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# A Comprehensive Survey to Identify System Concepts & ICT Requirements of IRAN Intelligent Transportation System (IRAN ITS)

Master's Thesis in Computer Network Engineering

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## **Preface**

This report is a master thesis in Network Engineering at Halmstad University. The survey was conducted through a close cooperation with Iran Telecommunication Research Center (ITRC), during June 2008 to April 2009.

I would like to express my sincere appreciation to my supervisor, Prof. Tony Larsson for his advice and inspiring ideas that helped me create this master thesis. I would also like to extend my special thanks to my project manager Mrs. L. Mohammady and other collaborators in Iran Telecommunication Research Center for their input during the process and help in conducting this thesis.

I wish to express my sincere gratitude to people and government of Sweden who so generously awarded this opportunity for me to learn and gain educational experience here in this beautiful country.

Last but not least come my family and girlfriend, who encouraged me and supported me at all times, good as bad. Thank you so much.

Kayvan Farzaneh

Halmstad University, April 2009



## **Abstract**

This thesis report describes the survey carried out in order to study the ITS practices in Sweden and Europe and indentifying their successes and failures as well as technical specifications. Furthermore, a requirement analysis work has been taken into account to identify the needs and requirements of ITS development in Iran from both business and technical aspects. This thesis aims to conclude and come up with a plan about the development strategy and system architecture of Iran ITS.



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## 1 Introduction

The information and telecommunication technology revolution is offering increasingly powerful options for solving most difficulties and problems any city in the world may be involved with such as congestion, traffic accident, and the environmental impact of surface transportation.

In recent years, there has been a significant interest towards the development of intelligent transportation systems (ITS), providing safety and comfort to the passengers and thereby increasing the efficiency of highway utilization [1].

IRAN ITS Project means any project that in whole or in part deploying the technologies or systems of technologies that provide one or more ITS user services as defined in the National IRAN ITS Architecture addressed in later chapters.

### 1.1 Motivation

Since there are several regional ITS projects running in IRAN at the time of conducting this research, there is an increasing demand and desire to build a national ITS for IRAN which integrates all existing ITS systems and infrastructures into a single national ITS system which provides a very extensible infrastructure to enable fully utilization of the latest ITS technologies.

As the main motivation stated in the initial proposal, the impossibility to create more and more infrastructures raises the needs for more intelligently solutions in transportation system.

### 1.2 Goals

The national IRAN ITS project aims to provide support and encouragement for national (as well as regional and local) ITS cooperation and assist in the creation of a national ITS strategy and system architecture.

IRAN ITS is a governmental project, and the project proposal is delivered to Iran Telecommunication Research Center (ITRC)<sup>1</sup>. ITRC is the most experienced research entity in the Information and Communication Technology (ICT) field in IRAN, with more than 37 years of scientific experience in research.

This master thesis work is accomplished in a close cooperation with ITRC as a part of work package 1 of the IRAN ITS project.

As shown in Fig. 1, Work Package 1 of the IRAN ITS project deals with the development of concepts and a architecture in order to provide the appropriate ITS services in IRAN. As a part of this work package, **the main objective of this thesis report is to identify, prioritize and agree on the requirements of IRAN Intelligent transportation system.** The resulting prioritized and organizational requirements will be used as the basis for the further technical works of the succeeding work packages.

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<sup>1</sup> <http://www.itrc.ac.ir>

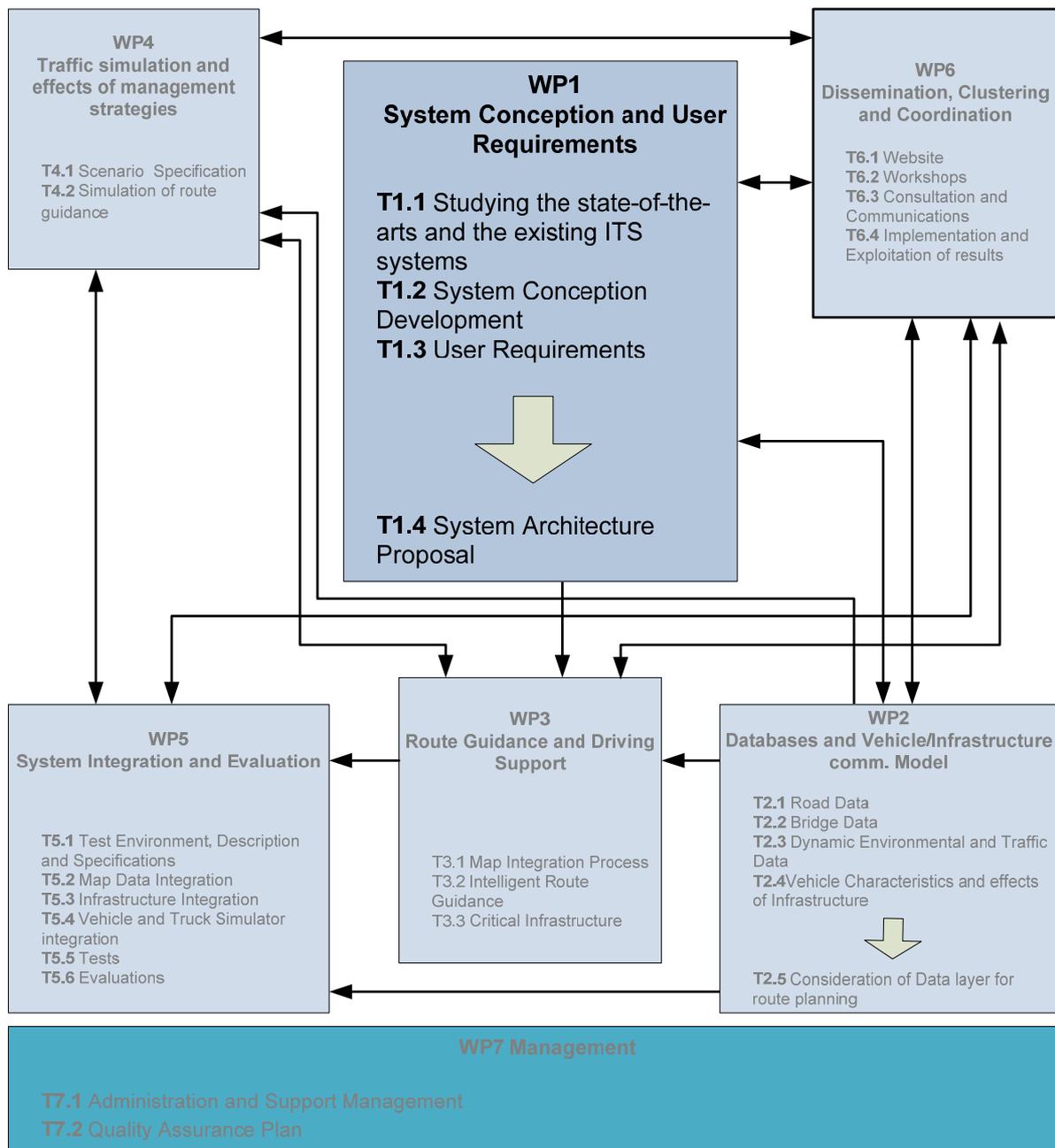


Fig. 1. IRAN ITS work package diagram

### 1.3 Structure of Document

Besides this introduction, chapter one covers the basic understanding of ITS and its concepts on the basis of the conducted surveys and case studies. This chapter concludes with some basic recommendations for ITS professionals.

Chapter two explains the technical core of ITS and its functional concepts. Moreover, it gives the overview of enabling technologies in ITS in addition to discussing about the possible transportation services to be deployed by ITS.

Chapter three addresses ITS architecture and standards. The architectures include the basic subsystems and the function of each subsystem.

Chapters four and five, cover the requirement analysis of IRAN ITS. Business requirements of IRAN ITS project is first addressed in chapter four and subsequently, chapter four covers system requirements of IRAN ITS, in which the technical requirements are discussed.

In chapter 4, some technical details about the working packages two and three are selectively presented and communication layer is discussed.

The report ends up with a conclusion about the results of this master thesis work.

#### **1.4 Methodology**

In analyzing the requirements of IRAN ITS project, conform to System Development Life Cycle (SDLC) conceptual model paradigm [2], Business requirement analysis is undertaken first and then system requirements are identified to comply the use cases resulted from business requirement analysis.

The results of this requirement analysis have been discussed with system owners (Governmental sector) during some full project meetings, and teleconferences. During the process, this document was circulated among the related authorities for commenting and giving valuable input.

The main standards used in this work are ISO 27001 for information security and standards like ISO 19115 for metadata elements, ISO 19119 for geographic information services, and ISO/TS 19139 for implementation of metadata in XML. A feature catalogue describing available spatial object types is also required, based on ISO 19110.



## 2 ITS System Concepts

ITS – Intelligent Transportation System- is all about integrating communication and information technology with the transportation system and deploying it to help reduce traffic jams, guarantee the safe and efficient operation of transport systems and protect the environment. As more and more ITS systems are being implemented by different countries and authorities, it is being discovered that how extra benefits could be generated by interconnections among transport networks, systems and organizations. As a result, it motivates developing and applying newer ITS tools which benefits the system owners as well as users who can benefit from a wider range of services that provides their convenience and greater safety.

In this chapter, ITS technologies and tools are discussed according to the ITS technologies available off the shelf and have been practiced around the world.

Acceptance of ITS is a critical subject, and a successful deployment of ITS system in Iran needs to gain an understanding and appreciation of its capabilities and opportunities.

### 2.1 Definition of ITS

Information, communications and integration are the three core features that ITS tools are based on. ITS tools enable both transportation system operators and users to be better informed and make more intelligent decisions by offering whether real-time information about the network and traffic conditions, or online information for pre-trip planning.

The earlier forms of ITS that had been first deployed were Time-proven adaptive traffic signal control systems. Such as SCOOT [3] and SCATS [4]. By advancing the ITS technology, newer control systems emerged such as adaptive cruise control, which can automatically keep the safe distance from the vehicle in the front according to the vehicle speed. Furthermore, dynamic route guidance and navigation is a more complex example of modern ITS tools which relies on information and communication technology. Cargo tracking and location systems are on the other hand widely used in order to improve efficiency of freight operations. Altogether, all ITS tools can be deployed to relive congestion, ensure safety and reduce vehicle emissions as well as make a significant reduction in transport costs.

### 2.2 ITS benefits for transport operators and users

The four main stakeholders of ITS can be defined as:

- Operators, system owners and managers
- Vehicle drivers
- Trucks, ships, trains and other transport consumers
- Regional authorities and city planners

Although ITS services covers all users' need, on account of the fact that these are mostly the vehicle drivers and other transport consumers who pays for and purchases the ITS products, therefore the trends on developing ITS tools are focusing developing products and services for the second group of users. Consequently, system owners and operators need to take more proactive steps to develop ITS services.

ITS provides greater safety, better information and increased comfort to travelers. System owners and operators can benefit from ITS to offer a better and more efficient service. City planners use ITS to implement policies to make a more sustainable transport system.

The examples of ITS benefits for all users are discussed in the following sections.

### **2.2.1 Decreasing Accidents**

ITS can help to reduce the number of accidents and their severity as well as offering a quicker rescue activities. Speed management and driver monitoring are two considerable applications for reducing accidents. Speed management can be performed by generating warnings, driver feedback and providing control on the speed. Some example tools for these applications include:

- Adaptive speed control
- Quicker emergency and rescue actions
- Road speed camera systems
- warning systems
- Automatic traffic control for pedestrians and cyclists
- Weather monitoring

### **2.2.2 Reducing Traffic Congestions**

In such a large city of Tehran, all groups of users always suffer from heavy congestion and terrible traffic conditions. Therefore, reducing congestion is the major goal of IRAN ITS. It can be better control through managing the demand and improving the efficiency of the transport network as well as diverting the demand for car travel to other modes of travel [5]. The corresponding ITS services can help to achieve these approaches include:

- For managing the demands:
  - Access control
  - Electronic payment
- For increasing the efficiency of network:
  - Regional traffic control
  - Speed control
  - Driver information
  - To divert travelers
  - Pretrip planning
  - Passenger information system
  - Bus priority

### **2.2.3 Helping the Environment**

Experiences from previous implementations of similar technologies show that they can never succeed and be widely used unless they concern environmental issues. In Tehran, as an example, air pollution is one of the major problems which everybody are involved with, and vehicle emissions are known as the major causes of this pollution. It gets even worse in congested traffic conditions, so consequently, any ITS services that could improve the congestions and traffic management efficiency, will reduce air pollution. Other more specific services include:

- Pollution monitoring
- Air-quality information
- Demand management strategies
- Defining high-pollution areas and enforcing access control in these areas

### **2.2.4 Addressing Comfort Factors**

ITS services can help the users to feel more comfortable, confident and secure. To give an example, the travelers can take the advantages of pretrip planning services and travelling information as well as real-time traffic conditions and weather information, which can help to reduce the driver stress.

For public transport users, ITS can generate early warnings about delays and alternative services so the passengers can continue their trip more efficient and comfortable. In this regard, other ITS services can be mentioned are:

- Information of real-time traffic condition
- Navigation and dynamic route guidance
- Vehicle tracking for providing security or quicker rescue responses
- Real-time public transportation information (e.g. Busses and trains)
- Modern automated payment systems for public transportation systems (e.g. smart cards)

## **2.3 ITS System Concepts**

Good practices of ITS usually can be obtained by the integration of multiple systems. With ITS, the total is nearly always greater than the sum of the individual parts. Implementation is often complex and there are many obstacles to overcome. Strong planning, good communications, and effective coordination between interested parties are essential elements for successful ITS implementation.

### **2.3.1 Deployment Framework**

No single ITS tool or service can meet the requirements of all cities. Instead, ITS should be used as a key part of a package of measures or an overall plan. Therefore a framework for deployment of ITS is necessary in order to successfully implement the ITS. The ITS plan can include the roadmap, the milestones and the hurdles along the way.

### **2.3.2 Coordination**

This is a fact that ITS development requires coordination between several different authorities and organizations. To give some examples, banks, retailers, broadcasters, telecommunication operators and commercial service providers can play a role in building the ITS vision. To build up a partnership for ITS development, their interests should be identified as well.

### **2.3.3 System Approach**

A system approach which contains both technical concepts and institutional measures to integrate must be taken in order to build a successful ITS system in Iran.

### **2.3.4 Technical Concepts**

The technical concepts of ITS can be referred to the information technology and control mechanisms in ITS. Many ITS problems arise from inaccurate and late information or from the lack of appropriate coordination among the decisions made by the users in the system. To give an example, about the dangerous accident possibilities in freeways, a close coordination is required between the traffic management, driver information and emergency management systems.

There are a lot of advanced technology are integrated in ITS today, specially while high-tech solutions continue to increase and their costs decreases, so they can help ITS to be more efficient and reliable.

### **2.3.5 System Architecture**

ITS are systems in which the components are complexly involved with each other. Systems architecture is a framework where all ITS services such as traffic management, navigation and pretrip planning are relying on. Through this framework, the interconnection of all components and their effects on each other as well as the entire system and, each subsystem

functionalities are defined. The systems architecture should be proposed to be extensible. It means that it should not need to assume specific technologies. Instead it should provide a framework in which different service providers can connect their services through standard interfaces. This enables the ITS to decrease the costs and risks while increasing the competition. Successful systems architecture will provide the strategic framework to integrate the role and activities of different players.

### **2.3.6 Key Technologies**

Some specific ITS technologies are at the heart of the ITS in which without them, ITS can not exist. These enabling technologies are required by the different ITS services and the ITS plan should focus on these technologies.

Definitely telecommunication infrastructure is one of these enabling technologies that enable many ITS services to communicate. In this regard, there are more concerns about the wireless communication between the vehicles and the system. The positioning systems like GPS, has become a practical technical alternative at a reasonable cost for vehicle location data acquisition, so many ITS service needing the vehicle location information such as navigators, can benefit from this technology.

On the other hand, centralized databases for digital maps are essential for many ITS services such as traffic data exchange.

### **2.3.7 User Services**

According to the International Organization for Standardization (ISO) [6], the user services are identified in 8 service categories and 32 user services. Table 2.1 includes all these services.

## **2.4 Advanced Traffic Management Systems (ATMS)**

Advanced Traffic Management Systems (ATMS) optimize the road network capacity and combine several separate services, including:

- Coordinating Traffic signals to minimize delays and control queues
- Ramp metering to keep vehicle density below saturation on expressways
- Detecting and managing incidents such as accidents and vehicle breakdowns

### **2.4.1 Urban Traffic Control (UTC)**

The goal of traffic control systems is to reduce traffic congestions, air pollutions, traffic accidents, and to save energy and protect the environment.

Reducing traffic congestions can be done by providing intelligent signal controllers. Traffic message boards can also be helpful by providing traffic condition information to the drivers.

By reducing the number of times that vehicle have to stop for the traffic congestions, the traffic pollution as well as noise generated when vehicles are stationary is reduced.

Saving energy can be achieved by making traffic flow smoother and reducing travel times.

The basic functions of a traffic control system are as follow:

- Automatic collection of traffic information, such as traffic volumes and congestion, using various sensors
- Control of traffic signals based on this information
- Providing drivers with information such as traffic congestion status via information boards and other devices
- Relying instructions from traffic control centers to the local traffic police

As one of the most successful implementation of urban traffic control systems, Japanese Highway Industry Development Organization has built a very complex model of traffic control systems in Nagano since 1998 [7].

Table 2.1 ITS User Services [6]

Advanced Traffic Management Systems (ATMS)	<ol style="list-style-type: none"> <li>1. Transportation Planning Support</li> <li>2. Traffic Control</li> <li>3. Incident Management</li> <li>4. Demand Management</li> <li>5. Policing/enforcing Traffic Regulations</li> <li>6. Infrastructure Management</li> </ol>
Advanced Traveler Information System (ATIS)	<ol style="list-style-type: none"> <li>7. Pretrip Planning</li> <li>8. On-trip Driver Information</li> <li>9. On-trip public transport information</li> <li>10. Personal Information Services</li> <li>11. Route Guidance and Navigation</li> </ol>
Advanced Vehicle Control Systems (AVCS)	<ol style="list-style-type: none"> <li>12. Vision Enhancement</li> <li>13. Automated Vehicle Operation</li> <li>14. Longitudinal Collision Avoidance</li> <li>15. Lateral Collision Avoidance</li> <li>16. Safety Readiness</li> <li>17. Precrash restraint deployment</li> </ol>
Commercial Vehicles Operations (CVO)	<ol style="list-style-type: none"> <li>18. Commercial Vehicle Preclearance</li> <li>19. Commercial Vehicle Administrative Processes</li> <li>20. Automated Roadside Safety Inspection</li> <li>21. Commercial Vehicle on-board safety monitoring</li> <li>22. Commercial Vehicle Fleet Management</li> </ol>
Public Transport (APTS)	<ol style="list-style-type: none"> <li>23. Public Transport Management</li> <li>24. Demand Responsive Transport Management</li> <li>25. Shared Transport Management</li> </ol>
Emergency Management (EMS)	<ol style="list-style-type: none"> <li>26. Emergency notification and personal security</li> <li>27. Emergency Vehicle Management</li> <li>28. Hazardous Materials and Incident Notification</li> </ol>
Electronic Payment (EP)	<ol style="list-style-type: none"> <li>29. Electronic Financial Transactions</li> </ol>
Safety	<ol style="list-style-type: none"> <li>30. Public Travel Security</li> <li>31. Safety Enhancement for Vulnerable road users</li> <li>32. Intelligent Junctions</li> </ol>

#### 2.4.2 Express Highway Management Systems and Ramp Metering

Express management systems monitor traffic conditions and then by processing the obtained information, provide the drivers with alternative routes information and when to reduce the speed. The system deploys some controlling and measuring tools such as ramp metering or lane control.

Ramp metering is a technique used to control traffic signals on some egress ramps to expressways. They control the rate of the traffic joining to the expressway to keep the vehicle density below saturation in order to improve the traffic flow on the expressway. Researches from implemented cases showed that by reducing the traffic speed in a controlled manner, the effective capacity of the road can be increased.

### **2.4.3 Demand Management**

Managing the demand for transportation can help to reduce the traffic congestions. It can be done by applying different techniques and controls such as changing the traffic signal timing to control the volume of vehicles entering an area. Other possible solutions would involve access control over some vehicles, as has been implemented in Tehran different traffic zones, or the rule of odd or even numbered license plates that have admission to enter to air polluted zone of Tehran in odd or even days respectively.

On the other hand, other possibilities of applying demand management would be taken by charging the vehicles for use of the roads during congested periods or allowing only those willing to pay a premium to travel on congestion-free lanes. A successful demand management system in this case would involve deploying more advanced and complicated communication technologies to implement automatic electronic tolling systems to reduce road congestion [7], improve vehicle safety and enhance environmental protection.

## **2.5 Advanced Traveller Information**

It is highly desired for a traveller to be able to plan as much certain as possible. They need to access to good information to make better decisions about their travelling plans. Since the transport authorities have been collecting traffic data for their other services, so providing a shared access to these data to travellers can be significantly useful. Advanced traveller information system (ATIS) aims to provide this shared infrastructure. ATIS works on the basis of the concept that when more information on the system conditions is available to travellers, they will adjust their time, route or mode of travel to their own advantage, which will also improve the transport system efficiency.

The ATIS system can provide this information to traveller in web format, or radio or other tools such as using the navigators that are connected to the roadside stations. These in-vehicle navigators can provide the driver with maps, traffic flow information and directions on how to reach their destinations.

### **2.5.1 Traffic and Traveller Information**

Traveller information systems aim to provide the travellers with the information about the current state of traffic conditions to enable them to make better decisions about their trip. To give an example, the information about congested roads and alternative routes can enable the drivers to change their route or park their car and continue to trip by public transport. On the other hand, predicted journey times, weather conditions, yellow-page information and parking information can be included in the services that a traveller information system can offer.

The communication part for this system can include cellular phones, electronic bulletin boards, and electronic kiosks with traveller information as well as internet technology.

Parking information systems may also help to reduce the traffic in severely occupied areas in the city by reducing the time that the driver spends to look for parking space.

### **2.5.2 Route Guidance and Navigation**

Vehicle navigation systems based on satellite-based GPS positioning system in combination of digital software containing a map can contribute with the driver to finding routes to

destinations in unfamiliar cities or roads. When the driver enters the destination into the software, it calculates the optimum route to follow and gives instructions to the driver by means of voice and images on the screen. When this system could be able to access to the congestion information, it could result in more efficient navigation and reducing the congestion. Centralized route guidance systems need two-way communication between the device and central computer. It can be done either via wireless connection (WIFI) or GSM-type link.

## **2.6 Advanced Vehicle Control Systems (AVCS)**

Advanced vehicle control systems (AVCS) is referred to systems aim to assist the driver either by providing information about the environment or aiding the driver in driving task. There are considerable trends toward supplying the new cars to AVCS technology by the manufacturers to capture the market by increasing the safety and facilitating driving task.

The technologies are varying. To give some examples, antilock breaking, traction control, and dynamic skid control, adaptive cruise control, driver drowsiness detectors, infrared night vision systems, and lane warning sensors are introduced by the manufacturers to help controlling their vehicles. More advanced and high-tech systems include automatic collision avoidance systems, which relieve the driver of some or more control of the vehicle. In the near future, these systems will be similar to auto-pilot systems in airplanes. Fully automated highways will require processing resources in both inside vehicles and some highway equipments that will guide vehicles to their destination.

There are some advances in the systems which can improve the vision of drivers in bad weather conditions. For this, these systems can generate images of the road ahead using infrared or other similar techniques. Collision warning systems, which are especially helpful in slow driving like driving in reverse, can warn drivers about the approaching obstacles.

Statistically, a considerable proportion of the accidents in the roads are resulted from drivers falling asleep during the trip. Driver drowsiness detector systems can detect this and make an alert sound to wake the driver.

## **2.7 Commercial Vehicle Operation Systems**

Large queues of trucks and other commercial vehicles usually can be seen behind route gateways for the investigations such as weight control, licensing and permit, and this matter results in significant delays for commercial vehicles. ITS applications for commercial vehicles could minimize these stops and improve the delays.

Commercial vehicle operation (CVO) technologies include automatic vehicle identification to allow truckers with all the required permits to bypass checkpoints at border crossing, weigh-in-motion (WIM) scales to screen vehicles so that trucks that largely loaded don't have to stop at weight bridges, electronic placarding and bill of lading (BOL) to monitor the movements of these vehicles.

Vehicle tracking systems are also widely used to improve fleet management.

## **2.8 Advanced Public Transport Systems**

Advanced Public Transport Systems are referred to the applications that enhance the efficiency and comfort of public transportation services. These applications include public transport information, automated fare collection systems and vehicle locator systems for fleet management to increase security and communicate to passengers to inform about the exact arrival time of the busses and trains.

### **2.8.1 Public Transport Information**

Public Transport Information systems enable public transport information to be accessible to the passengers. A well established public transport information system can attract more passengers to use the public transport rather than private vehicles. Information about timetables, connections, fares, and so on, can be provided to users at their home or vehicles by different media such as internet, interactive information kiosks, and telephone inquiry stations.

Systems may be able to bring real-time information about arrival of the next buses or trains in the stations, or to advise travellers about the best route to the destination.

### **2.8.2 Public Transport Fleet Management and Logistics**

ITS systems can significantly assist the operation and management of the public transport vehicle fleet. As mentioned before, some systems include automatic vehicle location (AVL), which enable tracking the vehicles as well as operators to take action if services are running off schedule.

The AVL device in the vehicle regularly sends the location and identity information of the vehicle to the computer center, and the software running in these computers match the received data with the estimated vehicle location according to the time table and then displays the position of each vehicle on the operator's console or map.

ITS can help public transport operators with various important traffic data, including loading and fare collection information, so that management and maintenance become more facilitate whereas expenses decrease. Operators can monitor the passenger loads and the demands for services accurately.

### **2.8.3 Public Transport Priority**

ITS systems can significantly assist the operation and management of the public transport vehicle fleet. As mentioned before, some systems include automatic vehicle location (AVL), which enable tracking the vehicles as well as operators to take action if services are running off schedule.

The AVL device in the vehicle regularly sends the location and identity information of the vehicle to the computer center, and the software running in these computers match the received data with the estimated vehicle location according to the time table and then displays the position of each vehicle on the operator's console or map.

ITS can help public transport operators with various important traffic data, including loading and fare collection information, so that management and maintenance become more facilitate whereas expenses decrease. Operators can monitor the passenger loads and the demands for services accurately.

## **2.9 Emergency Management Systems (EMS)**

Emergency services include automatic emergency notifications, route guidance for emergency vehicles and support for relief activities. ITS can also help in hazardous load management and tracking that is important performing in emergency service.

Automatic emergency notifications sometimes are very vital especially in the rural roads that mobile phones don't have enough coverage. These systems automatically alert the relevant authorities about the accident and its location. AVL and other telecommunication techniques are greatly needed in emergency services.

## **2.10 Electronic Payment Systems (EPS)**

Modern electronic payment (EP) systems have very many advantages rather than cash payments in transport infrastructure. Electronic toll systems have been developed in many countries enabling drivers to use toll roads without needing to stop in long queues to pay cash. Smart cards are a solution in electronic toll systems which enable more flexible ticketing, lower administrative costs, and better marketing information.

### **2.10.1 Electronic Toll Collection Systems (ETC)**

Electronic toll collection systems or electronic fee collection systems are installed in toll roads which enable drivers to electronically pay the tolls without needing to stop in any toll station. These systems generate a simple tag for each vehicle passing through the toll road including the vehicle identity and corresponding date and time, and then the cost of transaction will be recorded in the database for later payment. This will reduce delays while improving the toll security by eliminating toll avoidance and frauds. These systems need a very secure communication infrastructure.

### **2.10.2 Public Transport Fares and Ticketing**

Large public transportation systems are always involving in payment and ticketing systems that are increasingly costly and inefficient when the payments are all handled by cash, therefore ITS technologies can offer many advantages to reduce the costs and increase the reliability and efficiency of these systems. One of the basic technologies required to replace cash payments by electronic payment is Smart Card technology. Contactless ticketing systems use a combination of two technologies: the smart card for safety and transactions, and short range radio frequency transmission for convenience and speed of validation. By advancing the technology, now a relatively huge memory and processing capabilities are available on a chip, so it allows innovative fare products to be developed in combination with other services linked with public transport to generate a flexible mobility package. Examples are:

- Payment for congestion charge and tolls on urban highways
- Payment for parking in city
- In addition to mentioned benefits of electronic ticketing systems, they can improve services by offering:
  - More accurate information about passenger traffic which helps better public transportation planning
  - More and better security and protection against ticket fraud
  - More reliability of validation equipment

## **2.11 Safety Systems**

ITS is highly capable of providing security for all users including network operators, users or third parties. In public transport, a combination of AVL and mobile communications increase personal safety for passengers. For drivers, an intelligent intersection can provide information to drivers, warning them about vehicles approaching the intersection from crossroads but that are out of sight from the drivers. There are many ITS solutions to improve the security of pedestrians as well specially in intersections; they can feel safer and more convenient when ITS can detect pedestrians to adjust pedestrian period to their walking speed. On the other hand, ITS can offer enhancements for vulnerable road users. ITS can help to make road crossing easier for elderly or handicapped pedestrians. Given a small portable communication device to pedestrians, the time allocated for them can be extended by exchanging signals. The signals of these devices can also be received by the vehicles around and warn them about a vulnerable road user attempting to cross the road ahead of the vehicle.

Policing and traffic regulation enforcements can significantly reduce accidents. While traditional enforcement techniques only rely on police officers to impose a fine or other penalties, the potential for mistakes is very high. Automatic video surveillance, coupled with license plate recognition technology can lead to very higher control and lower disregards.

Other factors in accidents can be related to weather and surface conditions like ice formation, or failed traffic signal. The advance warning of hazardous weather conditions enable drivers to avoid the area and help road operators to take preliminary steps to protect the roads from hazardous accidents.

## **2.12 Conclusion**

The benefits and advantages of ITS is to improve transportation system operations including: saving time and lives, enhancing the quality of life, improving the productivity of commercial activities.

The basic understanding of ITS concepts can be concluded as the following results and recommendations:

- To build intelligent transportation systems, transportation professionals are needed who are aware of the possibilities offered by new technologies.
- Transportation professionals can not work individually without involving other stakeholders.
- Traffic managers will need to establish partnerships with other stakeholders in transportation area, such as public transport operators, private sector information service providers, city planning authorities, fleet managers of commercial vehicles, and, travelling public.
- Banks are needed to contribute in providing electronic payment systems.
- Building an ITS infrastructure require a system approach and a well-developed framework to enable cooperation of different authorities.

### 3 ITS Enabling Technologies and Functional Concepts

All ITS services and functions described in chapter 1, can only be developed by using a number of other technologies and technical concepts that are key to ITS functions. To build a national ITS system, it is necessary to study these enabling technologies for traffic information and vehicle control at their functional level, and not only how they are implemented individually, but also how they can be integrated and work together as a system to achieve the determined goals. This chapter covers the functional components and information chain in ITS.

#### 3.1 Functions of ITS Components

Fig. 2 shows the ITS information chain which includes data acquisition from transportation system, communications, data processing, information distribution, and information utilization for decision and control support for the ITS users [9].

The most significant technologies and concept of this information chain that should be considered as enabling technologies for ITS are:

- Information exchange and decision coordination among different centers such as traffic and transit management centers for intermodal transportation services
- Acquisition of information and integration between the vehicle and the road infrastructure
- Information exchange with new private-sector organizations such as information service providers to distribute traffic information through internet or other media.

##### 3.1.1 Enabling Technologies

Enabling technologies in ITS are categorized in Table 3.1, according to the information chain subfunctions. The technologies are divided into two columns: Infrastructure side and Vehicle side.

It should be mentioned that some of the technologies should be adapted or reviewed before deploying in national ITS project of Iran. To give an example, GPS (Global Positioning System) is borrowed from the defense industry of United States and using it in Iran will require further considerations. However, all of the mentioned technologies are available off the shelf in the market. A brief explanation of each enabling technology mentioned in this table and their related technologies at the functional level are given in the following sections.

##### 3.1.2 Data Acquisition System

Many ITS services will not be achieved without a timely and accurate system for collection of information about traffic and road conditions [11].

Video image detectors (VID) technologies are widely used in traffic detection. The images captured by video cameras in VID are processed to generate the traffic parameters such as vehicle presence, speed, lane occupancy, lane flow rate, and so on. Multiple cameras covering same traffic area can be connected to one processor unit to enable wider area coverage, and by deploying certain image processing software, they can eliminate the problems caused by shadows, occlusion, and direct sunlight to the cameras. Visual images from closed circuit television (CCTV) can provide complementary information to traffic management group. In addition to visual information, other information from other inputs such as polices, road maintenance departments, weather forecast, and cell phone calls from drivers on the road are used in traffic management. Moreover, inputs from sensors measuring the freezing point of the road surface enable network managers to have a estimation about the required amount of deicing chemicals and sands to improve the road condition [12].

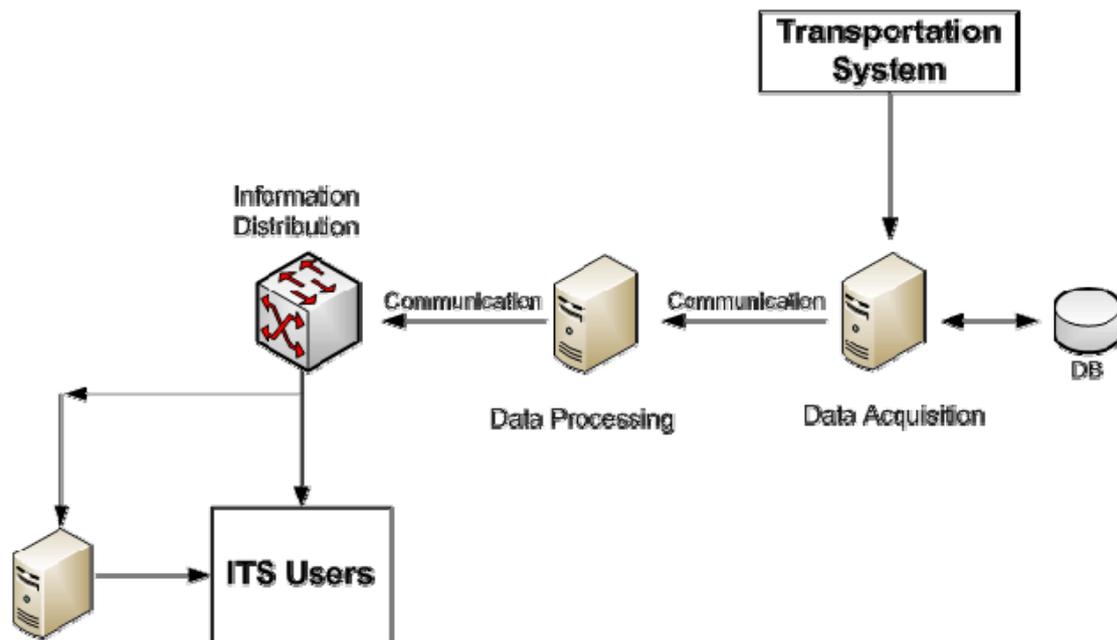


Fig. 2. ITS Information Chain

On the vehicle side, information about vehicle conditions, such as vehicle speed, fuel level, oil pressure, engine temperature, and so on can be collected through in-vehicle sensors for vehicle operation and maintenance.

Vehicle location information are also important in ITS to enable navigation operation to the destination as well as tracking of the vehicle for fleet management purpose. Moreover, this information can be useful for other agencies to enable rescue or repairing services for vehicles in trouble or to find and track stolen vehicles.

### 3.1.3 Data Processing

After data are collected, they should be processed, their accuracy should be verified and conflicting information should be adapted to present a reliable set of traffic data before they are distributed. This process is known as data fusion, which has been defined as “a formal framework in which are expressed means and tools for the alliance of data obtaining from different sources. It aims at obtaining information of greater quality; the exact definition of ‘greater quality’ will depend upon the application” [13]. Data fusion steps in traffic management center include processing of raw data, cleaning and checking the accuracy of data, making all data formats compatible and incorporating data from other agencies such as transit management center, highway maintenance organization, police department, etc.

One of the main data processing algorithms and applications includes image processing technique. As an example, in automatic incident detection (AID) application which described before, the images captured by variety of detectors and video cameras are tested against an image processing algorithm. These algorithms include a variety of methodologies to detect an accident, such as comparative, statistical forecasting of traffic behaviour [14]. Quick detection of incidents will help in reducing the rescue operation response time.

On the other hand, in-vehicle applications such as navigation guides need processing resources as well. These applications mainly depend on Global Positioning System implemented by US department of defence. This system works on the basis of receiving microwave radio signals from a network consisting about 24 to 32 satellites orbiting around the earth. The obtained three geographical dimensional coordinates (longitude, latitude and altitude) are used as inputs to navigation software where the positioning data are matched to the digital maps and enable path finding operations for the vehicle. The information of the

vehicle location then can be sent to other relative stations such as traffic center, bus stop or emergency center, as needed.

Table 3.1 Enabling Technologies (Adapted from [10])

ITS Enabling Technologies	Infrastructure Side	Vehicle Side
Data Acquisition	Traffic Detectors Weather Monitors	AVI Weight-in-motion
Data Processing	Data fusion AID	GPS Digital Map
Data Communication	Stationary Comm. Fiber Optics	Mobile Comm. DSRC
Information Distribution	VMS Internet	HAR RDS/TMC
Information Utilization	Ramp metering UTC	Route Guidance Crash avoidance

AID = Automatic Incident Detection	HAR = Highway Advisory Radio
AVI = Automatic Vehicle Identification	RDS/TMC = Radio Data System/ Traffic Message Control
DSRC = Dedicated Short Range Comm.	UTC = Urban Traffic Control
GPS = Global Positioning System	VMS = variable Message Sign

US department of defence allows the use of standard positioning system (SPS) which has a less accuracy than precise positioning system (PPS) for civilian applications. SPS has a accuracy of about 50 to 100 meters. However, this accuracy could be corrected by using correction base stations mounted on the ground, which enables differential global positioning system (DGPS) to improve the performance of the GPS and this result in a better accuracy. Fig. 3 shows the communication between navigation devices, satellites and base stations.

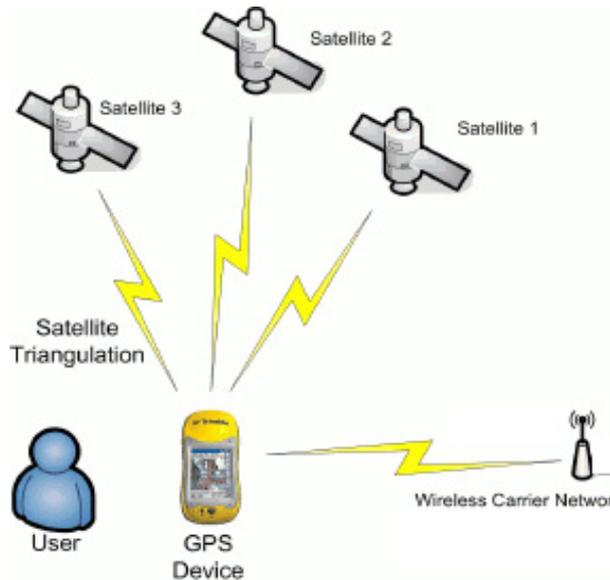


Fig. 3. Global Positioning System (GPS)

Digital Maps are also used in many applications for advanced traveller information systems such as route guidance. Collected data from paper maps and other resources are gathered and processed to build digital maps. Since the digital maps usually contain the whole road information of the country and the roads are always encountering changes, there is a great need for a reliable and regular update mechanism to provide more accurate and functional route guidance.

### 3.1.4 Data Communication and Network Subsystem

Data communication is the most important part of ITS technology infrastructure to enable data collection and distribution in information chain. On Infrastructure side, cable communications are more convenient whereas in vehicle side, wireless mobile communications are only possible.

Evaluating bandwidth usage for each communication link is necessary before building national ITS. Higher bandwidth capacity and bit rates require higher costs. Thus traffic parameters obtained from traffic sources are usually transmitted through relatively low-bandwidth cables or wireless links.

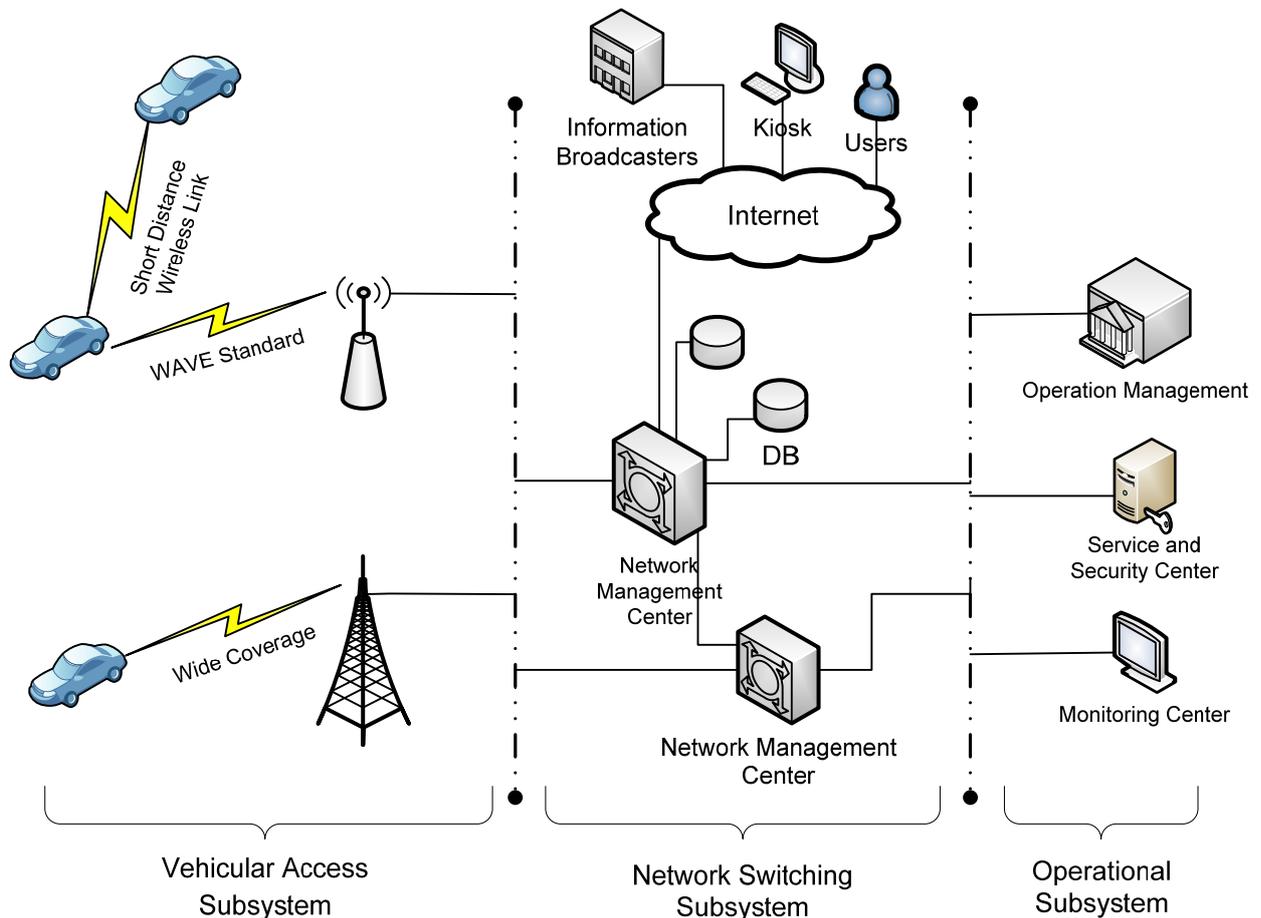


Fig. 4. ITS Logical Network Diagram and Subsystems

A logical network diagram illustrating the communications between various parties in the intelligent transportation system is proposed as depicted in Fig. 4. In this proposed model, the network consists of three subsystems to provide access, distribution and operation of information in the ITS network. These are Vehicle Access Subsystem to communicate with

vehicles, Network Switching Subsystem connecting the access subsystem to the end users and control center as well as enabling information distribution in ITS, and Operational Subsystem for ITS management and ensuring the operability of the system.

### 3.1.4.1 Vehicle Access Subsystem

This subsystem provides the communication link between the mobile vehicles and the ITS network as well as vehicle to vehicle communication. This subsystem is connected to the Network Switching subsystem through standard interfaces and landlines. Wireless is the basis of the communication system in this subsystem. Different wireless channels are used on the basis of the feasible distance between the communicators. Accordingly, three type of wireless system technologies are used in this subsystem. They are Dedicated Short-Range wireless Communications (DSRC), 5.9 GHz Band Wireless Access in Vehicular Environments (WAVE), Wi-Fi and WiMAX.

**Dedicated Short-Range Wireless Communications (DSRC):** This Wireless technology is commonly used for providing the vehicle to field communication (Fig. 5) in which the range is so short that the communication is useful only for some dedicated purposes and is not meant for common carriers, can be used in some ITS services and applications such as electronic toll collection (ETC), Commercial Vehicle Operation (CVO), parking management, signal preemption, in-vehicle signalling, in-vehicle traveller information, and beacon based route guidance system.

To give an example of DSRC, An ETC system requires installing an on-board unit inside the vehicle in addition to a two way microwave or infrared link, and roadside or tollgate equipment. The in-vehicle device is a transponder that is usually installed as a tag on the vehicle. An integrated circuit card with a card holder is also included in the package. The information about the toll transactions such as vehicle type, account identification and balance are being stored on the card. The roadside equipment consists of three parts: a transceiver, a lane controller which monitors activities occurring in a toll lane, and a processing board used to access account information and process the transaction requests [15].

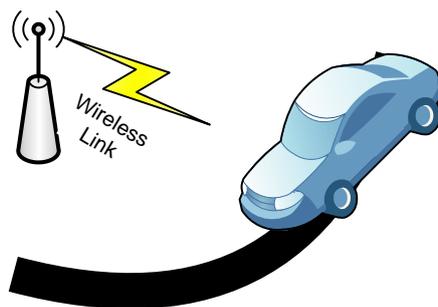


Fig. 5. Field Vehicle Communication

**5.9 GHz Band Wireless Access in Vehicular Environments (WAVE):** This wireless channel is used in both vehicle to infrastructure and vehicle to vehicle communication in a distance that is relatively short. Vehicles use IEEE802.11P wireless standard which aims to support ITS applications, to communicate with other vehicles or the infrastructure. This standard enables data exchange among high speed mobile vehicles in the road. To avoid spectrum interferences with the other wireless channels in the environment, this standard allocates the 5.9 GHz frequency band to the ITS applications [25]. On the other hand, to enable various automobile manufacturers to produce devices with similar communications

interfaces, IEEE 1609 Family of Standards for Wireless Access in Vehicular Environments (WAVE) have been presented to setup standards for organization of management functions and modes of operations of system devices to create the consistent communication interfaces and to enable secure wireless communications between vehicles and road infrastructure [16].

To give an example, advanced vehicle services may use these links in the future to support advanced collision avoidance implementations, road condition information sharing, and active coordination between advanced vehicle control systems. They require vehicle to vehicle wireless communications (Fig. 6).

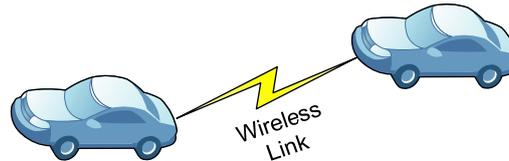


Fig. 6. Vehicle-Vehicle communication

**Wide Area Wireless Communications:** Wide area wireless communications provide wide coverage to enable the communications between the vehicle and infrastructure or mobile devices in any locations including rural roads (Fig. 7). These communications can be either one-way (broadcast) or two-way (interactive). These communication technologies may be targeted by some advanced ITS services such as real-time traveller information and different fleet management applications.

These communication technologies include cellular networks, WiMax, Wireless mesh networks and other wide coverage wireless technologies.

### 3.1.4.2 Network Switching Subsystem

Network switching subsystem is responsible for the distribution of information in the ITS system. It connects the roadside infrastructure to the operation subsystem as well as to information providers, information distributors and broadcasters and, users through internet or other mediums.

**Network Management centers:** they are the heart of this subsystem and manage the roadside infrastructures. They contain fast multilayer switches, routers, servers and database systems. This is the place, where the ITS operations are taken place. Each network management center is provided by some databases including information of ITS services or subscribers. For example, the information about the service transactions in payable services such as vehicle type, account identification and balance can be stored in these databases. Electronic toll collection (ETC), Commercial Vehicle Operation (CVO) and parking management applications can rely on the data stored in databases for accounting aims.

Information collected about the traffic status can be stored in separate databases and can be accessed by information distributors and TV broadcasters as well as users through internet. Therefore, the network management centers are connected to the external networks through internet, ADSL or optical fibre.

The connectivity in this subsystem can be implemented using different existing public or private communication infrastructures and technologies. The communications are established usually by the use of fiber optic, twisted pair, coaxial cable, microwave relay networks, spread spectrum and so on. A point to point network topology between sources and destinations are usually used as shown in Fig. 8. It is the easiest way to establish connection

between network management centers and other stationary nodes in the network such as different places in operation subsystem. To give an example, while network management centers are connected to each other, they are directly connected to gateway servers to enable data exchange with the external networks and internet, or they are connected to operation centers to provide control, maintenance, monitoring and other operational functions.

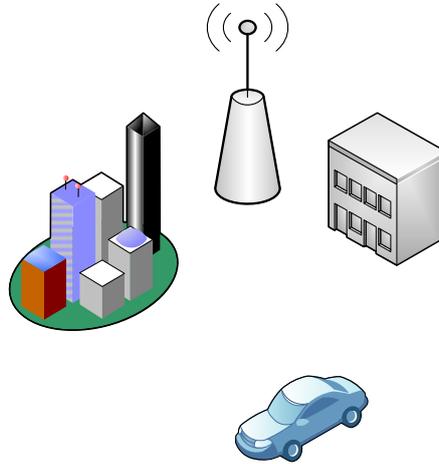


Fig. 7. Wide Area Wireless Communications

But point to point network infrastructure is not the only case can be used in this subsystem. Any physical network topology including Hub and Spoke where the network centers are hubs and other stationary nodes are spokes, as well as Bus topology that provides information transfer between peers can be used in this subsystem. Although bus topology is out of dated and is not suitable in these huge infrastructures.

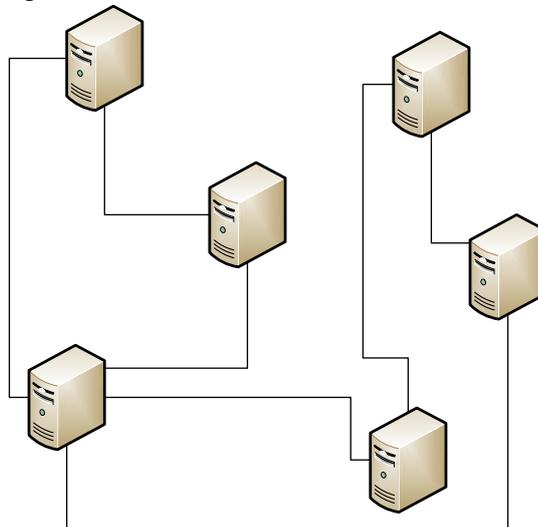


Fig. 8. Point to Point network infrastructure

### 3.1.4.3 Operational Subsystem:

This subsystem provides control, monitoring and security of the ITS system, in addition to ensure the operability of the whole system. Operational Subsystem can include different sections as below:

**Operation Management Centers:** To manage and maintain the ITS system, and include accounting and subscription of users as well as policy information for the system. There could be some commercial operation management centers to manage their private network of

vehicles as well. These centers are directly connected to the network management center where the operations are performed and applied.

**Service and Security Centers:** these centers are responsible to control and maintain the ITS services as well as providing security by applying encryption parameters or key management mechanisms. They are connected to the network management centers where the operations are taken place.

**Monitoring Center:** In these centers, the performance of the whole system is monitored and statistical information about the system status are generated and shown. The traffic control centers are developed here and they are connected to the network management center to monitor and control the operations.

### 3.1.5 Data Distribution

Public authorities may distribute traffic or other related information such as road conditions and Parking space availability in order to improve transportation safety, efficiency and environmental quality. Accordingly, private information providers that collect revenues through advertisement and other charges to the end users may be willing to distribute similar information.

Data distribution in ITS can be grouped into two major categories: fixed terminals and, mobile terminals. Fixed terminals are referred to as infrastructure side, and can include telephones, radios, televisions, computers, kiosks and so on. Mobile terminals include the devices can be used in side the vehicles such as car radios, cellular phones, laptops, pagers, and other hand-held devices.

Variable message signs (VMS) are road signs with messages that can be change. These messages can include warnings about hazardous conditions or information about free spaces from parking garages.

Internet is the most common media used by ITS to distribute information on infrastructure side. Thousands of millions of users around the world with access to computers, can react with the internet to obtain specific up-to-the-minute traffic and transit information in many cities for pretrip planning. In internet and on the related websites, Information can be accessed as real-time traffic flow maps, camera images, weather and road conditions as well as static information such as traffic legislation and technical papers available on websites.

Inside the vehicle, car radios are very preliminary devices that can provide relevant traffic broadcasts. The problem with car radio is that traffic information are always broadcasted in certain time slots, and on the other hand, the broadcast information covers a large area and often has little relevance to the current location of the vehicle in the road.

In order to broadcast traffic information on a more frequent way, FM subcarriers (sidebands) can be used to transfer a low bit-rate traffic data to be displayed in the radio screens.

In Europe, radio data systems (RDS) have been developed for such purposes as station identification. This is accomplished by providing coded message on subcarrier of 57 KHZ. It is agreed to use some of the coded messages for transmitting data traffic information. The advantage is the high degree of possible coverage.

### 3.1.6 Information Utilization

Information utilization in ITS means to advise the users to make intelligent and coordinated decisions, and to support control: both traffic and control and vehicle control [17].

Ramp metering controls the flow of vehicle merging to an expressway by means of a traffic light on the entrance ramp that turns green for short periods of time, allowing a limited number of vehicles to proceed onto the express way at a time.

The purpose of ramp metering is to keep the vehicle density below the saturation in highways. The cycle of the green signals can be determined by monitoring the traffic flow upstream and downstream, the traffic gap on the slow lane, and the queue length at the on-ramp and feeder streets [19]. In some locations, a special lane is provided on the on-ramp for transit and high occupancy vehicles, which gain priority by bypassing the ramp metering signals.

Coordinated traffic control in a large area can be performed at the traffic management center, where traffic information are visualized on the screen boards. Different traffic flows can be colour coded to differentiate the degree of congestion in the flows.

The traffic management center should be linked to other centers including neighbouring centers, centers of different types such as a service provider, public transport center and commercial vehicle operation centers.

On the vehicle side, traffic information utilization makes cars smarter. It can provide information to the driver like in route guidance, or can assist controlling the vehicle like crash avoidance systems.

For route guidance services, the digital map would need to include some attributes of road segments such as distance, turn restrictions, toll charges, travel time according to speed limits and time of day and so on. They can take traffic conditions into account. Finding the optimum route process can be done on the vehicle in vehicle-based systems, or at the traffic center in centered based systems. In-vehicle systems require less communication costs, but center based systems brings advantages such as always updated digital maps and better consideration about the traffic condition.

Automatic cruise control systems can automatically adjust the vehicle speed to keep certain distance from the next vehicles. Speed reduction can be accomplished through automatic closing of the throttle, gear down-shifting and braking.

Lane keeping applications aim to keep the vehicle in the lane by applying image analysis techniques to the images obtained from the front camera. Another approach to lane keeping applications is using wires along the white lines and signalling the vehicles so that vehicles can keep track of the lane.

Automatic Highway Systems (AHS) are defined as hands-off and feet-off driving. They can provide automatic crash avoidance applications. Other semi automated crash avoidance applications include collision warnings to the driver, hazard warnings, computer-assisted merging and overtaking among cooperating vehicles and truck convoys in which a single driver can operate a train of trucks coupled to each other electronically.

### **3.2 Conclusion**

Information and telecommunication technology forms the technical core of ITS, and enabling technologies in ITS should be taken into account while aiming to build an ITS system. The following recommendations and conclusions have been derived from studying these enabling technologies and ITS systems:

- Categorizing ITS technologies can be done on the basis of their functions in the information chain: data acquisition, data processing, communications, information distribution, and information utilization.
- On the infrastructure side, the ITS enabling technologies include: traffic detectors, weather monitors, data fusion, automatic incident detection, stationary communications, fiber optics, variable message signs, internet, ramp metering, and urban traffic control systems.
- On the vehicle side, the ITS enabling technologies include: automatic vehicle identification, weight-in-motion, global positioning systems, digital map, wireless

communications, dedicated short range communications (DSRC), highway radio, radio data message channel, route guidance and crash avoidance.

## 4 ITS Architecture and Standards

In the previous chapter, the functional concepts of ITS were explained. Various subsystems of ITS such as traffic control systems in the past had been built to work independently as separate subsystems. So there were considerable possibilities for conflicts to be occurred. Therefore in order to achieve the determined goals in ITS, all functions and services should be integrated and work together as single system. A system architecture can provide a framework for the design and implementation of ITS. The architecture identifies basic subsystems, defines the functions of each subsystem and identifies the data exchange mechanism between them.

In this chapter, the important concepts of system architecture and standards are covered. The series of steps for developing national Iran ITS architecture are discussed as well.

### 4.1 The Need for ITS Architecture

The complexity of the integration of information systems in transportation systems necessitates a national systems architecture as the first step on the way to create detailed designs. On the other hand, building an ITS architecture can add values to the overall ITS development process in different areas through the following methods [17]:

- Consensus transport policy and implementation
- Technology maturity and user drive
- Promotion of ITS standards development
- Risk management
- Linking ITS to the transportation planning process
- Providing a basis for software development
- Be prepared for future expansion

The systems architecture of ITS can be expressed in various forms. The following sections describe the several forms of ITS architectures.

### 4.2 Levels of Architecture

From the aspect of information exchange and control at various levels, ITS architecture can primarily be depicted in the multilevel model shown in Fig. 9 [21].

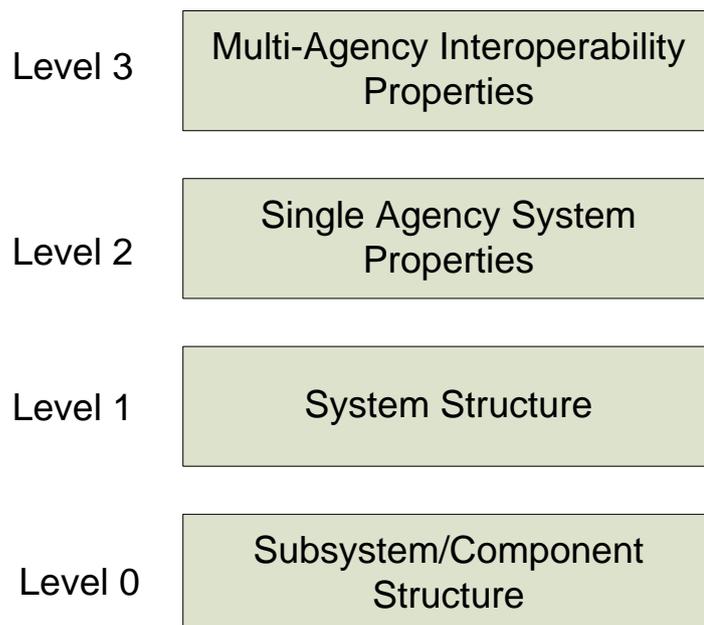


Fig. 9. Multilevel model for ITS architecture analysis

ITS and transport managers need to be connected with the ITS architecture at the higher levels (Levels 2 and 3). These levels are consistent with the lower levels.

The constraints defining interoperability between the participating agencies and the retention of the information control by the respective agencies are set in level 3. Moreover, Level 3 establishes the framework within level 2. Level 2 architecture defines the properties of those systems that are operated by a single agency.

Level 1 architecture is preliminarily the concern of the systems engineers. At this level, the systems structure will be defined, so that ITS functions can be grouped together for cost-effective implementation. Information systems can be logically decomposed into subsystems for design at level 0.

The series of steps for developing a national ITS architecture are discussed in the following sections.

### **4.3 Iran ITS user needs, functional requirements, and concept of operations**

I believe the preliminary steps in establishment of Iran ITS architecture are studying the possible services that ITS can offer, selecting and prioritizing them. Stakeholders should be identified as well. So, the previous chapters covered these preliminary steps, the possible services recommended by ISO were grouped and explained and the four major stakeholder groups involved with the ITS development were identified. The exact definition of previous steps can lead to better determination of requirements and operation that are covered in next two chapters: Business and System Requirement Analysis. So this section is a preface for the next two chapters.

In any single country, there are likely to be large differences between the set of ITS services useful for big cities and the set for rural areas. Different stakeholder groups involving in development of ITS may have different views and policies.

Once the services have been selected, the functional requirements for providing these services must be determined.

Different agencies and stakeholders involved in ITS need to understand what roles, interactions and activities are to take place in the system.

### **4.4 Logical Architecture**

Logical structure in ITS is usually defined in the domain of level 1 in the level architecture defined by Fig. 9. It depicts the processes and information flow needed to meet the functional requirements previously determined. In developing logical architecture, the similarities between the requirements of different services are examined so that their common requirements can be grouped in the same set of processes.

Fig. 10 gives an example of how the logical architecture can be looked like (eg. for guidance and road services) [22] that is shown as a data flow diagram. The arrows indicate the direction of the selected data services. The circles represent sets of processes at subsequent lower levels of the logical architecture.

An important part of the logical architecture is to describe how the system reacts against abnormalities. All failure modes need to be considered for safety, and logical steps need to be described to achieve smooth recovery in the abnormal conditions, and maintain consistency with the higher-level operations.

### **4.5 Physical Architecture**

According to systems engineering context, the physical architecture provides the physical resources and processes conferring the logical architecture, on the basis of the functional

similarity of the process specifications and the location where the operations are to be performed. On the other hand, physical architecture allocates specific processes to physical subsystems by taking into account the organizational responsibilities..

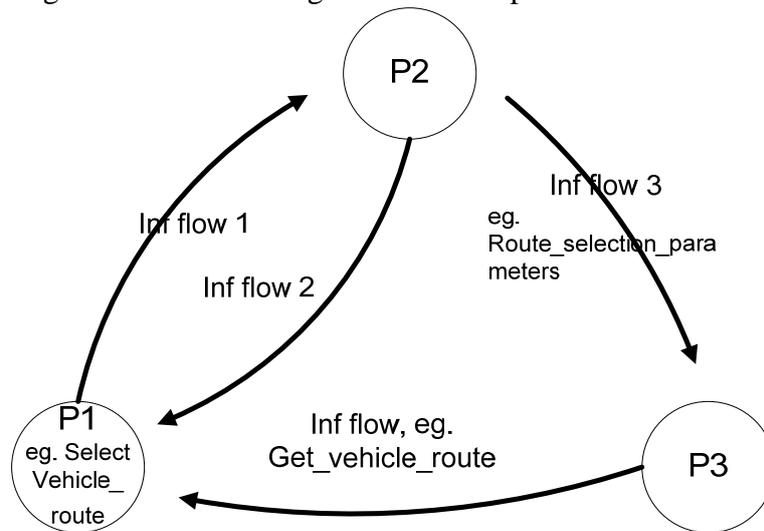


Fig. 10. Logical Architecture for guidance and route services in United States (Inspired from the logical architecture of US Department of Transportation) [22]

A top-level diagram of the national physical architecture for the United States is shown in Fig. 11. As shown in the figure, all interfaces between the four subsystems are depicted. Data flow between subsystems is through four types of communications media. As mentioned earlier, each country must establish its own set of service requirements. For this, table 2.1 provides a good starting point for Iran national ITS architecture. Some requirements may be differ from those which the US national architecture is based on. However it can provide the basis for many level 0 designs, which will serve user needs in Iran.

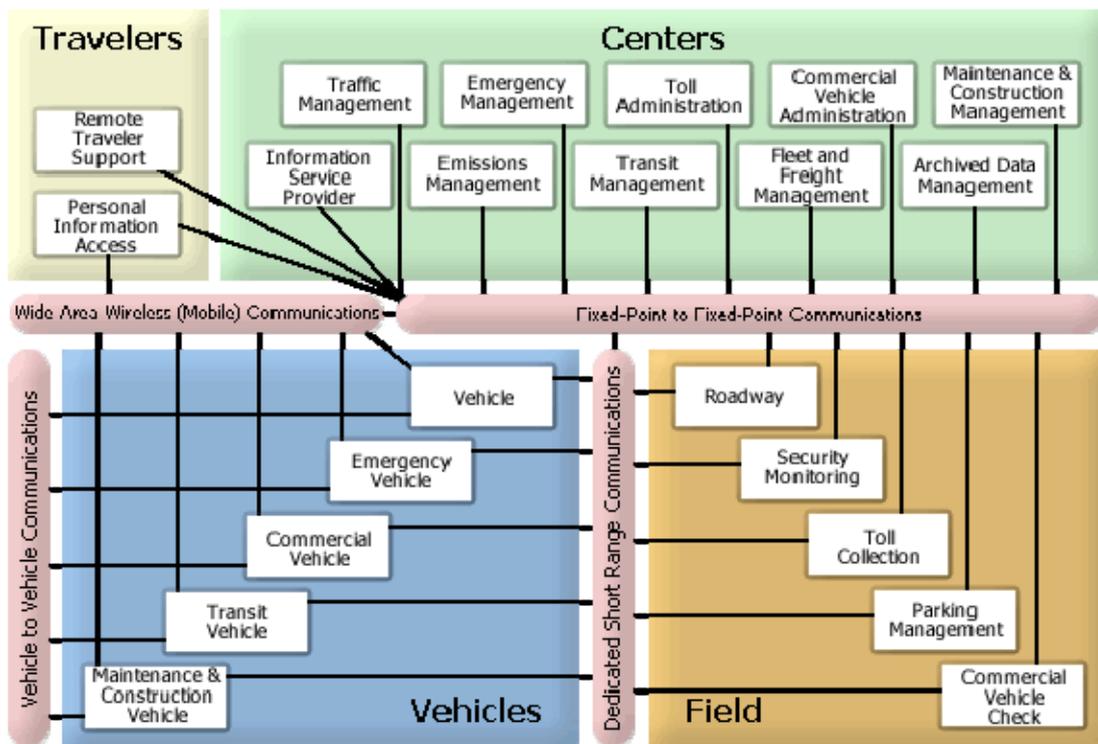


Fig. 11. Physical Architecture for United States (Source: US Department of Transportation) [23]

#### **4.6 Standards**

While system architecture defines the framework to enable different components in the system to fit, standards, on the other hand, ensure hardware and software components from different vendors in the system do fit.

The ISO technical committee 204 has developed an ISO architecture reference model. The goal is to harmonize international deployment of ITS through a common reference architecture.

The IOS working groups recognizes three identifiable stages of architecture development:

- Reference architecture
- Logical architecture
- Physical architecture

The reference architecture can be used as starting point for the development of Iran national ITS architecture.

#### **4.7 Conclusions**

The study of ITS architectures led to the following recommendations and conclusions:

- The architecture development begins with the selection of user services, so this process helps make the agreement among stakeholder groups. Therefore, the resulting architecture is a technical explanation of the transportation policies.
- An ITS architecture can be expressed in several forms according to the needs of different stakeholders: Decision makers can use the operations, functional and organizational architecture, whereas system engineers need to work with reference, logical and physical architecture.
- Based on systems architecture, ITS standards are developed to enable integrity of all the hardware and software from different brands.

## **5 Business Requirements Analysis of Iran ITS**

Conform to the SDLC<sup>2</sup> paradigm, this chapter and the following chapter together present the result of the second phase of this work in which the requirement analysis is carried out and user requirements as well as system requirements are identified respectively.

The main owner of IRAN ITS project is the Iranian Government and the project is delivered to Iran Telecommunication Research Center for undertaking the feasibility study and coming up with a technical proposal so called an RFP<sup>3</sup> document.

In this chapter, the stakeholders and their relationship are identified first. The business requirements are gathered and analyzed using common fact finding techniques such as making questionnaires, forms and meetings.

The result of this requirement analysis is to obtain a common understanding of project scope and functionality, and consequences in terms of organizational structure and system structure requirements. This will be an input to later development phases, making it possible to create compatible tools and systems in order to build IRAN ITS.

### **5.1 Methodology**

This report uses several viewpoints such as Functional viewpoint, Process viewpoint, Information view point and Component view point, in order to describe the high-level architecture of IRAN ITS. Each viewpoint gives a particular point of view upon the overall architecture.

#### **5.1.1 Functional Viewpoint**

The functional viewpoint includes the architectural elements that provide the systems functionality. It is related to user requirements, their roles and other entities.

#### **5.1.2 Process Viewpoint**

The process viewpoint focuses on the information flow between the system functionalities and their roles.

#### **5.1.3 Information Viewpoint**

The Information viewpoint includes all information that are used in the system. This focuses on discovering the information elements required by the process view and the relation between roles and functionalities. On the other hand, it defines the important pieces of information and the relation between them.

#### **5.1.4 Component Viewpoint**

The Component viewpoint consists of system entities and components in the IRAN ITS infrastructure.

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<sup>2</sup> System Development Life Cycle

<sup>3</sup> Request For Proposal

## **5.2 Results of business Requirement Analysis of Iran ITS**

In the earlier phase, a survey and some case studies was carried out and state of the arts in ITS in different countries have been identified and it was mentioned that the overall architecture of the ITS and selection of its services depends on each country and the business requirements of the related authorities.

After discussing the survey's result with the relevant authority in IRAN and obtaining their view point about the desired ITS process, functions and components, the overall needs and strategies was determined as summarized in the succeeding sections.

To consult the result of business needs identification, 10 meetings and teleconferences have been recorded in ITRC with agents and experts from the following organizations and authorities:

- Agent of the National Cartographic Center of Iran
- Transportation Expert from Tehran University
- The Agent of Iran Space Agency
- The Agent of Tehran Traffic Control Center (TMC)
- Telecommunication Expert from Khajeh-Nasir University of Technology
- Telecommunication Expert from Tehran University

The final statements and the output of the business requirement have been revised, finalised and agreed by the following authorities:

- National Traffic and Transportation Organization
- Iran Communication Regulatory Authority
- I.R.I Post Company (As an active partner in Iran ITS project)

Furthermore, 33 private companies and corporations in Iran who are already involved in some ITS activities as well as communication and transportation system activities have been identified for further contribution in development of the Iran ITS project. Most of the activities of these companies include navigation systems and vehicular transportation systems.

### **5.2.1 Iran ITS Overall Objectives**

On the basis of information provided by the mentioned authorities above, the below objectives should be considered in order to implement IRAN ITS for ground transportation network:

- To move towards integration and combination of communication systems (transceivers) with navigator and positioning systems to enable users to utilize one single multi-purpose device for all mentioned applications instead of using various devices.
- To provide all navigation services to users
- To facilitate access to ITS databases
- To enable supervision and management of users and services across the country.
- To utilize the concept of "intelligence" and "automation in different levels" through all network components.
- To consider the concept of "national" in IRAN ITS, which means implementing ITS in all over the country.
- To satisfy the identified needs of users, whether governmental sector or private sector, in providing optimized manageability of their ground transportation system as well as providing LBS services to their users.
- To provide easy and facilitated access to required services such as security, rescue and traffic services as well as cost and time management.

### 5.2.2 Iran ITS Network Classification

On the basis of information provided by the governmental authorities, we could classify the IRAN ITS network to several sub networks in which the control process of each could be performed within the same sub network.

These sub networks are:

- Local City ITS Networks
- Public Sector
- Private Sector
- Intercity ITS Networks
- Public Sector
- Private Sector

A user of public sector is able to employ the city network's services and installing the required information and map, the user can take the advantages of intelligent navigation as long as located inside the city, otherwise the intercity services are provided and the navigation can be performed for intercity routes.

#### Local City ITS

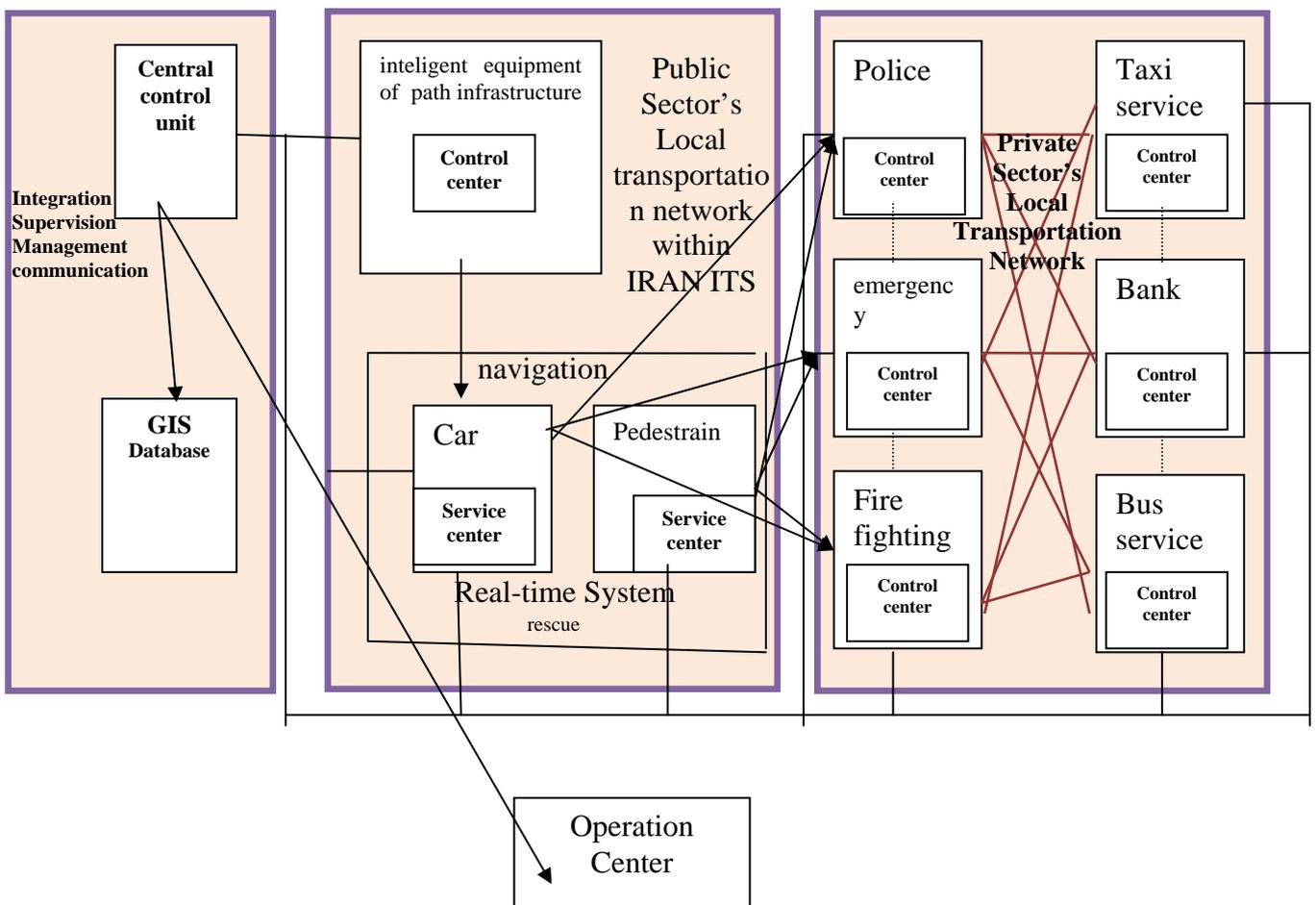


Fig. 12. Local City ITS Network Block Diagram

Fig. 12, presents the block diagram and its intercommunications for local city ITS network. Every city ITS network is formed by several public sectors such as emergency service centers, fire fighting centers, city bus transportation service, taxi service, police, banks and some governmental services. Moreover, an extended network for private sector as well as one

central control unit is created. The central control unit provides interfaces for ITS sub networks, administration unit and operation unit. Every network is provided with a local database containing the data specifically corresponds to the belonged network. Other required information can be handled and exchanged through the central control unit.

The private sector's ITS networks have their own internal control unit and generally intend to perform real-time positioning of their cars, in addition to provide the capability of communication between their cars and control centers.

Other public services can be directly provided to private sectors' mobile users such as rescue and emergency services by the public sector's network.

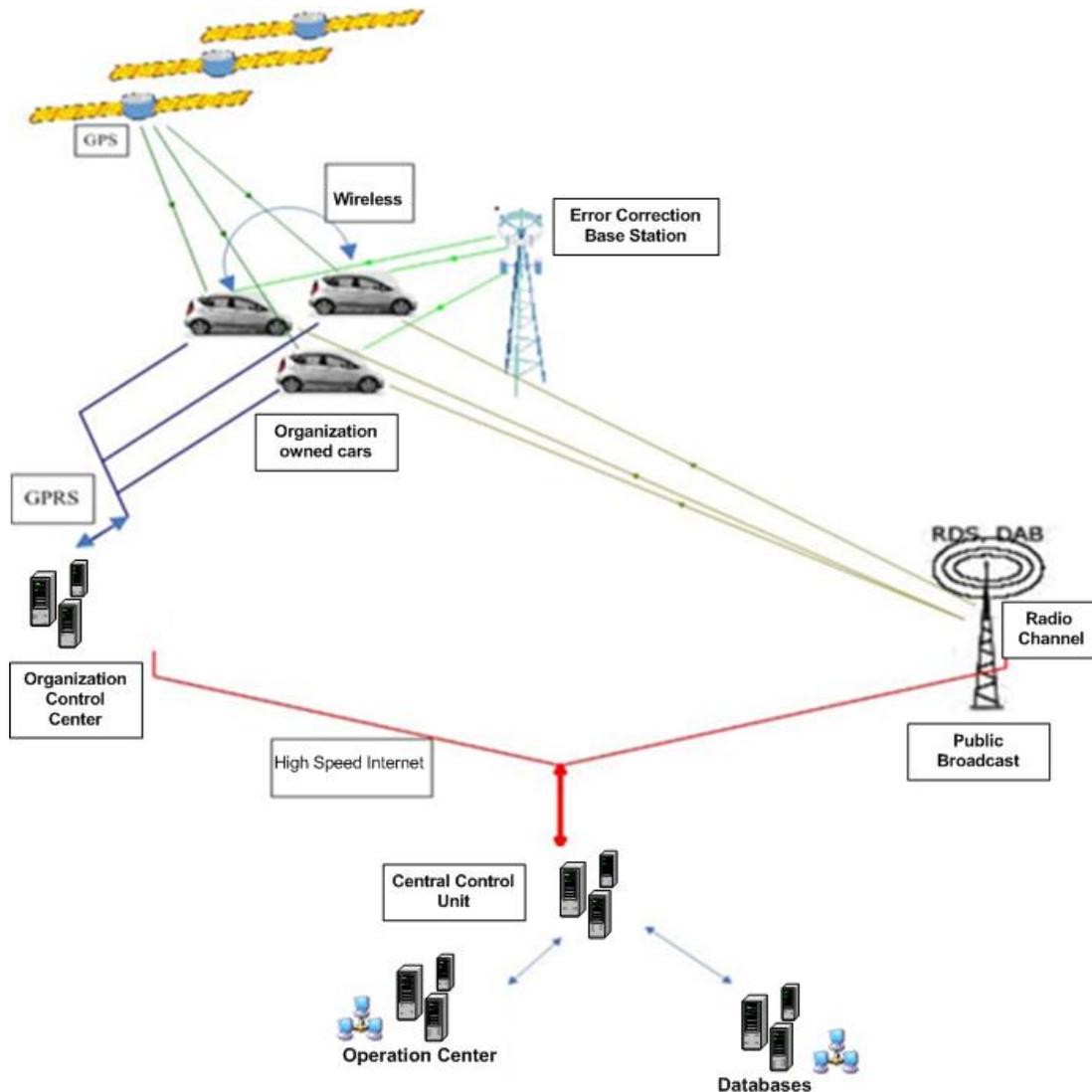


Fig. 13. Private sector's local ITS network infrastructure

At the present, this communication in Iran is being provided through wireless technology. Furthermore, some public or private sectors are able to broadcast the data through all mobile users. Fig. 13 demonstrates all possible communications among private sector's local ITS network and mobile users.

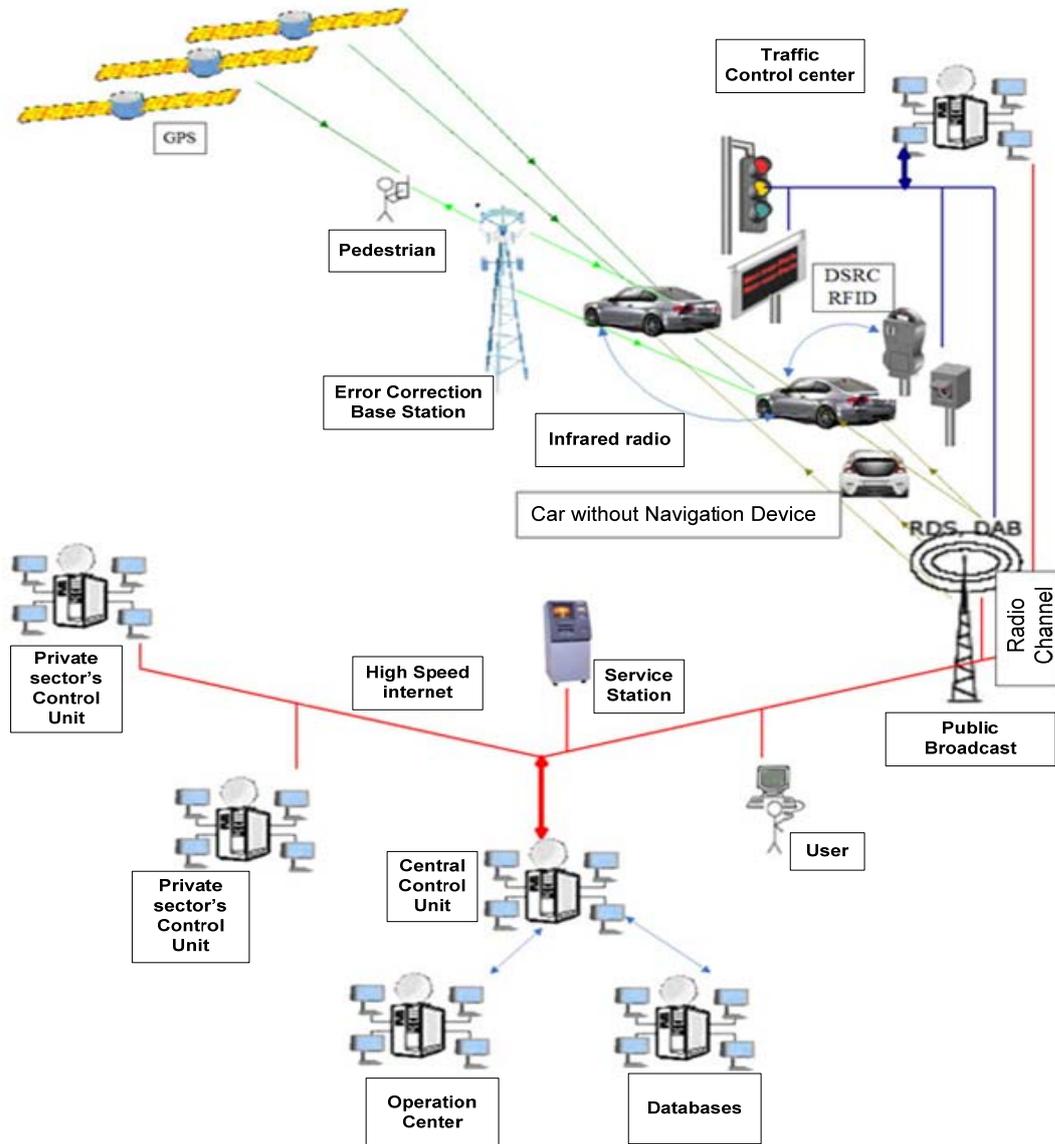


Fig. 14. Public sector's local ITS network infrastructure

In addition to private sector's network, there is a public sector's ITS network in the city to provide general services to all users. This network includes the intelligent equipments for transportation infrastructure (traffic lights, dynamic boards, traffic cameras, sensors and so on) that are generally implemented, controlled and managed by municipalities or traffic organizations (as a part of municipality). Fig. 14 shows the infrastructure of public sector's local ITS network.

Fig. 15 shows the block diagram of intercity ITC network and the intercommunications between different blocks. Similar to local ITS networks, there are several sub networks form public or private sector's ITS network.

The intercity ITS network is very similar to local ITS network in the city except that first, the intelligent equipment of the route infrastructure (traffic lights, dynamic screens, traffic cameras and sensors) are implemented, controlled and managed by Road and Transportation Ministry, and second, in addition to navigation services, the major service that is provided to

users is the rescue service that is supplied through a direct communication between users and rescue service center.

**IRAN Intercity ITS**

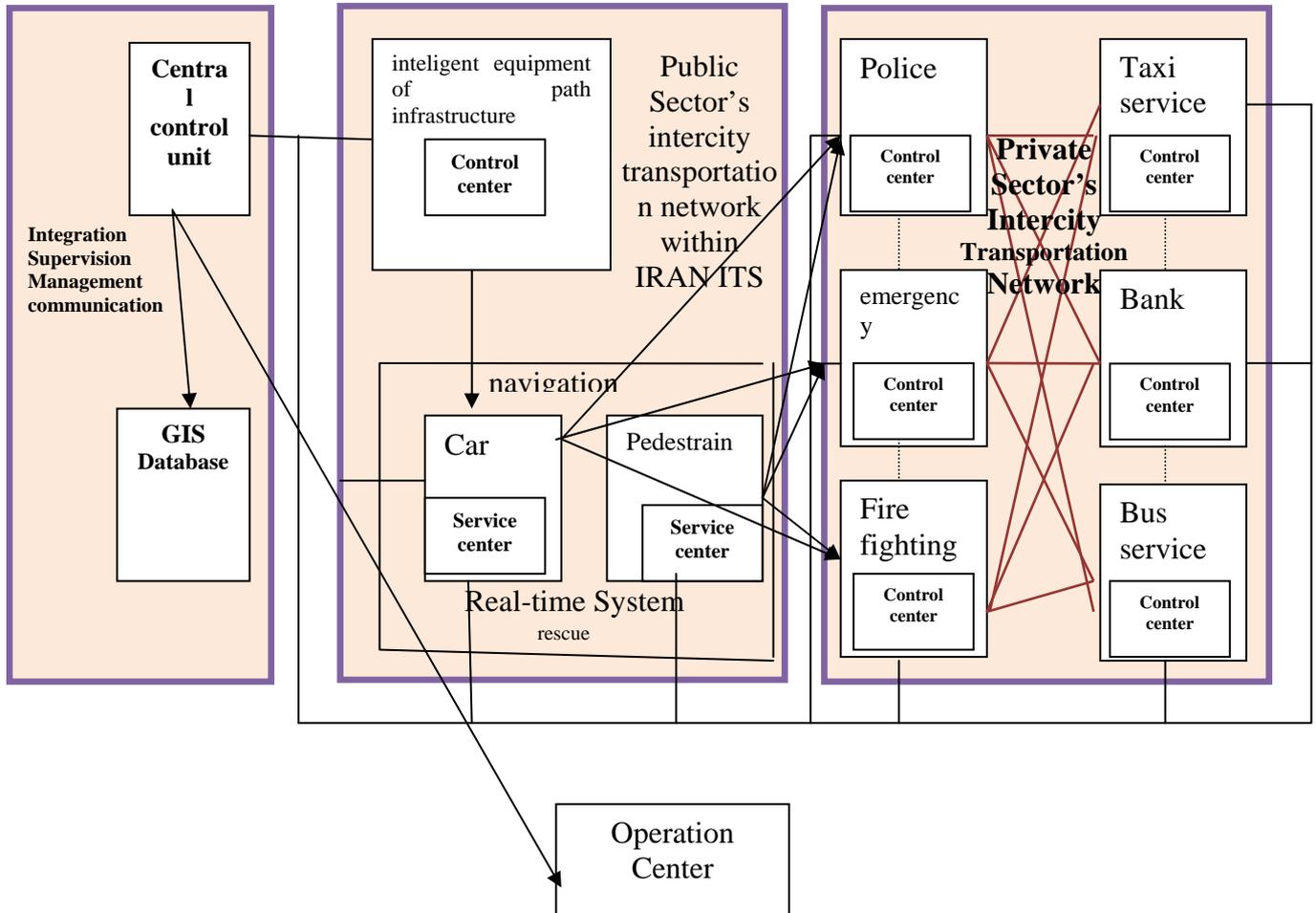


Fig. 15. Intercity ITS Network Block Diagram

Fig. 16 demonstrates how the required information for users and private sectors that should be archived in the central control units are exchanged through a high speed network.

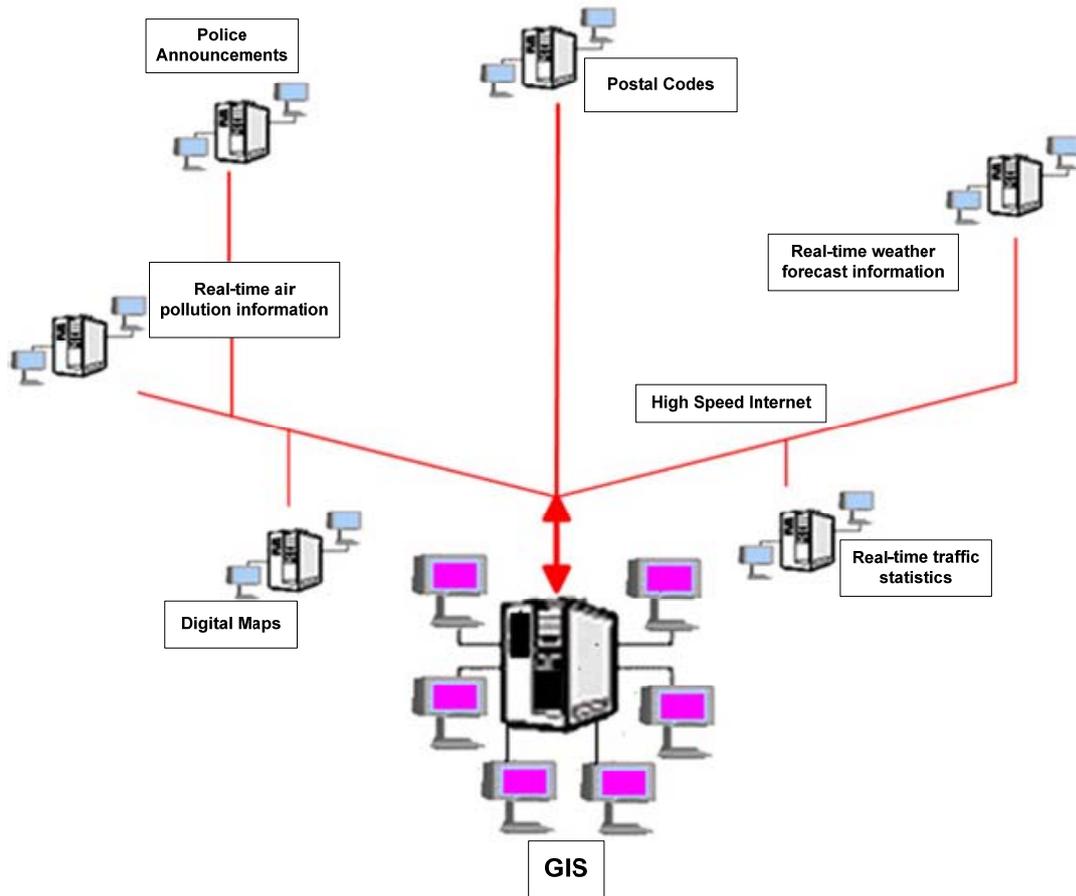


Fig. 16. The required information in the central station



## 6 System Requirements Analysis of Iran ITS

This document is following the concepts of SDLC model for developing IRAN ITS system. According to SDLC, after studying the business requirement and coming up with the overall system architecture, the system requirements should be analyzed and this phase involves with more technical detail in developing the system.

In Chapter 5, the business requirements and system functionalities were identified and described using the block diagrams. The primary system requirements will come from the defined view points (process, information and component viewpoints), and in addition to adding some other requirements by the system engineers and architectures to build the system. The System requirements can be classified into three groups: functional, non-functional and context requirements.

**Functional requirements** – identify the services and enabling functions needed and expected from the system.

**Non-functional requirements** – they are about the performance and/or quality attributes of the ITS system.

**Context requirements** - Identify the reaction to the constraints imposed by the environment on the system. They include statements and assumptions made about the environment.

In Fig. 17, a simplified schema of the process to identify different user requirements and system requirements is presented.

From the different users, general user requirements are collected.

Secondly, the user requirements are focused through the defined viewpoints.

Then, from these viewpoints, the system requirements are identified and categorized.

To present these system requirements, recommendations from the IEEE standard 830- 1998, IEEE Recommended Practice for Software Requirements are used and applied. From this standard, the following recommendations about system requirement analysis in IRAN ITS are considered: [24]

**“Correct:** The requirement specification is correct if every requirement in it is one that the software shall meet, i.e. that the software reflects the user needs.

**Unambiguous:** The different requirements shall have only one interpretation.

**Complete:** The requirement specification shall contain all significant requirements.

**Consistent:** The requirement specification shall comply with any higher-level document.

**Ranked for importance and/or stability:** The requirements are not equally important. Each requirement should be identified to make these differences clear and explicit. For instance, one could divide the requirements into essential requirements, conditional requirements and optional requirements.

**Verifiable:** A requirement specification is verifiable if all requirements in it are verifiable. A requirement is verifiable if there exists a process with which a person or machine can check that the system meets the requirements.

**Modifiable:** A requirement specification is modifiable if its structure and style are such that any changes to the requirements can be made easily, completely and consistently while retaining the structure and style.

**Traceable:** A requirement specification is traceable if the origin of each requirement is clear and if it facilitates the referencing of each requirement in future development or enhanced documentation.” [24]

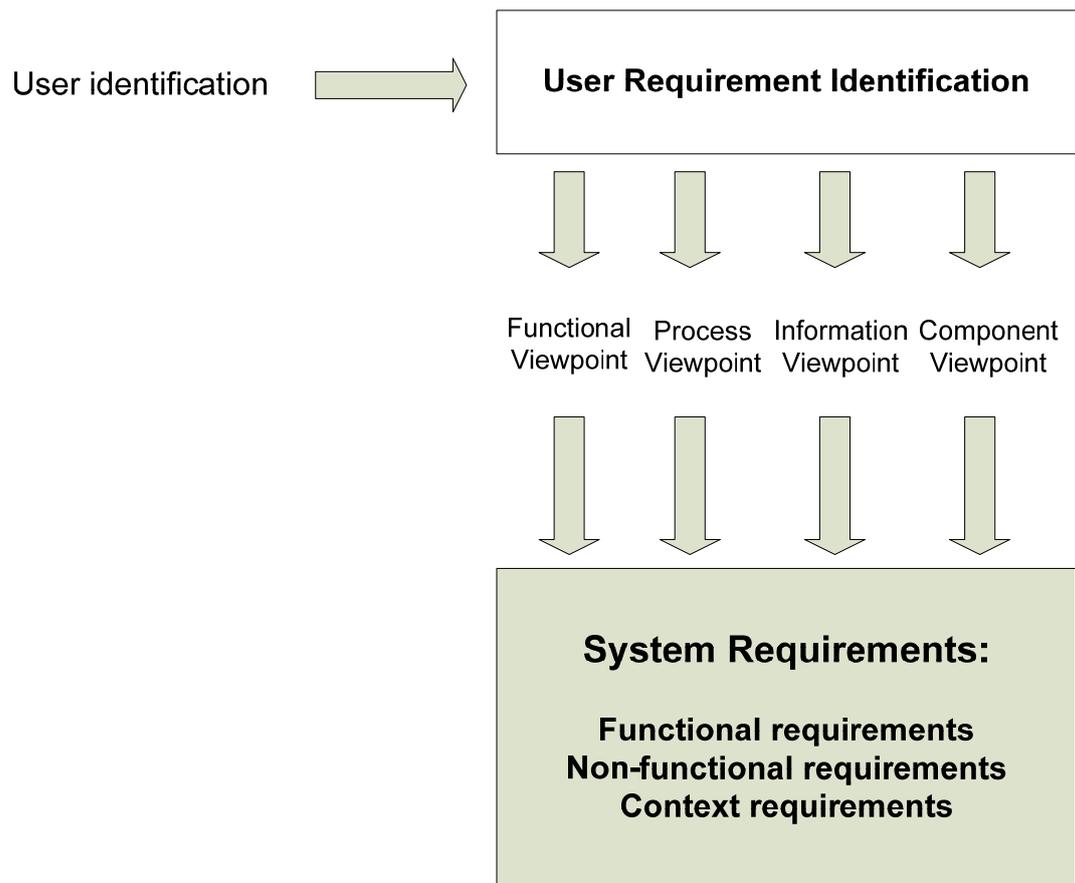


Fig. 17. Identifying Requirements

## 6.1 Iran ITS System Components

IRAN ITS system should be composed of some entities that are working together to provide the required infrastructure for IRAN ITS system. Therefore the below components are required to be created across the country.

### 6.1.1 Positioning Systems

It is necessary to compromise on either using one of the international positioning systems or planning to create a national positioning system. Positioning can be done using a combination of available services (ground based or satellite based).

At the present, it is possible to utilize the GPS system in combination with DGPS error correction system in IRAN, in which user needs a satellite positioning device and for error correction operation, there is a need to implement some reference ground stations in appropriate distances.

### 6.1.2 GIS Systems

One of the most important bases of any ITS system is digital maps and respective information such as post codes, places and descriptive information on the digital maps. Facilitating collection of this information and creating some integrated management software in order to manage information flow is one of the basic system requirements of IRAN ITS.

The most well-known GIS software products to provide geographic data management are the ESRI products, i.e. the Arc family software combined with an ORACLE DBMS (Fig. 19). GIS software products by ESRI, MapInfo by Mapinfo, Geomedia by Intergraph, Oracle Spatial by Oracle, Visum by PTV and Smallworld by Smallword are licensed products whereas PostGIS by Refrations Research is an open source software.

### 6.1.1 Communication Network Infrastructure

As shown in Fig. 18 and discussed earlier, the most common communication infrastructures in an ITS system are GSM Mobile Network, wireless networks, fiber optic, DSRC satellite channels and short length radars.

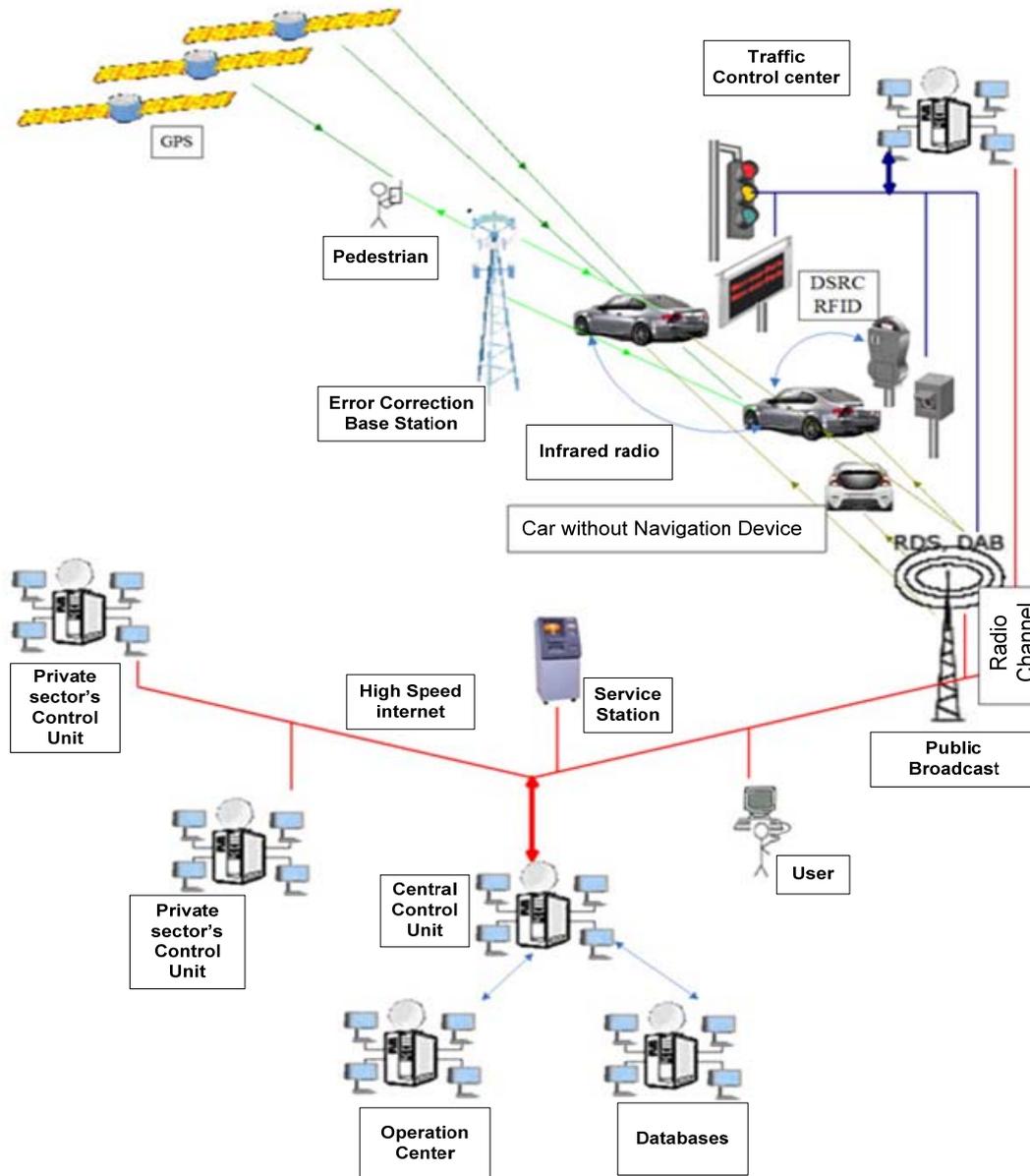


Fig. 18. Communication Network Infrastructure for IRAN ITS

### 6.1.2 End-User Devices

Receiving the information such as Geographical positions, time, and height above the sea level as well as traffic information, rescue and security information should be possible by using some end-user devices. Since they are a vast variety of similar devices in the market, so some identified devices should be chosen and introduced as standard devices for users.

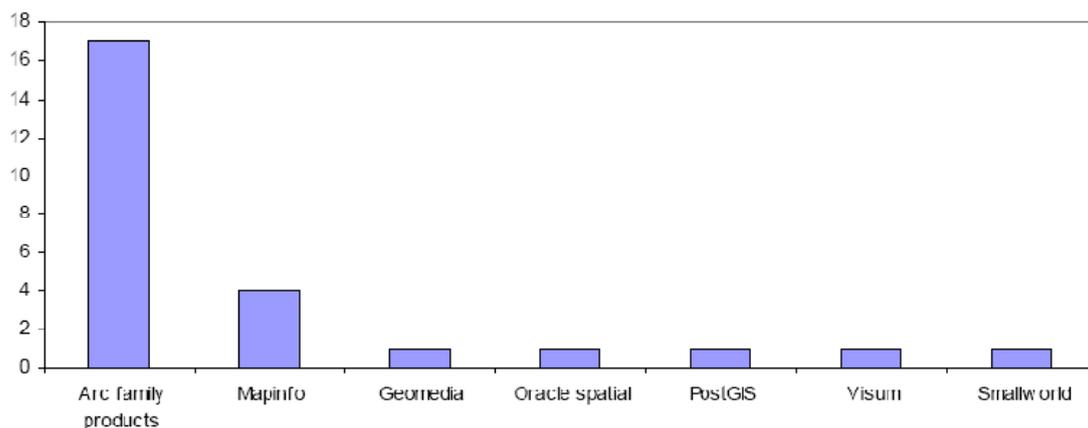


Fig. 19. GIS Software Products

### 6.1.3 Integrated Data Exchange Model

Only some certain data formats associated with the different GIS software. If a data set is presented in a format not supported by the GIS software, A transformation is required to convert it to the desired format, and this process makes the operation very complex and increases error probabilities.

Therefore, there is a considerable need to interchange data among traffic authorities internally and externally through a common and standardized exchange formats. On the other hand, where both sides are using the same data format, so the data exchange between them becomes more efficient. Fig. 1 shows an overview of data exchange formats used by the different countries through their ITS system.

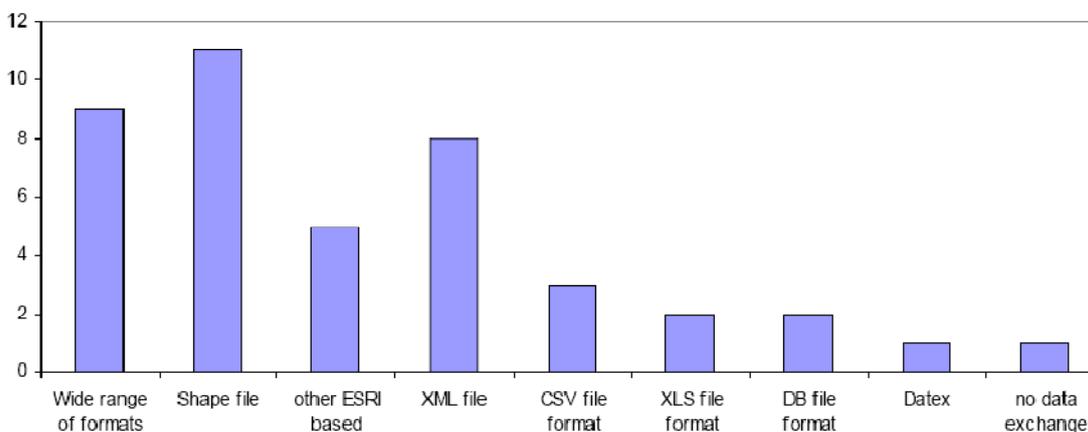


Fig. 1. Popular data exchange format in ITS

## 6.2 System Requirement Listig

Table 6.1. presents the list of major identified system requirement and their description.

## 6.3 Results

Within the requirement analysis described in this chapter and the previous chapter, user requirements were collected using some questionnaires, and then the answers were generalized into a list of requirements. These requirements have been discussed during some project meetings, and several teleconferences. During the process, this document was circulated among the related entities for commenting and giving inputs.

Work has been done to ensure that the requirements and architecture is associated to the existing standards. Building on existing work, previous projects (i.e. Tehran Traffic Control Project) and standards will help to guarantee the compatibility of the systems.



Table 6.1 List of System Requirements in IRAN ITS

ID	Requirement name	Short Definition	Type F: functional N: Non-functional C: Context	Priority C: Critical S: Significant I: Of interest	Comments, open issue
1	Standardized access	Data services and their use should be specified.	F	S	Guidelines explaining how to access Data Services in a standardized way.
2	Data Discovery	A specification of a discovery service shall be available.	F	C	The IRAN ITS infrastructure should provide discovery services using XML.
3	Specification of quality management procedures	Guidelines specify how to guarantee the quality received from road attributes.	F	C	Guidelines for quality check routines must be specified.
4	Incremental updates	The IRAN ITS infrastructure shall provide incremental updates.	F	C	
5	location referencing	The road attributes provided through the IRAN ITS infrastructure shall be organized to enable proper interpretation of the referenced locations.	F	C	
6	Workflow	In order to maintain the data integration and work flow, a specification of tools and guidelines should be presented.	F	I	
7	Maintenance tools	Guidelines and regulations to present and maintain the road attributes should be published.	F	C	Where existing tools are not suitable, the new tools should be developed according to the existing work and standards.

ID	Requirement name	Short Definition	Type F: functional N: Non-functional C: Context	Priority C: Critical S: Significant I: Of interest	Comments, open issue
8	Feedback loop	A feedback channel from information providers to the transportation authorities should be provided.	F	C	
10	Flexible Type Definitions		F	C	To enable adding and changing the available type definitions describing road attributes.
9	Integration Tools	The tools needed for integration of road attributes with existing information providers' systems should be developed.	F	S	Generic software components used to integrate the road attributes within a guaranteed quality should be developed.
11	Availability	The desired quality parameters related to availability issue shall be determined and defined through the XML language.	F	C	To determine which geographical data is available at a certain place. the major quality parameter related to availability is defined as "communication failure rate".
12	Up-to-dateness	The quality parameters related to up-to-dateness should be determined through the XML language.	N	C	To determine the adherence of geographic data to the reality changing with time. the quality parameters are: Date of origin Date of last update Rate of change

ID	Requirement name	Short Definition	Type F: functional N: Non-functional C: Context	Priority C: Critical S: Significant I: Of interest	Comments, open issue
13	Completeness	The quality parameters related to completeness factor should be defined through the XML language.	N	C	To determine the availability of the information required to describe the reality. Quality parameters are: Missing data
14	Correctness	The quality parameters related to correctness factor should be determined and defined through the XML language.	N	C	To determine the accordance of geographic data and their relationships to corresponding elements in assumed reality and up-todateness. The quality parameters are: Geometric correctness, Topological correctness, Thematic correctness
15	Consistency	The quality parameters related to consistency factor should be defined through the XML language.	N	C	To Determine the accordance of geographic data (data structure, their features, attributes and relationships) to the models and schemas (conceptual model, conceptual schema, application schema and data model). The quality parameters are: Geometric consistency Topological consistency
16	Accuracy	The quality parameters related to accuracy factor should be determined and defined through the XML language.	N	C	To determine the adherence of geographic data to the most plausible or respectively the true value. Absolute position accuracy Relative position accuracy Quantitative attribute accuracy



## 7 Conclusions

This master thesis report described our work on identifying system conception and requirements of national IRAN ITS project.

On the basis of information collected about some successful implementation of ITS infrastructures, and adopting these new trends to local condition and current position of ITS in IRAN, the project team has come up with following results and recommendations to the system owners in order to take the preliminary steps to implement the IRAN ITS project.

- To introduce the governmental authority responsible for supporting and executing the project and providing financial supports as well as system rule making.
- To collect and document all existing ITS infrastructures which are independently running in the country to integrate with IRAN ITS project.
- To complete this feasibility study by evaluating the costs and times of the project.
- To select the network infrastructure for provide the communications between ITS centers from the identified alternatives in this report
- To compromise on selecting the positioning system from the identified alternatives.
- To determine the format, standard and accuracy level of the road maps
- To define the technical specifications of the pilot project.

The work packages should develop the defined projects in the meantime by focusing the requirements below.

- To creating the required digital maps
- To develop the GIS software to match the maps by associated information
- To evaluate the added value of IRAN ITS services
- To define the required standard for in-vehicle equipment

It is recommended that one of the cities among Tehran, Shiraz or Isfahan should be chosen in order to implement the pilot of the project, because in these cities:

- The digital maps are already provided
- There are several experienced ITS entities which have already sorted out the time, logistic and practical problems.
- The required infrastructure to collect road attributes and traffic information such as traffic cameras and sensors are already implemented.
- Using in-vehicle devices for ITS is very common among the citizens.

Other system specifications that should be identified and determined for executing the project pilot are:

- The required accuracy level of the positioning system
- The update frequencies of maps and information (in second)
- The number of error correction reference stations should be implemented in the chosen city
- The capability of the in-vehicle equipments
- The number of control stations
- The components of control stations
- The expected services of the system

Implementation of IRAN ITS project will be carried out by cooperation of several organizations and entities. The engaged organizations in this project are:

- The Road and Transportation Ministry in order to provide transportation information of roads and ports of the country

- Municipalities, in order to allocate space and area, and cooperate in installing the equipments
- The traffic organization, as a subset of municipalities in every city.
- The telecommunication ministry, to provide the required communication infrastructure
- Police in order to control the frauds and control the security and trust of the system
- The national geography organization to provide the digital map and add the associated information layers to them
- Automotive manufactures in Iran to install in-vehicle equipment in their productions
- The weather forecast organization, in order to provide the weather information of the roads.

Four major milestones are defined for the project:

- Milestone 1 – Requirements and overall architecture has been defined and agreed (Finished)
- Milestone 2 – Developing Infrastructure and developing tools (20 months)
- Milestone 3 – Conducting the test and demonstrations (8 months)
- Milestone 4 – Collecting and applying organizational recommendations and finishing the project (3 months)

Most of the technical work will be done during milestone 1 and milestone 3. The project will be done according to a waterfall process model. It should be taken into account that that the results of the tests may prove the need for modifications and changes in the infrastructure and tools. If it happened, then a revised version of specifications will be presented. Then a testing process will be conducted and after a successful test period the infrastructure and tools will be finalized to use as parts of the operational systems of the IRAN Intelligent Transportation System.

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