Karbala International Journal of Modern Science

Volume 5 | Issue 2 Article 6

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Recommended Citation
Daeibal, Jaffar; Lapshin, Vyacheslav; Elkin, Dmitry; and Kucherov, Sergey A. (2019) "Features Of Designing The Architecture Of Intelligent Transport Systems," *Karbala International Journal of Modern Science*: Vol. 5 : Iss. 2 , Article 6.
Available at: https://doi.org/10.33640/2405-609X.1016

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Features Of Designing The Architecture Of Intelligent Transport Systems

Abstract

In the global experience, intelligent transport systems (ITS) are recognized as a general transport ideology for integrating the achievements of telematics in all types of transport activities to solve economic and social problems: reducing accidents, improving the efficiency of public transport and cargo transportation, ensuring overall transport security, and improving environmental performance. Considering the design features of the intelligent transport system (ITS), there is a need to develop requirements for the functional and physical architecture as the main part of the ITS development. The creation of functional and physical architecture touches upon issues such as: the scheme of interaction between subjects and objects of ITS proceeding from the requirements and interests of the customer; the definition of the interaction functions of individual elements and subsystems; structure of software, hardware of information and telecommunication technologies; places and methods of installing such systems; interaction and placement of the ITS element base. In this paper, we offer an overview of the main features of ITS design, and the identification of general regularities in the process of their design.

Keywords

Architecture, intillegent transport system, ITS, subsystem, functional and physical architecture

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1. Introduction

The constantly growing level of motorization in modern cities entails complications in the functioning of the automobile transport system, which often leads to a reduction in cars speed, regular traffic jams, increased accident rates and other significant problems in this area. The inability of the road transport network to meet a given level of demand and quality for road transport is reflected in various sectors of the economy as a separate region and the country as a whole. To date, the most promising solution for transport problems is the introduction of intelligent transport systems (ITS). According to the main category of architectural standards of the Russian Federation (document GOST R 56294−2014) [1], ITS is a system that integrates modern information, communication, telematic technologies and management technologies which is designed for automated searching and adoption of the most effective scenarios for managing the regions' transport system, vehicle or a group of vehicles in order to ensure a desirable mobility for the people, maximize the use of the network, and improve the safety and efficiency of the transport process as well as to ensure the comfort of the drivers and transport users.

Due to its universality and ability to cover a variety of transport activities, the development of ITS contributes to solve a variety of problems that are typical for transporting systems in modern conditions. The development of modern vehicles is unthinkable without the use of ITS.

The global goal of building and developing ITS can be formulated as the development of methods to improve the process of ITS creation for the real-time monitoring and managing of transport systems with the purpose of improving the safety and the quality of transport services to the economy and population, reducing transportation costs as well as the consequences of traffic on the environment [2]. To achieve this global goal, the following tasks must be accomplished:

- developing effective solutions to decrease the number of accidents as well as the severity of their consequences;
- optimizing traffic conditions on motor roads to increase their throughput and reduce the risk of accidents;
- provision of a high quality of transport services for all users;
- reducing the harmful impact of the transport complex on the ecosystem;
- increasing the efficiency of the functionality of transport and transport infrastructure;
- increasing the quality of planning and management in the field of transport and transport infrastructure;
- increasing the efficiency of control of transport and operational state of highways;
- increase the efficiency of work in handling emergencies and their consequences.

A project development for an intelligent transport system always begins with designing an architecture for such a system. The architecture of ITS defines the basic principles of organization and the interrelationship of components between each other and with the external environment, as well as the principles and guidelines for their development, implementation and evaluation of the effectiveness of use. It is a kind of framework, within which various approaches of designing can be proposed, taking into account the individual needs of the customer and the necessary services for the user. Standardization of the architecture contributes to the systematic and consistent implementation and continuous improvement of subsystems (services) of ITS. Since the transport industry is a particularly dynamic system, the architecture for this system must take into account the characteristics of such dynamics, in other words, it must have adaptive properties. The effectiveness of creating adaptive transport systems is mentioned in Ref. [17] which is dedicated to the methodology to design a Context-aware Adaptive System based on layered software architecture. To create systems that may have adaptive properties, a clearly formalized method of their design is needed. In this article, a study will be conducted and aimed to determine the general features in the construction of particular parts (subsystems) for such systems. To achieve this goal, you first need to perform an analysis of the progress, which will be discussed in the following section.

2. Materials and methods

In today's, the problem of "intelligent transport systems" technologies development is dealt by individual research teams financed by the state support, as well as private companies, the priority of which is the implementation of specific application solutions.

A striking example of the work of the researching teams (in this direction) is the development of

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standards for ITS. One of the most famous of these documents is the USA's standard for ITS which is discussed in Ref. [3]. Similar documents are developed in other countries, such as Japan, Singapore, Russian Federation, European Union, etc. The Main feature of such works is the development of conceptual models of ITS, on the basis of which specific application solutions should be created.

An example of the work of private companies can be served as a development related to SOA technology. SOA [4] refers to a new paradigm for building reliable distributed systems, where functions consist of services, and all interacting components are loosely interconnected. Z. Changyu et al. [5] is an intelligent traffic control data centre in Beijing based on SOA. It supports high-level decision making and it is able to change transport management operations. The main argument for choosing SOA for [5] is that it has standard features such as distributed architecture, service-based applications, platform independence, and a wide degree of detail. The architecture of the Beijing traffic data centre is aimed at integrated information integration, efficient information exchange, proper data exchange, on-demand service support, for a cost-effective standard model for future development.

C. Li [6] identifies the problem of ensuring the quality of traffic information due to the large number of tourism information service providers (TIS) [6]. introduces the idea of an SOA-based traffic information service that combines services or data from different providers to publish accurate, accurate, and complete information to travelers.

X-L. Lu [7] presents a scheme of a GIS transport system (Geographic information system) based on web services technology. The main purpose of GIST web services is to support IOS applications with spatial data and handle multiple geoprocessing related tasks such as duplicate address detection, map display, planning routes, and so on.

Cloud computing is also popular for efficient use of distributed resources, as it allows you to link them together for processing large amounts of data or for large-scale tasks. The main idea of this technology is to reduce operating costs, increase resource sharing and provide easy access to resources through various client platforms.

W−H. Cai et al. [8] present a modern intelligent transport system based on cloud computing, with the integration of information technology, control technology, sensor technology, communication technology and system technology. It looks at both technology and management perspectives and describes the architecture as well as the procedure for building a cloud transportation system (CTS).

Another example of the application of IT technology in ITS is the use of Grid computing technology [8]. X. Tao et al. [9] present a module for its Shanghai information system of data transmission services (STASEG) using the concept of Grid, SOA and web services. STISAG mainly focuses on the problem of traffic congestion in Shanghai and offers end users a variety of real-time traffic and travel information.

Neural network technologies are also used to create intelligent transport systems. For example, work [18] presents a personalized design model (ResDeconvNN) based on Convolutional Neural Network (CNN) for long-term traffic flow prediction of elevated highways in Shanghai. The next day the flow of information can be predicted using the previous day flow. Taking the correlation of traffic parameters into account, in this work comparing analogy flow, speed and occupancy (FSO) to three channels of RGB as the three inputs of the model. So, the raw data is collected from the loop detectors are transformed into a spatial−temporal matrix which has three channels.

Thus, the current state of development of intelligent transport systems technology is characterized either by the development of specific technical solutions, which are a finished product or by the development of fundamental strategies for the implementation of an integrated view of intelligent transport systems.

From the moment of the process, designing intelligent transport systems does not have a clear formalized representation model, it is not possible to design systems with adaptive properties. In this regard, in order to compile a formal model for the process of designing intelligent transport systems, it is necessary to determine the general patterns and characteristic features of such process. Thus, the main novelty of this work is presented in this study and the identification of patterns in the design of the ITS architecture to create a method of designing a local ITS project.

To achieve this goal, it is necessary to determine the main features of the ITS architecture design, which will be discussed in the following section.

3. General features of the architectural design of intelligent transport systems

The main feature of any intelligent system is its ability to perform creative functions, which are traditionally considered to be the prerogative of a person. In other words, the intellectual system, unlike the information system, is able to be active in the absence of an influence or direct instructions from the person. Any intellectual system, first of all, is a technical or software-technical system capable of developing creative solutions to problems belonging to a specific subject area, knowledge of which is stored in the memory of such a system. For the organization of such systems, at the initial stage, it is necessary to design its architecture. Since the processes of designing intelligent systems are closely related to the features of the spheres in which such systems will operate, the processes of building the ITS architecture also have their own peculiarities [10].

The created ITS systems must be architecturally and functionally compatible on the basis of a modern regulatory framework integrated with international standards and practical domestic and international experience. The architecture of transport telematics systems defines the basic principles of the organization of ITS and the interrelationship of ITS components among themselves and with the external environment, as well as the principles and guidelines for their development, implementation and evaluation of the efficiency of use. The architecture of ITS is a kind of framework within which different approaches to design can be offered, taking into account the individual needs of the customer and the necessary user services. The standardization of the architecture facilitates, the systematic and consistent implementation and continuous improvement of ITS subsystems (services). The architecture defines the functions, services and subsystems that have these features, as well as information and data flows that integrate functions and subsystems into a single integrated system. The lack of a specific architecture and consistent compatibility protocols leads to disparate and fragmented subsystems that are vague, complex and expensive for subsequent integration. In certain cases, integration is virtually impossible. The customer, the developer and the user are constrained in their choice, in fact, dependent on the specific product of the supplier, which leads to unjustified financial losses and operational problems [11].

A characteristic feature of the development of any intelligent transport systems around the world is the problem of implementing a strategic nature and the determination of the overall competitiveness of each country in the world market. Also, the significant capital intensity means that such projects cannot be realized without a direct involvement of the state. Mechanisms for implementation vary depends on the country, but its key components are the same for all: the state carries out a strategic-innovative function by supporting basic technological and economic innovations, giving them an initial impetus.

In the global experience, the development of the ITS is a highly organized process: its legal and regulatory framework has been established, the processes of strategic and current planning for the development of ITS and budget financing for the development and implementation of pilot projects for the development of ITS at the national level have been perfected, and organizational structures have been created. As a result, the development of ITS around the world is methodologically based on the system approach, forming ITS precisely as systems, and not as separate modules (services). Approaches to the creation of ITS are based on the principles of modernization, reengineering of operating transport systems. Hence, important principles for the phased development and modality of the ITS creation are discussed in the following section.

4. Result and discussion

The ITS architecture combines all the tools that solve the problems of traffic flow, takes into account both the security of the road network, the mobility of traffic flows and the environmental aspects. Thanks to the architecture, the work of the traffic control subsystems is coordinated at any level. Today's approach to the architecture of ITS in Russia is based on understanding this term as a structure of related subsystems that together provide the provision of user services using their functional capabilities and certain interfaces of interaction and interchange of information with each other and with external systems with respect to ITS [12]. The architecture of ITS is a complex concept which includes three main components:

- architecture of services (domain architecture);
- functional architecture;
- physical architecture.

4.1. Domain architecture

The domain architecture of ITS is a basic part of the knowledge system in the field of ITS.

The domain architecture forms a common complex view of the structure of objects and ITS entities. At the same time, for each project of the system, the set and functional description of objects and entities can be individual.

In principle, two objects are registered in the domain architecture: a vehicle, an infrastructure and a medium for maintaining their communicative interaction: direct (through communication channels) and mediated (through means of influence: technical means and technologies oriented to inform the traffic flow) (Fig. 1).

Thus, the domain architecture of ITS includes:

- functions to provide this service to the user;
- physical objects or subsystems where these functions are performed;
- interfaces and information flows between physical subsystems;
- communication requirements for the transmission of information flow.

Representation of the architecture in the form of service groups and services is performed to further detail the various sectors of ITS activities, to determine their functionality, and is justified by economic indicators [13].

4.2. Functional architecture

The functional architecture defines the modular structure of the ITS, which specifies the target directions for the deployment of ITS (security, traffic management, road and vehicle monitoring), as well as target groups of tasks, in accordance with which the ITS subsystems are formed. Such an architecture shows the necessary functions to satisfy users' requests. It is built in the form of a diagram of the data flow, which contains functions, applications, services, databases, as well as data transmitted between them. Each component has its own description, which reflects what function it performs. Upon completion of the functional architecture, the space for each function is allocated and the data stored in the subsystem or within the module that is part of the subsystem [14].

An example is a functional architecture of the US ITS, which consists of 33 user services, grouped into 9 categories (Fig. 2). shows a simplified logical top-level architecture, including task groups as well as information links between them and external objects.

The functional architecture of the ITS must meet the requirements of its subsystems (such as customers, road infrastructure, …) and describes:

- the level structure of the system, including description:
- line provisioning of the system (ITS road infrastructure);
- the level of dispatching – management of the functional tasks of ITS subsystems;
- the level of operational management – regulations of interaction with Russian and non-Russian (national foreign states, international) external information systems (other modes of transport, other ministries and departments);

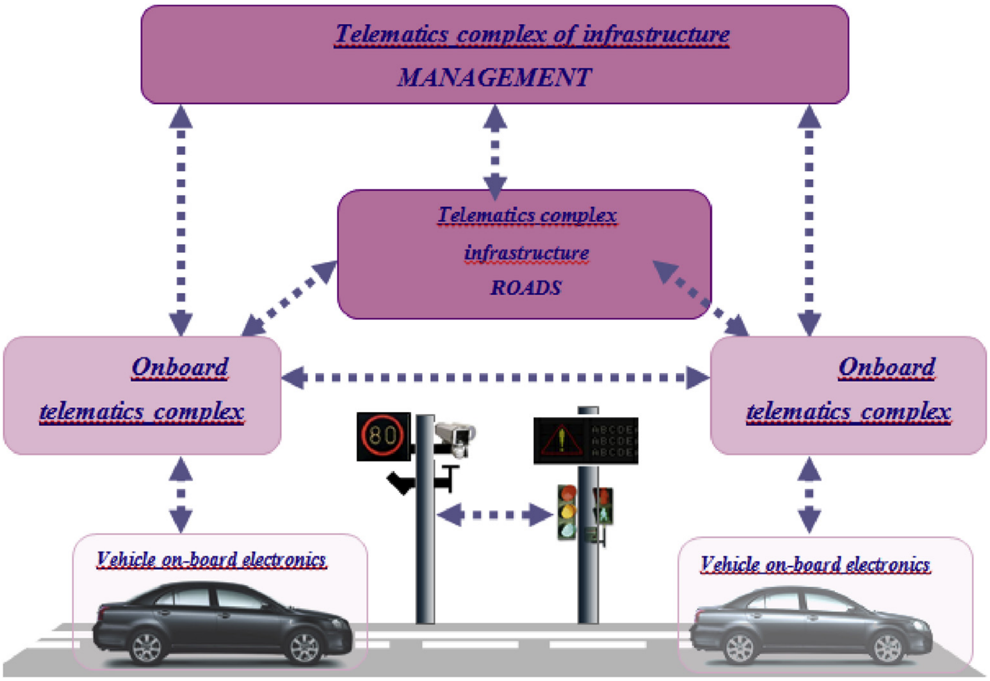

Fig. 1. Transport-telematic complexes (transport-telematics environment) of ITS, their interaction.

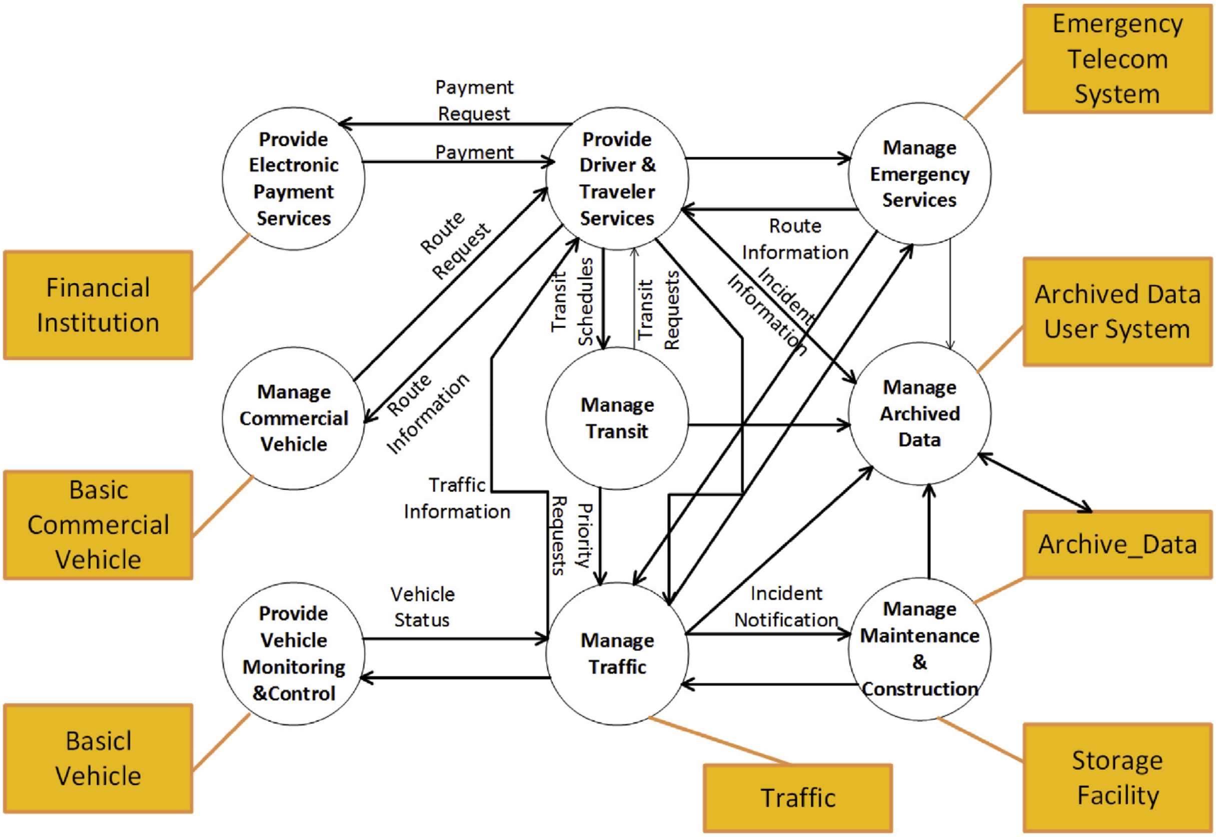

Fig. 2. Simplified functional architecture of the top level of ITS USA.

- authorities having competence in the field of ITS;
- the level of monitoring the system operation - analysis of ITS, performance indicators, compilation of information, provision of reports, decision-making on the strategy for further development of the system;
- the level of integration into the federal information system;
- means and priorities of interactive communication of all objects and subjects of ITS under different operating modes — regular, operational, situational (in case of emergencies and extraordinary circumstances).

4.3. Physical architecture

Having defined the priority services and the necessary functionality for their implementation, it becomes possible to establish priorities in the list of automated and informational subsystems (complex and instrumental) that need's to be included in the ITS, to identify the connections between them and to obtain a physical architecture. Physical architecture is the structure of the software and the hardware of information and telecommunication technologies, peripheral equipment. It defines the basic requirements for the functioning, interaction and placement of the ITS element base [15].

There is an opportunity to define the main stages of the formation of a physical architecture:

- determination of the necessary subsystems and their location;
- selection of functions and data for subsystems;
- if necessary, the creation of modules within subsystems;
- definition of functions and data for modules in subsystems;
- preparation of information on the content of physical architecture.

A subsystem of the ITS is to be understood as a complex of technological solutions completed within

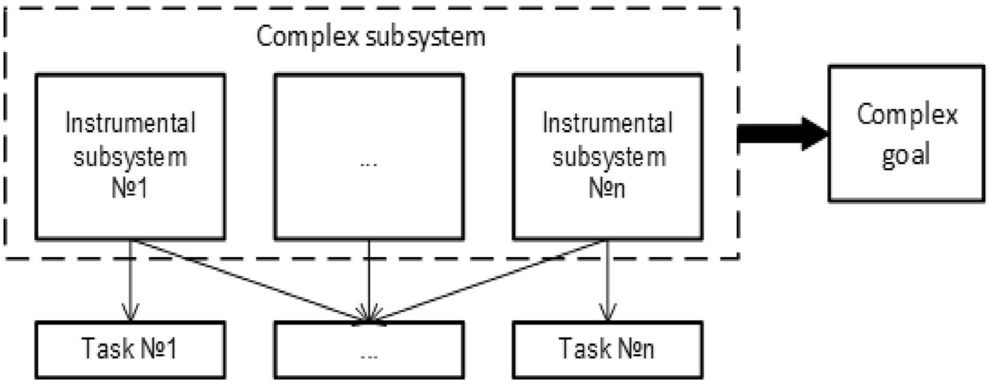

Fig. 3. The structure of ITS subsystems, constructed on the basis of one complex subsystem.

the framework of one applied task, implemented on the basis of the application of telematics technical means. The ITS subsystem should include a store of obtained target data (based on its own monitoring system or from an adjacent subsystem), a hardware-software complex for analysis and decision-making in accordance with the functional task of the subsystem, and may also include a complex and widely distributed set of peripheral devices [16].

Each of the considered ITS subsystems fully or partially provide the functions of one of the previously defined services. The complex subsystems of the ITS are directly involved in solving the tasks assigned to the respective services. The complex subsystem of ITS is a basic system completed within a defined functional task, including a complex of instrumental subsystems.

For any physical architecture of ITS, six of its common components (complex ITS subsystems) can be defined:

1) traffic management (direct and indirect management of transport flows);
2) the system of charging (e.g. toll roads);
3) systems for monitoring compliance with traffic rules and regulations;
4) user services and services;
5) management of road conditions;
6) the control and diagnostic system.

In turn, each such component consists of a number of instrumental subsystems. An instrumental subsystem of ITS is a complex of technological solutions completed in the framework of one applied task, realized on the basis of the application of the totality of telematics technical means [16]. There are eleven basic instrumental subsystems of ITS:

1) ATCS (Automated Transport Control System)
2) monitoring the parameters of traffic flows;
3) navigation and information support for road users;
4) monitoring and management of parking space;
5) photo-video recording of traffic violations;
6) video surveillance;
7) weight control;
8) identifying incidents;
9) monitoring of the meteorological situation;
10) monitoring the work of road machinery based on GLONASS;
11) identification of the TS and electronic fee collection.

The architecture of such instrumental subsystems is built in accordance with the necessary functionality. The nomenclature of functionalities determines the composition of peripheral equipment grouped into a collection of control objects. The nomenclature of peripheral equipment includes, but is not limited to, the following objects:

- local and master road controllers that provide traffic light control (intelligent and non-intelligent);
- Transport detectors;
- DIB (dynamic information boards);
- CTS (controlled traffic signs);
- Video surveillance and regulation systems (video cameras, decoders, etc.);
- means of restriction of entry (barriers, etc.)

In modern systems, up to 4 levels of control are allocated:

- the centre;
- sector (zone);
- group;
- object (peripheral device).

5. Conclusion

In the course of the research, the most popular methods of designing intelligent transport systems have been analyzed. In this process of analysis, general patterns were discovered and presented in the design process, on the basis of which a generalized block diagram of the standard ITS subsystem has been created, as shown in (Fig. 3).

As can be seen in the presented diagram, the structure of the ITS subsystems is a set of services that are satisfied by a set of certain instrumental subsystems. As the structural composition of such subsystems is rigidly determined by the nomenclature of functionality, this opens the possibility for the formalization of the process of designing individual parts of instrumental subsystems. Further research will be focusing on the creation of a formal model, a method for designing instrumental subsystems for a local project of an intelligent transport system. Also, the authors will plan to create a special program platform, which will realize a developed formal model.

Acknowledgement

The reported study was funded by RFBR according to the research project № 18-07-00854.

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