# INTELLIGENT TRANSPORT SYSTEMS AND SERVICES (ITS)

## New challenges for system developers and researchers

Eriksson O.

### 1. INTRODUCTION

Today there is a rapid development of information technology which can be used to support the mobility of people, vehicles and goods. The systems which are built with this new technology combine:

- mobile units for communication, e.g. units which are built into vehicles, cellular phones and PDAs;
- wireless telecommunication, e.g. 3G-mobile telecommunication and radio communication;
- positioning, e.g. Global Positioning Systems (GPS) and cellular phone triangulation;
- GIS-technology.

These systems can be used in different mobile use situations and for mobility management, i.e. for transport- and travel- management. These systems and services are of great interest because travel and transport activities are becoming increasingly important for industry and society.

### 1.1. Intelligent Transport Systems and Services

Intelligent Transport Systems and Services (ITS) is the concept used to describe how the new mobile information technology can be used in the transport sector [Ertico, 2001]. The idea with ITS is that the services should bring extra knowledge to travellers and operators in order to improve transport and travel activities. In cars, ITS is used to help drivers navigate, avoid traffic hold-ups and collisions. On trains and buses ITS is used for managing and optimising fleet operations and to offer passengers automatic ticketing and

real-time traffic information. At the roadside ITS is used for co-ordinating traffic signals, detecting and managing incidents and to display information for drivers, passengers and pedestrians. Today there are a number of ITS-services available and some of these applications are described below.

*1.1.1. Car navigation services*

Car navigation systems is a type of ITS-application which can be bought and used in vehicles. The systems are used for giving drivers advice how to find their destination.

*1.1.2. On trip information services*

On trip information is another service which is available and used in the ITS-sector. The aim of this type of service is to provide drivers with dynamic information about congestion, accidents and road conditions in order to make better and more informed decisions during the trip [Rodseth et. al., 2001].

*1.1.3. Parking information services*

The rise in individual transport and the use of cars has also become a big problem, especially in the large cities in Europe [Hinz, 2001]. As a consequence ITS-services have been developed to inform drivers about the parking situation in their destination area.

*1.1.4. Public transport management services*

Today there is a lot of money spent on developing ITS-services to support public transport passengers with better information [Van Ross and Hearn, 2001]. The aim of these services is to provide passengers with better information about:

- public transport routes and time tables;
- positions of buses and trains and their predicted arrival times based on prevailing traffic conditions;
- advice and guidance to help the passengers choose the most convenient public transport facilities.

*1.1.5 Pedestrian support services*

Pedestrian information systems support the movement, safety and convenience of pedestrians [Anttila et. al., 2001]. These systems provide facility and town information, e.g. weather information, shopping information, tourism information and navigation services.

*1.1.6. Tracking services*

To know the location of people, vehicles and goods is another application which the new technology makes possible. This is e.g. important for people who want to co-ordinate and manage mobility.

*1.1.7. Security and emergency services*

Security and emergency services are important in the ITS-sector. In the USA the Federal Communication Commission has required that wireless carriers have to provide the location of emergency callers to 911 operators. In Europe the European Commission is promoting location determination of all wireless emergency calls to the 112 number [Jaaskelainen, 2001]. In Japan Mayday Services [Masatomo et. al., 2001] have been developed, which provide assistance in the case of traffic accidents, sudden illness and vehicle breakdowns.

### 1.2 ITS provides researchers and systems developer with new challenges

An important aspect of the development of ITS is that a number of general IT-based services are developed which support mobile activities, and this development creates new and interesting opportunities for using information technology, e.g. the possibility to provide targeted information to mobile actors based on time and location. However a problem is that applications and services are developed from a technical perspective, and is driven by the vendors of technical equipment. Although the technology is important the big challenge will be to make ITS useful and understandable for people. This implies that ITS provide researchers and systems developers with a business, organisational and user perspective with new and interesting challenges, and that there is a need for knowledge development and research in a number of areas, some of these areas will be discussed in the paper, and they are are presented in the list below.

- theories and methods for analysing of mobile activities (section 2);
- transport network modeling and analyses (section 3);
- location based information (section 4);
- information systems infrastructures (section 5);
- development performed in an organisational network context; (section 6);
- mobile usability and actability (section 7).

## 2. THEORIES AND METHODS FOR ANALYSING MOBILE ACTIVITIES

The development of ITS have so far been driven by technology and have not primarily been based on the needs and requirements of users and customers. This implies that there is a challenge to learn more about mobile activities and the need for IT-support for mobile avtivities. In order to identify user and customer needs it is important to analyse the behavior of mobile actors, and activities where planning and co-ordination of mobility is essential. To be able do that there is a need for theories and system development methods which can be helpful to analyse the notion of mobility. This is important because the concept of mobility is crucial in order to develop ITS, and traditional systems development and theories are not focused upon this concept.

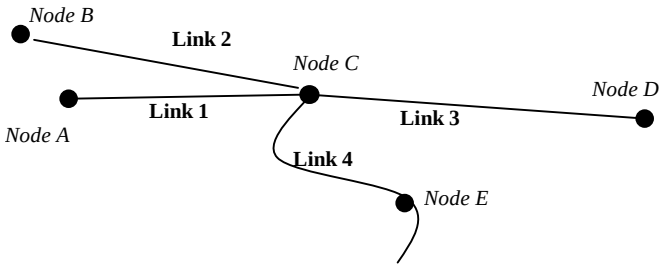
When we talk about the notion of mobility in the ITS context it is the mobility of people and objects in physical space that is of interest. An interesting theory that could be used to analyse physical mobility is time-geography [Hägerstrand, 1991]. The focus of

time-geography is to perform contextual analyses of human action based on the space-time dimension. In order to do that is geographical and spatial analyses important. However the advocates of time geography claims that in order to analyse physical mobility the spatial dimension must be analysed together with the time dimension. Hägerstrand [1991] the inventor of time geography claims that ”*We need to rise up from the flat map with its static patterns and think in terms of a world on the move*”.

An important idea in time geography is to analyse how actions and choices of the actor are constrained by physical restrictions. Hägerstrand claims that “*Even if many constraints are formulated as general and abstract rule of behaviour we can give them a physical shape in terms of location in space, areal extension, and duration in time*“. According to Hägerstrand [1991, p. 146] there are three large aggregation of constraints: capability, coupling and authority constraints. Capability constraints are those which limit the activities and choices because of biological constitution, and/or the tools that are available, e.g. the tools used for transportation and communication. Coupling constraints has to do with the need for, and problems of, coordinating human activities. In order to perform activities, actors, tools and materials have to be brought together, and the time-space dimension affects the coordination of these activities. The authority constraints implies a space-time perspective on authority, power and control. This aspect has to do with who is in control over a certain space, e.g. a buildning or vehicle, and who can access it. The athority constraints can also concern the time dimension, e.g. opening and closing hours for service facilities has a major impact for the activities and chocies of actors. Time-geography is of interest for systems analyses because it can be used to help systems developers to understand and analyse the concept of physical mobility. The fact that time geography describes events and actions in a situational context with a focus on the time-space dimension can be helpful in a number of ways. Time-geography can e.g. used to analyse the constraints imposed by the time-space dimension on human action and choices, and the needs actors can have in order to overcome these restrictions. This can be helpful in order to identify the demand for, and the usability of ITS-services, because the use of ITS can eliminate time and space constraints but also impose new ones.

## 3. TRANSPORT NETWORK MODELING AND ANALYSES

In order to analyse mobility is the concept of the transport network important, because mobile activities are performed along different paths, roads and routes. A transport network is a set of interconnected links through which people travel and goods are transported. The transport network can be described on a conceptual level with a network model constituted by a number of links and nodes. The nodes represent start- and endnodes and junctions in the transport network. This implies that the basic links show how navigation can be performed through the network [Rigaux et. al., 2002] see figure 1 below.




| Node ID |
|---|
| A |
| B |
| C |
| D |
| E |

| Link ID | Start Node | End Node | Road ID |
|---|---|---|---|
| LINK 1 | A | C | R1 |
| LINK 2 | B | C | R2 |
| LINK 3 | C | D | R1 |
| LINK 4 | C | E | R2 |

| Road ID | Road Name |
|---|---|
| R1 | Main road |
| R2 | City road |

**Figure 1. Transport network model**

Transport network models are used for describing roads, railways routes and paths by combining the links in different sequences, e.g. figure 1 shows that Road R1 is constituted by Link 1 and 2, and Road R2 by Link 3 and 4. The challange for system developers is to learn more about transport network modelling and analyses [Axhausen, 2000], because the core concept of many ITS-applications is the transport network. This implies that the basic information structure of many ITS-applications will the transport network model (see figur 1), and most of the information that is gathered and communicated has to be related to the network.

This imlies that it is important to be able to use and implement (see figure 1 above) the conceptual network model in a consistent and understandable way in systems and databases. It is also essential to be able to analyse and gather information about the activities performed on the network. This means that in order to develop ITS-services system developers must be able to analyse and model:

- the structure of the transport network (see figure 1 above);
- the activities performed on the network, i.e. the traffic, transport and travel activities that takes place on the network;
- the impedance which is the cost associated with traversing the network which will include traffic volume, traffic control systems, whether conditions, traffic accidents and parking conditions.

## 4 LOCATION BASED INFORMATION

To be able to develop ITS applications *location* is a key concept because virtually all information used is related to locations. Information about locations and the spatial dimension is complex, and this type of information have traditionally been handled in GIS-systems [Bernardsen, 1999; Worboys, 1995]. However in many ITS-applications we have to combine:

- information about locations;
- transport network and traffic information;
- business information.

This implies that ITS-applications cannot be developed with the help of traditional GIS-systems. Instead we have to develop information systems where the information presented in the list above is integrated. For example a fleet management system used by a truck driver could contain information which is described in figure 2 below.


| **Traffic message** | **Transport order** |
|---|---|
| Date: 2001-11-14 Time: 12:01<br>Type: Accident<br>Place: E 4 on Essingeleden Stockholm between Fredhäll and Stora Essingen.<br>Message: Traffic accident, one lane closed in direction Stora Essingen. | No : 1987987<br>Customer: Lars Ek<br>Address: Kungsgatan 50<br>Town: Stockholm |

**Figure 2.** Many ITS-applications combine business information, transport networks and traffic, based on location.

In this case we have a transport order which tells the truck driver the *location where to deliver the goods, the location is also represented with a cross on the map*. We have transport network information which is *location based* because the road is located in the

landscape. Furthermore there is a traffic message which tells the driver that there has been an *accident on a certain location on the road*.

Figure 2 illustrates that information about locations and positions is very important in order to develop and use ITS-applications. However in research projects we have performed [see e.g. Eriksson and Axelsson, 2000; 2001] we experienced that people who traditionally work with information systems development have little experience to work with location based information. The challange in this area is to learn more about how to model information about locations and to be able to combine information about locations, transport and traffic information, and business information based on the spatial dimension.

Another challenge that has to be met is the problem that people tend to see location as something that only can be represented by maps and coordinates [Couclelis, 1992]. This problem is important to recognise because we do not normally communicate locations in terms of coordinates [Couclelis 1992], instead we use geographical identifiers [ISO/DIS 19112], e.g. names of places and addresses. In figure 2 above we can see that adress information, e.g. "Kungsgatan 50" and names of places, e.g. "Essingeleden", "Fredhäll" and "Stora Essingen" are used. If we look at these concepts we can see that they have a meaning that cannot be represented only by coordinates on the map [Fitzpatrick et. al., 1996]. "Essingeleden" is a road in Stockholm and "Fredhäll" and "Stora Essingen" are names which are related to certain places on that road. Coordinates are very important if we want to represent the geometry of a location on a map, or if we have technical equipment which we can use to establish our exact position, but the concept of location is a complicated phenomenon. I maintain that if we are going to succeed in developing ITS-applications there is a need for research and analyses of concepts that we use to describe locations.

## 5 INFORMATION SYSTEMS INFRASTRUCTURES (ISI)

A special feature of the ITS-applications are that they are related to important transport network infrastructures, e.g. roads and rail-roads (see above), they are also dependent on location based information. This implies that in order to develop ITS-applications, systems developers must have access to databases which contain information about transport networks, traffic information, address information, maps and so on. The reason for that is the systems developers and service providers who want to develop ITS-services cannot gather this information by themselves [Dueker and Tu Ton, 2000]. For example if a service provider wants to develop a navigation system or a fleet management system he needs a road map database which includes maps and road network information, and it is not feasible to gather and structure all of this information on his own. He has to have access to a basic information systems infrastructure which can provide this kind of information.

The National Road Database (NVDB) which has been develop by the Swedish National Road Administration (SNRA) in co-operation with the National Land Survey Administration (NLS), the municipalities (there are 278 municipalities in Sweden) and the forest industry, is an example of this [Lundgren, 2000]. The NVDB contain information about the swedish road network. This implies that the NVDB together with a number of

other databases and IS, e.g. databases which contain information about postal and street addresses, constitutes an important part of the ISI in the ITS-sector in Sweden.

The things listed below are important features of the ISI illustrated in figure 3:

- The information about the road network.
- The functionality used to communicate the information between the data suppliers in the data acquisition process.
- The functionality used to communicate the NVDB-information to the service providers, i.e. the companies who develop ITS-services, e.g. navigation and fleet management applications.
- The standards which are used to facilitate the communication of information between different actors, business units and information systems.
- How responsibilities should be divided between different actors and business units, e.g. between data suppliers, the NVDB-organization and service providers.

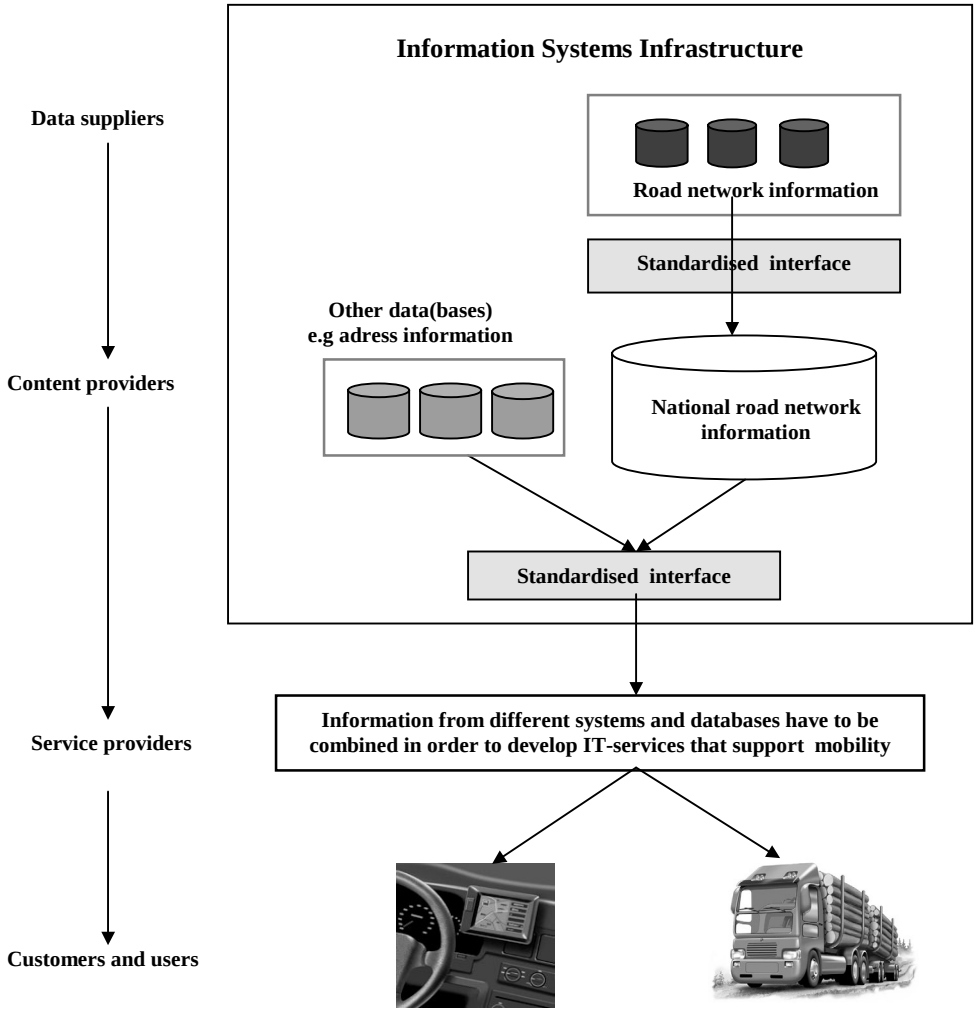


**Figure 3.** The NVDB is a part of an ISI that is a prerequisite for a number of ITS-services

In a research project we have evaluated and analysed the NVDB [Eriksson and Axelsson, 2001]. The analyses show that there are already a number of databases, both at the local and national level, that contain information about the road network.

The municipalities of Sweden store information about the roads and streets in the cities.

The SNRA keep the information about the roads that connect the cities.

The forest industry keeps information about the forest roads.

This is a problem because the service providers got to have access to information about all types of roads. To accomplish this the road network information has to be standardised and co-ordinated. This means that the NVDB-organisation which has the main responsibility to establish the NVDB has to cooperate with a number of data suppliers, content and service providers.

The challange in this area is to learn more about how to develop and maintain these types of information systems infrastructures because this is different compared to conventional systems development:

It is important to work strategically and with a long-term perspective, because it takes time to build an ISI [Hanseth, 2000].

The ISI should have an enabling function [ibid.], e.g. the ISI decribed in figure 3 should be designed to support a number of ITS-applications, it should not be tailored to one type of application.

The development, use and implementation of standards is essential in order to develop an ISI [ibid.]. In two research projects we have investigated the use of national and international standards in the ITS-sector [Eriksson and Axelsson, 2000; Forsman 2001], and we found that there is a lack of knowledge how to use and implement the standards.

## 6 DEVELOPMENT PERFORMED IN AN ORGANISATIONAL NETWORK CONTEXT

A typical feature of the development processes performed in the ITS-sector is their inter-organisational character. For example, the organisation of the data acquisition process in the NVDB-project is a complicated inter-organisational co-operative process [Eriksson and Axelsson, 2001]. Furthermore a service provider who wants to develop an ITS-service is dependent on a number of other actors because there is no single actor who controls the infrastructure that is needed to develop and deliver the service. This means that several private companies and authorities have to co-operate in a network organisational context. Co-operation in such a context is built on communication and relationships between different actors. Furthermore, the actors involved in the cooperation usually have other commitments with other actors. This implies that the development process have to be understood as acts of co-operation in a complex organisational network. Such development projects are often coordinated (the SNRA in the case of the NVDB), but not controlled, by a single actor as the driving force, and the expected effects

from these types of developing processes are more problematic to anticipate in comparison to systems development projects that is controlled by one single organisation.

The challange in this area is to learn more about how these processes emerge, are performed and how they should be managed. To be able to understand the complexity of these co-operative processes it can be fruitful to analyse them from a network organisational perspective which is discussed in network relationship theory [Håkansson & Snehota, 1995]. In this theory it is emphasized that the business processes of a single company are performed in a complex network of interorganisational relationships between several interacting companies and organisations. The network theorists also claim that actors can influence the development of the network but that the network is too complex to be controlled by a single actor. This implies that the development processes that take place in a network organisational context cannot be seen as a structured design process that is controlled by a single company or actor. It can be better described as a process of *evolution* and *dynamics*.

If we consider the *evolution aspect*, it is important to realise that evolution takes time and that the effects from a specific development activity (e.g. a design activity) is not possible to fully anticipate. This means that the network perspective emphasise the long term perspective of business development. The *dynamic aspect* of the development process concerns the web of actors and their interests, which can influence the development process. This implies that within the ITS-sector it is important that we analyse and understand the development of applications and information infrastructures in an evolutionary long-term perspective.

## 7 MOBILE USABILITY AND ACATABILITY

Questions that have to do with the users ability, motives and willingness to use ITS is of major interest. An important issue when we talk about user's motives and willingness to use ITS is the balance between empowerment and control. One reason why the balance with empowerment and control will be focused in ITS is the possibilities that the positioning technology creates. One important aspect of ITS is to deliver Location Based Services (LBS). LBS are services for mobile users that take the current position of the user into account [Francica 2001]. This implies that users can obtain driving directions and see local traffic conditions based on their actual location. In order to do that it must be possible to track and control the movements of people, but this is sensitive information which could be misused. It can e.g. be used for controling people's mobility against their will. This implies that information about locations of people and objects must be handled carefully. The challenge will be to allow flexible access to location information without violating privacy.

Another interesting feature of many ITS-applications are that they are used in mobile use situations. The mobile use situation will change the prerequisites and impose new constraints for developing usable systems. The reason for that is that the mobile use situations and the tools which are used are quite different compared to stationary use situations [Kristoffersen and Ljungberg, 2000].

In a mobile use situation you would e.g. expect that there may be a lot of disturbance from the environment compared to a stationary use situation. Using a system when driving a vehicle implies disturbance from the traffic, and the problem of using the system

and controlling the vehicle at the same time. This implies that new questions will araise when usability is discussed in this context, e.g. traffic saftey issues.

Another constraint is that mobile clients have low limited processing and storage capacity, small input and output devices compared to stationary computers. This implies that the mobile clients will impose restrictions, which are quite different compared to the use of stationary computers, and this will affect the possibilities to build usable systems.

In the mobile use situation there will also be a need for interfaces which are adjusted to mobile activities. For example digital maps are very important interfaces in these types of applications, but also voice interfaces, because looking at a computer screen can be difficult and dangerous when users are on the move, e.g. when they are driving a vehicle.

## 8 CONCLUSION

ITS is an emerging and interesting area for business and systems developers, because ITS creates new and interesting opportunities for using mobile information technology. In previous sections a number of areas have been discussed which we have to learn more about in order to be able to develop ITS. The reason for this is that ITS have special features which will make the business and systems development challenging in a number of ways, which also means the development of these services will be different compared to traditional systems development. This implies that there is need for knowledge development in these areas, but most of all there is a need for people who are able to integrate knowledge from these areas. There are specialists in GIS, transport modeling and information systems development but few people who are able to integrate knowledge from different areas. This is a major problem because knowledge and systems integration will be a key factor in order to develop ITS.

## REFERENCES

Anttila, V., Raino, A., Penttinen, M. [2001]. User Need Research in Personal Navigation Programme NAVI 2000 – 2002. In *Proceedings of the Eight World Congress on Intelligent Transport Systems*, 30 Sep – 4 Oct, Sydney, Australia.

Axhausen K. W [2000] Definition of Movement and Activity for Transport Modeling, In [Henscher D. A., Button K. J.] Handbook of Transport Modelling, Pergamon; Amsterdampp. 271-283

Bernhardsen T. [1999] *Geographic information systems an introduction*, second edition, Wiley, New York

Couclelis C. People Manipulate Objects [Cultivate Fields] : Beyond the Raster-Vector Debate in GIS, *Theories and Methods of Spatio-Temporal Reasoning in Geographic Space : proceedings / International Conference GIS - From Space to Territory: Theories and Methods of Spatio-Temporal Reasoning*, Pisa, Italy, September 21 - 23, 1992

Dueker K. J., Tu ton [2000] Geographical Information Systems for Transport, In [Henscher D. A., Button K. J.] Handbook of Transport Modelling, Pergamon; Amsterdampp. 253-268

Eriksson O. Axelsson K. [2000] ITS Systems Architectures - From Vision to Reality, In *Proceedings of The Seventh World Congress on Intelligent Transport Systems*, Turin, Italy, November 6-9, 2000.

Eriksson O., Axelsson K. [2001]. *The Swedish National Road Database – Analysing governing principles for an Information Systems Architectures, Proceedings of the Eight World Congress on Intelligent Transport Systems*, 30 Sep – 4 Oct, Sydney, Australia

Ertico [2001]. *What is ITS*. [WWW document] http://www.ertico.com/what_its/what_is.htm.

Fitzpatrick, G., Kaplan, S., Mansfield, T. [1996]. Physical Spaces, Virtual Places and Social Worlds: A study of work in the virtual. *Proceedings of CSCW'96*. ACM Press

Forsman A. [2001]. *Standardisering som stöd för informationssamverkan i samband med trafikinformation*, In Swedish, Högskolan Dalarna, Borlänge.

Francica J. [2001]. *Location-Based Services Where Wireless Meets GIS*. [WWW document], URL http://www.geoplace.com/bg/2000/1000/1000spf.asp

Håkansson H., Snehota I. [eds, 1995]. *Developing Relationships in Business Networks*. Routledge, London

Hägerstrand T. [1991] *Om tidens vidd och tingens ordning* , Carlestam G., Sollbe B. [red.], Statens råd för byggnadsforskning , Solna, [in Swedish]

Hanseth O. [2000] Infrastructures- From systems to infrastructures, In Braa K., Sörensen C., Dahlbom B. [eds.] *Planet Internet*, Studentlitteratur, Lund, pp. 179-216

Hinz R. [2001] Parking Space at the Push of a button, *Proceedings of the Eight World Congress on Intelligent Transport Systems*, 30 Sep – 4 Oct, Sydney, Australia

ISO/DIS 19112. *Geographic information- Spatial referencing by geographic identifiers.* [WWW document], URL http://www.statkart.no/isotc211/scope.htm#19112

Jaaskelainen, J. [2001]. Towards the Mobile Information Society – First Results of E-Europe2002 Action Plan Paving the Way to Q-Mobility. *Proceedings of the Eight World Congress on Intelligent Transport Systems*, 30 Sep – 4 Oct, Sydney, Australia.

Kriegl, J. [2000]. *Location in Celluar Networks – Automated Vehicle Monitoring based on GSM Positioning*. Diploma Thesis, University of Technology Graz, Austria

Kristoffersen S. [2000] Mobility, In Braa K., Sörensen C., Dahlbom B. [eds.] *Planet Internet*, Studentlitteratur, Lund, pp. 137-156

Lundgren, M-L. [2000]. The Swedish National Road Database – Collaboration Enhances Quality, *Proceedings of the Seventh World Congress on Intelligent Transport Systems*, 6-9 November, Turin, Italy

Masatomo, S., Kurokawa, H., Yoshida, S., Yamaguchi, K. [2001]. Development of a Navigation System Adapted to "Helpnet" Emergency Call Services. *Proceedings of the Eight World Congress on Intelligent Transport Systems*, 30 Sep – 4 Oct, Sydney, Australia

Rigaux P., Sholl, M., Voisard, A. [2002] Spatial Databases – with applications to GIS, Morgan Kaufman Publishers, San Francisco, USA

Rodseth, J., Jenssen, G. D., Moen, T., Asmundvaag, B. [2001]. ICT in Road Traffic, *Proceedings of the Eight World Congress on Intelligent Transport Systems*, 30 Sep – 4 Oct, Sydney, Australia.

Van Ross, P., Hearn, B. [2001]. Smart Bus Passenger Information Systems, *Proceedings of the Eight World Congress on Intelligent Transport Systems*, 30 Sep – 4 Oct, Sydney, Australia

Worboys M.F. [1995] *GIS a computing perspective*, Taylor & Francis, London