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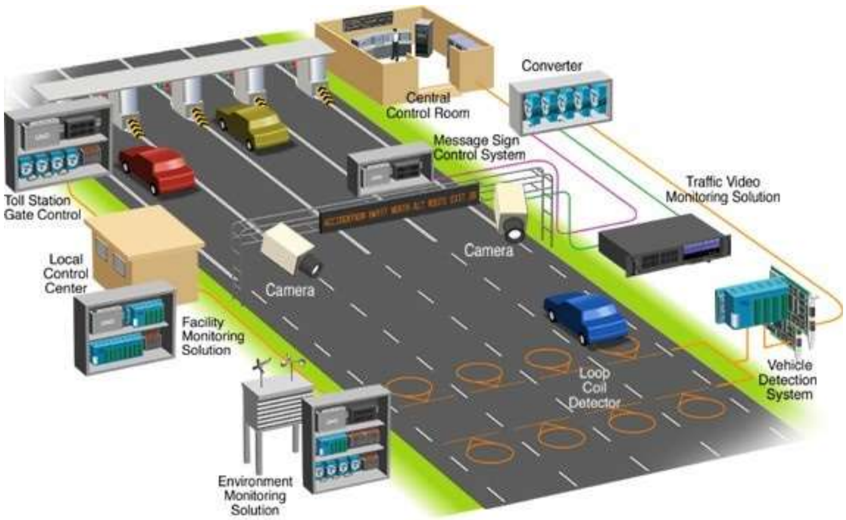

INTELLIGENT TRANSPORT SYSTEMS

Selected Lectures

Zagreb, 2015.

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CONTENTS

I. DEVELOPMENT OF INTELLIGENT TRANSPORT SYSTEMS

1. INTRODUCTION

Intelligent Transport Systems (ITS) can be defined as holistic, control, information and communication upgrade to classical transport and traffic systems, which enables significant improvement in performance, traffic flows, efficiency of passenger and goods transportation; safety and security of transport, ensures more comfortable travelling for passengers, reduces pollution, etc. ITS presents a crucial breakthrough by changing approaches and trends in transport and traffic research and technology aiming to solve escalating problems of congestions, pollution, transport efficiency, safety and security of passengers and goods, [1]. This is also proved by numerous programmes and projects related to ITS all over the world, introduction of new study programmes on ITS and foundations of ITS associations at national and global level (ITS Croatia was established in 2005). ITS replaced previously used concept for transport problem solving, which had already been exploited. Increasing transport-related problems in all major cities, centres or airports, raise the need for new approaches and new solutions.

Direct benefits from ITS deployment can be analyzed based on different sets of factors so called categories of ITS benefits. In literature ITS benefits are classified into the following categories, [1, 2]:

1. Safety,
2. Flow efficiency,
3. Productivity and cost reduction,
4. Environment benefits.

Beside the measurable benefits, many other advances can also be noticed, including new business opportunities, increase of employment; improvement of regional/urban/national technology status etc. Among common users and stakeholders, the following groups can be recognized: end users, network operators, system owners (stakeholders), service providers, tour operators, local authorities, civil government, etc. There are many approaches to measuring influences and benefits of new projects related to ITS development and deployment. Designing effective and usable ITS solution includes a possibility for estimating the ITS benefits using suitable methods, such as:

1. Method for physical impact measurement
2. Benefit analysis method
3. Cost – effectiveness analysis (C/E)
4. Benefit – cost analysis (B/C).

Recently, the European Union has made some significant efforts in the field of ITS deployment trying to find solutions for the escalating transport and traffic problems. A great number of activities has been stipulated by different European bodies with the single objective – to enforce the practical ITS deployment all over the Union [3]. The paper provides overview of these activities and their influence on the Republic of Croatia, and the surrounding region, as well.

2. DEVELOPMENT OF ITS ARCHITECTURE

Architecture can be defined as a basic system organisation consisting of crucial components, their relations and connections to environment, as well as principles for system design and development during the whole lifecycle, [1]. In order to enable development and upgrades, complex systems have to include additional characteristics such as: Compatibility, Expandability, Interoperability, Integrability, Standardability, [4]. Lack of architecture can result in difficulties because of incompatible components, higher cost for updates and complications in introducing or adjusting new technologies. ITS architecture provides a general framework for planning, designing and implementing integrated system in a given period and geographical area.

An ITS Architecture is important for a number of reasons:

- it ensures an open market for services and equipment, because there are “standard” interfaces between components;
- an open market permits economies of scale in production and distribution, thus reducing the price of products and services;
- it ensures consistency of information delivered to end-users;
- it encourages investment in ITS since compatibility is ensured;
- it ensures inter-operability between components, even when they are produced by different manufacturers, which is also good for SMEs (Small and Medium sized Enterprises);
- it permits an appropriate level of technology independence and allows new technologies to be incorporated easily;
- it provides the basis for a common understanding of the purpose and functions of the ITS, thus avoiding conflicting assumptions, [5].

Based on the content and mandatory use, three main type of ITS Architecture are defined:

- Framework ITS Architecture;
- Mandated ITS Architecture;
- Service ITS Architecture, [1].

Framework Architecture, most suitable for national level architecture, focuses on user needs and functional viewpoint. This type of architecture can be also considered as a starting point for the development of other two types of architecture. Mandated Architecture consists of physical, logical and communication viewpoints but also includes additional outputs (Cost-Benefit analysis, Risk analysis etc.), [4]. Content of Mandated Architecture is strictly defined and, as a consequence, choices for deployment options are limited. Service Architecture is similar to Mandated

Architecture, but includes services. Additionally, there are also physical and logical (functional) architecture. While the logical architecture consists of processes and interconnecting data flows, physical architecture includes physical components (parts of equipment) and related data flows. ITS architecture can live to its potentials only when logical architecture is based on user needs, vision and operational concept, and when physical architecture is developed based on the logical architecture. Defining the physical architecture is strongly connected with standardization and implementation strategy.

2.1 Functional Area and services in the field of ITS

Initial standardization of ITS services, focused on road transport, was set up by ISO (International Standardization Organization). First reference model for ITS included 8 functional areas and 32 services (ISO TR 14813-1 - Transport information and control systems - Reference model architecture(s) for the TICS Sector), [1]. The reference models for ITS architecture were improved in 1999 in the way that Part I (1999.), describing ITS Fundamental Services, replaced standards presented in Technical Report on Transport Information and Control Systems. Intention of new taxonomy is to relate similar and complementary ITS services. The taxonomy includes 11 functional areas:

1. Traveller Information
2. Traffic Management and Operations
3. Vehicles
4. Freight Transport
5. Public Transport
6. Emergency
7. Transport Related Electronic Payment
8. Road Transport Related Personal Safety
9. Weather and Environmental Monitoring
10. Disaster Response Management and Coordination
11. National Security.

National ITS architectures can include additional services and functions which are not listed in ISO taxonomy of services. Each functional area consists of interrelated services.

2.2 Development of European ITS architecture

Development of European ITS architecture is as the result of two project funded by the European Commission – KAREN (started in 1999) and FRAME. FRAME project includes early ideas of European ITS framework architecture with following documentation:

1. European ITS functional architecture;
2. European ITS physical architecture;
3. European ITS communication architecture;
4. European ITS cost-benefit analysis;
5. European ITS implementation study;
6. ITS implementation models, [1].

The European ITS Framework Architecture is designed to provide a flexible framework that individual countries can tailor to their own requirements. National ITS Architecture projects based on the European ITS Framework Architecture, such as ACTIF (France), ARTIST (Italy), TTS-A (Austria) and TEAM (Czech Republic), therefore have a common approach and methodology, but each has been able to focus on the aspects of local importance and develop them in more detail, [5]. Project frame has continued as the E-FRAME FP7 project. There are significant differences between approaches in designing the ITS architecture. US ITS Architecture is based on physical viewpoint, European architecture relies mostly on users' needs and functional viewpoint, while Japanese national ITS architecture uses object oriented methodology.

3. ACTION PLAN AND DIRECTIVE FOR ITS DEPLOYMENT

Action plan for deployment of ITS can be considered as the document that initiated stronger and more focused ITS development in European Union. Although there was a high level of harmonisation in strategic researches supported by the European Technology Platforms ERTRAC and ERTICO-ITS, framework for deployment of ITS in road transport was still to be designed, [6]. Preparation of Action plan included stakeholders' consultation, workshops, on-line survey (public debate) and discussion groups.

The introduction of the Action plan presents three major challenges:

1. congestion and congestion's costs;
2. road transport related CO_2 emissions;
3. fatalities.

The main policy objectives arising from these challenges are for transport and travel to become: cleaner, more efficient, safer and more secure. ITS has been recognized as a possible solution, and the purpose of the Action plan is to accelerate and to coordinate the deployment of ITS in road transport, including interfaces with other transport modes. The potential of ITS could be realised only if its deployment in Europe is transformed from the limited and fragmented implementation into an EU wide one. The role of the EU is to create frameworks that will include policy priorities, choice of generic ITS components and clear timetable for specific activities, [7].
The Action plan envisages six priority areas:

1. Optimal use of road, traffic and travel data;
2. Continuity of traffic and freight management ITS services on European transport corridors and in conurbations;
3. Road safety and security;
4. Integration of the vehicle into the transport infrastructure;
5. Data security and protection, and liability issues;
6. European ITS cooperation and coordination.

Within six priority areas the total of 24 activities were defined (Fig. I.1). Priority areas were later partially transferred in Directive 2010/40/EU.

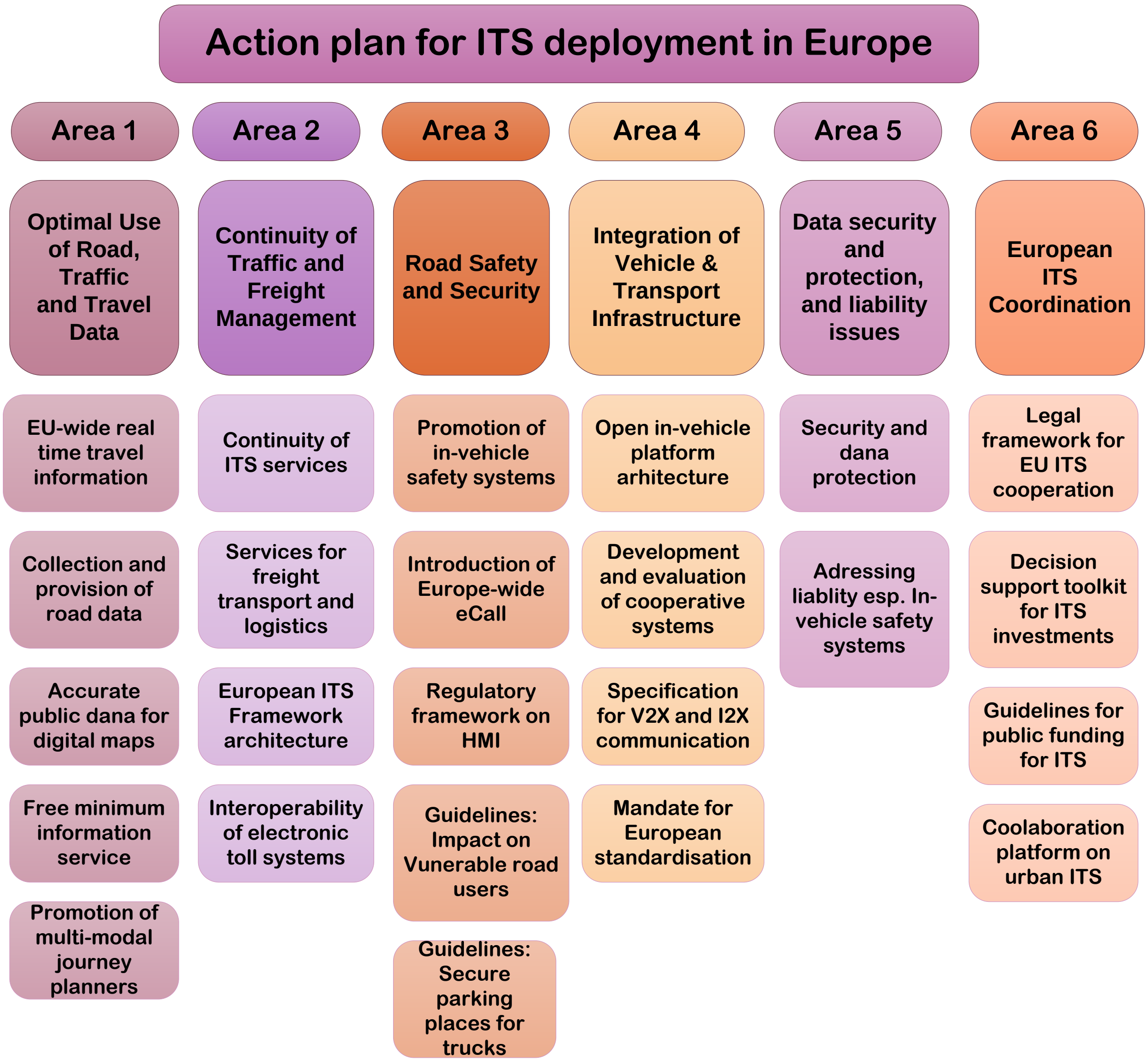

Fig. I.1 - Action plan priority areas and activities for deployment of ITS in Europe

3.1. Directive 2010/40/EU

Directive 2010/40/EU is a general document for coordination of ITS development in the European Union. Like other directives, it is not directly applicable in each Member state. However, it is the obligation of the Member states to adapt their national legislation in order to achieve goals set by directives. The essential part of the document is the list of priority areas and priority actions, as well as plans with set deadlines. The basic objective of the Directive is the setting up of framework for future activities, which will consequently lead to the harmonisation of ITS development in Europe.

The adoption of specification for priority areas is the first step toward a harmonised development. Specifications will be developed individually and, depending on area covered, they can include different types of provisions:

a) functional provisions that describe the roles of the various stakeholders and the information flow between them;
b) technical provisions that provide for the technical means to fulfil the functional provisions;
c) organisational provisions that describe the procedural obligations of the various stakeholders;
d) service provisions that describe the various levels of services and their content for ITS applications and services, [8].

After the adoption of each specification, the Commission notifies the European Parliament and the Council. They may object to the content of specification within a two month period and, at their initiative, the period for objections can be extended for additional two months. If there are no objections from The Parliament or The Council, specification is considered adopted and will be published in the *Official Journal of European Union*. The Commission may also adopt non-binding measures (guidelines and other) to facilitate Member States' cooperation relating to the priority areas.

Special attention is given to data protection and it is stated that Member states are obliged to ensure fundamental rights and freedoms of individuals. National ITS legislative must ensure that personal data are protected against misuse, including unlawful access, alteration or loss, [8]. For these reasons, the use of anonymous data is encouraged.

Implementation of tasks from the Directive is assisted by the European ITS Committee (EIC). The European ITS Advisory Group is also established in order to provide advices on business and technical aspects of ITS introduction and deployment. The Advisory Group includes service providers, users, manufacturers, professional associations and local authorities.

3.2. Priority areas and priority actions

The Directive establishes four priority areas:

1. Optimal use of road, traffic and travel data;
2. Continuity of traffic and freight management ITS services;
3. ITS road safety and security applications;
4. Linking the vehicle with the transport infrastructure, [8].

These four priority areas are also the priority areas of Action plan for ITS deployment. *Data security and protection, and liability issues*, which was included in the Action plan, is not included in the Directive but references to relevant legislation framework are made. *European ITS cooperation and coordination*, the sixth area in the Action plan, can be considered as a general issue. The existence of the Directive itself proofs the existence of mentioned cooperation. Within the priority areas, six priority actions are defined:

1. the provision of EU-wide multimodal travel information services
2. the provision of EU-wide real-time traffic information services;
3. data and procedures for the provision, where possible, of road safety related minimum universal traffic information free of charge to users;
4. the harmonised provision for an interoperable EU-wide eCall;
5. the provision of information services for safe and secure parking places for trucks and commercial vehicles;
6. the provision of reservation services for safe and secure parking places for trucks and commercial vehicles.

Annex to the Directive describes relationships between priority areas and priority actions. Three of them (1-3) are part of Area 1 (Optimal use of road, traffic and travel data), while the last three (4-6) are included in Area 3 (ITS road safety and security applications). For each priority action specification will be prepared in order to achieve compatibility, interoperability and continuity of implementation and deployment of ITS applications.

3.3. Expected timeframe for tasks set in the Directive

Expected deadlines for the implementation of specific tasks described in the Directive are listed in Tab. I.1.

Tab. I.1 Deadline for activities envisaged in the Directive 2010/40/EU

Activity	Responsibility	Deadline
Entrance into force	--	27 July 2010
Adoption of specifications for one or more priority actions	European Commission	27 February 2013
Power to adopt the delegated acts (specifications etc.)	European Commission	7 years following 27 August 2010
Adoption of the Working programme	European Commission and EIC	27 February 2011
Submission of report on progress to the European Parliament and the Council	European Commission	Every three years
Submission of reports on national activities and projects regarding priority areas	Member states	27. August 2011
Submission of a five year plan on national ITS actions	Member states	27 August 2012
Bringing into force the laws, regulations and administrative provisions necessary to comply with the Directive	Member states	27 February 2012
Submission of reports on progress made after the initial report	Member states	Every three years

Source: [8]

3.4 Working Programme on the implementation of Directive 2010/40/EU

Based on the deadline set in the Directive, the Commission adopted the Working Programme in February 2011. The Programme incorporates a detailed time schedule for each priority action according to the articles of the Directive (Fig. I.2). For each action the following steps are to be taken:

a) Analysis and Preparation (including external study, consultation with stakeholders and appropriate consultation with Member states experts);
b) Impact Assessment;
c) Drafting of specification (including opinion of ITS Advisory Group and appropriate consultation with Member states experts);
d) Final draft and Inter-service consultation;
e) Adoption.

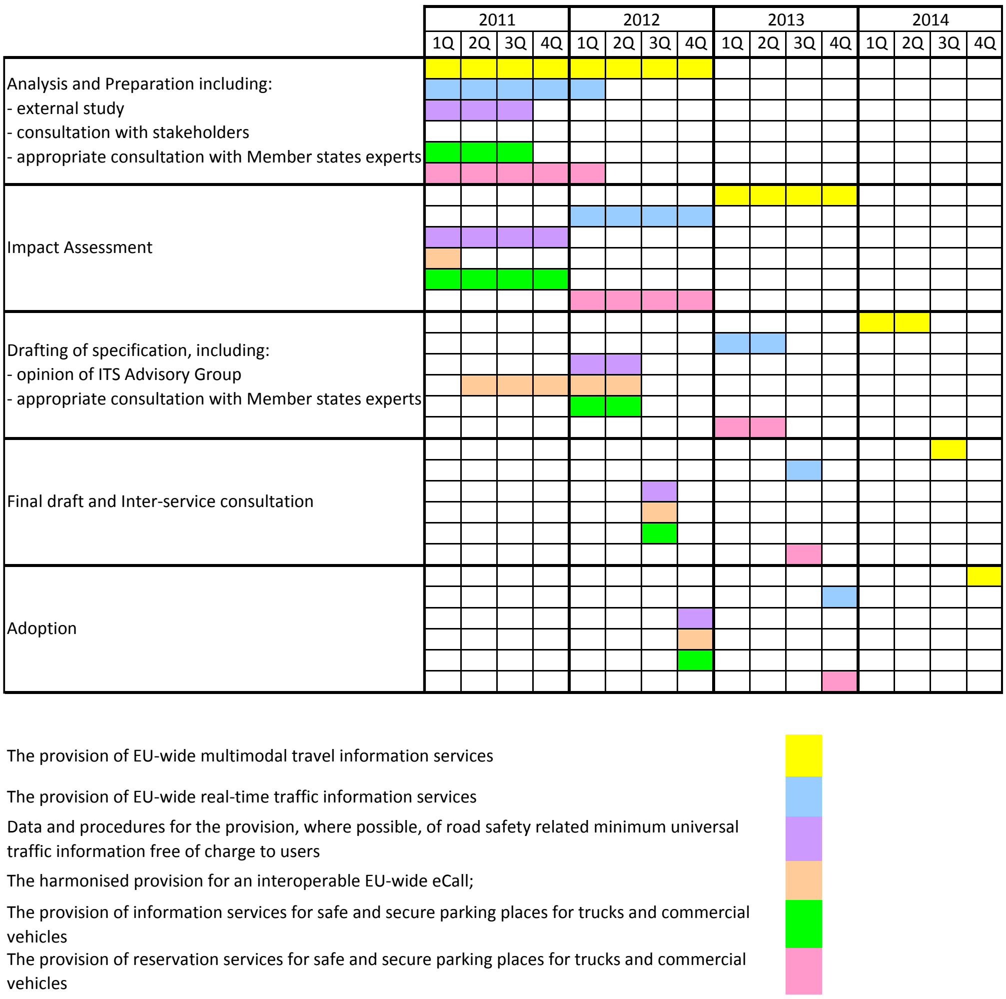

Fig. I.2 - Timeline for priority activities according to the Working programme

Time schedule for each activity is prepared considering the current state of preparation and complexity of the processes. As an example, at the time of preparation of the Working Programme, phase of Analysis and Preparation for priority action *The harmonised provision for an interoperable EU-wide eCall* has already been finalised. The longest period is foreseen for action named *The provision of EU-wide multimodal travel information services*.

3.5 Legal limitation for ITS deployment

The two main limitations for ITS deployment are incorporated in the EU legislation:

a) Personal data protection;
b) National security.

These limitations are not directly included in the legal framework for all modes of transport (Tab. I.2).

Tab. I.2 Personal data protection and National security in EU ITS legislative

Mode of transport	Legal document	Personal data protection	National security
Maritime transport	2002/59/EC	--	Article 24 Member States shall, in accordance with their national legislation, take the necessary measures to ensure the confidentiality of information sent to them pursuant to this Directive.
Inland waterways transport	2005/44/EC	Article 9. – Member States shall ensure that processing of personal data necessary for the operation of RIS is carried out in accordance with the Community rules protecting the freedoms and fundamental rights of individuals, including Directives 95/46/EC and 2002/58/EC.	--

Air traffic	219/2007	--	Annex Article 22. - The Joint Undertaking shall ensure the protection of sensitive information, the non-authorised disclosure of which could damage the interests of the contracting parties. It shall apply the principles and minimum standards of security defined and implemented by Council Decision 2001/264/EC of 19 March 2001 adopting the Council's security regulations
Road transport	2010/40/EU	Article 10. – Member States shall ensure that the processing of personal data in the context of the operation of ITS applications and services is carried out in accordance with Union rules protecting fundamental rights and freedoms of individuals, in particular Directive 95/46/EC and Directive 2002/58/EC.	Article 1. – without prejudice to matters concerning national security of necessary in the interest of defence

Sources: [8, 9, 10, 11, 12]

Although, the personal data protection is not always directly addressed in legal acts on ITS deployment, the protection is obligatory due to the existing EU legal framework.

4. IMPORTANCE OF THE EUROPEAN DIRECTIONS FOR THE REPUBLIC OF CROATIA

As a candidate country Croatia has to fulfil specific conditions including compliance of legal documents with the European legal framework (*acquis communautaire)*. Negotiations related to this harmonisation were conducted based on 35 chapters. Simultaneously, the European Union supports the necessary reforms in the pre-accession period providing co-financing through pre-accession funds. In the field of transport, international harmonisation is necessary even if it would not be related to accession to the Union. More precisely, lack of harmonisation could cause obstacles in the traffic flows on the important paneuropean corridors (V and X) passing through Croatia.

Receipt of co-financing is generally not possible without preparation of strategic documents. Instrument for Pre-Accession Assistance (IPA) includes 5 components.

For component IPA III and IV, Croatia had to prepare Operational programmes based on Multi-annual Indicative Planning Document (MIPD) and Strategic Coherence Framework (SCF). Operational programmes generally include overview of current situation, plans and list of potential projects (*project pipeline*). The implementation of subcomponent IIIA "Regional Development – Transport" is based on Operational programme for Transport. Management structure, interconnecting processes and related activities merge into a complex system for the Programme implementation. In the pre-accession period Operational Programme is focused on two modes of transport: inland waterway transport and rail transport. Strategic definition of the Programme includes three priority axes (Upgrading Croatia's rail transport system, Upgrading Croatia's inland waterway system, Technical Assistance) and related measures. In the course of preparation for the use of EU funds after accession, abstract of the draft for Operational Programme for Transport has been prepared (primarily intended for period 2012 – 2013). The new Programme incorporated all modes of transport in order to harmonize the development of the transportation network in Croatia and create successful connections to paneuropean networks. Funds will be available for regional and local development of road transport infrastructure, seaports, airports and public transport including support to cleaner urban transport, [13]. Ministry of Sea, Transport and Infrastructure is envisaged as the Managing Authority for Operational Programme for Transport after the accession to the EU.

4.1. Scientific and research capacities in Croatia

The most significant part of research activities in the last period was financed within the programme of the Ministry of Science, Education and Sports - MSES (former Ministry of Science and Technology - MST). Some of those projects are:

- General ITS models and their modal mapping (MST, 1998-2002)
- Methods of development of integrated Intelligent transport systems (MST, 2002-2005)
- Methodology for development of integrated adaptive transportation logistics systems (MSES, 2006-2013)

In recent years, as a result of previous research activities, the Republic of Croatia has been participating in several European R&D programmes, projects and activities. Some of those projects are:

- Intelligent Cooperative Sensing for Improved traffic efficiency – ICSI (FP7 - Framework Programme 7; 2012-2015)
- Intelligent Transport Systems in South East Europe - SEE-ITS (South East Europe Transnational Cooperation Programme - SEE TCP; 2012-2014)
- Computer Vision Innovations for Safe Traffic - VISTA (European Regional Development Fund, IPA- ERDF; 2012-2014)
- TU1102 Towards Autonomic Road Transport Support Systems, (COST Programme actions, 2011-2015)

Although the present situation of research and educational capacities is satisfactory, the biggest problem is insufficient connection of research capacities and economy. This elementary problem in the Republic of Croatia is being solved through several programmes on institutional and the project basis. The Croatian Agency for SMEs and Investment - HAMAG-BICRO - was established by the Government with the purpose of implementation of the Government's technological development support programmes. Its basic task is successful and effective support to technological development and commercialization of research results by connecting the economy with science and by creation of financial, material and other preconditions for successful innovation development. HAMAG-BICRO has recognised the importance and the role of Intelligent transport systems through repeatedly support to such projects.

4.2. Legal Framework

As of 1 July 2013, the Republic of Croatia became a member of the European Union. During the process of negotiation for the accession, the Republic of Croatia harmonised its legislation with that of the European Union and started with deployment of corresponding systems. The most significant step in the field of ITS legislation was made in the new version of the Act on the Amendments to the Roads Act, which was adopted by Croatian Parliament on its session on 19 April 2013. This refers primarily to implementation of the Directive 2010/40/EU of the European Parliament and Council from 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport. In accordance with Article 72.b of the same Act, the Government of the Republic of Croatia, at the proposal of the Ministry of Maritime Affairs, Transport and Infrastructure on 2nd. of July 2014. brought the National Programme for the development and deployment of ITS in road traffic on priority areas for 2014.-2018. time period, for planning of activities and projects and determining measures for implementation of the programme. Holder of activities for preparation and drafting of National programme was newly established National Council for the development and deployment of ITS in the Republic of Croatia.

4.3. Interests of Croatian industry

Latest progress in construction and modernization of highways and other infrastructure put the Republic of Croatia on the very top in the region considering the transport management system installed at highways and freeways. Modern transport-related information technology implemented to all Croatian highways and some freeways (region of Rijeka and Split) enables a continuous progress towards integration of transport infrastructure management. This can be considered as an important step in achieving harmonised transport management in the region.

Implemented technology is mostly produced by domestic industry which is the additional benefit from highway (or other transport infrastructure) construction and modernization – significant growth of small and medium enterprises related to telematic equipment, based on research and development, designing, manufacturing, implementation and maintenance of telematic systems for different purposes.

Technology for adaptive traffic signalisation and systems for centralized management are considered as the best example of verified and acknowledged products, not only in the region, but also on the global level. Some Croatian manufacturers are specialised in providing integrated technological solution for advance traffic management on highways, in tunnels or in the cities. Successful projects have been realised in Croatia and in more than 30 countries in the region and in the world.

ITS Development Strategy in Republic of Croatia, especially the development of ITS in the cities (adaptive traffic control, public transport management, parking lines management, intermodal transport in big cities and ferry ports, convoy management) is strongly related to the realisation of major projects in transport system management. This should enable further development of small and medium enterprises focused on manufacturing management systems and telematic equipment for these purposes.

4.4. SWOT analysis

Taking into consideration current situation of ITS development in the European Union and the Republic of Croatia, SWOT analysis was performed, and its results presented in Table I.3.

Table I.3. SWOT analysis

Strengths	**Weaknesses**
- the Republic of Croatia has the ability to develop new ITS applications and services, - transport telematics industry in the Republic of Croatia has good experience in technology and equipment development, - leading road infrastructure operators have very good experience in this area, - there is a high level of education in the field of ITS.	- in the previous period there were no clearly defined politics and strategies in ITS development and deployment, - insufficient coordination of different bodies in charge of transport, - ITS development has been aimed at fragmentary low level applications, which resulted in the lack of effective integration between the systems, - the existing approach resulted in high equipment maintenance costs, - the former approach to design of these systems did not take ITS features into consideration,

	- small number of domestic research and development projects, especially the ones stimulated by the economy and infrastructure owners.
Opportunities	**Threats**
- Croatia lies on very important South-East Europe traffic corridors, - reduction of traffic jams and delays, improvement of traffic flows through integration of traffic management and passenger information exchange systems, - domestic ITS scientists and experts have better understanding of local traffic problems, limitations and behaviours, - possibility of providing advanced ITS services for incident management on motorways, - ITS has potential for improvement of road safety through better utilization of different technologies of legislation implementation (detecting of offences), - ITS has significant potential for roads safety improvement (especially significant for improving the country image from the tourist aspect, since tourism is one of the most significant economic sectors), - ITS provides solutions for small towns on the Adriatic coast with pronounced traffic problems during the tourist season, - ITS as an export industry.	- financial crisis and problems of domestic economy and industry, - restructuring of the largest motorway concession holders (monetization project), where all consequences for the development and the deployment of ITS cannot be predicted, - ministries, government agencies and concession holders are interested only in goals of their own organisations, and not in interagency coordination and resource distribution, - the existing Public Procurement Act is not suitable for ITS projects because it is based more on technological specifications than on functional requirements, - ITS develops quickly in Europe, and Croatia has difficulties in adjusting to technological changes.

5. NATIONAL PROGRAMME FOR THE DEVELOPMENT AND DEPLOYMENT OF ITS IN ROAD TRANSPORT 2014-2018

The basic objective of this part is to give an overview of planned development and deployment of ITS in Croatia, in accordance with the National Programme for the development and deployment of ITS in road transport 2014-2018 adopted at the 172nd session of the Croatian Government on 2nd. July 2014. The four main strategic objectives are described: Road traffic safety and security, Improving the efficiency of the road transport system, Sustainable mobility in cities and ITS industry development. In accordance with the strategic objectives, five national priority areas are defined, which are related to the European priority areas. The description of the proposed measures necessary to ensure effective way to achieve the aforementioned strategic objectives is given. The measures are defined within individual European priority areas and particularly for national priority areas.

5.1. STRATEGIC GOALS OF ITS IMPLEMENTATION IN REPUBLIC OF CROATIA

In defining the strategic objectives of ITS deployment in the Republic of Croatia for the period 2014-2018, the following was taken into account:

a) Needs for the systematic deployment of Intelligent transport systems, arising from the characteristics of its road transport system, arising from the characteristics of its road transport system, the needs for the Croatian economy and the strengthening of the industrial sector in the technologies used in Intelligent transport systems,

b) Obligations towards the European Union, primarily in the area of cross-border availability of road, traffic and travel data services to the European Union, primarily for the neighboring Member States. In addition, special attention was paid to facilitating cross-border electronic exchange of data between relevant government agencies and stakeholders and relevant service providers ITS.

Within the framework of the National Programme for the development and implementation of ITS in road transport 2014-2018 are forseen four (4) strategic objectives:

Strategic Objective 1. - Road traffic safety and security

The National Road Traffic Safety Programme of the Republic of Croatia 2011-2020 has defined a vision of road traffic safety through a drastic reduction in mortalality rate and serious traffic injuries, reducing the high cost of traffic accidents, improved health and quality of life, and ensure a safe and sustainable mobility. As a quantitative target for that period (2011-2018) it is planned to reduce the number of deaths and injuries in road accidents by 50%. In this respect, following the policies and appropriate guidelines of the European Union, one of the strategic objectives of the National Programme for the development and deployment of ITS in road transport 2014-2018 is to raise the level of road safety.

In recent years, and especially with the Croatian accession to the European Union, the protection of participants in road traffic is becoming increasingly important . Besides standard protection functions of users in road traffic and the protection of critical road infrastructure, one of the priority measures of the ITS Directive is providing the information services for safe and secure parking places for trucks and commercial vehicles, as well as possibilities for the corresponding reservations.

Strategic Objective 2. - Improving the efficiency of the road transport system

In the introductory part of the National Programme it is shown that one of the fundamental reasons for development of ITS in the European Union was observed problem of efficiency of the road transport system. Systematic research in the field of efficiency estimation of its road transport system was not done in the Republic of Croatia, but it's to be assumed, that it is a lot less effective than in the rest of the European Union. Some experts conclude that a significant part of the national economy is lost in inefficiencies in the overall transport system. Past experiences have shown that the use of well-known ITS measures in this area gives significant results in improving the overall efficiency of the road transport system. In fact, with the deployment of new ITS solutions through individual specific systems, applications and services, we should strive for them to be effective and efficient.

Strategic Objective 3. - Sustainable mobility in cities

As part of this strategic objective are scheduled measures for the improvement of public transport system which has the following positive effects:

- increase of attractiveness of public transport (eg. giving priority to public transport vehicles in the city road network, advanced billing systems of transportation, etc.)

- managing transport demand (eg. system of congestion charging, charging for passing through certain urban areas at certain time, etc..)

- reduce greenhouse gas emissions (eg. using more efficient traffic management in cities).

This strategic objective is primarily intended for solving accumulated problems in urban transport of major cities and specific problems of traffic in tourist destination.

Strategic Objective 4. - ITS industry development

One of the significant possibilities of development and deployment of ITS in the Republic of Croatia is the encouragement of appropriate industrial sector (road telematics systems, the software industry, electronics, etc..). This is one of the fundamental objectives of the European Union in the field of ITS. On this basis it is possible to create new jobs with high added value. The prerequisite for these activities is to better connect the industry with research and development capabilities of the Republic of Croatia (e.g. higher education institutions, institutes, R & D companies, etc..).

Within the framework of the National Programme for the development and deployment of ITS in road transport 2014-2018 are envisioned five (5) national priority areas:

a) National Priority Area 1.: Road traffic safety management

b) National Priority Area 2.: Transport demand management and multimodality

c) National Priority Area 3.: Traffic management in cities

d) National Priority Area 4.: Raising the level of transport services to support the Croatian tourism

e) National Priority Area 5.: Improving maintenance of roads supported by ITS applications

Relation of certain strategic objectives, national priority areas and European priority areas (ITS Directive) are shown in Fig. I.3.

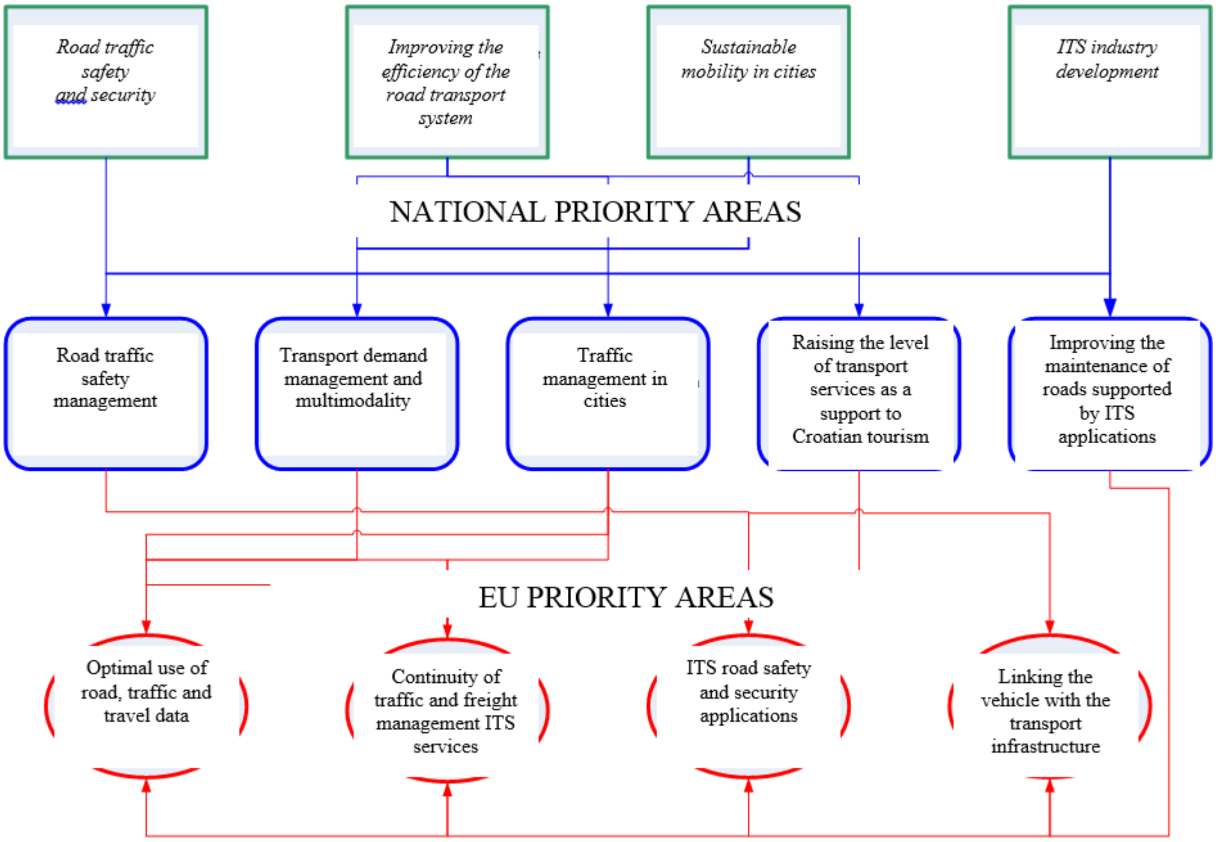

Fig. I.3 - National strategic objectives, national priority areas and their connection to the EU priority areas

5.2. PROPOSAL OF MEASURES FOR THE DEPLOYMENT OF ITS

An integral part of the National Programme are appropriate measures, which ensure more effective implementation of priority activities and some of the planned projects. They were established on the basis of defined national strategic objectives and European and national priority areas. At the time of their defining period, the experience of the past development of ITS in Croatia, and some of the European experience were used.

The following measures have been proposed within the priority areas:

1. Optimal use of road, traffic and travel data;

M.1.1. Establishment of free access to and a market of real-time traffic and travel data, which will enable access to this information to interested service providers in this area (web portal with a defined interface).

M.1.2. Defining procedures for optimal use of and access to map-related road data

M.1.3. Preparation of guidelines for the provision of multimodal traffic information in Croatian cities and regions

M.1.4. Implementation of advanced systems of pre-travel and travel information and traffic management in larger Croatian cities

M1.5. Preparation of guidelines for implementation of ITS applications and services in tourist locations on the Adriatic

2. Continuity of Intelligent transport systems services in traffic and freight management;

M.2.1. Development of the National ITS framework architecture

M.2.2. Defining the organisational model for the National (Road) Traffic Management Centre and the corresponding business models

M.2.3. Development of the national system and procedures for traffic management in emergency situations

3. ITS road safety and security applications;

M.3.1. Establishment of an information system with data concerning road traffic safety and security free of charge to end users

M.3.2. Implementation of the motorway safety management system

M.3.3. Establishment of the eCall system in Croatia

M.3.4. Establishment of the system of information services for safe and secure parking places for trucks and commercial vehicles and the corresponding reservations system

M.3.5. Launching research projects from the field of road safety management Research on the road safety local (national) characteristics.

M.3.6. Establishment of the National centre for operator training for traffic management and traffic incident management

4. Linking the vehicle with the transport infrastructure

M.4.1. Launching of the national programme for the monitoring of application of cooperative systems in road traffic in the European Union

M.4.2. Launching of research projects from the field of cooperative systems

5. National priority areas

M.5.1. Development of financing models for the establishment of particular ITS solutions

M.5.2. Promotion of public-private partnership in the field of implementation of ITS solutions in Croatia

M.5.3. Measures for stimulating the R&D sector in the field of ITS

M.5.4. Improvement of the road telematics equipment maintenance as an important part of the ITS

M.5.5. Development of efficient lifelong learning in the field of ITS for different users

M.5.6. Strengthening the coordination between key stakeholders in the field of ITS

6. CONCLUSION

Term „Intelligent Transport Systems" has been introduced in transport and traffic engineering during the 1990s, and can be defined as holistic, control, information and communication upgrade to classical transport and traffic systems enabling significant improvement in performance, traffic flow, efficiency of passenger and goods transportation, safety and security of transport, reduction of pollution, etc. Quality of implementation of Intelligent Transport System is primarily based on harmonization and possible integration of individual solutions into integrated systems. Achievement of that is related to design of the basic organization so called ITS Architecture and definitions of the necessary standards by official organisations. Background for Architecture and standardization development in modern society can be usually found in legal documents of individual countries or international organizations.

The European Union created a legal framework for ITS development based on the recognition of ITS advantages and need for an EU wide harmonized development. First legal documents were related to specific solutions, but during the first years of the 21^{st} century, general legal acts for each mode of transport were prepared. Adoption of legal document is, however, only the first step which is followed by standards adoption and activities realisation in deadlines that need to be respected. The legal document is often followed by Work plans or Communications dealing with its implementation. According to the EU legislation, the main reasons for ITS introduction are: improving safety, improving efficiency, reducing pollution and enabling interoperability between different systems.

In order to achieve harmonization of transport system with the European Union (which is one of the most important tasks), the Republic of Croatia should focus on the development of optimal ITS architecture (Framework Architecture, Mandated Architecture, Service Architecture). A possible solution is to take into consideration a wider approach – regional ITS architecture, [15, 16]. New Transport Strategy of Republic of Croatia is expected to be prepared soon and in the course of preparation adequate inclusion of ITS, based on EU experience, should be required.

7. REFERENCES

[1] Bošnjak, I., Intelligent Transportation Systems 1., (in Croatian), Faculty of Traffic Science, Zagreb, 2005.

[2] Mandžuka, S., Intelligent Transportation Systems 1., (in Croatian), Faculty of Traffic Science, Lectures, Zagreb, 2010

[3] Horvat, B., Directives of the European Union in the field of ITS, (in Croatian), BSc Thesis, Faculty of Traffic Science, Zagreb, 2011.

[4] Yokota, T., Weiland, R., ITS System Architectures For Developing Countries, Technical Note 5, Transport and Urban Development Department, World Bank, 2005.

[5] http://www.frame-online.net – March, 2011 – Why you need an ITS Architecture

[6] The Intelligent transport systems (ITS) practioners' guide to Europe, RTI Focus, London, 2011.

[7] Action Plan for the Deployment of Intelligent Transport Systems in Europe, COM (2008) 886 final, 2008.

[8] Directive 2010/40/EU of the European parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, Official Journal of the European Union, 2010., L 207, 1 – 13.

[9] Communication from The Commission to The European Parliament and The Council on the deployment of the European Rail Signalling System ERTMS/ETCS, COM(2005) 298 final, 2005.

[10] Council Regulation (EC) No 219/2007 of 27 February 2007 on the establishment of a Joint Undertaking to develop the new generation European air traffic management system (SESAR), Official Journal of the European Union, 2007., L 64, 1.-10.

[11] Directive 2002/59/EC of The European parliament and of The Council of 27 June 2002 establishing a Community vessel traffic monitoring and information system and repealing Council Directive 93/75/EEC, Official Journal of the European Union, 2002., L 208, 10 – 27

[12] Directive 2005/44/EC of The European Parliament and of The Council of 7 September 2005 on harmonised river information services (RIS) on inland waterways in the Community, Official Journal of the European Union, 2005., L 255, 152. – 159.

[13] http://www.strategija.hr – April, 2011.

[14] Mandžuka, S., Intelligent Transportation System - Experiences in Republic of Croatia, (in Croatian), ITS Workshop, Ministry of Sea, Transport and Infrastructure, Zagreb, 2009.

[15] Bošnjak I., Mandžuka, S., Šimunović, Lj., Concept and Implementation of regional ITS Architecture, (in Croatian), V. Croatian Road Congress, Cavtat, 2011.

[16] Mandžuka, S., Electronic Payment in Traffic and Transport - Challenges and Perspectives of Regional Development, (in Croatian), 6th ITS Croatia Forum, Zagreb, 2011.

[17] National Programme for the development and deployment of ITS in road transport 2014-2018, (NN 82/2014), 2014.

II. ROAD WEATHER INFORMATION SYSTEM

1. INTRODUCTION

Road weather monitoring is essential for traffic because ambient conditions have considerable influence on safety, functionality and efficiency of road traffic. Therefore, the monitoring system has to be set-up on the elements that enable fast exchange of information and good response. There are many scientific papers with examples that prove the importance of meteorological information in the traffic. Road Weather Information Systems are also very important part of Intelligent Transportation Systems.

The Croatian roadways agency Hrvatske caste Ltd. (HC) installed a series of road weather monitoring stations in the arterial road routes and in the Croatian regions that have challenging winter conditions. Data on specific ambient conditions measured at the stations is used to support scheduling and optimizing winter maintenance activities and to enhance road safety. All weather data is automatically collected at the Information Center of HC and is distributed to headquarters and regional winter maintenance centers. The information on weather conditions on a specific road route enables scheduling of maintenance actions to be taken to ensure road safety and mobilization of winter maintenance operative forces, but also to enable timely clearing of snow and de-icing chemicals spreading, issuing alert information to the travelling public etc. The primary objective and purpose of the project is to assist in winter maintenance operations. This implies the use of pavement sensors at main and auxiliary weather monitoring stations, the collecting of ambient data from the pavement, the development of prognostic software, the interpretation adequate for the field-use and the incorporation of weather information system in standard procedures of winter maintenance providers.

2. SYSTEM DESCRIPTION

Main road weather monitoring station collects general data on weather and pavement condition continually. The data measured at selected micro-locations is as follows: temperature, relative humidity of air and dew point temperature; wind speed and direction; air pressure; quantity, intensity and type of precipitation; visibility; pavement temperature; pavement condition, residual salt, ice point temperature etc.

Auxiliary road weather monitoring stations collects additional weather data continually and reports them to variable message signs that display advisory messages on challenging driving conditions to travelling public. The data measured at any micro-location is as follows: air temperature; dew point temperature; relative humidity of air; pavement surface temperature.

Central control centre consists of communication and application servers with an Oracle data base, connected through the local Ethernet network. The application server is in the network together with operator workstations – clients that use installed user software to retrieve data from the Oracle database. Data on the application server may be accessed by Local computer network, or modem / ISDN/ Web.

Configuration of the system has been designed at the dual interface of data and communication servers with the large data quantities long-term storing system, as shown in Fig. II.1.

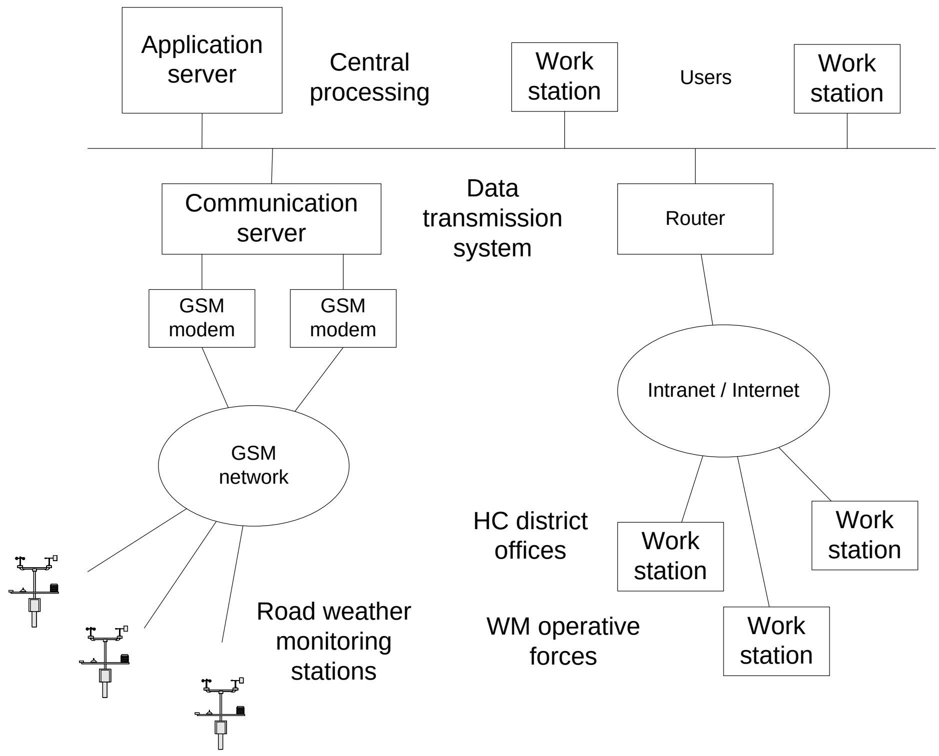

Fig. II.1. - The system configuration

The development of prognostic models for road meteorology has been described by substantial indeterminacy in initial and marginal conditions and difficulties in complex topography for specific areas. Additional problems in prognostic models of pavement surface temperature are seen in the complex and unknown mechanisms of impacts created by traffic characteristics, in the frequency of snow cover, on the previous spreads of salt and other spreading materials. This is a typical situation to be approached by artificial intelligence methods, in particular techniques based on the application of artificial neural networks (ANN). The technology has already become mature and is now widely applied in commercial systems. Significant results have been achieved in traffic and transport applications.

The main idea behind the use of the technology is to correct a prognostic system based on deterministic forecast resulting from thermodynamic modeling of pavement (energy balance). The correction is based on artificial neural network (usually three layers) that has been learned in previous measurements of pavement surface temperature. The artificial neural network that has acquired the knowledge in a proper manner is capable of identifying the size and form of an error in basic prognostic system for specific weather conditions. In such a way the forecasts of ice formation on pavement may be enhanced.

3. SYSTEM SOFTWARE

The system software of the central information system includes a series of software modules for processing of data collected from road weather monitoring stations, meteorological data base with data surveyed, prognostic models, reports and display of collected information to road users. The main components of the system software are:

a) Software for data collection and data display:

1. communication drive software
2. software for polling of stations (universal polling for main and auxiliary stations, VMS and additional panels) and collecting of real-time data in the process base with transmission to Oracle base
3. data display software – browsers (clients) for unlimited number of users in the local network and remote users

b) Control algorithms and decision models for control of variable message signs and additional panels

c) Analysis of data obtained, incorporation of other sources of data (CNMHS) and prognostic models for short-range forecasts (1-2 hours) of the road weather conditions. The structure of system software is shown in Fig. II.2.

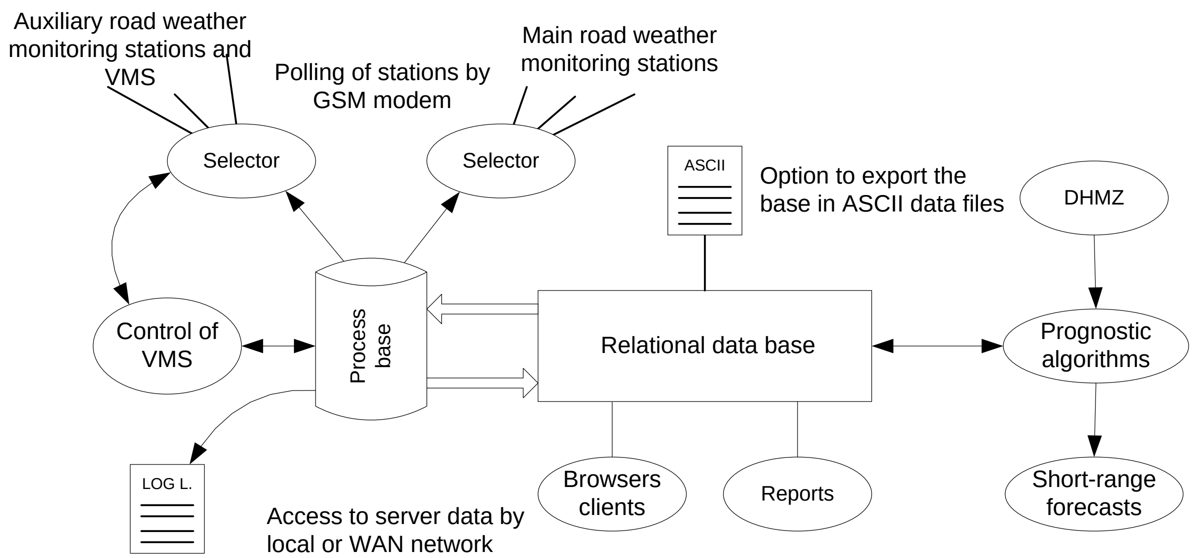

Fig. II.2. - System Software Structure

4. USER INTERFACE

Efficient user interface is an essential component of the system. The interface has to be tailored to the specific user needs and it has to take into account actual possibilities to interpret the weather data collected. Accordingly, the interpretation of the data on roadway conditions and recommendations for activities to be taken are quite simple in order to serve the needs of winter maintenance staff. The common questions used in routine winter maintenance operations are summarize as:

1. Is there any ice on the pavement?
2. When will the ice formation start on the pavement?
3. Where has the ice been detected, at which sections?
4. What to do, which activities to take?

Road weather information system uses warnings and alerts and thermal maps of the region to give response and information to assist the winter maintenance operations, as follows:

Precipitation – warning:

- There was precipitation (rain, snow), ice formation possible - pavement temperature close to or under 0ºC!

Frost – warning:

- Frost on pavement present or may appear!

Ice – warning:

- Ice will be formed in 1 to 2 hours!

Ice – alert

- Pavement temperature is under 0ºC, ice has begun to form!

Thermal maps of the area:

-Presentation of thermal colder and warmer sections, condition evaluation, recommendations for decisions on salt spreading.

5. USE THE ARTIFICIAL NEURAL NETWORK FOR SHORT RANGE FORECASTS

The development of prognostic models for road meteorology has been described by substantial indeterminacy in initial and marginal conditions and difficulties in complex topography for specific areas. Additional problems in prognostic models of pavement surface temperature are seen in the complex and unknown mechanisms of impacts created by traffic characteristics, in the frequency of snow cover, on the previous spreads of salt and other spreading materials [8]. This is a typical situation to be approached by artificial intelligence methods, in particular techniques based on the application of artificial neural networks (ANN). The technology has already become mature and is now widely applied in commercial systems. Significant results have been achieved in traffic and transport applications [9].

The main idea behind the use of the technology is to correct a prognostic system based on deterministic forecast resulting from thermodynamic modeling of pavement (energy balance). The correction is based on artificial neural network (usually three layers) that has been learned in previous measurements of pavement surface temperature. The artificial neural network that has acquired the knowledge in a proper manner is capable of identifying the size and form of an error in basic prognostic system for specific weather conditions. In such a way the forecasts of ice formation on pavement may be enhanced [8]. A simple solution model of forecast corrections is based on static artificial neural network with dynamics added from outside (Fig. II.3), [10].

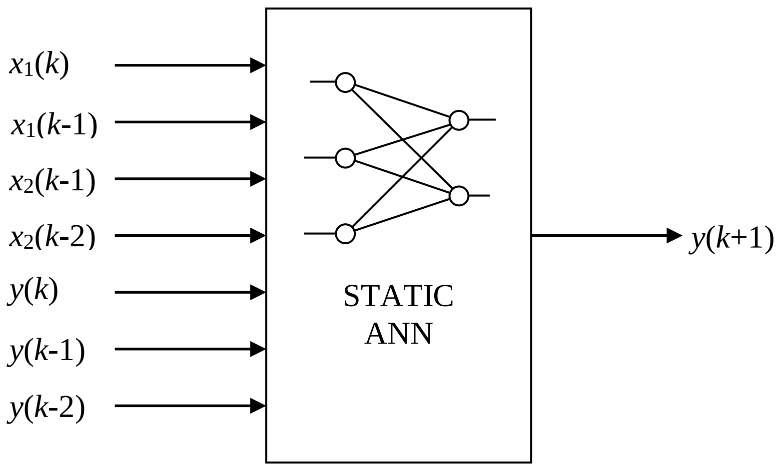

Fig. II.3. - Simple ANN for pavement surface temperature forecast

Some preliminary input information for ANN is presented on Tab. II.1.

It has to be mentioned that good knowledge of background of physical processes is a precondition for the selection of neural network structure, the procedure of learning and the interpretation of results. Some experiences have indicated that the increase in accuracy depends on a specific location and on a time interval segment (time of day). The main problem in neural network learning is local optimum traps.

Tab. II.1. Configuration of ANN inputs

No. of inputs	Symbol	Description	Relation
1	Ts	Time (hour) of day	sin(t)
2	Tc	Time (hour) of day	cos(t)
3	F_e[k-1]	Forecast error 1 h earlier	T_s[k-1]- T_f[k-1]
4	F_e[k-2]	Forecast error 2 h earlier	T_s[k-2]- T_f[k-2]
5	F_e[k-3]	Forecast error 3 h earlier	T_s[k-3]- T_f[k-3]
6	V_s[k-1]	Variation of surface temperature 1 h earlier	T_s[k-1]- T_s[k-2]
7	V_s[k-2]	Variation of surface temperature 2 h earlier	T_s[k-2]- T_s[k-3]
8	D_s[k-1]	Derivative of surface temperature variation	V_s[k-1]- V_s[k-2]
9	V_{ss}[k-1]	Variation of subsurface temperature 1 h earlier	T_{ss}[k-1]- T_{ss}[k-2]
10	V_{ss}[k-2]	Variation of subsurface temperature 2 h earlier	T_{ss}[k-2]- T_{ss}[k-3]
11	D_{ss}[k-1]	Derivative of subsurface temperature variation	V_{ss}[k-1]- V_{ss}[k-2]
12	V_a[k-1]	Variation of air temperature 1 h earlier	T_a[k-1]- T_a[k-2]
13	V_a[k-2]	Variation of air temperature 2 h earlier	T_a[k-2]- T_a[k-3]
14	D_a[k-1]	Derivative of air temperature variation	V_a[k-1]- V_a[k-2]
15	V_d[k-1]	Variation of dewpoint 1 h earlier	T_d[k-1]- T_d[k-2]
16	V_d[k-2]	Variation of dewpoint 2 h earlier	T_d[k-2]- T_d[k-3]
17	D_d[k-1]	Derivative of dewpoint variation	V_d[k-1]- V_d[k-2]
18	V_{sa}[k-1]	Difference of surface and air temperatures 1 h earlier	T_s[k-1]- T_a[k-1]
19	V_{ssa}[k-1]	Difference of subsurface and surface temperatures 1 h earlier	T_{ss}[k-1]- T_s[k-1]
20	V_{ad}[k-1]	Difference of air temperature and dewpoint 1 h earlier	T_a[k-1]- T_d[k-1]
21	MW3	Mean wind speed for the last 3 h	(W[k-1]+ W[k-2]+ W[k-3])/3
22	SMWD3	Mean wind direction for the last 3 h:	sin[(WD[k-1]+WD[k-2]+ WD[k-3]*)/3]*
23	CMWD3	Mean wind direction for the last 3 h	cos[(WD[k-1]+WD[k-2]+ WD[k-3]*)/3]*
24	RSS[k-1]	Road surface state (dry, wet, icy, etc.) 1 h earlier	RSS[k-1]

6. COOPERATIVE ROAD WEATHER MONITORING STATION

6.1. COOPERATIVE SYSTEMS IN TRAFFIC AND TRANSPORTATION

Cooperative Systems are important component of the intelligent transportation system architecture. It enables a driver (or its vehicle) to communicate with roadside equipment or other drivers (or their vehicles), [12]. As a result, this information can help improve the road traffic safety and efficiency. The general architecture of cooperative system network is presented on Fig. II.4.

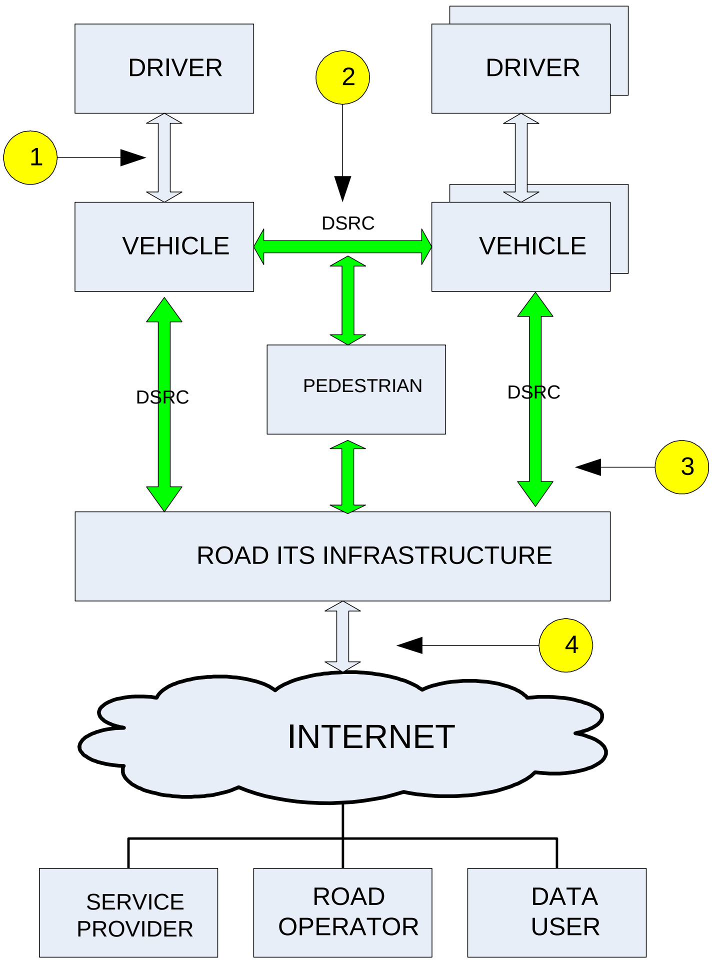

Fig.II.4 - General Concept of Cooperative Systems

Cooperative system networks are composed of mobile nodes, vehicles equipped with On Board Units (OBU), and stationary nodes called Road Side Units (RSU) attached to infrastructure that will be deployed along the roads. Also, there are some ideas for movable pedestrian equipment, especially for Vulnerable Road User (VRU). Both OBU and RSU devices have wireless/wired communications capabilities. OBUs communicate with each other and with the RSUs in ad hoc manner. There are mainly two types of communications scenarios in vehicular networks: Vehicle-to-Vehicle (V2V) and Vehicle-to-RSU (V2R), [13, 14]. The RSUs can also communicate with each other and with other networks like the internet by its users (service providers, road operators, other traffic data users) as shown in Fig. II.4.

6.2 ROAD WEATHER MONITORING STATION

Road weather monitoring station consists of multiple sensors that collect data of atmospheric conditions such as air temperature, visibility, air pressure, wind speed and direction, relative air humidity, quantity and type of precipitation, Fig. II.5. Also the station collects data of road conditions such as surface temperature, temperature beneath the surface. Also it can detect a difference between dry, wet or ice covered surface and it can measure water film thickness.

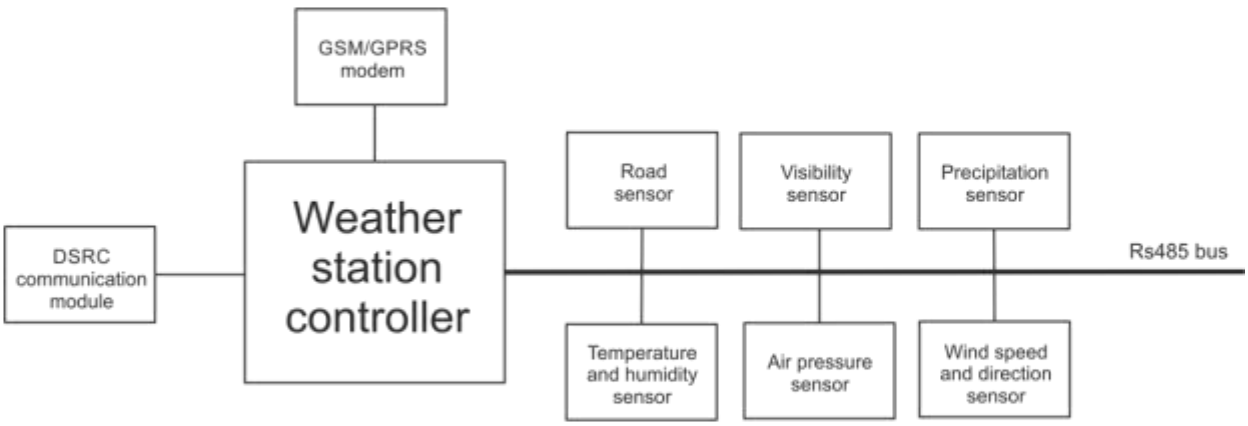

Fig. II.5. - Weather station block diagram

The central component of the weather station is the controller to which are sensors connected. The main task of the controller is to collect data from the sensor, log the data locally and send a data to the central weather server in regular intervals. For connecting sensors there are several different ports available. These ports can be configured as 2-wire RS485 or RS232 ports. There are also available ports for connecting sensors with current output (4-20mA) and voltage output (0-5V). Whole system can be powered from the local power grid but in the absence of the mains power connection it can be powered from the batteries that are charged via solar panels. In that case the controller is equipped with power monitoring board which monitors several crucial parameters of the system such as battery voltage, charging current, load current etc. If the batteries got over discharge the controller sends a warning message to the central server and in that case the maintenance service can react and change the discharged battery on the site. In order to the controller to send the data to the server it must be equipped with some kind of communication module. This communication module can be connected directly to dedicated local, in most cases optical, network that is connected to the monitoring center. In the other cases where local network is not available communication module could be a GSM/GPRS (or faster 3G, LTE) module. In the last case if we have more than a few weather stations and other smart traffic infrastructure we can have a dedicated short range communication between them and in the end one of them (could be a weather station, but it can be a separate dedicated device) has a direct connection to the monitoring center.

In the beginning of the last section are listed weather and road conditions that can be measured with this weather station. In the following section is going to be described configuration and types of the sensors which are used to measure these conditions. For measurement of these conditions will be described five different devices.

First device is for measurement of air temperature and relative humidity. For the air temperature is usually used some kind of resistance temperature detectors with positive (PTC) or negative temperature coefficient (NTC). Also there is available some semiconductor type of temperature sensors, but they usually have a slightly worse characteristics than the resistive types.

For the humidity in this case is used capacitive MEMS (microelectromechanical system) sensor. Both of these sensors (temperature and humidity) are connected to the electronics for attenuation and conditioning. Later on these prepared signals are sent to AD converter and later prepared for the output. As mentioned the output can be digital (RS485, RS232) or analog (current output, voltage output). Same technology (MEMS) is used for air pressure sensor.

Wind speed and wind direction can be measured with electromechanical sensors such as cup anemometer and wind wane or just with ultrasonic sensor. Cup anemometer has a three or four cups that transform wind into rotation of the axle on which end is mounted relative encoder. Depending on wind speed there is more or less pulses for controller to count and there is connection between wind speed and frequency of the pulses. Wind wane has a similar principle as cup anemometer but instead of relative encoder it has absolute 5-bit gray code encoder. In this case controller just need to readout the value of the absolute encoder. On the other hand the ultrasonic sensor is more reliable in the winter conditions because there is no moving parts which can froze in the low temperatures. It uses in the measurement two pairs of ultrasonic transceivers: one for the x axis and another for the y axis. Disadvantage of this kind of sensor is lower accuracy in the condition of extensive precipitations.

Precipitation sensor can also be very simple like tipping bucket but also complicated like Doppler radar. Tipping bucket is accurate way to measure rain but it cannot recognize the difference between snow and rain. Also there is a problem with freezing during the winter so it is not maintenance free. Doppler radar can recognize snow from rain and there are fewer problems with the freezing during the winter but in some condition on the road can sometime give a false measurement especially when is mounted incorrectly.

The data from visibility sensor is crucial for detecting the road conditions because the reduced visibility can produce all sorts of dangerous scenarios in traffic. Visibility sensors are using a forward scattered light procedure for estimating visual range of human eye. Sensor contains receiver and transmitter, usually an infrared diode and photo transistor on the other side. The transmitter and receiver are not turned to each other directly but they are turned for a certain angle in relation to horizontal line. After the fog is formed in the front of the sensor reflected light beams from the transmitter are detected by receiver. The amount of the reflected light beams is inversely proportional to visibility measurements. The more beams are reflected the worse are the road conditions. Usually the measurement range is 10 to 2000 meters [4] but there is on the market products for measurements up to 35000 meters [5].

The road sensor is like the visibility sensor very important for measuring road conditions. Also this sensor will be the theme of the future studies so here is going to be explained some principles that are used for building prototype. The goal of the research is to achieve the similar or better results than the sensors developed in the past and improve the algorithms for detecting the road conditions. Road sensor can be divided in two functional units. The first one is for temperature measurement. It can have one or several temperature sensors: one for the surface temperature and the others are for measurement of temperature beneath the surface. The temperature beneath surface can be useful because it can be indicator when or how long is going to be ice on the road. For example in conditions of low temperatures the ice can form very quickly on the surface but is the temperature beneath surface is over the freezing temperature it will melt faster when the outside temperature rises. The temperature sensors and the measurement principle is the same as was described for the air temperature sensor so additional explanations are not necessary. Second functional unit are the modules for detecting road conditions. For this purposes the sensor measures conductivity and capacity on the road surface. With conductivity measurements the sensor can detect the liquids on the road surface and detect a certain amounts of chemicals in the liquids. Capacity is measured at two different frequencies f and f/2 and the data is used to improve the results which sensor acquired with conductivity measurements. The goal with fusion of this two sensors, temperature sensor and learning algorithms will be to detect road conditions such as dry, wet, ice, black ice. Also it could be estimated water film thickness and chemical concentration. In this first stage in the prototype will be integrated micro radar for detection of water film thickness for comparing estimated results with measured results.

6.3 ROAD WEATHER INFORMATION SET FOR DRIVER

Road weather information collected from weather station is sent to central data acquisition server and the data is also stored locally at the weather station. Data on the weather station is processed locally and information about possible bad weather is sent to oncoming vehicles to avoid vehicles entering a bad weather area at high speed or without winter equipment [15]. To make it possible to send data to the vehicle weather station is equipped with some short range communication module. Also the protocol between vehicles and infrastructure needs to be developed and maybe the most important part is presentation of the data to driver. Communication module will have separate section further in this paper so here is going to be presented more about presentation of the collected data.

The goal is to present data to driver clearly and on time. There is two ways to present data to driver. The first one is concise and simple and its task is to warn the driver fastest way possible that driver can undertake necessary actions without endangering the other members in traffic. Proposed appearance of the weather warning icon is shown on the Fig. II.6.

Fig. II.6. - Proposal for weather warning icon, [15]

It is also possible to show some sort of text warning near the weather warning icon to emphasize the type of weather and the distance to the bad weather area. The warning could be presented on car console, near other informational icons, on screen of the trip computer or on the head-up display (HUD). Also it can be implemented some discrete sound indicators that will ensure that driver notices the weather warning icon. The second type of presentation is extended. This type of presentation presents full data from weather station. The driver can choose from the menu in the car trip computer is going to be presented on the screen. After the driver notices weather warning icon and see extended information about the weather can decide to change a route or adapt to new weather conditions. Use case diagram for road weather exchange information procedure is presented on Fig. II.7.

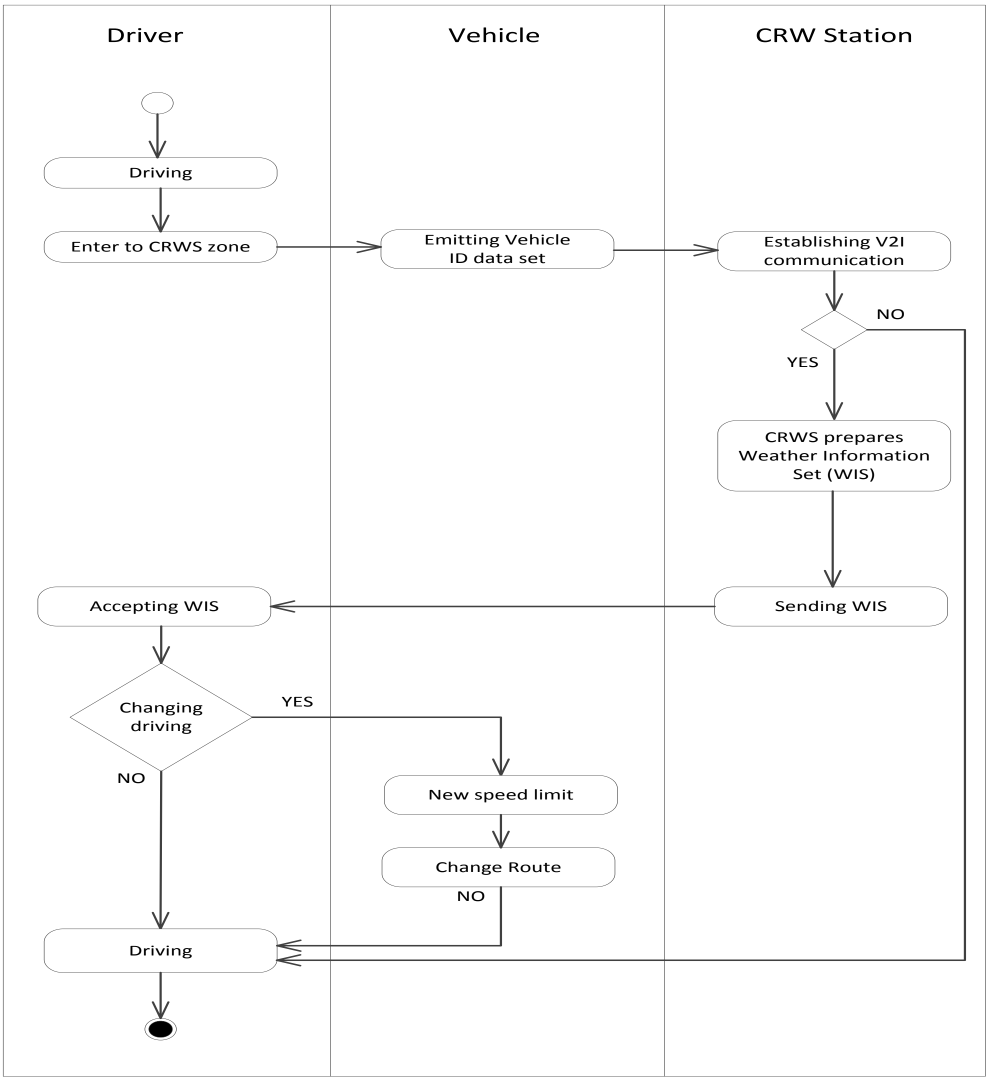

Fig. II.7. – Use case diagram

6.4 COMMUNICATION MODULE

As mentioned before weather station must have some sort of DSRC module for communication with approaching vehicles. This DSRC network must meet some requirements that are specific for the vehicular environments such as fast reconnection, high interference environment, impact of weather conditions to range of the network. For that purpose the IEEE 802.11 standard body made an addition to existing 802.11 standards to meet these requirements. The full name of the new standard is 802.11p WAVE (Wireless Access in Vehicular Environments) [17]. This network is going to operate at 5.9GHz so for the foundation is taken IEEE 802.11a because this standard already operates at 5GHz so there is small amount of changes in the physical level of this standard. Another difference between these two standards is that IEEE 802.11p allocates 10MHz channel while IEEE 802.11a has 20MHz wide channel. In the proposition of the standard 802.11p has allocated seven of 10MHz channels where the two channels at the ends of the spectrum are used for special uses. The channel in the middle of the spectrum is used as control channel and the rest of the channels are used for general purpose.

Communication module will include IEEE 802.11p integrated transceiver connected with a general purpose microprocessor for data processing and communication with the other systems in the vehicle, Fig. II.8. For that purpose communication module must be equipped with bus connection capability like CAN, LIN or FlexRay transceiver. When connected the communication module can show as previously described the data from weather station.

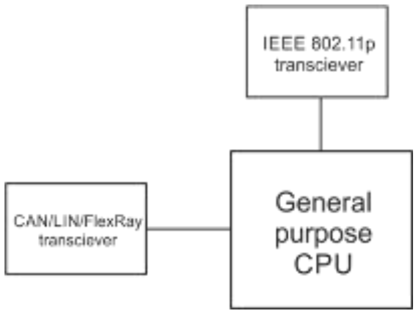

Fig. II.8.- Communication module block diagram

7. CONCLUSION

The accuracy of all conclusions on pavement condition relies on the accuracy of measurements. It is assumed that measuring methods used in the main and auxiliary weather monitoring stations are correct and that measuring that are conducted are accurate. Therefore, it is important to establish good cooperation with meteorology experts, especially in the identification of optimal micro-locations for stations and any future upgrading of the system. Functions and algorithms of the system have to be monitored and improved over a long period to improve safety and quality of data obtained and conclusions made. Besides, in future research and development advances special attention will be paid to those parts of algorithms that are related to short-range prognosis of pavement surface temperature. This is of particular relevance for contemporary use of Advanced Optimization Methods for Winter Services Organization, [11].

New cooperative approach for Intelligent transport systems development provides multiple opportunities in the development of new road weather equipments and system. Various useful information can be generated and transmitted between the roadside equipment and the vehicle. Many of today's complex pavement condition systems in the vehicle can be significantly simplified by transfer selected information from the road weather station to the vehicle. Significant research will be guided in the area of information presentation problem to the driver in the vehicle. Here we expect solutions from simple warnings to complex Advanced Driver Assistance Systems (ADAS).

8. REFERENCES

[1] Žibrat, Z., Tomšić, D., The Application of Road Weather Information System (in Croatian), Proceedings: Održavanja cesta 2006 – Zimska služba, Šibenik, 2006.

[2] Andrey, J., Knapper, C.K., Weather and Transportation in Canada. Department of Geography Publication Series, no. 55., 2003.

[3] Brijs, T., Karlis, D., , Wets ,G., Studying the effect of weather conditions on daily crash counts using a discrete time-series model, Accident Analysis & Prevention, Volume 40, Issue 3, 2008

[4] Mandžuka, S., Golenić, V., Močibov, B., Accurate meteo-information as critical elements of traffic safety (in Croatian), Proceedings: Medical, technical and legal aspects of traffic safety, Croatian Academy of Science and Arts, Zagreb, 2009.

[5] Bošnjak I., Intelligent Transportation System 1 (in Croatian), Uneversity of Zagreb, 2007.

[6] TEB – Elektronika d.o.o.: Hrvatske Ceste Ltd. Road Weather Information System (in Croatian), Final Project, Zagreb, 2005.

[7] Golenić, V., Hrvatske Ceste Ltd. Road Weather Information System (in Croatian), Proceedings, Održavanja cesta 2006 – Zimska služba, Šibenik, 2006.

[8] Shao, J., Improving Nowcasts of Road Surface Temperature by a Backpropagation Neural Network, Weather and Forecasting, Volume 13, Issue 1, 1998.

[9] Mandžuka, S., Application of artificial intelligence in the Intelligent Transport Systems (in Croatian), ITS forum, Zagreb 2007.

[10] Mandžuka, S., Application of artificial neural networks in intelligent telematics, TEB Elektronika, Zagreb, 2010 (in Croatian)

[11] Mandžuka, S., Perković, A., Ivanković, B., The Use of Operations Research in Optimization of Winter Services (in Croatian), Proceedings, Održavanja cesta 2009, Šibenik, 2009.

[12] Mandžuka, Sadko; Golenić, Vladimir; Gojić, Marko., LOW-COST COOPERATIVE ROAD WEATHER MONITORING STATION // ., Andorra : PIARC, 2014. 222-222

[13] ICSI - Intelligent Cooperative Sensing for Improved Traffic Efficiency project, http://www.ict-icsi.eu/

[14] Mäkinen, T., Schulze, M., Krajzewicz, D., Gaugel, T., Koskinen, S., (2011), DRIVE C2X methodology framework, Version 1.0.

[15] -------, Operating Manual VS20-UMB Visibility Sensor, Luft

[16] -------, ROSA: User guide, Vaisala.

[17] Jiang D., Delgrossi, L., (2008), IEEE802.11p: Towards and international standard for wireless access in vehicular Environments, Vehicular Technology Conference, VTC Spring 2008.

III. PEDESTRIAN NAVIGATION

1. INTRODUCTION

It is necessary to ensure accessibility to the desired destination as well as freedom of movement and stay at the desired location for all people, regardless of whether they have some degree of disability or not. Accessibility is expressed in the degree to which the environment is available to most people. In the transport context, it usually means physical accessibility to transport means and facilities in open spaces, such as station, stop, station platform, parking, pedestrian crossings, pedestrian island, pedestrian square, street, path, park, playground, walking path, underpass, overpass, stairs, etc. However, pedestrians walk in confined, unfamiliar areas, where problems of finding a certain room in the stations exist, such as ticket-office, info stand, restaurant, university rooms (classroom, Secretariat), hospitals, health centers (physician's room), shopping centers, hotels (room number, floor, reception, lift, tickets, etc.)

The main goal of navigating visually impaired people in urban areas is to determine the position and reach the destination. For that purpose, the electronic positioning systems (GNSS) integrated with GIS are used. Because of problems with satellite navigation (the receiver must have a direct connection with the satellite), the navigation of visually impaired people in enclosed spaces is limited and unreliable. That is the reason why the local navigation is applied. In addition, some systems and technologies can only exist in open spaces, and some only indoors. Systems and technologies should be simple to use and maintain. In order to enable mutual communication between the systems, it is necessary to ensure appropriate communication protocol or standard.

2. NAVIGATION

The word navigation is derived from the Latin "navis" which means “ship“ and "agere" which means "to move" [1]. Until the 20th century, the concept of navigation is mainly used in maritime affairs, as a term for keeping ships at sea. Today the term is used or the purpose of guiding an entity towards a goal in other types of transport (on land indoors and outdoors, in air and water transport). The term "navigation" means directing the user towards its ultimate destination, i.e. finding a way in a potentially unknown environment. Exact object positioning and orientation are particularly important for navigation. For accurate positioning of pedestrians, various techniques (GPS, Assisted GPS, a variety of Wi-Fi technology, LBS) are used. Showing the position on the map is called mapping. Only when a place where a person is located is known, messages and various instructions can be sent to that person. The algorithm for routing users to the main destination is the main task of navigation. Orientation is the correct understanding and experience of spatial relations between one’s own position and relevant points in the environment.

3. OUTDOOR POSITIONING SYSTEM

3.1. TRADITIONAL NAVIGATION

In traditional navigation dead reckoning and piloting are used. When piloting, the current position is calculated using the horizontal angle between the object and the known reference point.

With dead reckoning (the actual computation), positions are calculated at each point of the movement or just at a few. It is the process of determining the position in relation to a known starting position, which must be known.

3.2. GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

GNSS (GPS, Galileo and GLONASS) are satellite navigation systems that consist of 3 segments:

- space satellites (24 satellites circling at an altitude of 12,000 miles ~ 20000 km above the ground)
- control segment (controls GPS satellites, giving them a fixed orbit and time information) and
- user segment (GPS receiver and antenna).

Fig. III.1. shows the components of the Global Navigation Satellite Systems

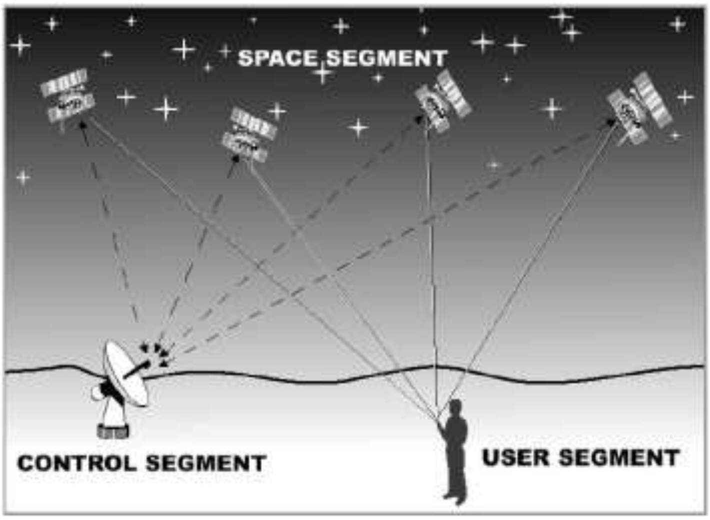

Fig. III.1. Components of the Global Navigation Satellite Systems (GNSS) [2]

GNSS provides information on the location, such as latitude, altitude and size (requires min. 3 satellites). GNSS works based on the signal propagation time (t - transmission signal, t - receiving the signal) and the speed of the spread of electromagnetic waves l = vxt). The accuracy of positioning using GPS is:

- 10 m - „OS“ (Open Service) mobile phone, PDA

- 1 m – „CS“ (Commercial Service) / ships / using reference stations for differential correction
- 1 cm - 1 mm „SOL“ (Safety of Life Service) services with increased security, static measurements, not available to everyone).

Accuracy of locating objects / subjects can be improved by using differential GPS (DGPS), as shown in Fig. III.2.

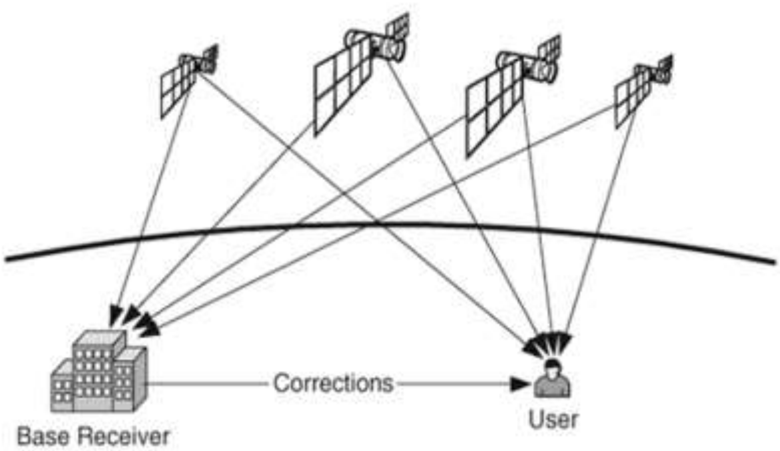

Fig. III.2. DGPS Correction

Although this system has enormous capabilities, it suffers from a number of problems. Different weather conditions can negatively affect the accuracy of the positioning of pedestrians. High buildings in densely populated areas and indoor areas are obstacles to signals from satellites so that the GPS receiving device can not always determine the exact location where the pedestrian is (see Fig. III.3.).

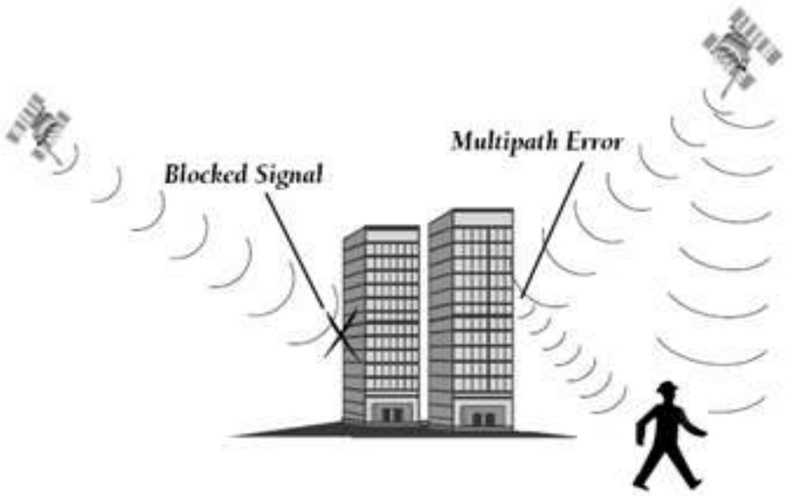

Fig. III.3. - Sources of GPS signal errors

Due to these reasons, GPS technologies are suitable for positioning outdoors, while the problem indoors can be solved by cell phone location technologies and other technologies by local navigation.

The successful application of GPS technology for positioning and monitoring the movement of pedestrians on a particular network or area is significantly improved by the use of GIS technology (Geographic Information System). Connecting GPS and GIS technologies into a single system provides the tracking of mobile objects / subjects in real time and displays the exact position of objects / subjects at the appropriate geographical map. The idea of the application of global positioning satellite and navigation of pedestrians is not new and it is now extensively used in developed countries. The interaction of pedestrians with this system begins by defining the destination. If the destination address is unknown, the system requires for it to be entered. Based on the known map, the path between two points is given. GIS tools can generate a walking path with respect to the shortest route, the safest way, comfort, or a preferred route can be insisted on (based on the preferences selected by the user: walking through the countryside, along the river, on better streets, beautiful facades, etc.). Avoiding certain locations is dictated by the needs of users (go to the store, stop by at a friend's place). After the recognition of the destination, the pedestrian hears the proposed plan and, if it is acceptable, a sequence of navigation and travel begins, as shown in Fig. III.4., [3].

Fig. III.4. Graphical interface for pedestrian navigation

3.3. CELL PHONE LOCATION TECHNOLOGIES

Cell phone location technologies are techniques for positioning of a cell phone or a pedestrian using radio network and additional features of cell apparatus. The operator knows the exact position of each base station and the size of the surrounding cells. When a cell phone is switched on, it sends an identification code to a base station, which enables the operator to determine the cell in which it is located. Position accuracy depends on the size of the cells and it is at least c2 / 2 at the time of entry of cell units in the area of base station b2. Accurate position, that is the distance of a d2 cell phone, can be determined based on the speed and the time needed to get the signal from base station b2 to the cell phone. More precise position of a cell phone can be calculated by combining the time of arrival of signals from base stations b1, b2 and b3 to the cell phone, which will improve the precision of locating cell phones. This positioning technique is applicable both indoors and outdoors. Fig. III.5. presents positioning using cell phone technique [4].

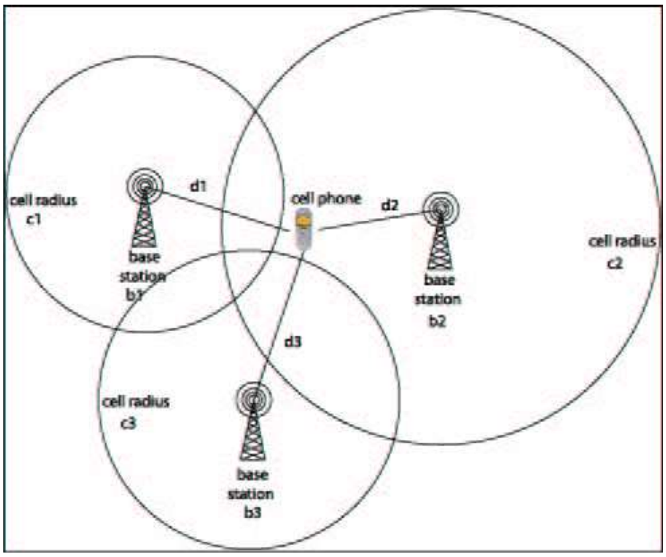

Fig. III.5. - Cell phone technique positioning

4. INDOOR POSITIONING SYSTEM

For indoor positioning mainly two groups of techniques are used. PVA group uses a dead reckoning technique (DR and allows the mobile system to calculate its position without the use of external information sources). Another group requires that the space in which a visually impaired person walks is equipped with additional hardware:

- Internal GPS (pseudo-satellite)
- Ultrasound sensor
- Infrared transmitter and receiver

Pseudo-satellite is installed on the ground and sends synchronized signals, as well as a satellite from space. Based on the knowledge of the exact position of a pseudo-satellite, it is possible with standard GPS receiver to determine the precise position of pedestrians in places where it is difficult to receive signals from GPS satellites. Pedestrian positioning accuracy can be increased depending on the number of pseudo-satellites (Fig. III.6.). This technology is very expensive [5].

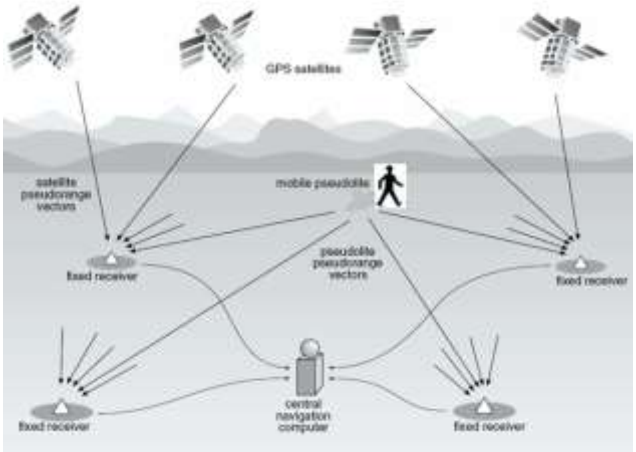

Fig. III.6. - Pedestrian positioning using GPS pseudo-satellites

4.1. INFRARED TECHNOLOGY FOR INTERNAL NAVIGATION

Infrared transmitters are installed at key locations and continuously transmit signals from base stations. When a user enters the area of mobile communication, the device is activated (vibrating or sound signals given). By pressing the appropriate button, the speaker is activated and the user gets the information that lead him towards the destination (Fig. III.7.).

Fig. III.7. - Establishment of communication between transmitter and user

Infrared transmitters send signals of a certain level, which are shaped like a cone. That means that the area of availability is discrete, as well as receiving of the information. The user searches the area by the receiver and intercepts the transmitted beam. When the receiver catches the beam, it appears as a voice message. As long as the user hears the message, he knows he is moving towards the adequate location. Cone beam becomes smaller and ends in a point which brings the user exactly at the desired destination (see Fig. III.8.) [6].

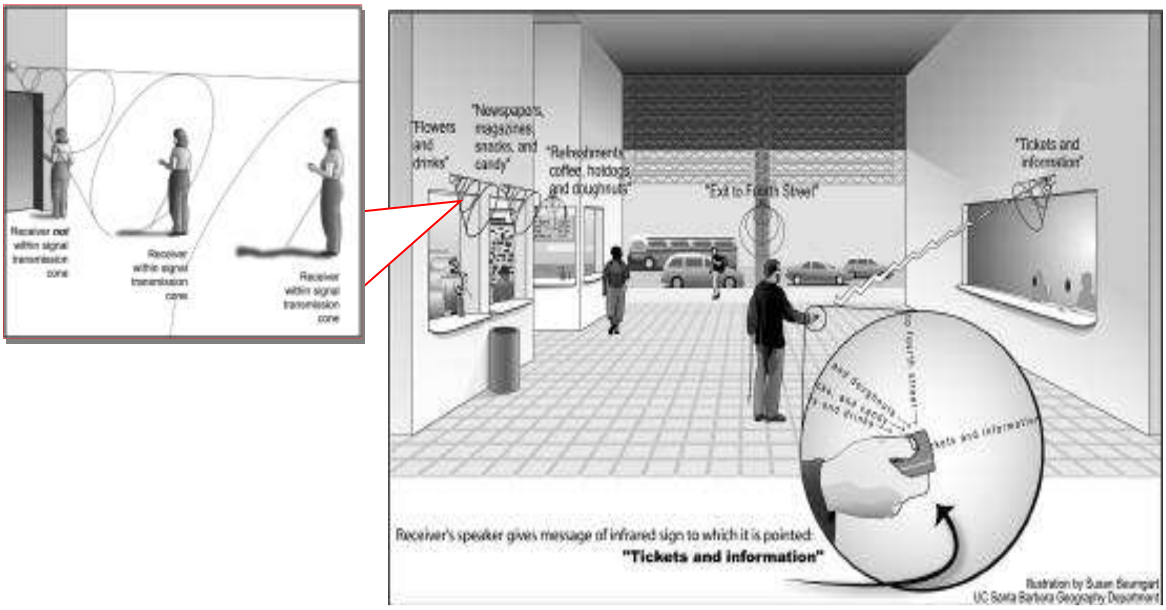

Fig. III.8. - Infrared technology for internal navigation

These devices can operate independently (stand-alone devices) and in that case all transmitted information on the location / object are stored on the microchip (position and other relevant data). They can also operate in integration with the central server and can get more information in the interactive way, upon request.

4.2. ULTRASONIC SENSORS

Ultrasonic sensors are used for an autonomous indoor navigation system, and their purpose is to avoid collision with movable and immovable objects. When a transmitted signal encounters an obstacle, it is reflected back to the sonar, which is converted into a sound that the human ear can detect. The human brain recognizes a variety of tones and gets an idea of the environment ahead, i.e. creates a “mental map" of the buildings ahead. In that way it detects an obstacle on the road and the distance to it. The user with a white cane must come in direct contact with the object in front of him, while the ultrasonic device covers a larger area ahead. Using ultrasonic sensors increases confidence and reduces stress from the sudden contact with an unknown object. Fig. III.9. shows an ultrasonic sensor.

Fig. III.9. - Ultrasonic sensor

4.3. RADIO-FREQUENCY IDENTIFICATION (RFID)

RFID is a wireless identification technology which exchanges data via radio waves. It consists of the following components:

- Transponder /Tag/ consists of an antenna and a microchip that contains information about the object that is identified.
- Reader is used to read data from the tag. They usually transmit low power radio signals on tags. Tags then reflect the energy / information (their identity and other relevant information) back to the reader, which now acts as a receiver. Reader captures the information that came from the tag, decodes and submits them to the host computer for further processing.

- Portable media (tags) transfer data to different readers through different (RF) radio frequency (LF), (HF), (UHF) and microwave. Reader is connected by wired and wireless connections to the server (Bluetooth, Wi-Fi, WiMax).

Fig. III.10. presents interaction between tag and reader [7]

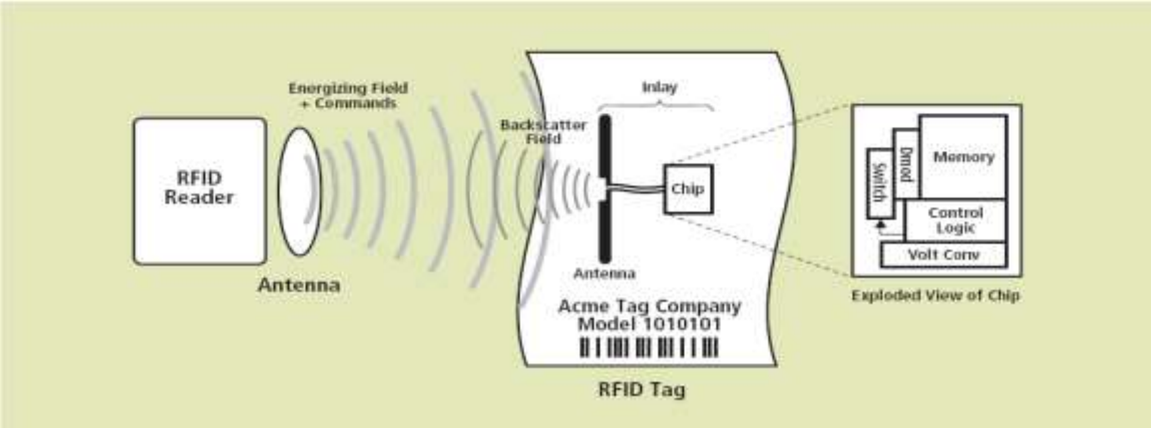

Fig. III.10. - RFID Transponders and Reader Interaction

RFID devices are cheap, produced in large quantities, tags last a long time and are very robust. Major investment in this system are the readers and the corresponding software.

The following figure (Fig. III.11.) will show a practical example of the use of RFID technology to identify a bus station. When a visually impaired person comes near a bus station, RFID reader attached to a bus station identifies the mobile transmitter (IR). After that, the server sends a request for RDF / XML package. Returned package is decoded in the user's device, where text is transformed into voice (text-to-voice engine), which says that the visually impaired person is at the bus station XY.

Fig. III.11. - Identification of a bus station using RFID

Integration of different sensors applied for the navigation of blind people is shown in Fig. III.12. When a pedestrian passes a checkpoint, the reader denotes a passing pedestrian and forwards the information to the headquarters in real time. Feedback is given to the pedestrian in the form of voice messages. The role of server in this system is to manage dialogues with the voice as an XML language.

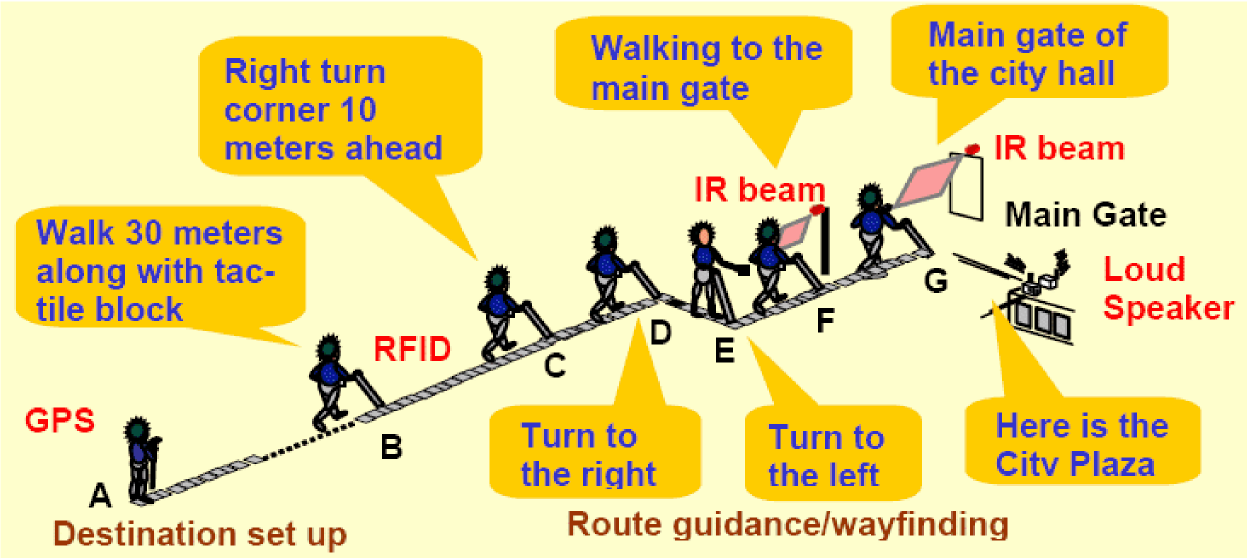

Fig. III.12. Pedestrian navigation using RFID technology and IR sensors

One of the possible interfaces or the ways to transfer audio message to pedestrians is shown in Fig. III.13.

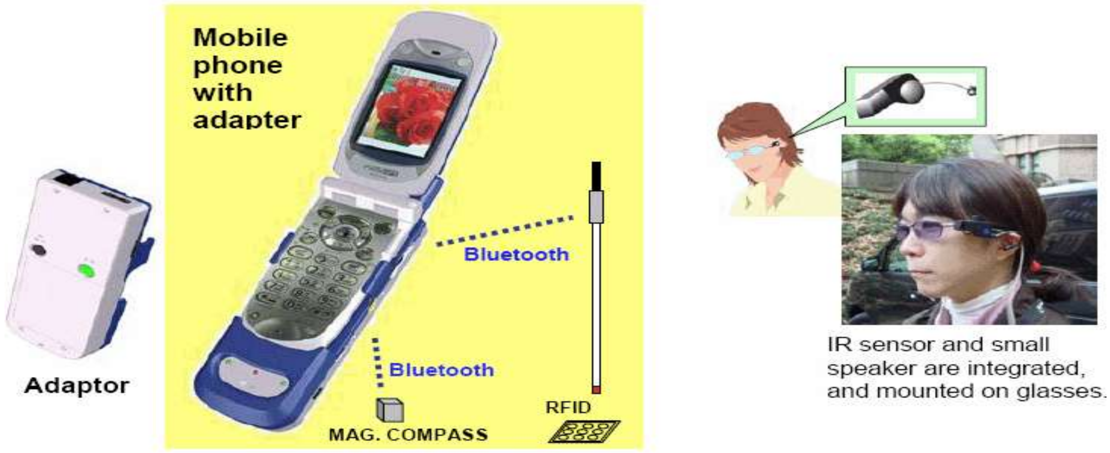

Fig. III.13. - Voice interface (transmission of voice instructions)

5. OVERVIEW OF THE SITUATION IN CROATIA

In Croatia there are around 430,000 persons with disability, out of which 5,800 are completely blind persons and from 12,000 to 15,000 are visually impaired persons. The number of persons with disabilities has recently increased because of the war this region was at. The existing traffic conditions are generally improved by traditional measures to remove architectural barriers (lowering curbs, building ramps, elevators, lifting platforms, etc.). There is little use of advanced traffic management measures. Using advanced ITS technology to solve traffic problems in the Republic of Croatia is in the initial phase, which comes down to individual use of telematic solutions. It is important that in 2003, the Faculty of Transport and Traffic Sciences in Zagreb started the undergraduate ITS study. Urgent task in the future is to build a national ITS architecture (HITS) that would be harmonized with the existing European standards and adapted to specific Croatian needs. A quality model which can be exemplary is the approach to ITS in Japan, where a development area is dedicated to support for pedestrians.

7. CONCLUSION

The pedestrian traffic used almost all design measures for the increase of mobility and accessibility for persons with disabilities: curb lowering, curb extension, reducing the turn radius for vehicles, traffic calming measures, the construction of tactile paths for the navigation of blind persons, etc. As a result, attention is focused on traffic control with the help of ITS upgrades. World experience has confirmed that the integration of ITS can significantly improve mobility and safety of blind people, and thus allow them the execution of basic human rights, which include movement and access to all facilities.

Using services provided by Intelligent Transport Systems for traffic and transport, alleviates shortcomings and reduces discrimination against people with disabilities. It is therefore very important that when building the future architecture of ITS in the Republic of Croatia (HITS), special attention is given to pedestrian traffic. In addition, high-quality model can be accessed in the ITS in Japan, where a development area is dedicated to support for pedestrians.

7. LITERATURE:

[1] Johansen, J.: History of navigation, stand 2001.
http://pip.dknet.dk/~janj/navigation.html

[2] GARMIN, Gps guide for beginners, stand 2001.
http://www.garmin.com/manuals/gps4beg.pdf.

[3] Šimunović, Lj., Bošnjak, I., Mandžuka, S.: Intelligent transport systems and pedestrian traffic, Promet - Traffic – Traffico, Vol 21, 2009., pp. 141-152

[4] Mannesmann Mobilfunk. Standortbestimmung Mobiltelefonen im D2-Netz, 2001.http://www.d2vodafone.de/askd2/D2-Netz/Telefonieren_im_D2-Netz/Ortsbestimmung_im_D2-Netz/ o_im_d2-netz.html.rtsbestimmung

[5] O’Keefe, K., Sharma, J., Cannon, M.E.: and Lachapelle, G.: Pseudolite-based inverted gps concept for local area positioning. In Proceedings of GPS99 (Session D4, Nashville, 14-17 September), 1999.

[6] Marston, J. R.:Towards an Accessible City: Empirical Measurement and Modeling of Access to Urban Opportunities for those with Vision Impairments, Using Remote Infrared Audible Signage, University of California, Santa Barbara, September 2002

[7] Macalanda, E. C.: Radio Frequency Identification (RFID) for Naval Medical Treatment Facilities (MTF) Monterey, California, September, 2006.

[7] Bošnjak, I.: Intelligent Transportation Systems 1, University of Zagreb, Faculty of Transport and Traffic Sciences, Vukelićeva 4, Zagreb (in Croatian)

[8] Bošnjak, I., Mandžuka, S., Šimunović Lj.: Possibilities of Intelligent transport systems to improve traffic safety, Proceedings: Incidents and traffic accidents and measures for their prevention, pp. 12-20, Croatian Academy of Sciences and Arts, Zagreb 2007. (in Croatian)

[9] Šimunović, Lj., Mandžuka, S., Missoni, E.: Contribution of ITS to Road Transport and Traffic Safety, 13th International Conference on Transport Science, ICTS 2010, Transport, Maritime and Logistics Science, Portorož, 2010.

[10] Wayfinding in the Built Environment, Research Project 2002-053-C, Brisbane, Australia, July 2004

[11] Gartner, G., Frank, A. and Retscher, G.: "Pedestrian Navigation System in Mixed Indoor/Outdoor Environment - The Navio Project", CORP 2004

IV. MOBILE COMMUNICATION AND TRAFFIC INCIDENT MANAGEMENT PROCESS

1. INTRODUCTION

Everyday life in most cities of the world is becoming more dynamic. Growing needs of the population of urban areas are realized through continued increase in mobility and requirements for quality and travel safety. Urban and transportation planners are faced with many demands on the one hand and infrastructure constraints on the other hand. Increased mobility adversely affects the environment and the climate, human health, quality of life, social conditions and safety aspects of people and the wider society. We do not and cannot give up mobility, so we look for answers that introduce innovative, sustainable and energy efficient solutions that will contribute to the quality of life of citizens. Increased mobility has resulted in a significant increase in road traffic incidents and the induced damages and costs, [1].

An “incident” is defined as any non-recurring event that causes a reduction of roadway capacity or an abnormal increase in demand. Such events include traffic crashes, disabled vehicles, spilled cargo, highway maintenance and reconstruction projects, and special non-emergency events (e.g., ball games, concerts, or any other event that significantly affects roadway operations). Although the problems most often associated with highway incidents consequence is traveler delay, by far the most serious problem is the risk of secondary crashes. Another related issue is the danger posed by incidents to response personnel serving the public at the scene.

Other secondary effects of incidents include:

· Increased response time by police, fire, and emergency medical services
· Lost time and a reduction in productivity
· Increased cost of goods and services
· Increased fuel consumption
· Reduced air quality and other adverse environmental impacts

· Increased vehicle maintenance costs

· Reduced quality of life

· Negative public image of public agencies involved in incident management activities, [2].

Road traffic incident management is a functional part of the holistic approach to solving traffic problems known under the term Intelligent Transportation System – ITS. The advanced development of communication and navigation technologies and their implementation in various phases of incident management can significantly reduce the consequences of incident event such as congestion, delay, pollution and especially dangerous secondary incidents [3].

Real-time incident management in traffic comprises coordination activities undertaken by several actors in order to reduce the negative impact, i.e. recovery of the traffic flow to the conditions of normal flow. One of the basic problems in incident management is the warning of other participants in traffic, as well as effective coordination of various organizations, i.e. services included in this process [4, 5]. Besides, incident management comprises also legal regulations which require careful planning of all segments. The success of the incident management lies in careful development of clear (and efficient) instructions and procedures, which are acceptable and understandable for all the involved services, organizations and individuals. One of the important conditions to achieve this is high-quality communications among the participants, i.e. information transparency and real-time data flow. Absence of such an approach which combines cooperation, communication and training, represent one of the main reasons of inefficient incident management process, today [6, 7].

The critical point in the traffic incident management chain is the procedure after detecting the incident and the appropriate verification thereof. It is the process of informing other participants in road traffic (special importance are the motorists) by using different technologies. Motorist information involves activating various means of disseminating incident-related information to affected motorists. Media used to disseminate motorist information include the following:

1. Commercial radio broadcasts

2. Highway advisory radio (HAR)
3. Variable message signs (VMS)
4. Telephone information systems
5. In-vehicle or personal data assistant information or route guidance systems
6. Commercial and public television traffic reports
7. Internet/on-line services
8. A variety of dissemination mechanisms provided by information service providers

Motorist information needs to be disseminated as soon as possible, and beyond the time it takes clear an incident. In fact, it should be disseminated until traffic flow is returned to normal conditions. This may take hours if an incident occurs during a peak period, and has regional impacts, [2]. Recently, the increasing importance has mobile (wireless) communications and their associated technologies and services.

The development of wireless communications systems and their application in everyday life of citizens have enabled the use of mobile communications technology in urban processes, and opened the possibility of entirely new solutions that until now could not be realized. This new, technologically advanced solutions based on mobile communications systems have opened new possibilities in the creation of an urban and traffic policy, which should serve the increasing population needs to ensure their mobility, accessibility, efficiency, rationality of energy and environmental conservation.

The penetration of mobile communications is growing rapidly levels of 90% coverage are no longer exceptions, [8]. Telecom operators, due to competition and saturation, are offering new services and focus on differentiation through value-added services.

The paper provides the description of one such technology, known as the Cell Broadcasting. In the second section a general model of Traffic Incident Management System is described. In particular, the importance of timely information about traffic incidents is pointed. The problem of traffic congestion caused by the incident is described. Some features of the Cell Broadcasting technology and some systemic functions are described in the third section. The basic features of its architecture and a description of some specific interfaces are given. In the fourth section, several examples of using Cell Broadcasting are shown. Some possibilities of GIS interfaces are presented. The concluding part gives the basic results of the work and the guidelines for future research.

2. TRAFFIC INCIDENT MANAGEMENT PROCESS MODEL

There are several different events that influence the normal or desired traffic flow in road network. In [4] the following events are identified which may lead to temporary reduction in road network capacity (compared to requirement):

- vehicle-conditioned incidents, ranging from minor vehicle damage to multiple accidents with the injured and fatalities;
- debris / barriers on the road;
- maintenance activities;
- unpredicted congestions;
- any combination thereof.

Another cause is extreme weather conditions, such as heavy rain or storms. Planned events (e.g. sport / cultural activities) or repeating events (e.g. peak congestions in the cities), are less interesting here due to the possibility of planned action.

The incident management process, as shown in Fig. IV.1., is divided into four phases: incident detection and verification, incident response, clearance of the incident and recovery to normal traffic flow

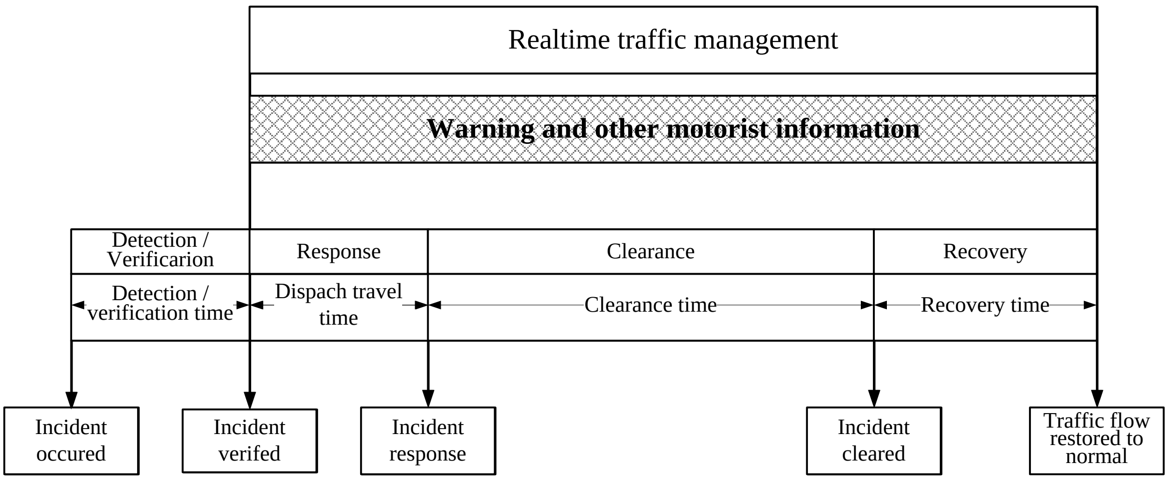

Fig. IV.1. - Phases in incident management

Incident detection may be defined as a process of identifying the space and time coordinates of the incident (incident situation) and possible nature of the incident itself. Incident detection methods are realized by private calls (phone, mobile phones), calls from SOS road phones, police report, report of the patrolling services and the operation of the automatic incident detection system. Incident verification means checking, which is used to determine the exact position and nature of the incident. In this way the possibility of responding to false alarms is reduced. Incident verification is carried out by the employees using the image obtained by specialized cameras (CCTV), or based on the comparison of several incoming calls about the incident.

The next step is very important. It is necessary to inform (warn) all participants in this road section about the nature of the incident. Implementation of this type of systems reduces the negative consequences of adverse events or sometimes an early warning of danger results in the adverse events not occurring. Fig. IV.2. shows the relationship between the size of damage made in relation to the starting time of reaction. The figure is a display of statistically processed information on fires and their consequences. The diagram shows the impact of the shortest response of human and technical resources. It also shows the effect of sending real-time management information and alerts to people in danger, and in some cases, to participants in traffic approaching a site affected primarily or secondarily by consequences of accidental events, [9, 10].

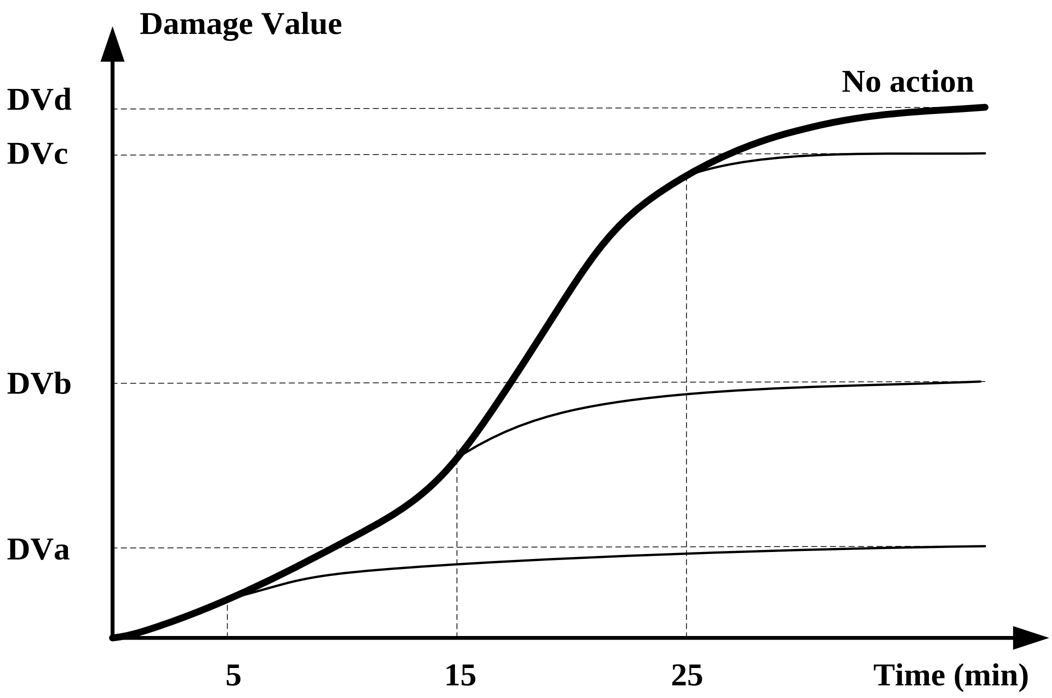

Fig. IV.2. - Quantity of caused damage in relation to initial response time

We see from figure 2.2, that if the intervention, which can range from intervention management of informing people to physical rescue of endangered, started after only 5 minutes, according to curve a) the damage remained at the DVa level. If the intervention starts later, after 25 minutes, the damage was much higher, at DVd level. Similar, Fig. IV.3. shows graphically the effect of reducing the cumulative arrivals of vehicles due to traffic flow diverting to alternative routes via cell broadcast messages about the emerged incidental situation, [4, 11]. Also, as a positive consequence the response time of urgent services is shortened at the incident the situation due to the decrease (diversion) of traffic flow, and instructions to drivers on how to conduct themselves as they approach the place of incident.

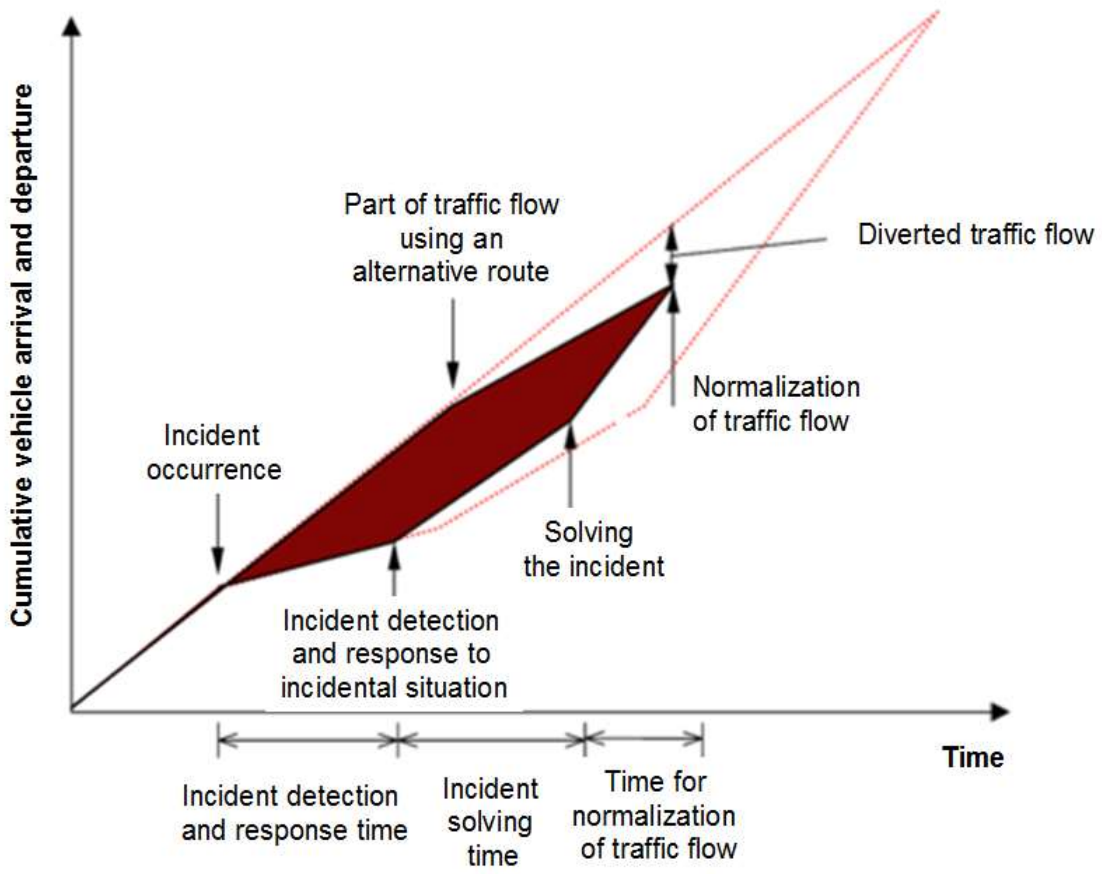

Fig. IV.3. - Relationship of cumulative vehicle arrival and departure

Timely and accurate incident management and provision of information in real or near real time can significantly reduce the unwanted side effects that can exceed several times the incident that caused them.

According to the experience of leading projects in this area, it is generally considered that one minute lost for detection and verification requires four minutes to normalize the traffic flow.

3. BASIC TECHNICAL CHARACTERISTICS OF CELL BROADCASTING

The key to successful delivery of mobile services with added value is in finding the right combination of network services and content. An example of such a combination of content and functionality of the mobile network is providing the location-based technology, recently often used in entertainment and marketing industry.

These innovative telecom services began to develop more strongly after 2000. One of the services is "Location-qualified telecom messaging" which allows end users to receive different kinds of "push" specific information in relation to their current location, from multiple senders. One of the pioneering services in this area is the cellular broadcast system for sending telecom messages for emergency activities. Such services are based on sending alphanumeric messages to mobile phones (cell phones) that are found in a particular area that is dynamically determined by the content provider. The smallest area to which the content provider can send the contents is a radio cell, and the largest is a complete wireless network.

Cell Broadcast System distributes information in a message format, very similar to the familiar SMS messages. These messages can be in a text or binary form. The length of a message is between 1 and 15 pages of 82 bytes (93 characters). A very important feature of this system is the distribution of information to a large number of users in a very short time. Processing required for the distribution of information is completely independent of the number of users that receive the information. The end user determines what information is to be presented to him and whether he wishes to receive this content. There are more than 65,000 channels available (in the ETSI terminology called "Message Identifiers"), each corresponding to a particular type of information.

The user individually activates and deactivates the reception of the first 999 broadcast channels. The rest of the channels must be activated via the OTA. Moreover, such a messaging system offers a range of unique functionalities such as support for sending specific information about location.

Apart from features provided by work in real time, the terminal required to receive broadcast information is continuously with the user, so he can read it immediately upon message delivery.

The system architecture of "Location-qualified telecom messaging" gives the operator complete control over the network topology, whether it is a GSM or a UMTS (Universal Mobile Telecommunications System) network, Figure 3.1.
It also allows the content provider to work under largest load and with most complex cellular networks with their frequent changes. This is accomplished by dividing the system into two components, usually placed in two domains:

- CBC (Cell Broadcast Center) is a network element in the mobile network, which sends broadcast messages to a specific radio cells.
- One or more CBE (Cell Broadcast Entities) are connected to the CBC, and can be used locally (by operators) and remotely (by independent content providers) to define and send telecom messages with location importance.

Using the Cell Broadcast function, the end user selects relevant information, while blocking all other information. Received Cell Broadcast messages are displayed instantly on the display of the cell phone, or can be stored as SMS (Short Message Service) in the memory for later reading. The user selects relevant information by activating the so-called Cell Broadcast Channel (in ETSI terminology: "Message Identifiers").
This kind of telecom messaging supports messages in several languages, encoded in the ETSI Default Alphabet and Unicode (UCS2), as defined in GSM 03.38 Phase 2 +] and [3GPP TS 23.038], [12, 13].

Furthermore, such information can be sent in binary format for processing using machine-to-machine applications). A range of applications can take advantage of Cell Broadcast technologies, including the following examples:

- Traffic signs and information boards along the road can be equipped with mobile receivers.
- Dispatching systems can use the CB messages to send information to vehicles (taxis, police or firefighters).
- Traffic information for the navigation systems.

User interfaces of today's mobile phones support different procedures to activate the Cell Broadcast channel. Although manufacturers of mobile terminals develop and enhance functions, it is extremely important for the service of content providers to facilitate the activation of the Cell Broadcast channels. There are two ways to do this:
- Using the index message
- Use the activation via OTA (Over the air activation - of services and tariff changes)

The index message is a specially formatted CB message with which channels from the menu can be selected and activated.

In the case of activation via OTA, remote activation of CB channels (e.g. via a website) can be done by sending a binary SMS (also referred to as an OTA message) to the mobile device which updates the SIM (Subscriber Identity Module) card and activates the CB channels. In addition to improving the user interface, activation of CB channels via OTA can provide a CB charging service (or its activation), Fig. IV.4.

The center for location-specific telecom messaging is the central point for distribution of CB messages via a GSM network or a UMTS network. CBE submit broadcast claims to the CBC, [14, 15]. Several CBE can be also interfaced to the center. CBC will address the appropriate cell controllers (Base Station Controller in a GSM network and Radio Network Controller in a UMTS network), which in turn will ensure the transmission of broadcast messages by the corresponding radio cells (Base Transceiver Station in a GSM Network and Node-B in a UMTS network). CBC supports a number of cell controllers in accordance with ETSI standards.

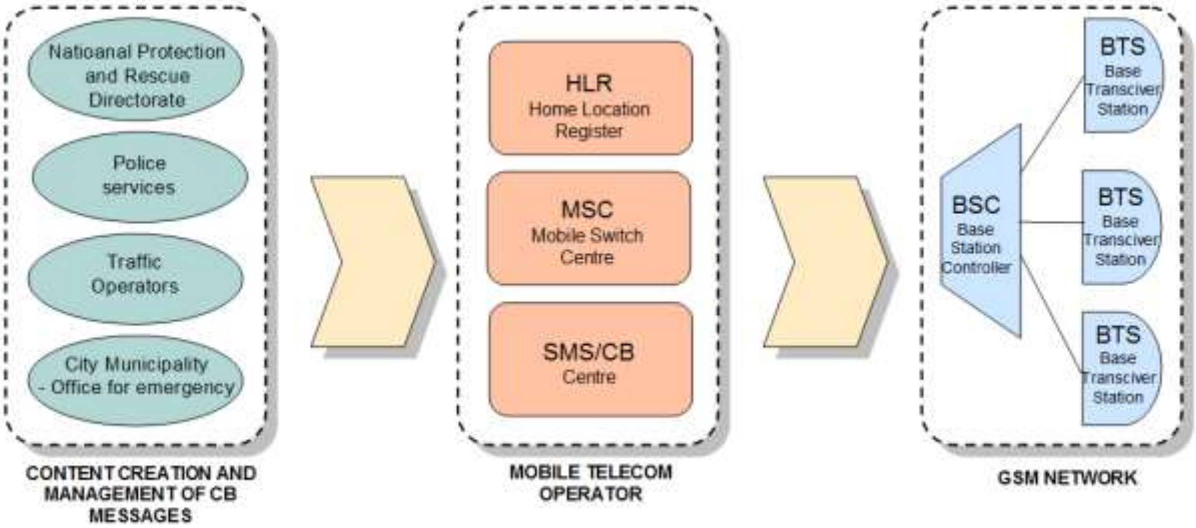

Fig. IV.4. - Functional Diagram of Cell Broadcast System

4. INTERFACES FOR CELL BROADCAST SYSTEM

The CBE-CBC interface allows the CBE access to functions of the CBC. The interface accepts requests, processes them and transfers error messages or confirmation to the CBE. Message encoding (e.g. Universal Character Set 2) is transparent to the CBE-CBC interface.
The CBC provides two protocols for access to CBE:

- Protocol based on ASN.1
- Protocol based on HTTP / XML

CBE is connected to the CBC Center via LAN or a network interface, such as ISDN, X.25 or the Internet, Fig. IV.5.
In the CBC, bandwidth control is performed on the CBE-CBC interface. That means when CBE exceeds the configured maximum bandwidth, the CBC will slow down sending replies.

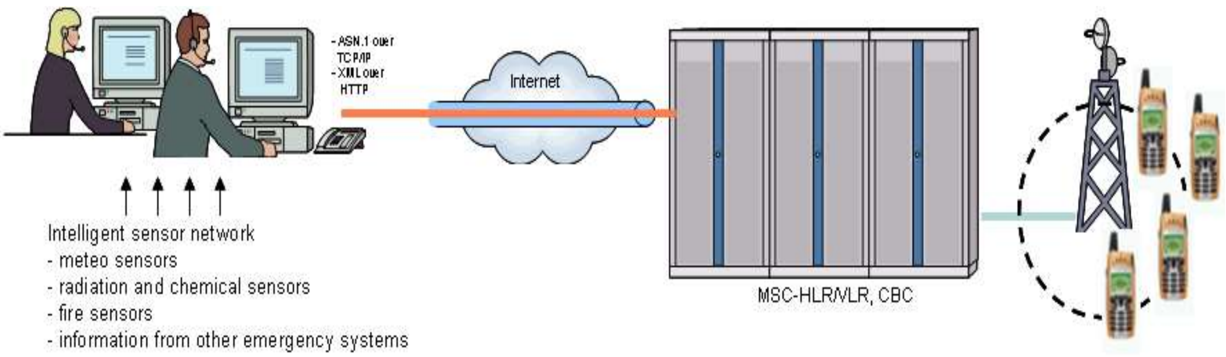

Fig. IV.5. Cell Broadcast System Architecture

Commands for cell controllers are provided with a list of cells, identifying the radio cells involved in commands. The cell controller is also responsible for the repetition of CB messages at a certain frequency. When a CB message is stopped, the cell controller reports the number of broadcasts by radio cell. ETSI has defined a standard for this interface (GSM 03.49 and [3GPP TS 25.419]), which the CBC supports. The CBC also supports interfaces to cell controllers that are not in accordance with ETSI standards.

The replies of the cell controller can change the internally maintained status variables of cell controllers and radio cells. The CBC attempts again to send failed messages for a configurable number of times. If after these attempts, the command is still not accepted, the command will be canceled.

The CBC Center can be controlled remotely using the OMC (Operations and Maintenance Centre) via the web interface, Fig. IV.6. Functions, which the web interface provide are basic functions such as:

- start up and shut down of the CBC or its parts,
- entering basic information about the system (for e.g. position of a radio cell or which cell controller controls a specific radio cell),
- monitoring CBC activity.

Fig. IV.6. - Alphanumeric Cell Broadcast System interface

The same functionality is provided in the CBC. An SNMP interface is available for remote monitoring of alarms.

The CBC automatically imports data on the topology of the GSM and the UMTS network (ie. the relationship between radio cells and cell controllers) with file import tools. Data must be presented in the files, transferred using a file transfer protocol (FTP).

For a network element such as a Cell Broadcast Center, characteristics such as availability and capacity are of decisive importance.

Basic features are:

- Scalability, CBC can be implemented as CBS Smart (entry level platform), or dual-node Power CBS

- Availability, several techniques are used in the CBC to improve system availability (Fail-take: if one node fails the other will take over.

5. COMPARISON OF CELL BROADCAST SYSTEM AND SHORT MESSAGE SERVICE

SMS is one-to-one technology whereas CB is one-to-many. This significantly impacts the cost structure of such services allowing for easier network dimensioning. In an average network it would take 100 SMS with the same content approximately 30 seconds to reach its destination, whereas in a CB-enabled network, a similar message transmission takes 30 seconds to reach all end users tuned into a CB channel, up to several million at a time. Unlike SMS, the time to broadcast a message over a CB channel is insensitive to the number of subscribers scheduled to receive the message. In a typical CB, a message can be sent within 30 seconds to all handsets. Efficiency of communicating the message does not decline in peak hours and CB does not use the signaling network (IN7) to carry messages as with SMS. Some basic characteristics of Cell Broadcast System and Short Message Service are presented in Tab. IV.1.

Tab. IV.1. Basic Characteristics of SMS and CBS [16].

Characteristic	Short Message Service	Cell Broadcast Service
Handset compatibility	All handsets support SMS	Most handsets support CBS except Few numbers.
Transmission form	Unicast and Multicast communication	Broadcast service. Message received indiscriminately by every handset within broadcast range
Mobile number dependency	Dependent. Foreknowledge of mobile number(s) is essential	Independent. Message is received on activate broadcasting channel
Location dependency	Independent. User receives the message anywhere	Dependent. Targets one cell or more
Geo-	Achieved by obtaining cell	Cell(s) location is known for

information	ID from the network operator	broadcaster beforehand
Service barring	No barring	Received only if the broadcast reception status is set to "ON"
Reception	Message is received once the mobile is switched on	No reception if handset is switched on after broadcasting
Congestion and delay	Affected by network congestions. Immense number of SMS may produce delays	Congestion is unlikely as CBS are sent on dedicated channels. Almost no delays except if received in poor coverage area
Delivery failure	Network overload might cause delivery failure	Busy mobile handset might fail to process a CBS message
Delivery confirmation	Sender can request delivery confirmation	No confirmation of delivery
Repetition rate	No repetition rate	Can be repeated periodically within 2 to 32 minutes intervals
Language format	Identical to all receivers	Multi-language messages can be broadcast on multiple channels simultaneously
Spamming	Some mobile service providers support internet connectivity. Internet-based SMS spamming is possible	Not possible expect through uncontrolled access to mobile network infrastructure and lack of safeguards by an irresponsible service provider

6. APPLICATION OF CELL BROADCASTING IN TRAFFIC

The main application of Cell Broadcasting in traffic is sending alphanumeric messages for location-specific alarms and messaging within the framework of mobile telecommunications network. The main purpose is to warn and inform motorist and other participants about the event in this road section. Also, same system can be used to inform about other incidents such as natural disasters, infrastructure or chemical accidents, and terrorist or other security incidents. In Japan, since 2008, DoCoMo (Japan's premier mobile provider of leading-edge mobile voice, data and multimedia services) has implemented an alarm and messaging system for dangerous weather conditions and alert for earthquakes using the cell broadcast service. New York City in 2007 launched the "Crisis text via CB" project intended for early warning of citizens. The Indian operator BSNL (Broadband - Bharat Sanchar Nigam Ltd) has introduced a cellular broadcast of important information on disaster, as well as crisis management. The U.S. FEMA (Federal Emergency Management Agency) under the Department of Homeland Security in the United States implements the "Emergency Cell Broadcast Network" system for cities and areas till now frequently threatened by natural disaster.

Several operators and content providers develop traffic information services in real time. Two main types can be distinguished in these applications. One is the basic version in which location and traffic information is sent to users and displayed as text messages on their mobile devices. More advanced versions of these services are continually sending dynamic information on road conditions and their display on a navigation system, Fig. IV.7.

⚠ **TRAFFIC INCIDENT !**
LOCATION: Zagreb Bypass (Knot Jankomir)
MESSSAGE: Traffic Congestion
DESCRIPTION: The chain collision on the east-west
START TIME: 2010-07-12 18:25
END TIME: 2010-07-12 19:25

Fig. IV.7. - Example of traffic messaging, [17] For content providers, Cell Broadcast is a unique way of distributing information to large groups of users. Combining geographic information with demographic information, the content provider can target specific areas in a very advanced and effective manner. The areas are selected using the alphanumeric designation of the CBS or with GIS, (Geographical Information System), and using an intuitive graphical user interface for entry of text messages and parameters, Fig. IV.8.

Fig. IV.8. - GIS interface for CBS

Mobile networks are constantly expanding with new radio cells. The Cell Broadcast Center automatically retrieves updated information about the network topology in a preset time. Newly-added cells are now used for all current messages whose broadcast area overlaps with the new cells. This process is automatic and transparent to the content provider.

7. CONCLUSION

Reactions to incident events in real time reduce material damage and human casualties. Such properties have systems for early warning, that allow dislocation of people out of vulnerable locations. Especially an important role is played by these telecommunications systems in traffic that is very dynamic and therefore complex in terms of management. The introduction of advanced telecommunications solutions increases safety in unfolding traffic reduces the number of casualties in traffic accidents and leads to faster response and actions by emergency services. Due to the success of implementation of such telecom systems, they become an integral part of the strategic program for design and deployment of regional ITS systems (ITS - Intelligent Transportation Systems). Tracking the number and severity of the consequences of accidents before and after the introduction of ITS provides a relatively objective quantification of the security gains and mitigates the effects of these events. Except in traffic incidents, similar processes and technology can be applied in the case of other emergencies, major accidents and disasters. Measuring the percentage reduction in response time is not a direct indicator of benefits, but is a very important factor. Reducing response time significantly affects the reduction of fatalities and prevent further casualties after the initial traffic (or other) accidents. Warning systems on highways improve driver perception of the accident scene and help reduce stress while traveling. Perception of safe travel is not only about reducing the number of accidents and their consequences, but also about increasing the perception of personal safety and security in transport. Also, dynamic and location-selective management of large incidents reduces the possibility of uncontrolled process (for e.g. panic in humans). The introduction of new telecommunications technologies with the above properties, such as Cell Broadcast Systems, substantially increases the effectiveness of security systems in the public and the transport sector.

REFERENCES

[1] Mandžuka, S., Kljaić, Z., Škorput, P., Application of ICT in the traffic incident management system, Proceedings Vol. II CTI – MIPRO, pp. 359-362, Opatija, 2011.

[2] Traffic Incident Management Handbook, Federal Highway Administration Office of Travel Management, Nov., 2000.

[3] Bošnjak, I., Intelligent Transportation Systems 1, Faculty of Transport and Traffic Sciences, Zagreb, 2006 (in Croatian).

[4] Škorput, P., Real-time incident management system, M.Sc. Thesis, Faculty of Transport and Traffic Sciences, Zagreb, 2009 (in Croatian)

[5] P. Škorput, S. Mandžuka, N. Jelušić: “Real-time Detection of Road Traffic Incidents”, pp. 273-283, Promet, 22, 4; 2010

[6] Dudek, C.L, Messer, C.J. and N.B. Nuckles, N.B, Incident detection on urban freeways. Transportation Research Record, 495 pp. 12-24., 1994.

[7] Dia, H., Rose, G., Snell, A., “Comparative performance of freeway automated incident detection algorithms,” in Proc. Roads 96: Joint 18th ARRB Transp. Res. Conf. and Transit New Zealand Land Transp. Symp., pt. 7, pp. 359–374, 1996

[8] Global mobile statistics 2011: all quality mobile marketing research, mobile Web stats, subscribers, ad revenue, usage, trends…, (http://mobithinking.com/mobile-marketing-tools/latest-mobile-stats), visited June, 2011.

[9] Mandžuka, S., Kljaić, Z., Kordić, Z., Mobile Telecommunication technology for Incident Management System, Proc. XVII Telecommunications Forum TELFOR, 2009.

[10] Wattegama, Ch., ICT for Disaster Management, Asia-Pacific Development Information Programme, 2007.

[11] Evanco, W. M. The Impact of Rapid Incident Detection on Freeway Accident Fatalities. Virginia : Mitretek Center for Information Systems McLean, 1996.

[12] Ericsson; “Content Delivery System”, FC 101 097/3, , Stockholm, Sweden.

[13] Ericsson; “Mobile Positioning System”, FC 101 0351, Stockholm, Sweden.

[14] 3GPP TS 23.041; 3GPP TS 23.041, “Technical realization of Cell Broadcast Service (CBS)”, 3GPP, V4.1.0

[15] GSM 03.41; “Digital Cellular Telecommunications System (Phase 2+); Technical Realisation of the Short Message Service Cell Broadcast (SMSCB)”, ETSI

[16] Aloudat, A, Michael, K and Yan, J, Location-Based Services in Emergency Management- from Government to Citizens: Global Case Studies", Recent Advances in Security Technology, Australian Homeland Security Research Centre, Melbourne, 2007, 190-201.

V. THE DECISION SUPPORT SYSTEM FOR DISASTER TRAFFIC RESPONSE MANAGEMENT

1. INTRODUCTION

Crisis Management System consists of two phases; Pre-incident and Post-incident phases, (Kang and Shneiderman, 2006). Pre-incident tasks include predicting and analyzing potential dangers and developing necessary action plans for mitigation. Post-incident response starts while the disaster is still in progress. At this stage the challenge is locating, allocating, coordinating, and managing available resources. An effective emergency response plan should integrate both of these phases within its objective (Tufekci and Wallac, 1998). Separating Pre-incident and Post- incident objectives may lead to suboptimal solutions to the overall problem.

Managing the system of protection and rescue of the City of Zagreb, following legal provisions, is a hierarchical set - consists of several levels of management and refers to management in all situations: emergencies, disasters, major accidents and disasters. The system is a combination of civilian management and elements of command and leadership. Management is implemented in various centers of decision-making levels, and these are centers or sites which are shipped all processed and analyzed relevant information in relation to the emergency situation, unfortunately, a great misfortune and disaster upon which to make appropriate decisions in various phases of crisis development (Fig. V.1.).

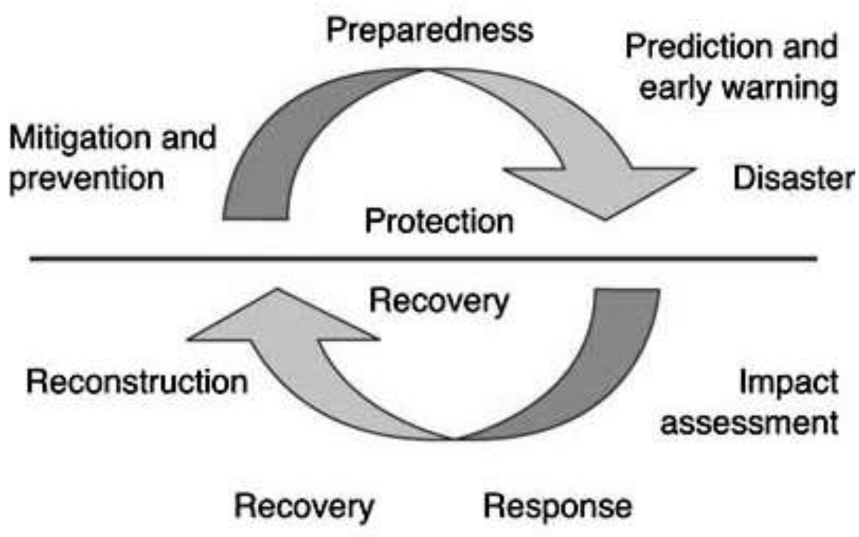

Fig. V.1. - Phases of Crisis Management

The seeming randomness of impacts and problems and uniqueness of incidents demand dynamic, real-time, effective and cost efficient solutions, thus making the topic very suitable for OR/MS research (Altay and Green, 2006). In the case of connection Geographical Information System and some Operations Research Methods and Approach this leads to Spatial Decision Support System – sDSS.

2. STRUCTURE OF DSS

Decision Support System (DSS) capable to supporting the most needs of Crisis Management is divided in five subsystems (Fig. V.2.):

1. Communications Subsystem (CS) are supported DSS by advanced data acquisition, positioning and communications technologies to better understand the current state of operations,
2. Optimization Subsystem (OS) optimizes the most controllable processes in Crisis Situation (Network Optimization, Evacuation Routing, Resource Allocation etc),
3. Geo-information Subsystem (GIS) for Crisis Management, (Fuhrmann, 2007)

4. Simulation Subsystem (SS) simulates partial problem of the realworld environment for the supervised area (pollution propagation, dynamic of traffic system, dynamic of river flooding, etc.)
5. Knowledge Subsystem (KS) gives the corresponding reasoning methods required to perform the monitoring and management of emergency situations.

The interface with the outside world is Communications Subsystem. A special part of this subsystem is an alert system. In this case it works with Cell Broadcasting technology. The main application of Cell Broadcasting in Crisis Management is sending alphanumeric messages for location-specific alert/alarms and messaging within the framework of mobile telecommunications network, (Mandžuka and all, 2010).

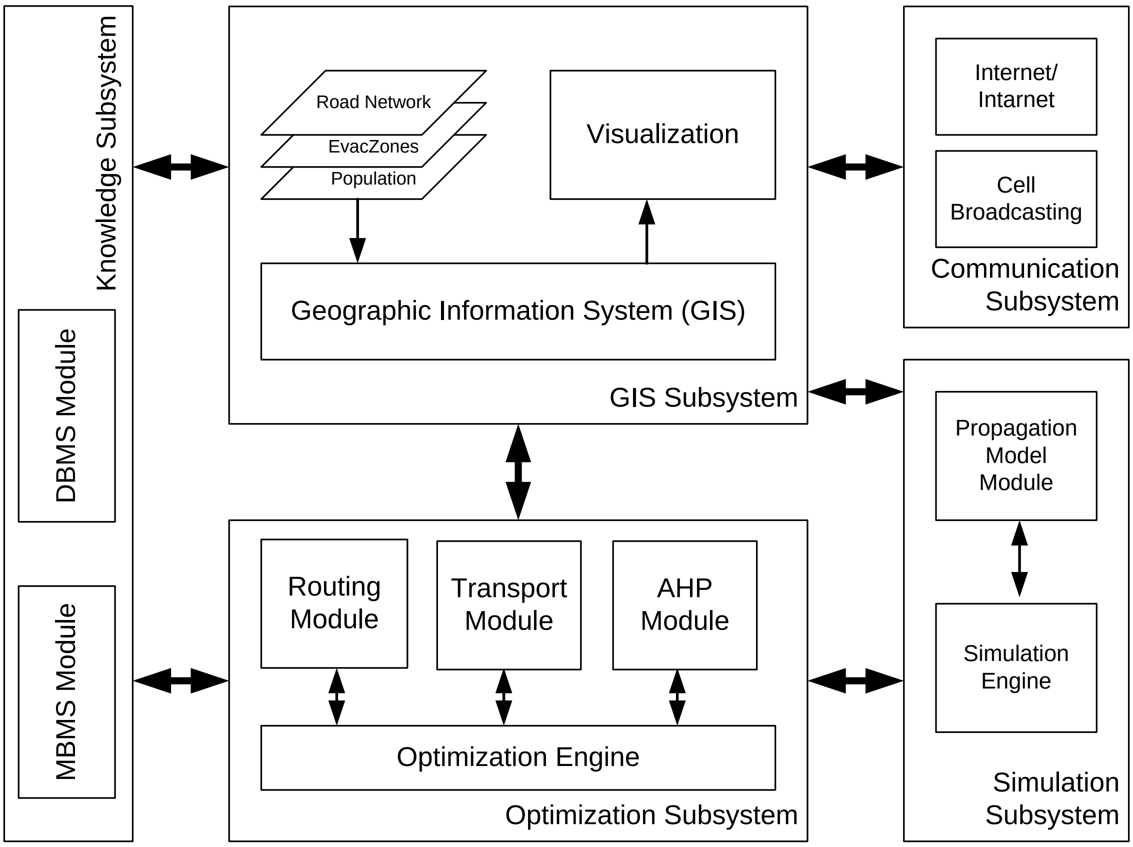

Fig. V.2. - Structure of DSS

The main purpose is to warn and inform all relevant participants about the incident event in critical area. The system can be used to inform location-dependent about different incidents such as natural disasters, infrastructure or chemical accidents, and terrorist, large traffic incidents or other security incidents.

3. OPTIMIZATION MODULE

The Optimization Subsystem (OS) optimizes the most (full or partially) controllable processes in Crisis Situation. The main optimization tasks are Network Optimization, Evacuation Routing, Resource Allocation etc. is proposed to find the optimal solution for some emergency evacuation planning problem (Transport/Transshipment on Road Network, Optimal Routing Evacuation, Optimal Allocation of different resources, etc. The Optimization Engine simultaneously solves for the choice of destination (shelter), evacuation route, and departure time for all evacuees from given origins (evacuations zones). It is envisaged that the Optimization Engine works with the classic numerical and (or) heuristic methods (Barbarosoglu and Arda, 2004; Cret et all, 1993).

AHP (Analytic Hierarchy Process) module is designed as a multi-criteria decision-making tool, (Saaty, 1989). The objective of multi-criteria decision-making is the choice of the best alternative according to the defined set of criteria. If the results of multi-criteria decision-making are the final evaluations of the alternatives, and if these evaluations reflect their place on the scale of priorities, this procedure may be called multi-criteria evaluation. Previous studies indicate the great utility of AHP method for decision making in crisis management. In this project, the standard AHP method extends the capabilities of various models of operational research. For example, this tool is applied in estimating of basic features (values) of arches in a traffic network. We now study the possible application of integrated measures of arcs in the form:

$$s_{ij} = r_{ij} c_{ij} k_{ij} l_{ij}$$

where:

s_{ij} – integrated measure of arc between nodes i and j,

r_{ij} – reliability coefficient of arc between nodes i and j,

c_{ij} – capacity coefficient of arc between nodes i and j,

k_{ij} – congestion coefficient of arc between nodes i and j,

l_{ij} – distance of arc between nodes i and j.

The values of coefficients r_{ij}, c_{ij}, and k_{ij} are given by multi-criteria AHP evaluation (Jelušić et all, 2009). In order to estimate the particular coefficient, a survey has been carried out among a group of experts in the area of crisis management, traffic experts, city traffic policeman, etc. The survey group consisted of respondents such as: public services involved in urban traffic management, companies that deal with design in traffic and scientists and experts from the University of Zagreb.

4. GEO-INFORMATION SUPPORT IN CRISIS MANAGEMENT

Within the management of urban crisis management, geoinformation systems (GIS) are used in any of the phases of mitigation, preparedness; response and recovery as most of the required data have a spatial component (Zlatanova et. Al, 2006). GIS can combine many layers of different information, creating products that are much more sophisticated than flat maps. By linking maps to databases, GIS enables users to visualize, manipulate, analyze, and display spatial data.

All phases of crisis management depend on data from a variety of sources. The appropriate data has to be gathered, organized, and displayed logically to determine the size and scope of crisis management programs. During an actual crisis it is critical to have the right data, at the right time, displayed logically, to respond and take appropriate action (Johnson, 2000). Crisis can impact all or a number of government departments. Emergency personnel often need detailed information concerning pipelines, building layout, electrical distribution, sewer systems, and so forth. By utilizing a GIS, all departments can share information through databases on computer-generated maps in one location. Without this capability, emergency workers must gain access to a number of department managers, their unique maps, and their unique data. Most emergencies do not allow time to gather these resources. This results in emergency responders having to guess, estimate, or make decisions without adequate information. This costs time, money, and in some cases lives. GIS provides a mechanism to centralize and visually display critical information during a crisis. GIS is a flexible technology enabling full integration with other information systems. Linking people, processes, and information together and being able to access that information at command centers and out in the field, are strengths GIS offers agencies as they respond to events.

In an emergency case, not only the location of the event but many other information is needed, like How many people are affected? Which road network is available? Can the location be reached by vehicles? Where are the most nearby hospitals located? How much and which kind of capacity do the hospitals have? Such and many other questions can be answered very quickly if and only if reliable spatial data are available in digital form and if the data are processed in a powerful GIS (FIG, 2006).

Depending on the specific tasks, different types of GIS are to be used:

1. Spatial information portals and data warehouses
2. Modeling and simulation systems
3. Monitoring and early warning systems
4. Planning support systems

In the city of Zagreb, the Office of emergency management (OEM) is responsible for the coordination of the City's emergency planning, training, response, and recovery efforts of major disasters such as fires, floods, earthquakes, acts of terrorism; and for major planned events in the city that require involvement by multiple City departments. OEM was established in 2008 and has immediately started with implementation of GIS system. GIS is implementing with the main purpose to mitigate the consequences of possible disasters but also for different analysis in the phase of preparedness and planning (Cetl, et. al. 2010). It must be mentioned that the city of Zagreb is located in a seismically active area and there is a real expectation of earthquakes in the future period. The last great earthquake in the city of Zagreb was in 1880.

Currently GIS database consists of more than 20 data layers such as: communications, evacuation areas, shelters, health institutions, fire protection units, police stations, settlements, different utilities, shopping centers, industrial objects, educational objects, etc. However GIS is still in developing phase. As a background, digital orthophoto is used (Fig. V.3.)

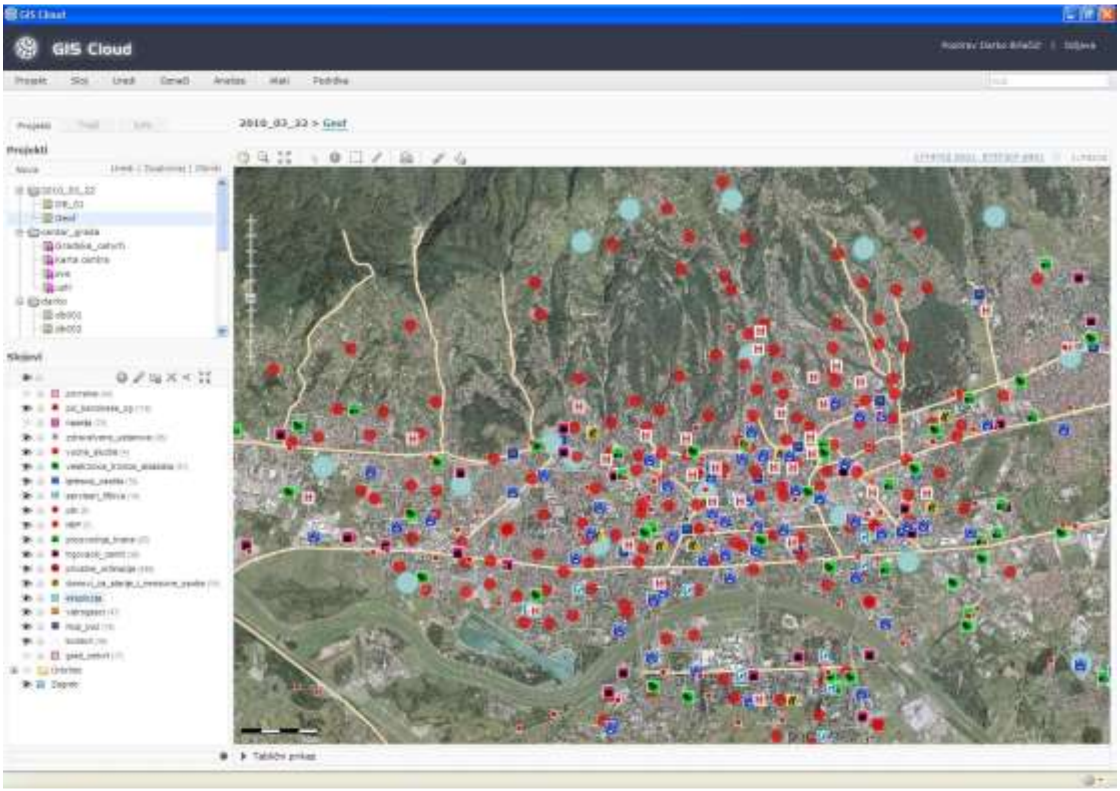

Fig. V.3. - Current view of OEM's GIS

GIS is based on the GIS Cloud software (http://www.giscloud.com/) and PostgreSQL database with PostGIS extension. GIS Cloud is the web based GIS that can visualize any data as maps. It is a very innovative solution that enables easy data sharing and collaboration within different organizations. The main challenge in the further development is exactly sharing of data between different city offices. In the city of Zagreb an official GIS was established already in 1992. Today it consists of more than 40 different spatial layers. The intention of OEM is not to have a parallel GIS but rather to combine their data with other spatial datasets. Thanks to the technology development, nowadays is such solution possible through standard OGC (Open Geospatial Consortium) services such as WMS (Web Map Service), WFS (Web Feature Service), etc.

5. CONCLUSION

The development of Knowledge-based Decision Support Systems for Crisis Management requires the management of complex information (Recourses, Geospatial information, Traffic etc). Some preliminary results (concepts and structure of DSS, application of GIS in our system etc.) is described in this paper. Future research will include the selection of appropriate numerical methods and the possibility of heuristics for particular situations. In this area there are many opportunities to improve existing knowledge.

6. REFERENCES

1. Altay, N., Green, W. (2006), OR/MS research in disaster operations management, European Journal of Operational Research 175, 475–493

2. Barbarosoglu, G., and Arda, Y.,, (2004), A two-stage stochastic programming framework for transportation planning in disaster response, Journal of the Operational Research Society 55 No. 1., pp. 43–53.

3. Cetl, V., Mađer, M., Guberina, B. (2010), Risk Management in the teaching at the Faculty of Geodesy in Zagreb. Proceedings of Second conference of the Croatian platform for reducing risk of disasters, October 14-15, Zagreb.

4. Cret, L., Yamazaki, F., Nagata, S. and Katayama, T., (1993), Earthquake damage estimation and decision-analysis for emergency shutoff of city gas networks using fuzzy set-theory, Structural Safety 12 No. 1, pp. 1–19.

5. FAO, Drought impact mitigation and prevention in the Limpopo River Basin, A situation analysis, FAO SubOffice SEA, Rome, 2004.

6. FIG, International Federation of Surveyors (2006), The Contribution of the Surveying Profession to Disaster Risk Management. FIG Publication no 38., Copenhagen, Denmark.

7. Fuhrmann, S., Maceachren, A.M., Cai, G., (2007), Crisis Management with Modern Geographic Information Technologies: Kartographische Nachrichten, Vol. 57, No. 2, pp. 92- 99.

8. Jelušić, N; Anžek, M; Mandžuka, S., (2009), Evaluation of Sensor Technologies for Intelligent Transport Systems, Proceedings of 16th ITS World Congress, Stockholm

9. Johnson, R. (2000), GIS Technology for Disasters and Emergency Management, ESRI White Paper. ESRI (Environmental Systems Research Institute, Inc.) 380 New York St., Redlands, US.

10. Kang, H., B. Shneiderman, (2006), Exploring Personal Media: A Spatial Interface Supporting User-Defined Semantic Regions. Journal of Visual Languages & Computing, Vol. 17, No. 3, pp. 254-283.

11. Mandžuka, S., Savi, I., Kljaić, Z. (2010): Intelligent transportation system and crisis management, International Conference: Crisis management Days, Velika Gorica, ISBN 978-953-7716-07-3 (in Croatian)

12. Saaty, T.L., (1989), Group Decision Making and the AHP. In: B. Golden, E. Wasil and P.T. Harker, Editors, The Analytic Hierarchy Process: Applications and Studies, Springer-Verlag, New York

13. Tufekci, S., Wallace, W.A., (1998), The emerging area of emergency management and engineering. IEEE Transactions on Engineering Management 45 (2), 103–105.

14. Zlatanova S., Van Oosterom P., Verbree, E. (2006). Geo-information support in management of urban disasters. Open House International, Volume: 31, Issue: 1, Pages: 62-69.

VI. ROAD TRAFFIC INCIDENT DETECTION

1. INTRODUCTION

Road traffic incident management is a functional part of the holistic approach to solving traffic problems known under the term Intelligent Transportation System – ITS. The advanced development of communication and navigation technologies and their implementation in various phases of incident management can significantly reduce the consequences of incident event such as congestion, delay, pollution and especially dangerous secondary incidents [1]. The development of the incident management system is approached in a new and technologically innovative manner starting from adequate basis of the traffic flow theory, theory of dynamic system estimation, general theory of classification, as well as adequate ITS architectures, available technologies, etc. [2, 3, 4].

Real-time incident management in traffic comprises coordination activities undertaken by several actors in order to reduce the negative impact, i.e. recovery of the traffic flow to the conditions of normal flow. One of the basic problems in incident management is effective coordination of various organisations, i.e. services included in this process [5]. Besides, incident management comprises also legal regulations which require careful planning of all segments. The success of the incident management lies in careful development of clear (and efficient) instructions and procedures, which are acceptable and understandable for all the involved services, organisations and individuals. One of the important conditions to achieve this is high-quality communications among the participants, i.e. information transparency and real-time data flow. Absence of such an approach which combines cooperation, communication and training, represent one of the main reasons of inefficient incident management process, today [5, 6, 7].

The critical point in the traffic incident management chain is the procedure of detecting the incident and the appropriate verification thereof. There are today different technologies used to achieve this. The basic classification of such systems is into:

1. traffic incident detection systems in/on road structures (tunnels, bridges, viaducts, etc.),
2. traffic incident detection systems on open road sections.

The first group systems are based mainly on the processing of video-signals of appropriate CCTV cameras. The specialised products of this type are available on the market and represent the usual solutions e.g. in tunnels and especially important sections of roads, where they detect a stopped vehicle, illegal half turns, driving in wrong direction, and similar. A much more complex system for traffic incident detection is the one on open road sections. Due to economic reasons, the installation of CCTV system is here unacceptable. These systems are based on estimation of the traffic state variables (space mean speed, traffic flow, traffic density, etc.), [8, 9, 10]. Based on the reconstruction of the traffic state variables, using various algorithms of the theory of classification and sample recognition, possible incidents are detected. These procedures allow also prediction of incident occurrence.

The application of the procedures of traffic state variables estimation is based on the macroscopic traffic flow models [11]. The basic problem here is the selection of the appropriate model. It is necessary to assess the complexity of the model and its real possibilities for such an application. Recently, several approaches have been studied and they are more or less based on various applications of the second order traffic flow model [10, 12]. The next step is the application of appropriate incident detection algorithms. In this paper the classification of various approaches is used by using the results of general theory of process faults detection [13, 14]. There is, namely, great similarity of traffic incident detection and the appropriate well-defined area of process faults detection in the classical theory of automatic control. The latest research in the field of automatic incident detection is directed to the usage of complex systems that use various sources of information and processing procedures. These solutions lead to the proposal of using the decision support system (DSS), [15].

The paper provides the description of the main elements of the incident management system. The second chapter describes the generalised model of incident management. The main phases of the management process are described (detection/verification, response, clearance, recovery) and general classification of detection/verification methods is presented. The third chapter focuses on the mathematical model of estimating the traffic state variables. For this purpose the appropriate development of the discrete mathematical model of the traffic flow has been presented, as well as the structure of estimator based on the application of the Extended Kalman Filter. An overview of the theory of automatic detection of traffic incidents on open road sections is provided in the fourth chapter. The main algorithm groups that are applied today for these purposes are briefly described. In the end a description of the incident management decision support system as a possible promising future solution is given. An analysis of several factors is made, which in practice significantly affect the quality of work of the incident detection system. The concluding part gives the basic results of the work and the guidelines for future research.

2. INCIDENT MANAGEMENT PROCESS MODEL

There are several different events that influence the normal or desired traffic flow in road network. In [5] the following events are identified which may lead to temporary reduction in road network capacity (compared to requirement):

- vehicle-conditioned incidents, ranging from minor vehicle damage to multiple accidents with the injured and fatalities;
- debris / barriers on the road;
- maintenance activities;
- unpredicted congestions;
- any combination thereof.

Another cause is extreme weather conditions, such as heavy rain or storms. Planned events (e.g. sport / cultural activities) or repeating events (e.g. peak congestions in the cities), are less interesting here due to the possibility of planned action.

The incident management process, as shown in Fig. VI.1, is divided into four phases: incident detection and verification, incident response, clearance of the incident and recovery to normal traffic flow. Only first two phases are described in this paper.

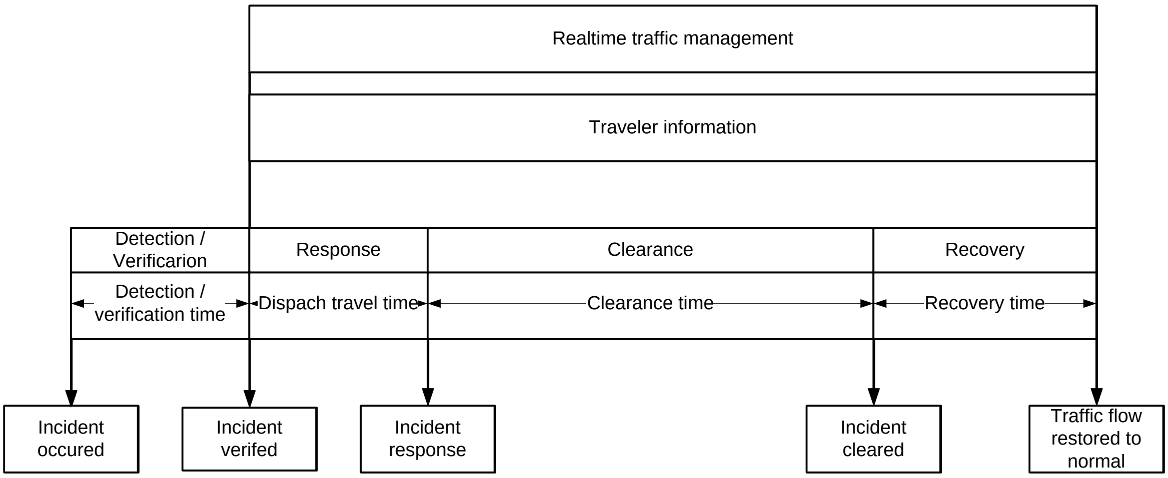

Fig. VI.1. - Phases in incident management

Incident detection may be defined as a process of identifying the space and time coordinates of the incident (incident situation) and possible nature of the incident itself. Incident detection methods are realised by private calls (phone, mobile phones), calls from SOS road phones, police report, report of the patrolling services and the operation of the automatic incident detection system. Incident verification means checking, which is used to determine the exact position and nature of the incident. In this way the possibility of responding to false alarms is reduced. Incident verification is carried out by the employees using the image obtained by specialised cameras (CCTV), or based on the comparison of several incoming calls about the incident. Fig. VI.2. shows the basic incident detection/verification methods and procedures.

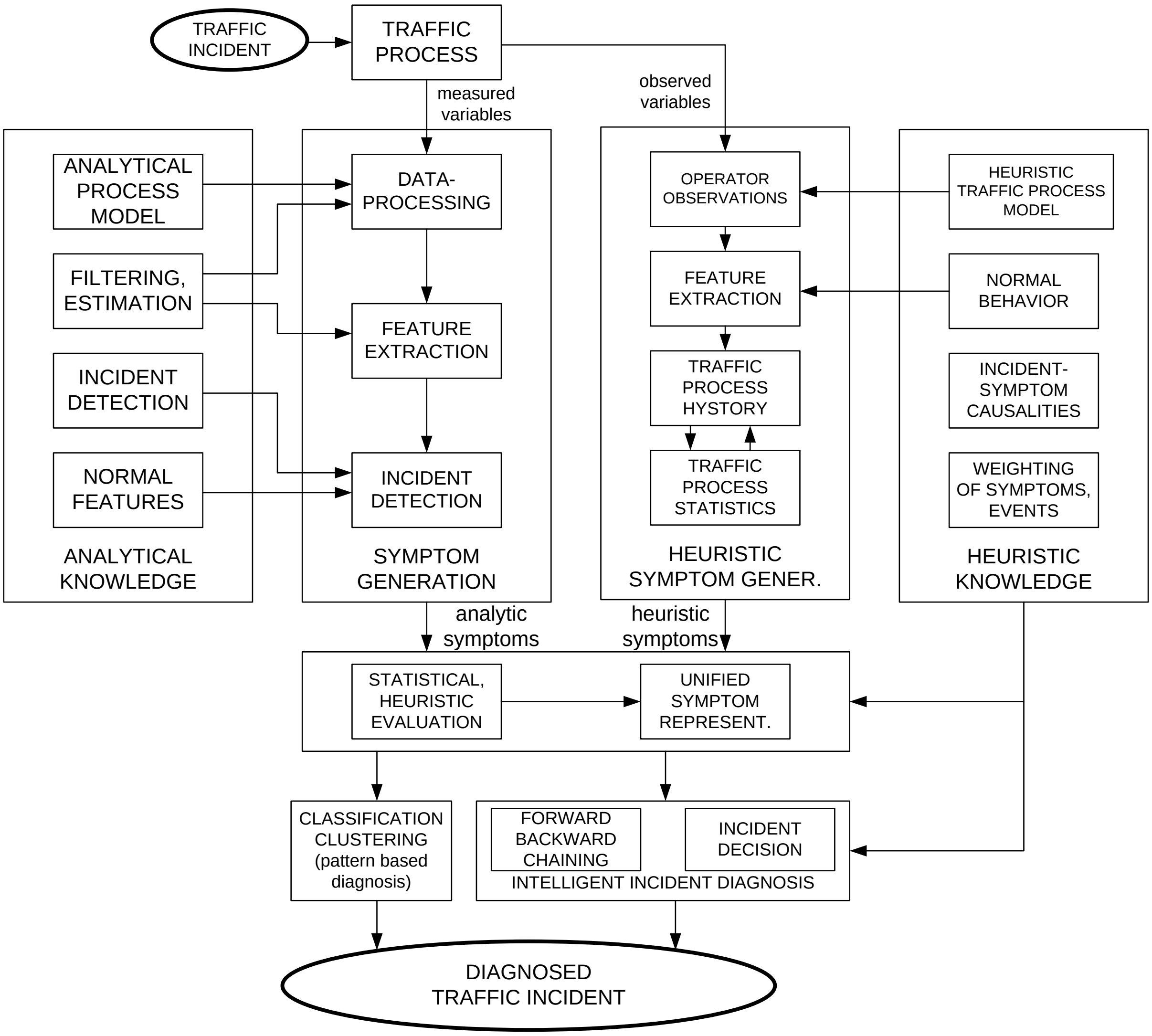

Fig. VI.2. - Incident detection/verification methods and procedures [13, 16]

The basic classification of detection/verification methods is into heuristic and analytic approach [13, 16]. The heuristic methods are based on qualitative assessment made by the operator (human) about the existing traffic situation and their conclusion whether the concrete traffic situation can be regarded as an incident situation. Analytic knowledge about the process is used to generate measurable, analytic information. Therefore, based on the measured traffic flow variables, the data are adequately processed. As result of this processing certain characteristic values are generated. The most significant values can be obtained by:

a) checking whether certain measurable traffic flow variables exceed the pre-defined values (limits),

b) analysing the measurable traffic flow variables by using advanced methods of signal analysis such as correlation function, frequency spectrum, auto-regressive moving average process (ARMA), and similar,
c) analyses using mathematical models of the process which includes identification of the road parameters, estimation of the traffic state variables, etc.

In this way, special indicators (coefficients) can be deduced from these characteristic values, i.e. special filtered and transformed residuals (deviations from the normal condition). This analysis uses different methods of Traffic Flow Change Detection and Traffic State Classification Methods.

For this, special importance is on the use of adequate sensor technologies. With advance in technology and improvement of hardware new incident detection and verification possibilities are opened up which result in rapid shortening of the time and increase in reliability. Although inductive loops are the most used and very reliable technology for vehicle detection, other technologies are becoming increasingly acceptable as a substitute or addition to inductive loops, especially in cases when the setting of new or replacement of the existing inductive loops is difficult to perform or economically unjustified. The selection of adequate technologies is of special interest in defining the system in road telematics. In this sense, the selection based on multi-criteria decision-making is of special interest [17, 18, 19].

The detection time is the most important parameter in the incident management process. For maximally efficient incident management the incident detection time has to be maximally shortened. Delay in incident detection usually results in queues and traffic congestion, and often cause secondary incidents which very often multiply exceed the incident that caused them.

3. MATHEMATICAL MODEL OF ESTIMATING TRAFFIC FLOW VARIABLES

In the introduction of this paper it was mentioned that the most demanding part in incident management is the detection procedure on open road sections (freeway). Since the application by using CCTV cameras on open road sections is still economically unacceptable, different detection methods are used that are based on measuring the variables of the traffic flows. During the incident, the normal traffic flow is disturbed, and this is reflected in the respective traffic flow variables. A simplified scenario of detection is presented in Fig. VI.3. It gives visual presentation of a typical traffic incident situation, traffic pattern and respective sensor installations.

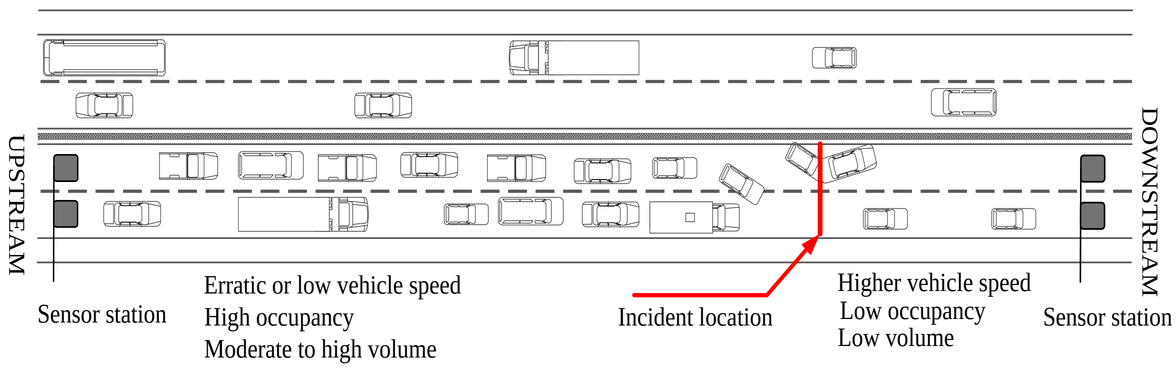

Fig. VI.3. – Incident detection principle on open road sections (freeway)

The characteristics of individual traffic flow features during an incident on an open road section can be described in detail by a traffic flow in four adjacent segments, as presented in Fig. VI.4. The flow in segment A, far upstream from the incident, operates at normal speeds with normal density. The flow in segment B, which is immediately in front of the incident location is characterised by vehicle standstill. This segment features the phenomenon of upstream propagation of the shock wave. The speeds are generally low and there is high density of vehicles. The flow in segment C, which is immediately downstream of the incident is characterised by lower traffic density than normal and adequate traffic speed is generally higher than normal. The flow in segment D, which is sufficiently far downstream from the incident, has normal density and speed, the same as in segment A.

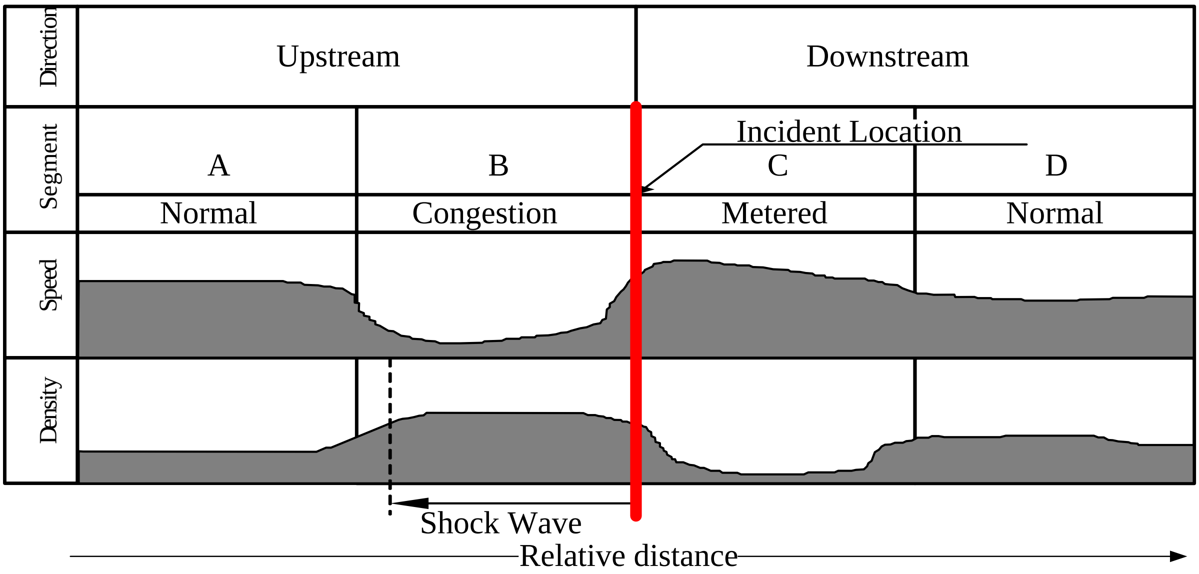

Fig. VI.4. – Traffic flow characteristics during incident [2]

3.1 Discrete mathematical model of traffic flow

The traffic variables estimation is based on the familiarity with the macroscopic mathematical traffic flow model. The basic equation of the macroscopic mathematical traffic flow model is the equation of conservation in the following form:

$$\frac{\partial \rho(x,t)}{\partial t} + \frac{\partial q(x,t)}{\partial x} = r(x,t) - s(x,t) \qquad (1)$$

where:

ρ - traffic density (veh./km/lane),

q – traffic flow (veh./h),

r – on-ramp inflow (veh./h),

s – off-ramp outflow (veh./h),

t – time coordinate,

x – location coordinate.

For computer model requirement, the upper partial differential equation is space/time discretized and the set of difference equations is produced. Therefore, the test section is defined by the model presented in Fig. VI.5.

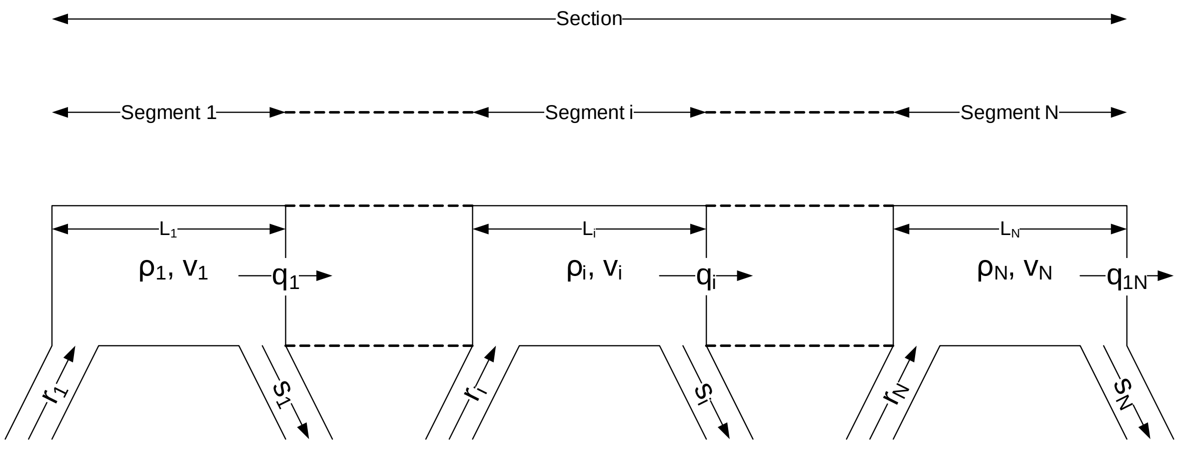

Fig. VI.5. – Physical discretisation of the test section

The basic discrete model of individual segment (i) is given in the form:

$$\rho_i[k+1] = \rho_i[k] + \frac{T}{L_i}(q_{i-1}[k] - q_i[k] + r_i[k] - s_i[k]) \qquad (2)$$

Where k is a time discretisation step. In the procedure of discretisation of partial differential equations special attention should be paid to the size of the space/time step of discretisation. One conservative approach defines the criterion of the size of the space/time step of discretisation in the form:

$$\frac{L_i}{T} > v_f \qquad (3)$$

where:

L_i – space discretisation value,
T – time discretisation value,
v_f – free flow speed.

The above state may be simply explained by the fact that vehicles that move at a speed of the free flow must not pass the entire segment during one time interval.

It is especially favourable to build into the basic model of the equation of conservation (2) the multi-lane model. In this way partial reduction of road capacity by losing one or several lanes can be modelled. In this case the model of the equations of conservation acquires the form:

$$\rho_i[k+1] = \rho_i[k] + \frac{T}{L_i \lambda_i}(q_{i-1}[k] - q_i[k] + r_i[k] - s_i[k]) \qquad (4)$$

Parameter λ describes the multi-lane impact on the road traffic flow, which is dependent on the reduction coefficient (influence of several traffic lanes on the throughput capacity) [16, 20]. The values of coefficient λ are presented in Tab. VI.1.

Tab. VI.1 – Impact of several road lanes on traffic flow

Number of active traffic lanes	1	2	3	4
λ	1.00	1.80	2.25 - 2.34	2.40 – 2.60

In order to define the second order macroscopic stochastic mathematical model, the equation of conservation is supplemented by the following equations:

- stationary speed equation

$$V(\rho_i) = v_f \exp\left(-\frac{1}{a}\left(\frac{\rho_i}{\rho_{cri}}\right)^a\right) \qquad (5)$$

- dynamic speed equation

$$
\begin{aligned}
& v_i\left[k+1\right] = v_i\left[k\right] + \\
& + \frac{T}{\tau}(V(\rho_i\left[k\right]) - v_i\left[k\right]) + && (a) \\
& + \frac{T}{L_i} v_i\left[k\right]\left(v_{i-1}\left[k\right] - v_i\left[k\right]\right) - && (b) \\
& - \frac{\nu T}{\tau L_i} \frac{\rho_{i+1}\left[k\right] - \rho_i\left[k\right]}{\rho_i\left[k\right] + \kappa} + \xi_i^v\left[k\right] && (c)
\end{aligned}
\qquad (6)
$$

- traffic flow equation

$$
q_i\left[k\right] = \rho_i\left[k\right] \cdot v_i\left[k\right] \cdot \lambda_i + \xi_i^q \qquad (7)
$$

The above system of equations is described by the well-known Payne model [21]. The dynamic speed equation describes the actual drivers' behaviour taking into consideration the mean traffic flow speed and the traffic state in segment after and in front of the current segment. Term (a) is convection part, term (b) is relaxation part, and term (c) defines the anticipation drivers' behaviour. Parameters τ, ν, κ describe the local traffic characteristics of individual segment, and they are obtained in the procedure of dynamic identification of traffic characteristics of the road section [16, 22]. A special problem lies in determining the statistical characteristics of additive noise of model ξ_i^v (standard deviation). One of the possible methods is to use the approach such as Singer manoeuvre model and its derivatives [23, 24].

3.2 Integral mathematical traffic flow model in state space

In the discrete mathematical model of traffic flow (4, 5, 6, 7) the state variables are the traffic densities ρ_i, space mean speeds v_i, and traffic flow q_i, where i=1,...,N. The external inputs into the system are boundary conditions of the systems q_0, v_0 and ρ_{N+1}. In order to model the traffic flow on a road section this flow is usually described as Brownian dynamic system, that is:

$$s[k+1] = s[k] + n[k] \qquad (8)$$

where:

$$s = \begin{bmatrix} q_0 & v_0 & \rho_{N+1} \end{bmatrix}^T \qquad (9)$$

is the vector of exogenous inputs, and n[k] is a sequence of Gaussian white noise, of zero mean value and standard deviation depending on the characteristics of the traffic flow of the concrete segment.

The integral model of the traffic flow for the road section (freeway) can be expressed in the form:

$$\boldsymbol{x}[k+1] = \boldsymbol{f}(\boldsymbol{x}[k]) + \boldsymbol{\gamma}[k] \qquad (10)$$

where:

$$\boldsymbol{x} = \begin{bmatrix} \rho_1 & v_1 & \dots & \rho_N & v_N & s^T \end{bmatrix}^T \qquad (11)$$

is vector which defines the traffic state variables, and γ[k] is a sequence of the Gaussian white noise, of the zero mean value, and standard deviation depending on the inaccuracy of the mathematical model.

The output equation can be presented in the form:

$$y[k] = g(x[k]) + \zeta[k] \qquad (12)$$

where function *g(x)* describes the used measuring system and measurement algorithm, and ζ[k] is a sequence of the Gaussian white noise, of the zero mean value, and standard deviation depending on the accuracy of the measuring system. Usually it is:

$$y[k] = \begin{bmatrix} q_0[k] & v_0[k] & q_N[k] & v_N[k] \end{bmatrix}^T + \zeta[k] \qquad (13)$$

The measurement procedure depends on the used measuring system. The optimisation procedure in selecting the measuring system is described in [17].

3.3 Traffic state variables estimator

By using the model of estimation error in the form of the covariance matrix:

$$P[k] = E\left\{\left(x[k] - \hat{x}[k]\right)\left(x[k] - \hat{x}[k]\right)^T\right\} \qquad (14)$$

where $\hat{x}[k]$ is the optimal state estimate of state $x[k]$, the goal is to realise the optimal estimator in the sense of minimising the upper covariance matrix. One of the approaches is the well-known Extended Kalman Filter [25, 26]. Its standard approach has the following form:

$$\hat{x}[k+1] = f\left(\hat{x}[k]\right) + K_f[k](y[k] - g\left(\hat{x}[k]\right)) \qquad (15)$$

where K_f is Kalman filter gain matrix, which is calculated by using the Riccati matrix equation in the discrete form:

$$K_f[k+1] = (F[k]P[k]G[k]^T + M[k])(G[k]P[k]G[k]^T + R[k])^{-1} \qquad (16)$$

where the estimation covariance matrix is calculated recursively in the form:

$$P[k+1]=(F[k]-K_f[k]G[k])P[k]F[k]^T+Q[k]-K_f[k]M[k]^T \quad (17)$$

In the above equations certain terms are:

$$F[k]=\left\langle \frac{\partial f}{\partial x} \right\rangle_{x=\hat{x}[k]}$$
$$G[k]=\left\langle \frac{\partial g}{\partial x} \right\rangle_{x=\hat{x}[k]} \quad (18)$$

Jacobian matrices which describe the linearised system around estimated state, and matrices Q, R and M adequate covariance matrices of excitation noise, measurement and cross-covariance of excitation and measurement. There is the possibility of implementing different approaches in determining their values [23, 24]. In using the above algorithm (in one of different applicable versions) the real-time estimate of traffic state variables on the selected road segment is achieved. The selected structure of the model facilitates various possibilities of simulating the incident events (blocking traffic in one or several lanes, complete traffic standstill, traffic congestion on road section, etc.). In order to model the influence of merging vehicles on the inflow ramp, the above model can be extended by adequate members of influence in the dynamic speed equation [27, 28, 29].

By using the presented estimate procedure, based on the traffic measurement on a limited number of points of a certain section, it is possible to reconstruct the traffic signature per single segment. These data are the starting element for the usage of the algorithms of automatic traffic incidents detection.

4. AUTOMATIC DETECTION OF TRAFFIC INCIDENTS ON OPEN ROAD SECTIONS

In the introduction to this paper it was said that the implementation of CCTV cameras on open road sections /freeway) is still economically unacceptable. For the incident detection requirements various methods based on the estimate of traffic state variables are used. Based on the good estimate of traffic state variables the detection of possible traffic anomalies is carried out. This area generally belongs to the part of the general classification theory.

As the measure of the quality of success of a certain algorithm the following indicators are used [30, 31].

a) DR – *Detection Rate* is the ratio of the number of detected incidents and the total number of actual incidents,
b) FAR – *False Alarm Rate* is the ratio of the number of “false” detected incidents and the total number of detection algorithm decisions,
c) TTD – *Time to Detection* is the time interval from the moment of incident to the moment when the incident has been detected, and it does not include the time necessary for incident verification.

The relation of the detection rate (DR) and false alarm rate (FAR) is not independent and it behaves qualitatively as presented in Fig. VI.6. This figure shows the optimal area of parameters DR and FR. Insisting on the increase in the detection rate above these values leads to unacceptable growth in false alarm rates (the “price” of increasing the detection rate is connected with the significant rise in “false” alarms).

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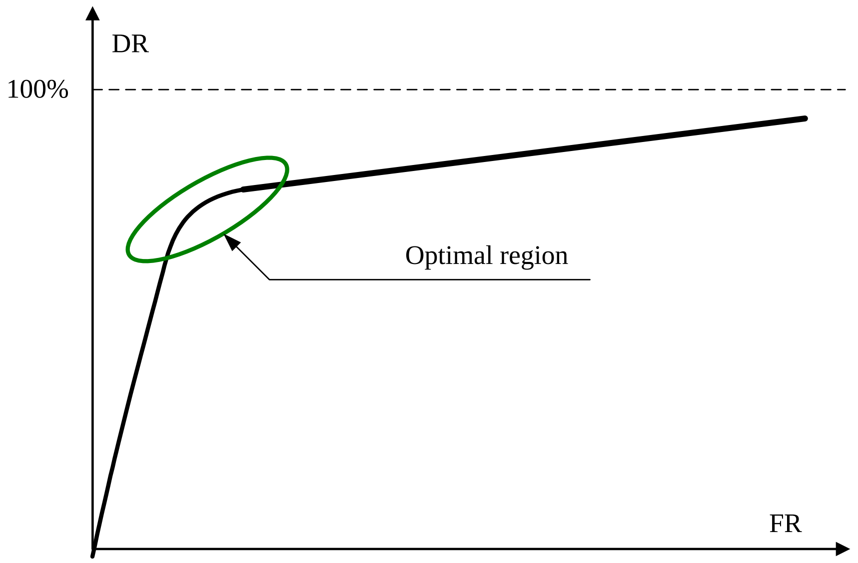

Fig. VI.6. – Theoretical model of DR and FR relation

In past research and implementation, the algorithms of automatic incident detection in traffic could be divided into the following approaches:

1.) Statistical theory;
2.) Pattern based algorithms;
3.) Catastrophe theory;
4.) Artificial intelligence.

Statistical theory

Such approach was developed as early as in the 1970s and it is based on the statistical deduction of the relation of measurement and estimated state of "normal" traffic. The especially appropriate method is based on the Bayesian algorithms of calculating the probability of incident occurrence in the downstream area [32]. The algorithm calculates the conditional probability that the traffic has "deteriorated" due to an incident.

Pattern based algorithms

Algorithms based on the pattern theory are usually algorithms in present operative. They operate on the principle of traffic flow occupancy, traffic volume and information on the traffic flow which are usually taken over from the measurement system. By sample identification in the data that are not considered “normal” for a certain road, the potential incident is recognised. The best known representative of this approach in automatic incident detection is the so-called California algorithm, developed in the late 1960s for the usage on the Los Angeles highway [33]. The algorithm is based on three tests that are performed on the data about the passage between two adjacent detectors, and the calculation of “thresholds” with which the results are to be compared. If the planned threshold is exceeded, incident is pronounced.

Catastrophe theory

The catastrophe theory is a relatively older scientific discipline originated from the theory of sensitivity. It studies the influence of minor changes of single parameters on the total system behaviour. In case of incident detection in traffic these are speed, flow and occupancy of the traffic space. For instance, when speed is significantly reduced, without respective increase in occupancy and flow, this will result in incident announcement. The algorithms based on the catastrophe theory can distinguish between the incident and normal congestion. Congestions are created gradually, whereas incidents cause sudden changes which drastically affect the current flow speed. The representative of algorithms which belongs to this group is the McMaster algorithm [34]. Basically, it uses the model of catastrophe theory to describe the flow – lane occupancy relation.

Artificial intelligence

Algorithms based on artificial intelligence use different procedures of Fuzzy logics and Artificial Neural Networks (ANN). In the early 1990s the researchers at the

University in California presented the possibility of using artificial neural network for incident detection [35, 36]. The artificial neural network consists of three layers: input layer which receives the data from the measurement system, hidden layer which processes the data and external layer which generates the signal depending on whether it is an incident or normal traffic flow state. In application of artificial neural network the selection of adequate learning examples is of special importance. The "intelligence" of these methods depends most on this selection. Today the orientation is increasingly towards the structures known as neuro-fuzzy expert systems.

The recent approaches in incident detection in traffic are based on the usage of several different approaches through the decision support system (DSS) [15]. Usually, such decision support systems are based on the voting principle, with built-in restrictions.

5. DECISION SUPPORT SYSTEM FOR INCIDENT MANAGEMENT

The latest research in the field of automatic incident detection in traffic refers to the usage of complex systems that use different sources of information and processing procedures [15, 37]. Such solutions lead to the proposal of using the decision support system. The information flow in one such system is presented in Fig. VI.7. Such systems require significant integration of information from various sources. The past experiences, namely, of implementing the traffic incident detection system show significant correlation of different causes of incident occurrence. In this sense different procedures of information fusion are proposed, with the aim of improved detection (better level of detection, reduction of false alarms, and shortening of time necessary for safer detection).

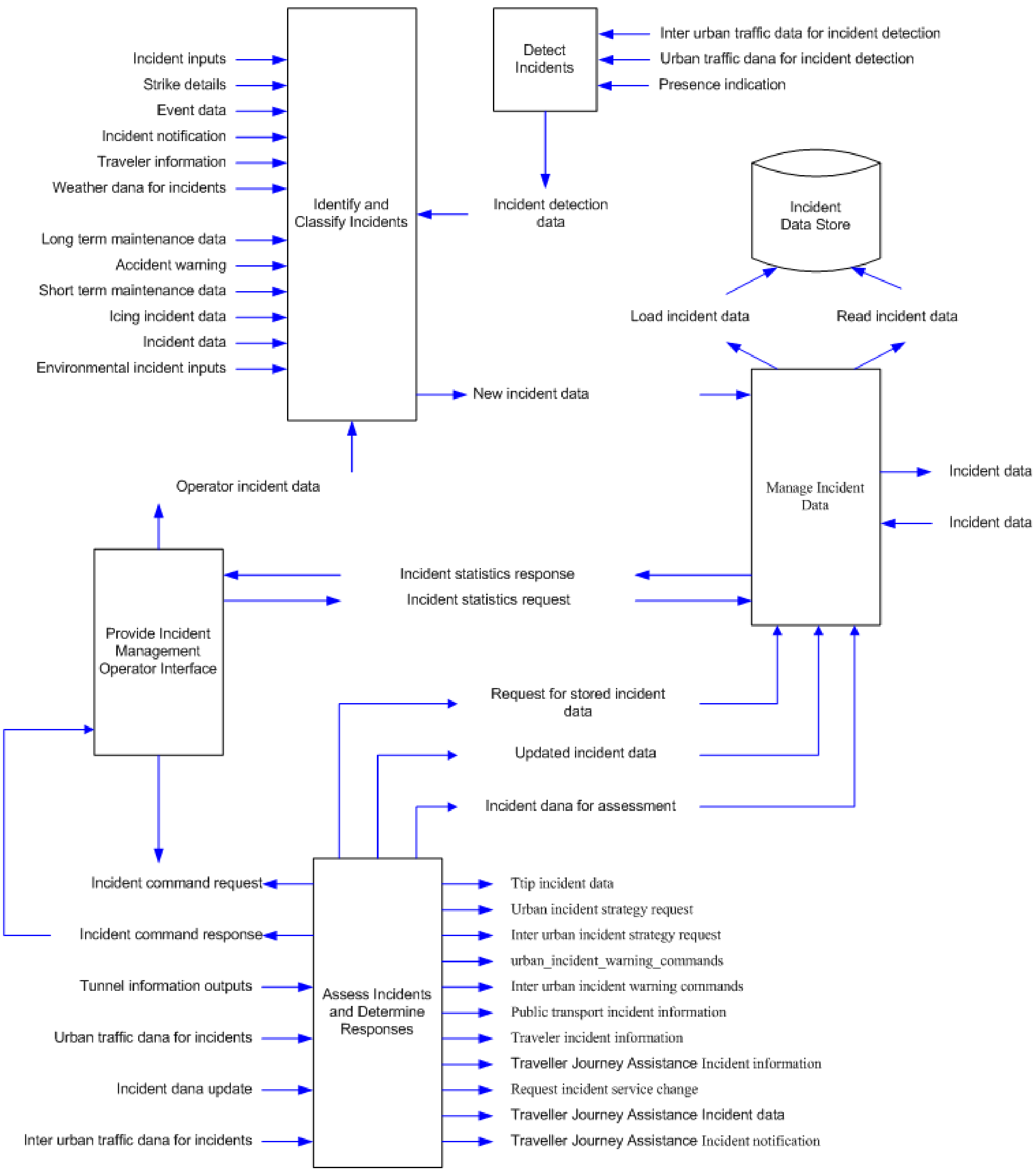

Fig. VI.7. – Information flow model in IMDSS

Apart from the standard parts, a system like this has the following functionalities:

- monitoring and reporting of the services in the field,
- predictive estimate of danger, dangerous spots and law violation,
- real-time monitoring of vehicles and creation of traffic situation picture,
- saving and referencing of all events related to the incident,

- real-time reconstruction of events,
- intelligent contact lists of the crucial participants in incident management,
- generation of automatic messages that are forwarded to different control panels in control centres, different agencies, technical groups or individuals.

In construction of such systems one should pay attention that several factors affect the quality of the operation of the incident detection subsystem. The crucial factor is the currently operative condition of the road (freeway) in relation to its design capacity. The experience shows, namely, that it is very difficult to determine that a traffic incident has occurred on the road, in case when the current traffic is significantly lighter than the highway capacity. This is the consequence of information insufficiency. Besides, the variations in traffic flow have a daily rhythm, with two - three peaks in the hours of the busiest traffic. In this case, these daily and hourly variations in traffic exclude the application of simple threshold algorithms. Such algorithms do not recognise the nature of temporal variation of traffic picture during the day.

The grade of the road, the change in the number of lanes and the existence of approach ramps makes the identification of certain traffic situations difficult, as well as the patterns of single traffic incidents. Similarly, the external factors such as the condition of road surface and meteorological condition will affect the traffic picture regardless of the incident occurrence (for example heavy rain and snow change the picture of the traffic flow).

The performances of simple detection algorithms that use the comparison of measurements on two or more spaced detectors depend significantly on the gap between detector stations. The presence of approach ramps, lane merging and other geometrical road characteristics need to be considered with special attention. Good starting basis for the determination of the positions of detector stations is that the same throughput conditions on the selected measurement segment are valid.

In the previous studies have shown that vehicle heterogeneity on the road section significantly affect the performances of the detection algorithm, [31, 37]. Most of the algorithms assume large participation of the vehicles of the same type, which dictate a certain picture of the traffic flow. A disproportionate percentage of big trucks will have the tendency of slowing down the traffic and increase the headway. This may cause such a change in the picture of the traffic flow, that some detection algorithms pronounce this as incident.

All the mentioned elements indicate the need for application of a far more complex structure. Some experiences in the application of the decision support system, as expert systems derivative, indicate the possibility of these artificial intelligence technologies. Such approach allows the installation of knowledge bases and inference engines that have the capacity of high-quality processing of such complex information.

6. CONCLUSION

The objective of this paper is to present the possibilities of achieving maximally effective and efficient development and implementation of the real-time traffic incident management system. It emphasises the special significance on the timely incident detection. The efficient management of available information, data exchange as well as intelligent real-time decision-making can reduce the consequences of traffic incidents, especially, prevent secondary incidents. Advanced inventive technologies and the approach based on the intelligent transport system paradigm, significantly improve the system performances. The main performance characteristics taken into consideration are response time and reduction of harmful consequences from incidents. .

The future work should study the possibilities of different realisations of the algorithm for traffic flow variables estimation. Therefore, a promising approach is based on the implementation of neuro-fuzzy estimators, which may include also the incident detection algorithms. The authors' opinion is certainly that such systems will lead in the future to technologies based on the today already proven approach to the decision support system i.e. expert systems. Special effort should be directed also to the study of the possibility of predicting the incident. Some past researches have shown that in some situations an incident can be predicted (forecast) with fairly sufficient probability. In that case, the final results referring to the prevention of the incident itself can be of great significance.

7. LITERATURE

[1] Bošnjak, I., Intelligent Transportation Systems 1, Faculty of Transport and Traffic Sciences, Zagreb, 2006 (in Croatian)

[2] Intelligent Vehicle Highway Systems: The State of the Art, JHK and Associates, New York, NY, March 1993

[3] Hegyi, A., Girimonte, D., Babuska, R., & De Schutter, B., A comparison of filter configurations for freeway traffic state estimation. In Proceedings of the 9th international IEEE conference on Intelligent Transportation Systems, 2006

[4] Roy, P., Abdulhai, B., GAID: Genetic adaptive incident detection for freeways, TRB 82nd Annu. Meeting, Washington, DC, 2003.

[5] Škorput, P., Real-time incident management system, M.Sc. Thesis, Faculty of Transport and Traffic Sciences, Zagreb, 2009 (in Croatian)

[6] Dudek, C.L, Messer, C.J. and N.B. Nuckles, N.B, Incident detection on urban freeways. Transportation Research Record, 495 pp. 12-24., 1994.

[7] Dia, H., Rose, G., Snell, A., "Comparative performance of freeway automated incident detection algorithms," in Proc. Roads 96: Joint 18th ARRB Transp. Res. Conf. and Transit New Zealand Land Transp. Symp., pt. 7, pp. 359–374, 1996

[8] Papageorgiou, M., Blosseville, J.-M., & Haj-Salem, H., Modelling and real-time control of traffic flow on the southern part of Boulevard Périphérique in Paris, Part I: Modelling. Transportation Research A, 24, 345-359, 1990

[9] Kotsialos, A., Papageorgiou, M., The importance of traffic flow modelling for motorway traffic control, Networks and Spatial Economics, 1, 179-203, 2001

[10] Wang, Y., Papageorgiou, M, & Messmer, A., Real-time freeway traffic state estimation based on extended Kalman filter: A case study. Transportation Science, 41, 167-181, 2007

[11] Cremer, M., Flow variables: estimation. In: Concise Encyclopedia of Traffic and Transportation Systems. Pergamon Press, 143–148., 1991.

[12] Wang, Y., Papageorgiou, M., Messmer, A., Renaissance–A unified macroscopic model based approach to real-time freeway network traffic surveillance, Transportation Research Part C 14, 190–212, 2006

[13] Isermann, R., Process faults detection based on modelling and estimation methods, A survey, Automatica 20 (4), 387-404, 1984

[14] Willsky, A. S., A survey of design methods for failure detection in dynamic systems, Automatica 12, 601-611, 1976

[15] Mitrovich, S., Valenti, G., Mancini, M., A Decision Support System (DSS) for Traffic Incident Management in Roadway Tunnel Infrastructure, Association for European Transport and contributors, 2006

[16] Mandžuka, S., Application of artificial neural networks in intelligent telematics, TEB Elektronika, Zagreb, 2010 (in Croatian)

[17] Jelušić, N.: The Evaluation of Sensor Technology in Automatic Road Traffic Control System, Ph Thesis, Faculty of Traffic and Transport Sciences University of Zagreb, 2008 (in Croatian)

[18] Jelušić, N., Anžek, M., Ivanković, B., Information Source Quality in Intelligent Transport Systems, Promet-Traffic-Transportation, 125-134, 2010

[19] Jelušić, N., Anžek, M., Mandžuka, S., Evaluation of sensor technologies for ITS, Proceedings of 16th ITS World Congress, Stockholm: Ertico, 2009

[20] Legac, I., Roads 1, Public Roads, Faculty of Transport and Traffic Sciences, 2006, (in Croatian)

[21] Payne H.J., Models of freeway traffic and control, Mathematical Models of Public Systems, (G.A. Bekey, ed.), Vol. 1, No. 1, Simulation Council Proceedings Series, pp. 51-61, La Jolia, California, 1971

[22] Papageorgiou M., Dynamic modeling, assignment, and route guidance in traffic networks, Transportation Research B, vol. 24B, no 6, pp. 471-495, 1990

[23] Li, X.R., Jilkov, V.P.,Survey of Maneuvering Target Tracking, Part I: Dynamic Models, IEEE Transactions On Aerospace and Electronic Systems Vol. 39, No. 4, 2003

[24] Mandzuka, S., Ship tracking control: Optimal estimation of navigation parameters, In Proceedings of the 42th International Symposium, ELMAR, Zadar, 2000

[25] Jazwinsky, A. H., Stochastic processes and filtering theory. NewYork: Academic Pres, 1970

[26] Sorenson, H. W., Kalman filtering: Theory and application, IEEE Pres, New York, 1985

[27] Wang, Y., & Papageorgiou, M., Real-time freeway traffic state estimation based on extended Kalman filter: A general approach. Transportation Research B, 39, 141-167, 2005

[28] Wang, Y., Papageorgiou, M., & Messmer, A., An adaptive freeway traffic state estimator and its real data testing, Part II: Adaptive capabilities. In Proceedings of IEEE 8th international conference on intelligent transportation systems, 537-542, 2005

[29] Wang, Y., Papageorgiou, M, & Messmer, A., Real-time freeway traffic state estimation based on extended Kalman filter: A case study. Transportation Science, 41, 167-181, 2007

[30] Ritchie, S.G., Cheu, R.L., Simulation of Freeway Incident Detection Using Artificial Neural Networks, Transportation Research Part C: Emerging Technologies. Vol. 1, No. 3. Pergamon Press, 1993.

[31] Al-Deek M., Implementation of Incident Detection Algorithms, UCF Transportation Systems Institute, August 1999.

[32] Levin, M., Krause, G., Incident Detection: A Bayesian Approach. Transportation Research Record 682 (52-58), 1978.

[33] Payne, H.J., Tignor, S.C., Freeway Incident Detection Algorithms Based on Decision Trees with States, Transportation Research Record 682 (30-37),1978.

[34] Antoniades, C.N., Stephanedes, Y.J., Single-Station Incident Detection Algorithm (SSID) for Sparsely Instrumented Freeway Sites. Transportation Engineering, 1996.

[35] Stephanedes, Y.J., Liu, X., Artificial Neural Networks for Freeway Incident Detection. Transportation Research Record 1494 (91-97), 1995.

[36] Ritchie, S.G., Cheu, R.L., Simulation of Freeway Incident Detection Using Artificial Neural Networks. Trasportation Research Part C. Volume 1, (313-331). Pergamon Press, New York, 1993.

[37] Zografos K.G., Androutsopoulos K.N., Vasilakis G.M., A real-time decision support system for roadway network incident response logistics, Transportation Research Part C: Emerging Technologies, 10 (1), 2002