The role of ITS architecture and standardization in achieving sustainable transport development

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Abstract—To achieve efficient functionality of Intelligent Transport Systems (ITS) and so to bring maximum benefit to end users and other stakeholders and to support sustainable development of transport in general, it is necessary have an ITS architecture, which defines how the deployed systems would fit into overall ITS structure. The other important component of ITS deployments is their compliance with standards. How to support the ITS deployment both by ITS architecture and by standards requirements is the subject of this paper.

Keywords—cooperative systems, ITS architecture, European FRAME architecture, E-FRAME, standards.

I. INTRODUCTION

ITS systems nowadays provide a useful tool for increasing safety, capacity, comfort and other parameters of transport systems. Today there are many different areas of ITS developing quickly and bringing new applications to customers. Examples of such quickly developing areas with great potential for future are e.g. systems for human-machine interaction in vehicles [7] [9] [6], cooperative systems, systems providing traffic information [10], etc. In implementing ITS systems however, complexity grows with the number of installed systems [1]. This poses a threat to their effectiveness, manageability, maintainability, extendibility, refurbishment over time and to overall costs. For instance, if a city wishes to implement ITS systems for Public Transport management, Parking Management, Traffic Management and Traveller Information, they would also like them to co-operate, at least to a certain level and to produce benefits of synergy, rather than to counteract or contradict each other. It is therefore evident that having a certain level of integration and interoperability would produce significant benefits in terms of consistency, overall cost, maintenance and sustainable development in future [12]. Refurbishment with emerging technologies over time and extension with new systems and services would also be easier, more effective and less expensive. Overcoming the possible problems with too many incompatible systems, and benefiting from possible synergies of having interoperable systems, and assuring compatibility also in the future requires the use of agreed Architecture.

II. ITS ARCHITECTURES

According to [2] and [3], the basic objective for the creation of a transport-telematic architecture is the achievement of the interoperability between individual telematic applications, including the maximum use of available infrastructure by all telematic applications, while keeping their own individual system requirements (technical requirements: safety, reliability, availability, integrity, etc.; transport related requirements: transport comfort, minimisation of external requirements of the transport related process, maintaining transport policy objectives at national and European level.

The result of the ITS architecture should be a design of individual subsystems and functional blocks, including the definition of their system parameters, telecommunication environment and processing centres for all kinds of transport telematic applications. Correctly conceived architectures of transport telematic systems in systems development have a direct impact on the following factors:

- Efficient building of telecommunication environment [11] and corporal networks reduces their expenditures;
- Considerable reduction of transmitted information reduces expenditures of transmission;
- Definition of requirements from the part of organisations allows the existing operators to offer services with these over-standard requirements, which results in reduction of expenditures when building special telecommunication environments;
- Economical convenience of new solutions of the information transmission leads to the increase of demand for new
telecommunication networks technologies, particularly in the field of access networks;

- It is possible to secure modular development of telematic systems in single branches and organisations using the existing systems.

![Fig. 1 ITS architecture in system development process (source: [8])](image)

Going all the way down in development of telematic applications with the use of ITS architecture would result in unique architectures for each deployment, therefore it was realised that it would be much more efficient to have a Framework Architecture, from which individual ITS Architectures can be developed. In 2000 the European ITS Framework Architecture was produced by the European Commission funded project KAREN [1]. This architecture is called FRAME. The principal advantages of having Framework Architecture are:

- It is quicker, and therefore cheaper, to produce a suitable ITS Architecture from a Framework Architecture.
- Each derived ITS Architecture has the same properties as the Framework Architecture from which it has been produced. This facilitates the use of similar equipment in different deployments, and thus extends their potential market.

In general one can distinguish two levels of architectures used in the ITS area – the high-level architectures and the low-level architectures.

### A. High-level architectures

The high-level architectures provide the description of the system mainly from the functional viewpoint. All the functionalities are indicated as “component specifications” together with the “communication specifications” giving information on the link between the components. All of these specifications are technology independent and give suppliers the freedom to employ the most appropriate technical solution when tendering, and still comply with the architecture. The component independency also enables the architecture to be generally valid for many years, despite of the rapid technical development (e.g. new emerging telecommunication technologies). Examples of this level of ITS architectures are the European Framework Architecture FRAME and the US National ITS architecture.

### B. Low-level architectures

Low level architectures describe the system in more details needed for the implementations. They use the high-level architecture results as their starting point and describe the system down to the particular technologies, devices and communication specifics. Usually there are several low-level viewpoints created – one for each specification – e.g. physical viewpoint, communication viewpoint, etc.

### III. USAGE OF ITS ARCHITECTURES

The example of how ITS architectures are used is presented on the European FRAME architecture.

#### A. European ITS framework architecture

The European ITS framework architecture (FRAME architecture) provides the high level view of ITS systems and their implementation. Together with standards, it helps national, regional and local authorities, as well as service providers, to plan and realise their goals within ITS in a way that is coherent, cost effective and extendible in area and over time. It also helps industry and service providers to produce and procure in a cost-effective way in markets that are European in scale. Travellers and drivers do not directly use the European ITS Framework Architecture, but may be involved in market research when a specific ITS implementation is defined and will experience the benefits of its results once implemented.

![Fig. 2 The FRAME methodology](image)

The European ITS framework architecture is technology independent, i.e. particular technologies are not included. Thanks to this fact the FRAME architecture is durable and enables the use of different technologies even those that are not yet introduced. The FRAME architecture is based on functions. During an ITS implementation using FRAME architecture the requirements are based on stakeholder aspirations, i.e. demands that ITS stakeholders have on the ITS system. The stakeholder aspirations (often expressed in natural
language) are transformed into User Needs – from a formalized set of more than 500 needs covering most possible ITS application and services. In the functional viewpoint (formerly called functional or logical architecture) necessary functions to fulfil these User Needs are defined. These two items are covered by the FRAME Architecture (see Figure 2).

Based on the Functional Viewpoint the Physical Viewpoint and subsequently Communication Viewpoint (formerly called physical and communication architecture) are developed.

From its beginning, the FRAME Architecture is being continuously upgraded and supported by subsequent European projects (FRAME-NET, FRAME-S). The current support project, E-FRAME (2008-2011) has integrated the functionalities needed for the implementation of cooperative systems into the architecture.

B. National ITS architectures in Europe

It has been stated that FRAME architecture provides the groundwork for the creation of national ITS architectures. These national ITS architectures can be adapted to local specifications covering their special local needs – e.g. User Needs for ITS systems can differ for a given regional or national area and the ITS architecture has to follow these demands.

The history of national architectures goes back to the end of 1990’s when the first national architectures (in similar time as the FRAME architecture) were created. It was the result of recognizing the need for ensuring cooperation between different quickly developing systems, which were resulting from the boom of technologies. Since that time several European countries have introduced their national architectures. The important ones in Europe are as follows [4].

All mentioned architectures have been influenced by the FRAME architecture; some of the architectures are directly based upon the FRAME. However, it is important to notice that creation of the architecture is “the easy part”, once it is created, it has to be continuously supported by government and even embedded in requirements for ITS projects. Without available support and regulations an ITS architecture will never be widely used.

C. US National ITS Architecture

We will briefly mention the US national ITS Architecture just to complete a picture. The Architecture is modular; it comprises a set of fixed “Market Packages” and “Equipment packages” that can be put together to fit the requirements of the stakeholders. The Market packages and Equipment packages are examples of “real” implementations and therefore require great deal of effort to develop and maintain them.

D. Usage and support of framework ITS Architectures

Whilst the European approach could be considered to be more flexible, there is still a major disparity in their support which results in perceived differences in both their quality and their ease of use. There is also a major difference in their political backgrounds, legislation support and their consequential manner of use.

The use of the US National ITS Architecture is effectively mandatory throughout the USA (unless the region does not want Federal financial support for it’s ITS deployments).

The European ITS Framework Architecture has been designed for a set of Member States for whom the concept of subsidiarity must apply. It is for this reason that everything in the FRAME Architecture is optional. This makes the use of the FRAME Architecture extremely flexible, but the creator of a bespoke ITS Architecture from the FRAME Architecture must understand it, and the creation process takes some time to do, i.e. a number of days.
IV. ITS ARCHITECTURE AND STANDARDS

Link of the standards to ITS architecture and its importance in system deployment is reviewed in this section. Standards are required to ensure compatibility between the various sub-systems and components of ITS. This is particularly relevant when the various sub-systems and components may be produced by a number of different manufacturers. The standards ensuring this are usually concerned with communications between sub-systems and their functions. However, “simple” communications standards are not always sufficient to produce a working and workable system. Of equal importance are the data that they use, and the behaviour of the sub-systems and functions at each end of the communications link, e.g. that one end can produce information in time for the other to make use of it, and the receiving end will understand the units and format in which the data is being provided.

Five categories of standards can be defined with regard to their link to ITS architecture, they are:

- Architectural standards – used only when the architecture is being created or updated. They have no influence on ITS systems.
- Communication standards – used at defined interfaces, where data transmission from one function to another function is needed.
- Data and interface specification standards – used for definition of data structures needed inside ITS functions and behaviour (data / protocol) of the function interaction.
- System parameter specification standards – used for setting of levels of functionality, robustness and interoperability of ITS functions within desired functionality.
- Test procedures standards – used for ensuring that particular ITS components could be used within specific ITS function.

For concrete use of an ITS architecture it is necessary to have a link between functions and “function related” standards (third to fifth category). The communication standards (second category) are usually outside of the scope of high level architecture. The reason for this is the fact that the FRAME Architecture does not describe any physical and communication viewpoints and is independent of technologies.

A. Link to standards in ITS architectures

Way, how to support usage of ITS architecture is to align it with standards and such ease to work of system designers. The linkage between standards has not been achieved yet for the FRAME and subsequent architectures and as can be seen from the paragraphs below, creation of permanent linkage is neither feasible neither efficient.

We have analyzed the relevance of ITS architectures and standards [10] [5], asking ourselves about their relationship. While it is a fact that the architecture had been used for several times to identify “white spaces” where standardization is needed, other link than this is difficult to find. However the situation is different in Europe and in the USA.

The US National architecture comprises a set of fixed “Market Packages” and “Equipment packages” that are examples of “real” implementation. Linkage of standards is made directly at this level. The architecture was also used to identify and develop national communication standards. Simply said both tools – ITS architecture and ITS standards specify the rules for ITS systems implementations and so they should be used together – an ITS architecture gives the rules for planning (investors), the standards give rules for supplying (suppliers) ITS systems. If both exist and are used (required) the interoperability is achieved.

In Europe, only small part of standards [5] can be linked directly to the high-level ITS architecture. Therefore it is neither effective neither reasonable to create direct links between such architecture and the standards. FRAME architecture was also, due to subsidiarity issue, not used for identification and development of new standards.

The situation on the level of national architectures is slightly different. Mainly it depends on the level the national architecture is describing. If the national architecture also gives the functional viewpoint only, the relation between standards and architecture is similar to the FRAME architecture. In case the architecture describes also the communication viewpoint, there are standards that can be linked to it.

B. Usage and support of framework ITS Architectures

The US concept is based on regional administration motivation to fulfil the requirements of National ITS architecture that brings the possibility to get some federal funding for a regional ITS project. Europe does not support any regional efforts for ITS architecture deployment and ITS standards management so there is no motivation to use a common approach (ITS architecture) within adjacent regions. It is then hard to reach the ultimate goal of ITS in Europe – the interoperability.

C. Maintenance of the link

The linkage of architecture to the standards may be a great benefit that could support architecture usage. However, the need for continuous updating of the link due to the ongoing process of standardization is quite hard task. Even the architecture has to be updated regularly, in the period of years, the standards then have to be maintained practically constantly, as new standards are being published every month.

The question this article evolves is whether this situation is manageable and actions can be done to strengthen the link between standards and the architecture.

Practical use of ITS architecture in a project set up, implementation and use deals with standards that have to be followed in order to ensure the conceptual and factual interoperability, therefore aiming at design of processes and tools facilitating the work with standards and architecture together is worth.
V. Definition of a Problem

It may seem that everything is working in order since the use of the architecture and its concepts is so well argued. The advantages of using ITS architectures are clear; however there are several reasons causing infrequent actual use in Europe. It is mainly lack of support both from authorities and industry, lack of supporting tools and hugeness of the architecture and there from resulting difficult “start”.

Taking as example Czech Republic, we can say that there was no real footprint of the ITS architecture in daily practice, so we tried to investigate an recommend the best approach to change this unwelcomed state.

VI. Ideal Use of ITS Architecture

Based on previously mentioned causes the following solution, resulting from the experience and work in the Czech Republic is proposed. The proposal is based on Aristotle’s approach of solving problems called Aristotle’s square of logic, this approach has four basic steps. First is the Organization that shall be accomplished by setting up a so called ITS Forum, second is the Conception with the ultimate goal to find common interests. The third is Information for relevant ITS applications and final level of our approach is Realization that shall be simplified by development of needed tools.

A. Organization

Organization component means it is necessary to have organizational subject taking care of the ITS future. This organization should comprise both the stakeholders from this area and the public authorities, in order to bring the needed benefits. Therefore the proposal is to create “ITS Forum” – organization governed in the Czech Republic by the Ministry of Transport bringing together people form the public sector and the suppliers. Such organization would be able to create a common platform (Forum) to discuss, develop, implement and promote national rules governing ITS. Proposed organization of such forum is in Figure 3.

![Fig. 3 Proposed organizational structure for effective ITS implementation](image)

B. Conception

The conception means the need to have common strategy for the ITS development – a long term plan (“master plan”) in order to raise policy objectives, appropriate answers from the field of technology and ITS applications and set up a frame for an open market competition – sustainable budget, common rules (standards and architectures), incentive system for regional investors (administration) and rules for ITS projects assessment and ITS realization enforcement.

C. Information

To have all the important information is the basic step for any successful decision making. Therefore the Concept (ITS master plan) provided by the Organization (ITS Forum) has to be supported by means of knowledge system. Important part of such system is the advice on using standards (standards deployment). Standards usage together with the ITS architecture provides very strong support for the ITS deployment.

In theory, standards might be linked with the architecture directly, but doing this would be extremely complicated and moreover practically impossible to maintain during time, due to the hugeness and complexity of ITS standards changing and being created all the time. But to know the relevant standards during system design or preparing contracts is necessary. Moreover standards as such are complex documents that it is not possible for any person to be able to read and become familiar with all the standards that might be relevant. Therefore a tool is needed to help finding the relevant standards.

D. Realization

The final step is the realization that can be also supported to ease the ITS architecture creation and ITS system design.

Many of the analyzed architectures have tools for selection of concrete architecture from provided national architecture. In the USA a tool called Turbo Architecture is used and it is an interactive software application that assists transportation planners and system integrators. In Europe it is Oscar (France) and Browsing and selection tool for FRAME architecture. Since the European approach is more flexible it does allow users only to select functional architecture and divide it to physical components. First problem to solve in the Realization phase is how to make the tool more usable for the people that really shall use it – system engineers.

VII. Results

In this section we would like to develop the Information and Realization steps and how we approached the issues raised above in these steps.

A. Standards database

Need of standards in the Architecture is evident, the problem is, just a full-text search would not do the job. Therefore, creation of database of excerpts from standards together with web search tool supported by different search patterns (key word, categories, full text search) have been studied extensively in the Czech Republic within the project.
STANDARD that came up with the idea of a special document type, an extract that is a strictly formalized text about a standard, with emphasis on its intended use. The extract does not describe the scope of the standard, nor replaces the standard itself, its purpose is to provide the reader the possibility to make a good choice among the standards for his/her intention and guide him/her to buy and use the standard, simply said its purpose is the marketing of the standard.

Such freely accessible database shall make linkage of standards to the architecture irrelevant and also should speed up the process of system development by giving the users tool easy to use, which would help them to find out the right standard. To update the database (extracts of standards and terminology) regularly there should be an administrator financially supported but independent on business interests. Therefore the tool should be supported by European funds as a means of vital contribution to worldwide ITS harmonization.

B. Tools for using ITS Architecture

The issue was how to make supporting tools more user friendly to the system engineers? This can be done by enabling them to work in the software environment they are already used to. There are many tools for system design in general; the advantage of them is often the general graphical representation of particular components. To have a tool for ITS architecture offering similar functionalities, the easiest way is to use existing system design tool and create a plug-in into such tool.

In the Czech Republic such plug-in called Rapid has been created as a module for the Enterprise Architect software. This plug-in than allows user not only to browse and select through entire ITS architecture, but also to search in full text for required function/user need, easily add new functions and data flows. Finally the selection process is made intuitive so the engineer can always check what the related functions to function he/she is deciding to select are.

VIII. CONCLUSION

ITS architecture is powerful tool that based on facilitation of the design and ensuring the compatibility of ITS systems provides important contribution to the sustainable development in the transport area. There are several types of architectures, in Europe the ITS framework architecture FRAME is high level architecture that supports the creation of national architectures.

Experiences show that so far standards that also serve for ensuring compatibility of systems do not provide efficient support for ITS Architecture and are not used together with the Architecture.

The situation can be improved by a general conception of work with ITS architecture and ITS strategy in general. This conception is based on several steps - recommendations for public authorities to have on their agenda the support or enforcement of use of ITS architecture, proposal of a tool that will ensure easy work and look up of the standards and creation of tool (module for standards software) to ease the practical work with the ITS Architecture.

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