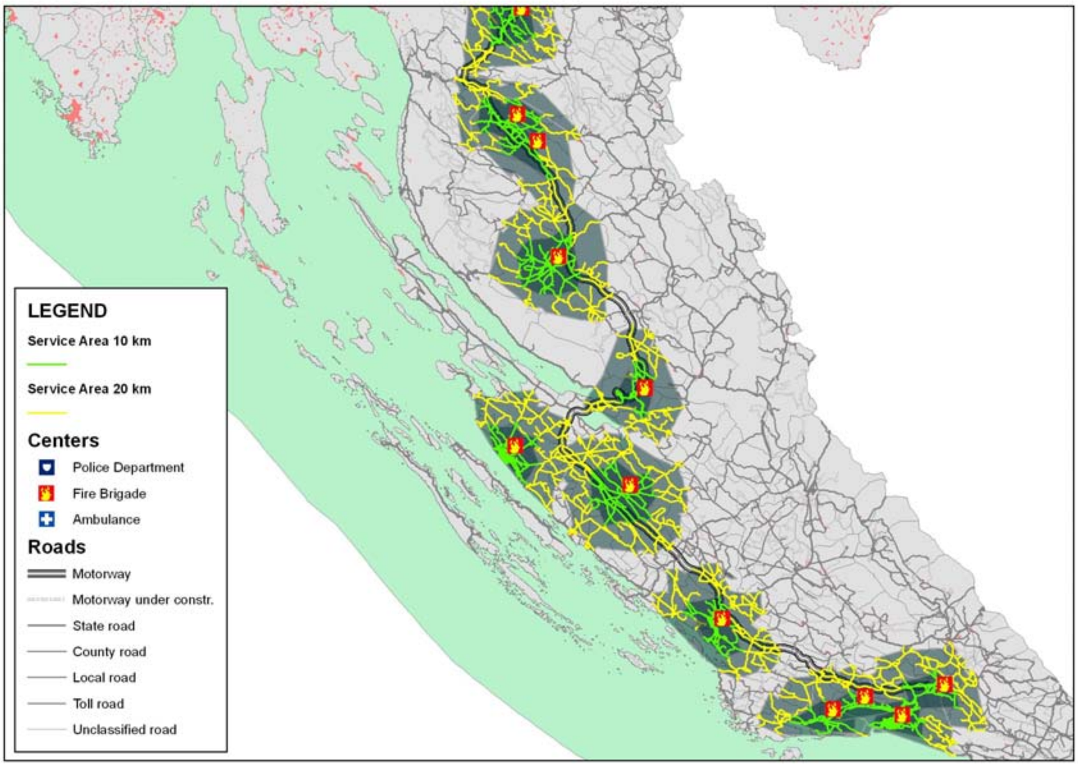

Figure 5: Service area (10 and 20 km) for fire brigades

The next step includes simulation of the vehicles' velocity. The intention was to define real coverage of the motorway within the 10 or 20 minutes. Starting time is an event when vehicle leaves the station (garage), while an average velocity of 60 km per hour on the local roads is estimated based on the experience. For the entrance and travel on the motorway an average speed of 100 km per hour is estimated.

Figure 6 and Table I show the results of the simulation for the part of the motorway from the toll 15 to the toll 19. These data are put into correlation with the real time starting from the emergency call to the time when the vehicle enters the road. Based on the simulated travel time to the accident spot (it is saved in the knowledge base), the dispatcher decides form which stations the units for intervention and rescue should be employed (resources management**)**. From figure 6 we can see how coverage could be poor if police vehicles are situated in the Zadar station, because within 20 minutes they can reach only point ZD-17-Left, ZD-17-Right, ZD-16-Left and ZD-16-Right, thus covering only 8 km of the motorway (Table I). Medical emergency units present better coverage because form the Benkovac station they cover 44 km of the motorway BE-19-Left and Be-19-Right, together with units from Zadar (ZD-17-Left, ZD-17-Right), and 24 km from both entrance of the tunnel St. Rok covered by the medical emergency unit from Lovinac. Regarding the location of the fire brigade in front of the entrance of the St. Rok tunnel, the whole motorway segment from the toll 14 to toll 20 is covered by the fire brigades within 20 minutes.

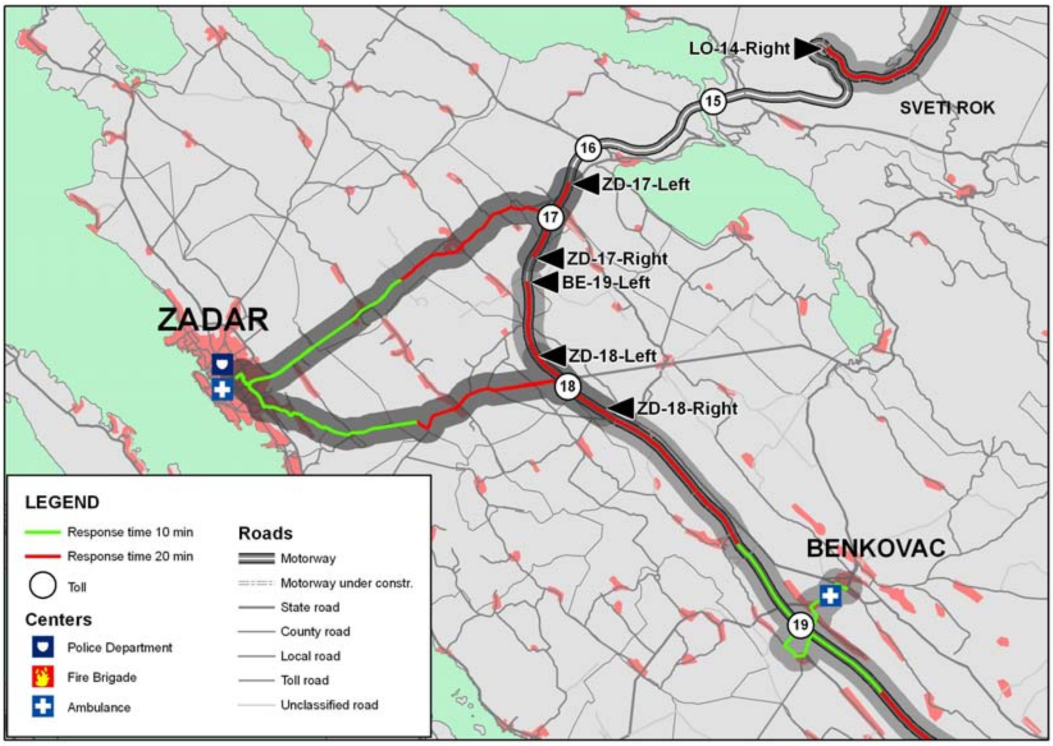

Figure 6: Layout of the coverage of the motorway with response time (10 and 20 min) for the both police and medical emergency vehicles

Poor coverage of the certain segments of the motorway A1 with the medical emergency units demands additional medical emergency teams as well as police during the summer months when there is higher accident risk due to the huge number of tourists. The additional units are located on the motorway and cover the most critical areas evaluated by the simulation in GIS.

Table I

Emergency Station	2	4	6	10 min	12	14	16	20 min	TOTAL
Zadar				10 km				19 km, 21 km	10 min **10 km** 20 min **21 km**
Benkovac*				7 km, 12 km				29 km	10 min **12 km** 20 min **29 km**
Lovinac*			6 km	13 km				30 km	10 min **13 km** 20 min **30 km**

Local Road – Average speed: 60 km/h

Motorway – Average speed: 100 km/h

*** only medical emergency**

A special function of SDSS is supporting of so called «route guidance systems». A problem is that route guidance systems do not always consider the relative risk between different routes. An obvious improvement would be to add to the traditional optimization criteria (the shortest or the fastest route) a new option: the safest route. In theory, this would require a large amount of accident statistics to be added to the digital maps on which the route calculations are based. In practice, however, estimates of the accident risks of certain road types would be a reasonably good approximation (ETSC 1999).

It is also clear that in-car route guidance systems distract the drivers from their normal driving task, but, on the other hand, to a lesser extent than a conventional map (CEC, 1998; Ståhl, Berntman & Petzell,; 1997). Additionally SDSS should support transportation of the injured people to the hospital that could give an adequate treatment. A Swedish physician estimated in 1991 that 50 out of 800 fatalities (6%) could be prohibited with improved emergency service at Swedish hospitals. A part of this can be prohibited by faster transport from the location of the crash, the other part by improved medical treatment. (Bo Brismar, 1991).

Conclusion

Affiliation of Croatia in the unique European system PSAP and establishment of Emergency call Centres 112 initiated conceptualization of DSS for Enhanced Emergency Call Services at operative level.

There is some obstacle s during establishing of the emergency management systems on motorways because the newly built motorway Zagreb – Split (A1) is often situated away from the urban areas and number of vehicles on the motorway has seasonal character because of tourists (discrepancy between summer and winter). Paper proposes introduction of SDSS which helps to establish efficient emergency management using GIS and its spatial analysis tools. After the analysis it should clear where the territories which cannot be reached in reasonable time are situated and what strategy has to be undertaken. Moreover, using statistical data about vehicles on the motorway, operational emergency management plans, for each period of the year, can be precisely evaluated. Improvement of the emergency services that can save lives and reduce injuries caused by the traffic accidents is posed as imperative. The study of an introduction of eCall technology in motorway network and its connection with 112 European emergency system demands an intensive research and application of both organizational methodology and technological possibilities. Achievement of the synergetic effect is possible by intensive application of ICT technology and GIS support.

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