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RECOMMENDATIONS FOR THE DEVELOPMENT AND MAINTENANCE OF NATIONAL ITS ARCHITECTURES

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ABSTRACT

Intelligent Transportation Systems (ITS) play a major role in the safe and efficient use of transport infrastructure and contribute towards sustainable mobility. Numerous countries have created their national ITS architectures which function as valuable aids for the planning of integrated ITS while in other countries, e.g. Germany, such architecture is not yet available. This article provides an overview on current deployments of national ITS architectures. In analysing such ITS architectures, huge differences have been identified, e. g. regarding the included modes of transport or the related processes for the development, maintenance or updating of the ITS architectures. In addition, national ITS architectures are sometimes mandatory in character to some extent to ensure their application in practice. As a major result of the analysis, general recommendations for the development of national ITS architectures have been identified, and they are presented in this paper. The first part of recommendations is related to the process of developing, maintaining, and updating an ITS architecture, and the second part addresses the contents of a national ITS architecture. This paper refers to a research project which has been conducted at Technische Universitaet Darmstadt (Germany) on behalf of the German Federal Highway Research Institute (BASt) concerning international and national guidelines for telematics and ITS architectures in road traffic (Boltze, M., P. Krüger, A. Reusswig, 2011).

Keywords: ITS, ITS ARCHITECTURE, ITS PLANNING, INTEGRATED ITS, ITS SERVICES

1. INTRODUCTION

Intelligent Transportation Systems (ITS) play an important role in transport policy and are a major element of modern traffic management. ITS have substantial effects for improving safety, capacity, efficiency, and reducing negative traffic-related environmental impacts. Furthermore, ITS support sustainable mobility and transport as well as the efficient use of transport infrastructures. To provide the maximum benefit of different ITS services, ITS need to have clearly distinguished functions and to be compatible with each other. To achieve integrated ITS, it is the main purpose of an ITS architecture to provide a framework for the planning, implementation and operation of ITS.

In several countries, national frameworks for the implementation of ITS exist since many years. As the first country, the United States have published their National ITS Architecture (NITSA) in 1996, which is now available in its version 7.0. The USA have implemented a network of responsibilities and organisational units to ensure the efficient and sustainable use of the NITSA. For that purpose, the U.S. Government has initiated certain legal measures to achieve the application of the NITSA to be mandatory and to ensure its dissemination. Besides the USA, many other countries throughout Europe and other parts of the world have developed their national ITS architectures, meanwhile.

Since the early 1990s and even before, research on a European framework architecture for ITS has been funded by the European Union. The first version of a European ITS framework architecture was published in 2000 as the result of the KAREN project. This architecture has been updated in the FRAME projects and was recently revised in the E-FRAME project.

Furthermore, the use of ITS plays an important role in the European transport policy. The ITS Action Plan (COM(2008) 886) and the Directive for the Agreement on a Framework for the Implementation of ITS (COM(2010) 40) contain specific measures for the implementation of ITS in Europe and a European framework architecture for ITS.

Being aware that many countries are deploying their national ITS architectures since many years, but Germany still did not establish such architecture, a recent research project at TU Darmstadt analysed national ITS architectures from different countries (Boltze, M., P. Krüger, A. Reusswig, 2011). The analysis has identified conditions and requirements for the development, maintenance, and updating of such national ITS architectures. These results are consolidated in recommendations for the development of national ITS architectures. The first part of recommendations is related to the process of developing, maintaining, and updating a national ITS architecture, and the second part addresses the contents of a national ITS strategy, the ITS framework architecture, and the reference architectures. For this paper, some major recommendations are summarised, which can be generally applied, and the information regarding the deployment status of the national ITS architectures has been updated.

This paper starts with some basic definitions of fundamental terms in the field of ITS architectures (Chapter 2). Subsequently, the benefits of establishing a national ITS architecture are described in Chapter 3, and Chapter 4 gives an overview of selected ITS architectures from outside Europe, from the European Union, and from European countries. Chapter 5 summarises general recommendations regarding the implementation of national ITS architectures and finally, chapter 6 will detail the conclusions.

2. DEFINITIONS

A huge number of different terms is finding widespread use in the field of ITS. Frequently, same terms are used with different meanings. For example, “System Architecture” is commonly used to describe ITS deployments in countries, states, or cities. But also a single section control system can be described by using the term “system architecture”. Furthermore, every single device of this section control system has its own “system architecture”. Generally, none of these descriptions seems to be wrong. But this particular example indicates, that a common understanding on the use of basic terms in the field of ITS is required to avoid misunderstanding. Giving reference to existing definitions, e. g. by Busch et al. (2007) and Rittershaus (2009), the above mentioned research project (Boltze, M., P. Krüger, A. Reusswig, 2011) elaborated basic definitions of such relevant terms in the field of ITS.

Generally, it seems necessary to distinguish between national guidelines and standards from various implementation levels. For instance, the implementation level may be regional, or it may be related to a city, a single transport operator, or any other institution. It is essential that the national guidelines or any higher level deployment should always form the basis for lower level implementations. Figure 1 gives an overview of the terms used for national deployments and for implementations which are explained in the following text. In combination, the three levels of national guidelines / standards constitute the national ITS architecture.

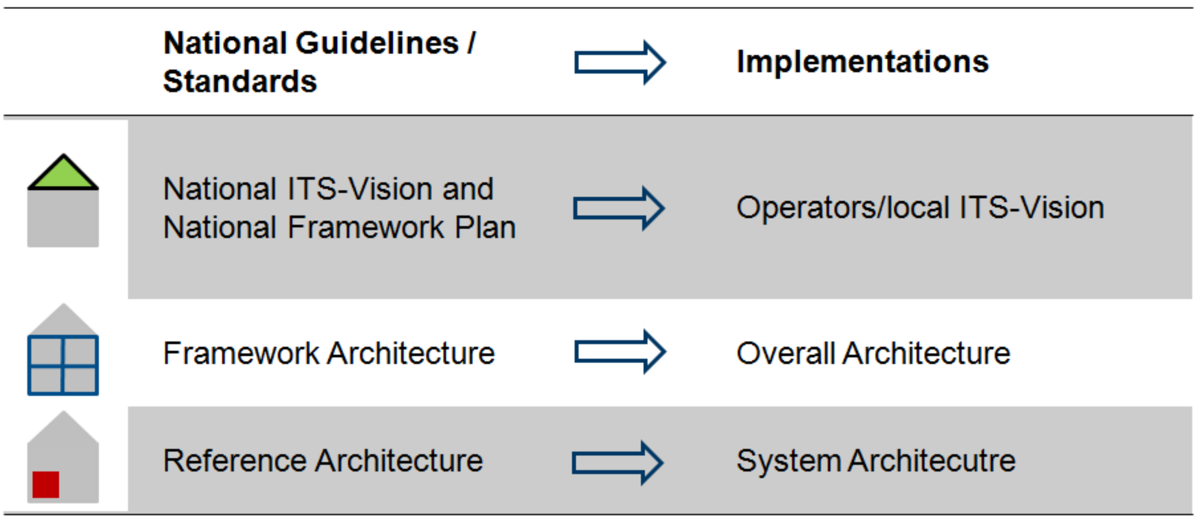

Figure 1 – Classification of basic terms and symbolism

National ITS Vision and Operators/Local ITS Vision

The National ITS Vision represents a high-level, long-term orientated and political strategy for the use of ITS. It should be a commitment for ITS which encompasses the aspirations of all stakeholders including the users. It also illustrates the aims as well as the expected benefits of using ITS. Furthermore, the National ITS Vision will be substantiated in a framework plan which comprises specifications regarding roles, responsibilities, as well as general specifications for measures and a timeline for the implementation.

When defining an ITS Vision on the level of a transport operator or local authority, the term "Operators/Local ITS Vision" is used. It correspondingly comprises the content of the National ITS Vision. The National ITS Vision as well as the Operators/Local ITS Vision are illustrated as a rooftop (Figure 1).

Framework Architecture and Overall Architecture

The Framework Architecture is based on the national ITS Vision as well as on the framework plan. It is more concrete than the ITS Vision but still technology-independent. The Framework Architecture contains functional (equivalent: logical), physical, and organisational aspects, which aims to ensure interoperability on the level of the reference architecture, but also has to provide flexibility for the detailed implementation of ITS in specific projects.

When defining a Framework Architecture on the level of operators or local authorities the term Overall Architecture is used which correspondingly comprises the content of the Framework Architecture. The Framework Architecture as well as the Overall Architecture are illustrated as the structure of a house (Figure 1).

Reference Architecture and System Architecture

The Reference Architecture specifies the framework architecture for one ITS-related function, e. g. traffic signal control systems, and the Reference Architecture is used as a blueprint for implementing this function. The Reference Architecture comprises all specifications and, if necessary, also standards to ensure integrated ITS implementations. These elements are generally specifications

- of the related function,
- for implementing components of the related function,
- of interfaces as well as for the communication between components,
- of data protocols,
- of roles and responsibilities for the involved stakeholders.

When defining a Reference Architecture on the level of operators or local authorities, the term System Architecture is used which correspondingly comprises the content of the Reference Architecture. The Reference Architecture as well as the System Architecture is illustrated as the rooms or suites of a house (Figure 1).

ITS Pyramid

Furthermore, research group 3.1.4 "ITS System Architectures" of the German Road and Transportation Research Association (FGSV) has developed a model, which illustrates the structure of a prospective national ITS architecture in Germany and is representing an ITS pyramid. Initially, the ITS pyramid constitutes the structure of a prospective national framework architecture in Germany and is specified for reference architectures and for architectures of real systems (see Figure 3).

Aim of the ITS pyramid is to provide an holistic view on ITS and to illustrate the relationship between all relevant aspects for describing ITS. Integrated and harmonised ITS equipment is achieved by considering all layers of the ITS pyramid for different systems.

Firstly, a vertical interrelation exists between the levels of the ITS pyramid, beginning from the top. At the highest level, a strategy for the use of ITS needs to be defined which comprises objectives and the scope of the system. Subsequently, (business) processes have to be defined in order to fulfil the strategy. The business processes also include specifications of roles and responsibilities, a functional decomposition of the system, an information model, and an exhaustive answer to the question "who interacts when why with whom?". Afterwards, information structures have to be embedded which comprise the semantics of data and information structures. The (Technical) services serve for the implementation of the information structures. They must also specify interfaces and data exchange mechanisms and illustrate "how all functions of the system interact". Finally, the infrastructure for the implementation of the (technical) services has to be defined. This includes a description of the technology used for this purpose (see Figure 2).

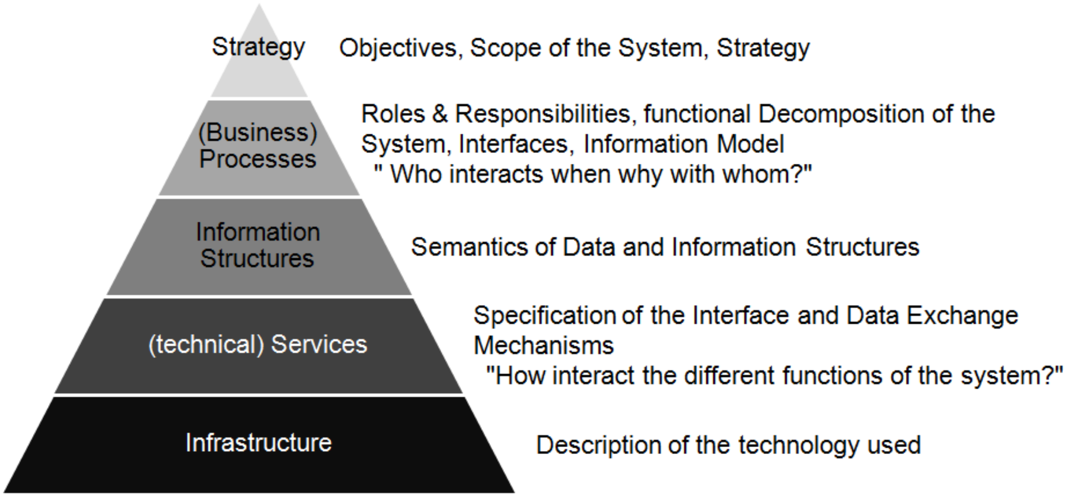

Figure 2 – Model for a German ITS Architecture: The ITS Pyramid (FGSV 2012)

Secondly, the entire ITS pyramid needs to be specified beginning with the abstract strategic framework architecture, followed by domain-specific reference architectures, and finally in terms of architectures of the installed systems. This issue can be described as a horizontal specification of the ITS pyramid's layers. In this process, the attributes of abstract concepts are mapped onto practical systems. So long as care is taken to avoid conflicts between layers, this specification will encourage the adoption of interoperable ITS equipment (see Figure 3).

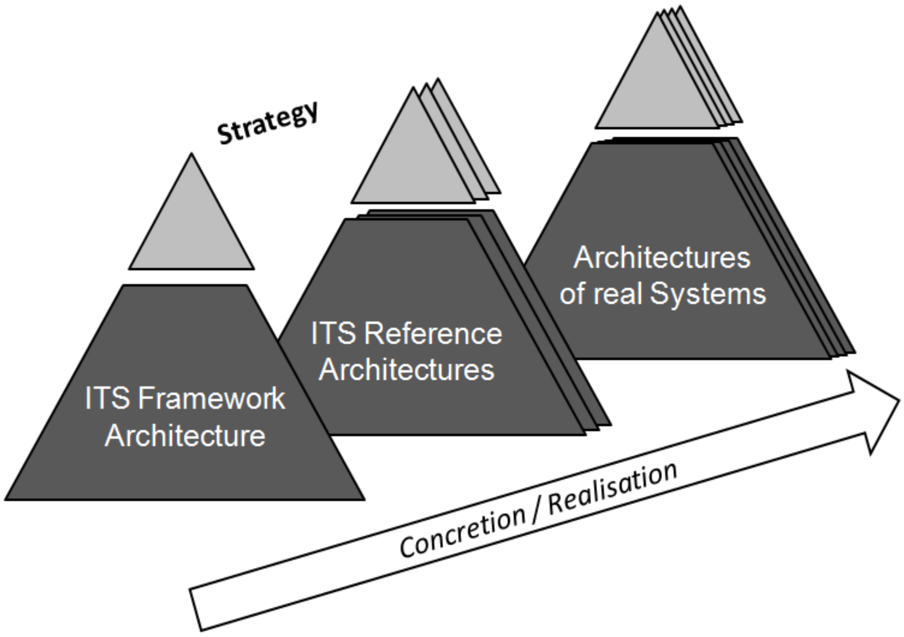

Figure 3 – Context of different levels for Concretion / Realisation (FGSV 2012)

3. BENEFITS OF A NATIONAL ITS ARCHITECTURE

Benefits of national ITS architectures affect different actors (e. g. public authorities, operators, suppliers, manufactures, or users) and can be described following different methodologies. For this report, they were structured in “benefits for planning – general advantages”, “benefits for planning – improved ITS services”, and “economic benefits”. The description in the following section is based on Busch et al. (2007), FRAME (2000), Halbritter (2008), PIARC (2004), SINTEF (2009), Törönen (2003), and VÄGVERKET (2004). Several aspects have been added to the information retrieved from these sources.

Benefits for Planning – General Advantages

Cost- and Time Savings. Using a common structure for system development leads to cost and time savings. For instance, less staff is required for the development of ITS. By using a national ITS architecture, potential problems can be identified early in the development process and fixed at lower cost. Furthermore, the entire planning process is made easier and simpler.

Identification of Potential Areas for Standardisation. A national ITS architecture puts all functions in a clear order. Potential areas for standardisation can thus be identified. This also contributes to reducing proprietary interfaces. Furthermore, requirements for existing or upcoming standards are highlighted.

Reducing Complexity. By focussing on the relevant elements of the system at a higher level of abstraction the national ITS architecture helps to render the system more comprehensible.

Ensuring Defined Quality. Using the national ITS architecture and its specifications a consistent structure and quality of the ITS deployments is achieved.

Basis for System Development. The national ITS architecture is used as a common basis for the deployment of systems. This also strongly supports the interoperability of all deployments using the ITS architecture.

Enhanced Communication between Stakeholders. The design of the system, created by using the national ITS architecture, also supports the communication between actors.

Benefits for Planning – Improved ITS-Services

Supporting Interoperability and Multimodality. The main purpose of using a national ITS architecture is to achieve interoperable and integrated ITS. Using a national ITS architecture as a starting point for system development contributes towards integrated ITS.

Identification of Potential for Improvement or Potential for Enhancements of ITS-Services. The systematic illustration of ITS functions and services in a national ITS architecture allows identifying potentials for improvement or enhancement of ITS services. Also the need for new ITS services or functions can be identified by using the national ITS architecture.

Ensuring a Specific Quality of ITS-Services. The national ITS architecture comprises specifications developed in consensus between the participating stakeholders. Therefore, the application of the national ITS architecture ensures a specific quality of ITS deployments. Also a common behaviour of the systems is realised by using the national ITS architecture.

Enhanced ITS-Services. Application of the national ITS architecture leads to integrated ITS services with improved consistency of information, e. g. for users. Furthermore, the reliability and flexibility of ITS services is increased.

Economic Benefits

Developing a Transparent Market for Hard- and Software. The national ITS architecture also sets the basic conditions for the ITS market in the long run. Thus, barriers to market entry are going to be reduced. Competition between actors will be encouraged, and prices for users will decrease.

Reduction of Development and Implementation Costs. Using the national ITS architecture as a common starting point for the deployment of systems ensures a faster development and implementation at reduced costs.

Reduction of Costs for Operation and Maintenance of ITS. Common system structure based on the national ITS architecture also decreases costs for the operation and maintenance of systems.

Reduction of Prices for ITS. Due to standardisation, suppliers may develop ITS at reduced costs which may result in lower prices for customers. Moreover, increased competition between actors can promote a reduction of prices.

Basis for Supporting PPP. As a strategic framework, the national ITS architecture promotes PPP's by setting a transparent market environment.

4. OVERVIEW ON EXISTING NATIONAL ITS ARCHITECTURES

There is a very large number of existing national ITS architectures. The following section comprises a brief description of selected national ITS architectures. Many more national ITS architectures have been analysed and documented in detail by Boltze M., P. Krüger, A. Reusswig (2011). The descriptions included in this paper comprise a brief summary of this report and have been updated for this purpose. The following descriptions are divided into ITS architectures outside Europe, the European Union, and European Countries. For every section one ITS architecture is described as an example.

Outside Europe - Example USA

As the first country in the world, the USA have published the first version of their U.S. National ITS Architecture (NITSA) in 1996. This architecture was a new development and didn't use another ITS architecture as its basis. Since 1996, the architecture has continuously been updated and is now available in its Version 7.0. The National ITS Architecture of the USA may be the most sophisticated in the world. Leadership for the development of the ITS architecture has been exercised by the U.S. Department of Transport (DoT) and especially through its Federal Highway Administration (FHWA). The development of the ITS architecture has predominantly been financed by the U.S. DoT. The stakeholders have been extensively involved in the development of the architecture which comprise also private companies. Actions in this context were the establishment of a team for the architecture development, the establishment of a technical review team, and the involvement of ITS experts for the detailed review of the architectures content. The use of the ITS architecture in the USA is mandatory if the states intend to receive federal funding for their ITS projects (TEA21: rule 940). Many aids have been developed, e. g. a software tool for developing ITS architectures (Turbo Architecture; currently available in version 7.0). Private companies are also contracted for maintaining the architecture, or to hold training courses or workshops to support the architecture's dissemination. The architecture is also linked with Service Packages which need to be used for the implementation of specific functions, wherever the NITSA is applied. The architecture is primarily related to the road traffic but also includes interfaces for the exchange of information with other modes. The USA have also developed a joint Border Information Flow Architecture (BIFA) with Canada (ITERIS 2012, Bossom R. A. P. n. d).

In relation to the definitions in chapter 2 the analysed documents of the USA predominantly correspond to the ITS Vision and framework plan (ITS Strategic Plan from 1992), framework architecture (NITSA), and reference architecture (Service Packages). With its Service Packages, the National ITS Architecture comprises detailed specifications. For the development of many other national ITS architectures, the U.S. National ITS Architecture has been used as the basis (e. g. Canada, Chile) or to some extent (e. g. Japan, Norway). Besides the USA and Europe, the ITS architectures of Canada and Japan have been analysed by the authors (Boltze M., P. Krüger, A. Reusswig 2011).

European Union - Example FRAME

First projects related to the development of an ITS architecture for Europe have been started in the early years of the 1990s (e. g. CORD, SATIN, CONVERGE). The first version of the European ITS Framework Architecture (EITSFA) has been published as a result of the KAREN project in 2000. In the FRAME (Framework Architecture made for Europe) projects, EITSFA has been updated and a new version of the architecture has been published. The FRAME Architecture has been recently updated in the E-FRAME projects (Extended FRAMEwork Architecture for cooperative systems) and now also includes cooperative systems. It is currently available in its version 4.1. Leadership for the development of the architecture has been taken by the European Commission. Also the funding was provided by the European Commission due to several research projects. Several stakeholders have been involved in the architecture development as partners in the research projects (e. g. governmental organisations, industry, science). The use of the architecture is not mandatory and moreover based on the principle of subsidiarity of the European Union. Beside several supporting projects (FRAME-S, FRAME-NET), many aids have been developed such as software tools for the development of ITS architectures or tools for risk-analysis (Browsing Tool, Selection Tool, RAID). Furthermore, trainings and workshops on E-FRAME are offered. The architecture relates primarily to road traffic but also includes interfaces to other modes of transport (FRAME 2012, Bossom R. A. P. n. d).

Related to the definitions in chapter 2, the analysed documents vastly correspond to the framework architecture. Beside this, the various regulations and commitments of the European Commission regarding integrated ITS and ITS architecture can be characterised to be vastly corresponding to a national ITS vision (e. g. EU Directive 2010/40EU, EU Action Plan COM(2008)886, White Paper 2050, COM(2011)144). FRAME has been considered (at least partly) for the development of many other national ITS architectures, such as Austria, France, Italy, Norway, Finland, Czech Republic and Hungary.

European Countries - Example Norway

In Norway, a close cooperation between the Public Road Administration, Rail Administration, Coastal Administration and Avinor for air transport has been established since 1998. As a result of this collaboration, a joint "National ITS Strategy" was published which marked the starting point for the development of the national ITS architecture ARKTRANS in 2000. As the basis for the development of ARKTRANS, the ITS architecture of the USA as well as FRAME have been used. The first version of ARKTRANS was published around 2004 and has been updated continuously since then. Meanwhile, Version 6.0 of ARKTRANS is available. One of the main characteristics of ARKTRANS is that the architecture can be used for ITS deployments for every mode as well as for freight and passenger transport. Leadership for the development of ARKTRANS has been taken jointly by the related Ministry of Transport and Communication as well as by the Public Road Administration, Rail Administration, Coastal Administration and Avinor for air transport. Funding for the development of ARKTRANS was provided by the Ministry of Transport and Communication and the Government Departments for Transport. Many stakeholders related to all modes were involved in the development of ARKTRANS. This process was led by SINTEF, a governmental organisation, since 2001. The use of ARKTRANS is not mandatory. The architecture's structure is described in the ARKTRANS Reference Model. In addition, supporting actions have been realised. Since the publication of its first version in 2004, ITS Norway, a national non-profit association of public and private entities, has been responsible for maintaining and updating ARKTRANS. ITS Norway is also responsible for encouraging the use of ARKTRANS in practice, the development of manuals for the use of ARKTRANS, and the preparation of a sustainable concept for financing the architecture. Furthermore, an ARKTRANS forum has been established to support ITS Norway and SINTEF (ARKTRANS 2012).

Regarding the definitions in chapter 2, the analysed documents predominantly correspond to the ITS vision and the framework architecture. ARKTRANS has been used in several projects (e. g. Freightwise, SMARTFREIGHT, MarNIS, ROSATTE, EasyWay, EFFORTIS, Door-2-Door, MultiRIT, INTRANS).

Beside this, for European countries the ITS architectures of Austria, France, Italy, Finland, Czech Republic, Hungary, Switzerland, the Netherlands and Great Britain have been analysed by the authors (Boltze M., P. Krüger, A. Reusswig 2011).

5. RECOMMENDATIONS

Based on the analysis of national ITS architectures – as described in the section above using three examples – elements can be identified which have had positive impact on the processes related to the definition of a national ITS architecture. Linked to these elements, recommendations for the development and maintenance of national ITS architectures can be described. The recommendations are divided in two parts. The first part is related to the processes of development, maintaining and updating of a national ITS architecture. The second part contains recommendations regarding the contents of the national ITS strategy, the ITS framework architecture and the reference architectures.

The recommendations described in the following section are an abstract of those in Boltze M., P. Krüger, A. Reusswig (2011) and comprise a subset suitable for all countries that plan to develop their own national ITS architecture or need to maintain an existing one. Furthermore, the recommendations in Boltze M., P. Krüger, A. Reusswig (2011) specifically refer to the situation in Germany.

Recommendations Related to the Process for the Development, Maintenance, and Updating of a National ITS Architecture

Leadership: In the analysed countries the initiative for the development of a national ITS architecture has been taken by a federal ministry, in most cases the ministry of transport (e. g. USA, Canada, Austria, Italy, Czech Republic, Hungary and the Netherlands). Within the ministries, the responsibilities regarding the ITS architecture have been detailed (e. g. USA: FHWA, France: CERTU, Switzerland: ASTRA).

<u>Recommendation 1:</u> The leadership and responsibility regarding the ITS architecture should be held by the respective ministry of transport. If necessary, additional ministries should be also involved.
<u>Recommendation 2:</u> A clear assignment of the tasks related to the ITS architecture should be organised within the ministry.

Responsibilities: In some countries, organisational modifications have been implemented, e. g. in the USA where FHWA has established a team for the development for the national ITS architecture. In the European Union, the Directorate-General for Mobility and Transport (DG MOVE, former Directorate-General for Energy and Transport, DG TREN) and the Directorate-General Communications Networks, Content and Technology (DG CONNECT, former Directorate-General Information Society & Media, DG INFSO) respectively recommend constituting teams for the development of national ITS architectures.

<u>Recommendation 3:</u> The responsibility for the development of the national ITS architecture should be assigned by the leading ministry to a suitable institution and involve all relevant stakeholders.
<u>Recommendation 4:</u> If there is no suitable institution for the development of the national ITS architecture within the existing organisational structure, a new institution should be established.

Participation of Stakeholders: In many countries, active participation of the relevant stakeholders (e. g. federal ministries, regional and local authorities, industry) in the development of the national ITS architecture have been achieved. At least, advisory function of those stakeholders is realised, if an active participation is not feasible. By involving all stakeholders in the development of the national ITS architecture a broader consensus and stronger support for the results is achieved. This also encourages the subsequent use of the national ITS architecture. Actions to strengthen the consensus have been observed e. g. in the USA, Austria, France, Finland, Switzerland, and the Netherlands.

The involvement of private companies has been identified as an essential measure. They can be integrated in the development or maintenance of the ITS architecture by closing limited contracts. By including private companies those actors can contribute their specific know-how and reduce the strain on public authorities.

Recommendation 5: All relevant stakeholders, including private companies, should be involved in the process of the development or maintenance of the national ITS architecture. This also includes the states and cities as well as scientific bodies. By involving all stakeholders the outcomes, such as national ITS vision or framework architecture, should meet the expectations of all stakeholders and ensure a high acceptance. The acceptance between stakeholders also enhances the later use of the ITS architecture in practice.
Recommendation 6: If active participation is not feasible, at least an advisory function of those stakeholders should be ensured.
Recommendation 7: Private companies should be involved in the development, operation or maintenance of the ITS architecture, e. g. by closing limited contracts. By this they can contribute with their specific know-how and also relieve the public authorities.

International Integration: Transport doesn't end at borders and today there are significant traffic links between neighbouring countries, which will be intensified in the future. The physical, functional, and organisational compatibility of ITS with other countries also supports competition between companies and helps to establish new market opportunities.

Recommendation 8: As part of the development or maintenance of a national ITS architecture the exchange of information with neighbouring countries should be encouraged.
Recommendation 9: Compatibility to ITS architectures of neighbouring countries should be achieved, including common definitions of basic terms.
Recommendation 10: It should be analysed which models of existing ITS architectures can be used or modified to serve as a starting point for the development of the national ITS architecture or whether they can be considered for the updating of an existing ITS architecture.

Maintenance and Updating: The maintenance as well as the updating of a national ITS architecture is crucial as new functions or services have to be included in the architecture and operational experiences should be utilised. Some of the analysed ITS architectures are updated sporadically (e. g. Canada) and some of them periodically (e. g. USA, Norway).

Recommendation 11: The ITS architecture should be able to adopt new services or functions within its updates. The architecture needs to provide a flexible structure which also allows including new functions that don't belong to the respective version of the ITS architecture.
Recommendation 12: The ITS architectures content (for instance, included functions and services) should be continuously maintained and updated. If necessary, organisational modifications, as well as the involvement of private companies, should be considered. The

ITS architecture shall include new ITS and upcoming ITS and be therefore "ahead of the times".

Financing: In all countries analysed the development of the national ITS architecture was primarily funded by public authorities.

<u>Recommendation 13:</u> The development and maintenance of the national ITS architecture, are governmental responsibilities and should therefore be financed by public authorities. A detailed funding concept for the development and maintenance of the national ITS architecture should be developed.

Binding Character: Some ITS architectures are mandatory to some extent. Such obligation is achieved for example by linking public funding for ITS projects with the use of the ITS architecture (e. g. USA, Japan, Italy). Those actions strongly support the subsequent use of the ITS architecture in practice.

<u>Recommendation 14:</u> Generally, the use of the ITS architecture should be mandatory to ensure its dissemination.
<u>Recommendation 15:</u> For this, public funding should be linked with the use of the ITS architecture.

Aids and tools: For most of the analysed countries, different aids and tools have been developed to support the implementation as well as the use of the national ITS architecture. This comprises software-tools, manuals, guidelines, training courses, workshops etc. (e. g. USA, Canada, FRAME, France). Many countries operate websites to inform users regarding their ITS architectures and to provide supporting materials and further aids.

<u>Recommendation 16:</u> Suitable aids and tools, e. g. software tools, manuals, guidelines, training courses, workshops etc. should be developed and offered to encourage the dissemination and application of the national ITS architecture.
<u>Recommendation 17:</u> Websites should provide all relevant information and aids regarding the ITS architecture.

Recommendations related to the content of a national ITS architecture

Content of National ITS Vision and National Framework Plan: Some countries link their national ITS vision with a timeline for realising its purposes and funding concepts have been developed for realising the ITS vision (e. g. Austria or Switzerland). Furthermore, cost-benefit analyses serve for identifying suitable measures for a framework plan (e. g. Austria).

<u>Recommendation 18</u>: A timeline as well as a funding concept for realising the ITS Vision should be developed and linked with a framework plan.
<u>Recommendation 19</u>: By defining the national framework plan cost-benefit analyses should be applied to identify suitable measures.

Content of Framework Architecture: Most of the analysed ITS architectures are primarily related to road transport and are therefore not multimodal. These architectures usually include the interfaces to other modes of transport and/or the exchange of information with them (e. g. USA, Canada, FRAME, Finland, Switzerland and the Netherlands). In contrast, Norway provides a clear multimodal approach with its ITS architecture ARKTRANS.

Beyond functional (or logical) and physical aspects, some ITS architectures also include organisational issues (e. g. Italy, the Netherlands, Norway, Switzerland). The European Commission states in its Directive COM 2010(40), Article 5, paragraph (4) that specifications of ITS services may comprise functional (or logical), physical and organisational aspects. ISO Standard 14813-5 (ISO 2010) also describes functional (or logical), physical and organisational aspects amongst others as elements of ITS architecture.

Many of the analysed ITS architectures also take legacy systems into account (e. g. USA, Canada, FRAME, Switzerland).

Lastly, multiple additional requirements regarding the content of a framework architecture need to be considered, such as the modelling type (e. g. process-orientated or object-orientated) or the set of provided viewpoints. These elements are not addressed in this paper and will be revised in the current research work at TU Darmstadt.

Recommendation 20: The ITS framework architecture should be designed to include all modes of transport.
Recommendation 21: The ITS framework architecture should comprise functional (or logical), physical, and organisational aspects. Furthermore it should be elaborated whether additional aspects should be included in the ITS framework architecture.
Recommendation 22: Embedding of legacy systems should be ensured by the ITS framework architecture.

Content of Reference Architectures: Many of the analysed ITS architectures comprise standards at detailed levels of architectural description (e. g. USA, Canada, Japan, France, Italy, the Czech Republic). Some countries have defined specific modules as a part of their national ITS architectures (e. g. service packages of the USA or Canada).

Recommendation 23: As a part of reference architectures, standards should be comprised to ensure interoperability of ITS services. In particular, existing established standards should be considered for this purpose.
Recommendation 24: It should be elaborated whether the development of specific modules is appropriate, such as service packages in the USA.

6. CONCLUSIONS

The analysis of current deployments in different countries indicates a clear need for the development of a national ITS architecture. Many benefits, e. g. regarding the planning of integrated ITS or new market opportunities, are achieved by establishing and maintaining a national ITS architecture. For the future, an even stronger need for integrated ITS is expected, as the increasing integration of today's transport indicates. Many countries have developed their national ITS architectures and implemented them successfully in practice. Existing ITS architectures should be revised continuously to keep their contents up to date. Furthermore, the deployment status of national ITS architectures varies notably (e. g. regarding the included modes of transport, the level of detail of included specifications, or related to their binding character). By analysing those ITS architectures, detailed recommendations regarding the development as well as for the operation and maintenance of national ITS architectures can be identified. Those could be utilised by countries that plan to develop a national ITS architecture or need to maintain an existing one.

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