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# Development of an architecture framework for Intelligent Transport Systems

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**Abstract**

Intelligent Transport Systems (ITS) are considered to be the answer to current challenges in road traffic, such as increasing congestion and energy consumption. With the increasing deployment of ITS and new possibilities of digitalisation, the connection and interworking of ITS and ITS services in the form of ITS value chains and networks have become more and more attractive or even indispensable. However, the interoperability of systems and services and the smooth cooperation and collaboration of involved organisations and actors are not an obvious matter. ITS architecture addresses the issue of interoperability in particular, incentivises the deployment of ITS even further and provides organisational, functional and technical guidance.

This report describes the outline and the status of a German research project with the objective of developing a National ITS Architecture Framework which aims to support ITS activities in Germany. The framework is not based on existing ITS architectures since it is expected to provide a wider view than any ITS architecture before. A common strategy and vision of all involved actors are the core of the approach. They are the foundation of the business architecture which describes the functional decomposition of the system and the relationships between organisations. Strategy and business architecture also represent the top layers of the so called ITS architecture pyramid and distinguish the presented ITS architecture framework from others. The TOGAF Architecture Development Method has been used and tailored to the needs of ITS architecture since it excellently integrates the core aspects and provides a step-by-step guidance for the complete process of developing an ITS architecture.

*Keywords:* Intelligent Transport System, ITS, ITS architecture, architecture framework, ITS architecture pyramid, TOGAF, Architecture Development Method, ADM, roles, responsibilities, capabilities

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**Nomenclature**

| | |
|---|---|
| ADM | Architecture Development Method |
| ARC-IT | Architecture Reference for Cooperative and Intelligent Transportation |
| IT | Information Technology |
| ITS | Intelligent Transport Systems |
| FGSV | Road and Transport Research Association (Forschungsgesellschaft für Straße und Verkehr) |
| FRAME | Framework Architecture Made for Europe |
| NITSA | National ITS Architecture Framework (of the US Department of Transport) |
| TOGAF | The Open Group Architecture Framework |

## 1. Introduction

The steadily increasing number of vehicles on the roads results in increasing congestion and energy consumption, as well as environmental and social problems. Tackling these challenges solely with traditional measures is not sufficient, but needs advanced applications as described in the ITS Directive [2010/40/EU]: Intelligent Transport Systems (ITS) provide innovative services and are fundamental for manifold applications in road traffic with the ultimate objectives of enhancing road safety and efficiency.

The growing tendency to connect these systems evokes new obstacles for the deployment of new and the integration of existing ITS. Intelligent mobility with consistent and interoperable services for all travellers requires common objectives of the involved stakeholders and mutual comprehension of the tasks in order to define the essential interfaces and processes concerning functional, technical and organisational aspects. ITS architecture in general has the objective to provide guidance and support in all respects.

### *1.1. Historical and International Perspective*

The USA was the first to publish a national ITS architecture in 1996. The former NITSA has been extended and evolved continuously and is available in the latest release 8 as an Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT). It provides a common framework for planning, defining and integrating ITS and assists in the development of regional ITS architectures [USDoT 2017].

In Europe, the ITS architecture activities also started in the 1990s. The first European ITS Framework Architecture was published in 2000 and has been extended and evolved in several research projects under the label FRAME [FRAME]. Unlike in the USA, there is no obligation of using FRAME for European ITS projects and deployment; the ITS Action Plan [COM/2008/866] and the ITS Directive [2010/40/EU] merely claim the implementation of a European ITS Architecture. Several European countries have developed national ITS architectures based on FRAME, others have developed independent national ITS architectures. Further countries like Japan, Canada or Australia have launched ITS architectures.

A national ITS architecture for Germany does not exist yet. Early ITS activities in the 2000s were collated and elaborated in a working group of the German Road and Transport Research Association (FGSV), which resulted in a final report [FGSV 2012]. In the same year, the German ITS Action Plan for Road Traffic was published [BMVBS 2012]. It stipulates the development of such an architecture framework for ITS, which is currently being developed in a national research project on the basis of the crucial concepts developed in the FGSV working group.

While the focus of FRAME is on functional and technical aspects, the new ARC-IT initially covers relationships between organisations in the so-called Enterprise Architecture. On the contrary, the German National ITS Architecture Framework spotlights strategic aspects, especially common vision and objectives, as the essential elements of each ITS architecture. This strategy layer builds the foundations for the organisational, functional and technical aspects. The comprehensive overview of the organisational aspects is indispensable for ITS. The Open Group Architecture Framework (TOGAF) covers these aspects in the business architecture. This is one of the reasons why TOGAF has been assessed as an excellently appropriate guide and tool for ITS, which makes the German ITS Architecture Framework exceptional.

### *1.2. Scope*

The core of the currently developed National ITS Architecture Framework is featured by the fundamental concepts for ITS architecture. In addition, it encompasses the methodological basics and a detailed tailored ITS Architecture Development Method, as well as a comprehensive glossary. The architecture framework is being applied concurrently in the development of three reference architectures. The incorporation of the first experiences of those reference architectures is used for validation and evaluation of the method. This leads to an adaptive and future-proof National ITS Architecture Framework. Recommendations and suggestions for the subsequent maintenance and evolution concept will complete the project.

This paper intends to give profound insights into the essential components of the National ITS Architecture Framework. The principles and approaches regarding ITS architecture in Germany which preceded the project are depicted and related to the TOGAF Architecture Development Method. The suitability of TOGAF as a tool for ITS architecture is shown. The project results are outlined and examples are examined in detail. Among them, the roles and responsibilities are essential for the description of cooperation and collaboration in every system architecture. The novel approach of adopting an institutional role model for ITS and integrating the TOGAF concept for capabilities will be explained.

## 2. Basic Principles and Procedure

### *2.1. ITS Architecture Principles*

ITS architecture handles the functional, technical and economical design and the constructive planning of ITS and ITS services. For that purpose, ITS architecture is based on general principles and objectives of the "builder-owner". In this respect, the core capabilities of an ITS architect are knowledge about realisation of ITS and ITS services, as well as the creation of an ITS architecture by proposing and forming ITS architecture characteristics. These characteristics are based on own conceptions of the ITS architect and follow the objectives of the builder-owner.

#### *2.1.1. The ITS Architecture Pyramid*

The so called ITS architecture pyramid is a suitable model and methodological tool to structure the whole scope of the ITS architecture hierarchically into five layers, cf. Fig 1 [FGSV 2012]. Overall, the pyramid represents the structural composition of ITS services in order to better identify, classify and relate their properties to each other and delivers the semantics for the description of ITS services and ITS business models.
The ITS architecture pyramid contains the following layers:

- The **Strategy layer** describes the goals of ITS and ITS services in terms of general principles and describes the ways ITS goals can be reached.

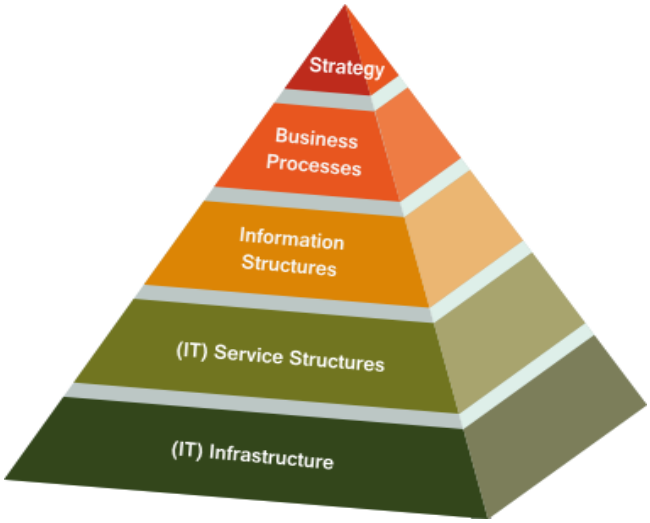



Fig. 1 The ITS architecture pyramid

- The **Business Process layer** specifies the ITS roles that are part of the ITS value chain creating added value by means of ITS. It also describes how ITS roles interpret ITS goals and ITS strategies for their own business cases and how the collaboration/cooperation of ITS roles generates an added value. The operationalisation of ITS goals is specified in ITS business processes.
- The **Information Structures layer** identifies which ITS information objects contribute to the ITS added value, and it describes the structure of these information objects.
- The **Service Structures layer** specifies IT services that are used to generate ITS information objects and interfaces that are used to exchange these ITS information objects.
- Finally, the **Infrastructure layer** describes how the services and information objects are provided physically, and it defines the structure of hardware and software components that run an ITS service.

The ITS architecture pyramid can be applied to all relevant aspects of ITS and ITS services in all phases of the corresponding discussion. Above all, demands for a modified understanding of ITS roles can be easily identified and substantiated. Particularly, if distributed services shall be realised, the ITS architecture pyramid can always provide the logical context between multiple actors.

*2.1.2. Instances and implementation of ITS architecture*

For the development of an ITS architecture three instance levels are defined.

- First, the **ITS architecture framework** defines design principles for an ITS architect, such as architecture building blocks or the semantics of concepts and terms (ITS glossary).
- Second, an **ITS reference architecture** describes a category of ITS services and instantiates the concepts and methods of the ITS architecture framework for a specific domain.
- Finally, the **ITS architecture of a real ITS service** describes the effective realisation of relevant ITS reference architectures in a concrete use case.

To implement ITS architecture, the definition and development of architecture concepts are required. These architecture concepts are expressed by architecture characteristics and their semantics, which continuously determine the essence and character of ITS services. The entirety of ITS architecture concepts can be defined as a school of architecture. If “interoperability” is an example of an ITS architecture concept, this characteristic can be found on any parts and levels of the ITS architecture, for instance, as one of the ITS architecture building blocks in Fig. 2.

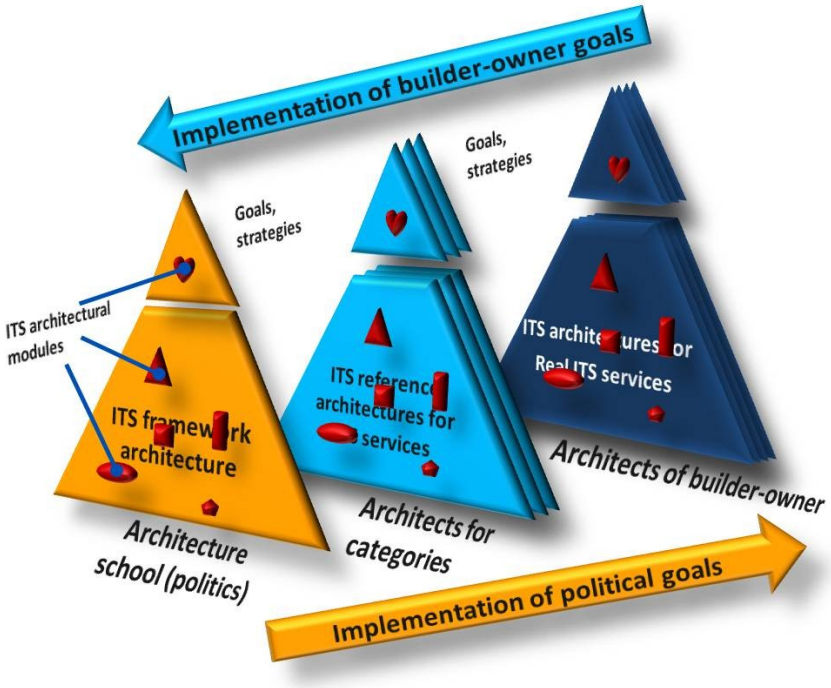



Fig. 2 Instances of ITS architecture and implementation of goals throughout the instances

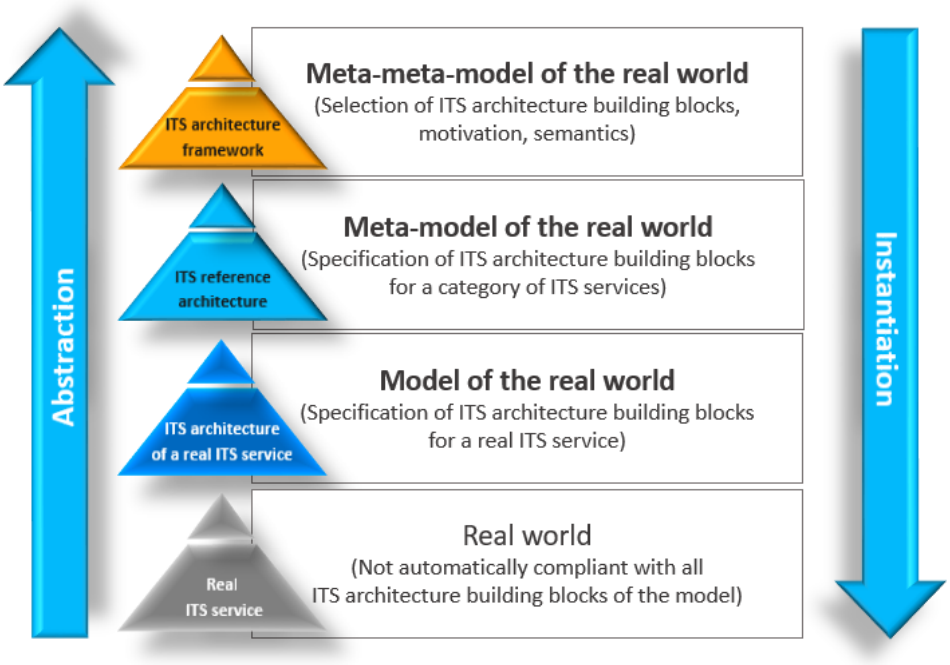



Fig. 3 "Going Meta" – implementation of ITS architecture

Fig. 2 shows that the school of architecture, that is represented by the ITS architecture framework, is used to implement political goals. Since sagacious policy always integrates the interests of the basis, the return path is also implemented. It is used to implement the goals of builder-owners of real ITS services and to integrate stakeholders and actors into the process of defining and developing ITS architecture.

Fig. 3 illustrates the instantiation and abstraction of ITS architecture concepts. The method of instantiation of ITS architecture concepts consists of the transfer and mapping of ITS architecture building blocks and their semantics, starting with the ITS architecture framework migrating to the ITS reference architectures and finally arriving at the ITS architecture of real ITS services.

- The **ITS architecture framework** (meta-meta-model of the real world) is used to motivate, semantically describe and structure the architecture concepts of ITS services by means of architectural characteristics and building blocks.
- **ITS reference architectures** (meta-model of the real world) are used to substantiate and concretise the concepts of the ITS architecture framework for specific categories of ITS services.
- An **ITS architecture of a real ITS service** (model of the real world) is used to substantiate and concretise the architecture concepts of categories of ITS services for a real ITS service.
- A **real ITS service** is not a model but the implementation of the ITS service in the real world.

*2.2. TOGAF Architecture Development Method*

The Open Group Architecture Framework (TOGAF) is a de facto standard for developing enterprise architectures and contains, besides a step-by-step instruction on building and maintaining an enterprise architecture – the Architecture Development Method (ADM) –, supporting techniques, content metamodel and artefacts that represent views of an enterprise architecture [The Open Group 2011]. TOGAF has been established by experienced architecture practitioners and the ADM has already been applied in more than 300 companies. Although TOGAF is primarily used for developing enterprise architectures, the ADM encompasses multiple architecture domains, e.g. the ITS domain, and can be tailored to the needs of individual companies or specific projects. In general, the ADM consists of nine phases which display an iterative approach, cf. Fig. 4. These phases provide step-by-step guidance for setting up an enterprise architecture. The phases B, C and D are used to develop the business architecture, the information systems architecture and the technology architecture. The remaining phases define the essential basic information for building an effective architecture and provide approaches for implementing and managing the architecture in an organisation. Since changes within the lifecycle of an architecture constantly occur, all the phases are linked to the requirements management. With the

help of the requirements management, changes are gathered, stored and related to the affected phase of the ADM.

Going through the phases of the ADM, there are several steps in each phase, which guide the creation of so-called architecture deliverables. Architecture deliverables can be visualised either in the form of catalogues, matrixes or documents describing building blocks, e.g. roles, architecture principles, services, strategies, etc., and their relationships. Architecture deliverables represent or describe the actual architecture. Furthermore, architecture deliverables from previous phases are often used as input for following phases.

The building blocks are related not only to the phases of the ADM, but also to the different architecture layers – the business architecture, the information systems architecture and the technology architecture. For example, a role is a building block within the business layer of the architecture. A list of roles is created in phase B of the ADM (Business Architecture) and constitutes an architecture deliverable.

*2.3. Mapping of the Architecture Domains*

For the application of TOGAF in the field of ITS, the previously explained ITS architecture pyramid and the ADM from TOGAF have been mapped. Besides the mapping, the necessary building blocks given by TOGAF have been selected. This selection represents the main part of the tailoring process. The result of the tailoring process as well as the mapping are illustrated in Fig. 4.

The preliminary phase and the architecture vision can both be linked to the strategy layer of the ITS architecture pyramid. Important building blocks, besides an ITS glossary and ITS architecture principles, are ITS domain, ITS roles, ITS goals, ITS capabilities, and key performance indicators in order to measure the value proposition. The business process layer can be linked directly to phase B of the ADM cycle – the business architecture. ITS roles and their responsibilities within ITS domains are important building blocks, as well as ITS business processes and stating an ITS roadmap. Phase C of the ADM cycle – information systems architecture – can be divided into two architecture layers, namely the data architecture and the application architecture. Both can be mapped to the information structure layer and (IT) service structures layer of the ITS architecture pyramid. Typical architecture building blocks in this phase are ITS data objects, ITS data models, ITS applications and ITS interfaces. Phase D – the technology architecture – can be mapped to the (IT) Infrastructure layer of the ITS architecture pyramid. This phase deals with the used and needed technologies and hardware that are required to execute the applications and services, which have been defined in the layers above.

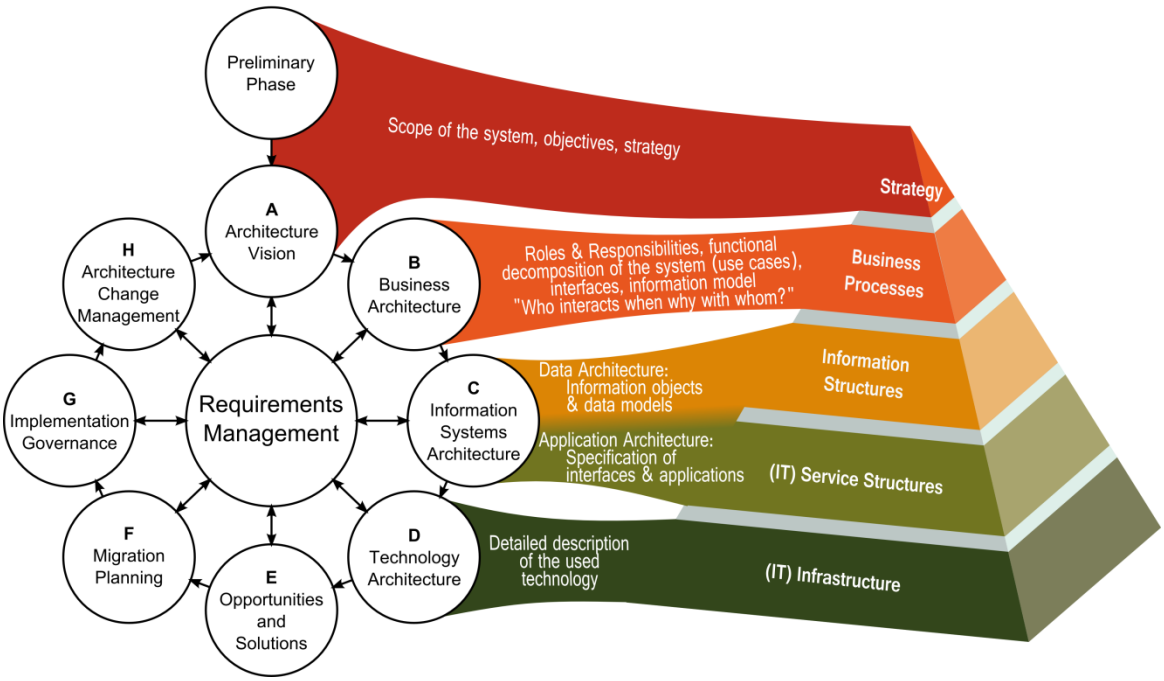



Fig. 4 Mapping the Architecture Development Method (TOGAF) to the ITS Architecture Pyramid

The described approach of tailoring the ADM to the ITS architecture pyramid turned out to be well applicable within the three different Reference Architectures. The approach has also been presented and thereby evaluated at the TOGAF Conference in Paris 2016 and has been approved by the TOGAF community.

## 3. National ITS Architecture Framework

The National (German) ITS Architecture Framework will be the final result of the project consisting in total of 7 basic ITS-Architecture Concepts and the TOGAF-based ITS Architecture Development Method. This section encompasses the preliminary results. Examples are used to create an overview of the German ITS Architecture Framework.

### *3.1. Basic ITS Architecture Concepts*

#### *3.1.1. Overview*

The German ITS Architecture Framework consists of 7 basic concepts, which describe the ITS Architecture approach, as well as the meaning of the ITS Architecture components and deliverables in detail. These are:

- The concept of ITS services and ITS added value
- The concept of ITS roles and ITS actors
- The concept for the formulation of ITS goals and realisation requirements
- The concept of ITS capabilities and cooperation
- Means, views and tools for the ITS business architecture
- ITS reference models and tools for the ITS data architecture
- ITS reference models and tools for the ITS application architecture

These comprehensive concepts consist of a definition and a semantic description of the key terms, as well as their relationships. The textual descriptions are supported by UML models and are illustrated by graphic representations. In order to give an example, the concept of ITS roles and ITS actors is explained below.

#### *3.1.2. The Concept of ITS Roles and ITS Actors*

*Definition: An ITS role ...*

- is an ITS architecture building block which defines and describes the semantics of ITS capabilities, ITS responsibilities and ITS tasks, which are necessary and typical for the creation of added value by ITS services.
- is an important element of ITS value chains, which is undertaken by ITS actors or ITS stakeholders. A single ITS actor or ITS stakeholder can undertake one or more ITS roles.
- realises its ITS capabilities, ITS responsibilities and ITS tasks in the form of activities, which in combination with activities of other ITS roles form the ITS business processes of an ITS service
- is undertaken in ITS reference architectures by stereotypes of ITS actors and in ITS architectures of real ITS services by ITS actors.

*TISA value chain as classification background for ITS roles*

As a background model for the development of ITS roles and actors concepts, the “TISA Traffic and Travel Information Value Chain model” is used, which was specifically developed by TISA for the representation and description of ITS value chains and networks for ITS traffic information services, and which is shown in Fig. 5. At the highest level, the model defines two added value segments, namely the content segment and the service segment, each with a total of four added value stages, which are typically required to set up an ITS service:

- Content segment with Content detection and Content Processing
- Service segment with Service provision and Service presentation


Fig. 5 TISA ITS value chain for traffic and traveller information services

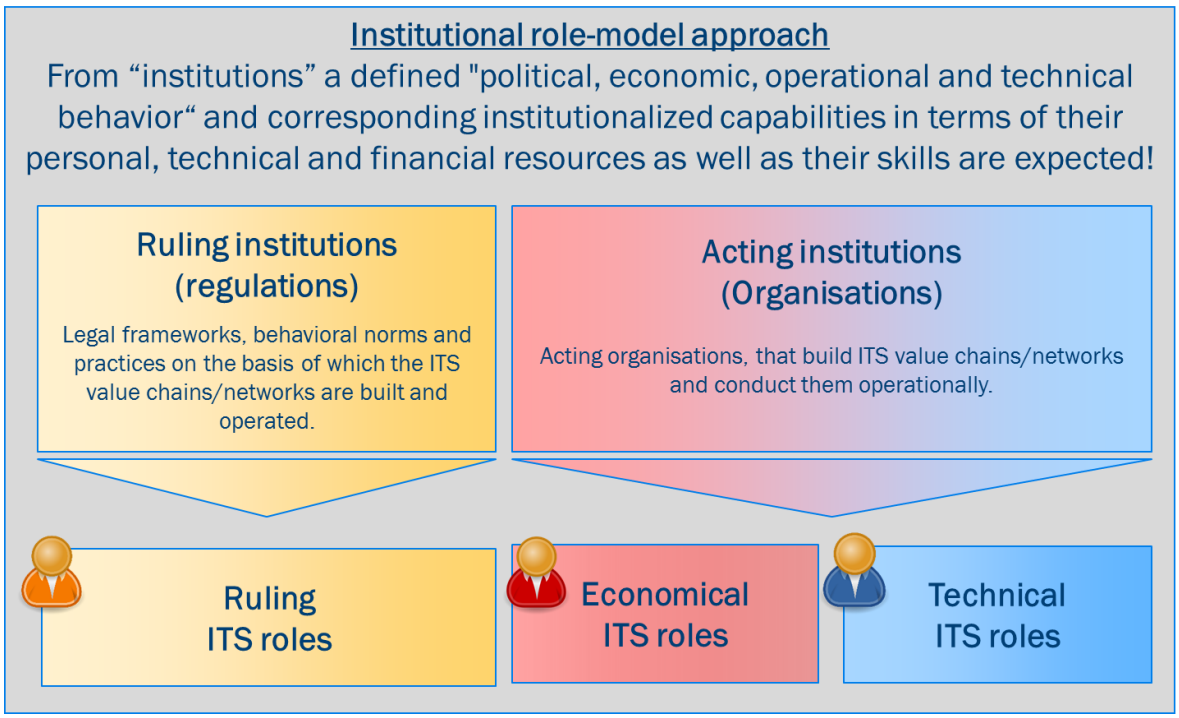



Fig. 6 Institutional role-model approach

*Institutional role-model approach as meta model for ITS roles*

For the definition and description of the ITS roles required for the above-mentioned individual ITS value stages, an institutional role model approach is proposed according to Schulz (2013) and Schulz / Wieker (2016), which was applied in the CONVERGE project (2015) for a C-ITS system network. Institutional means, in this context, that ITS roles which are necessary for the establishment and operation of an ITS value chain are characterised by means of institutionalised (i.e. expected) behavioural norms and skills. Typical examples of institutionalised roles are:

- Road traffic authorities, which approve and order measurements on traffic,
- public road operators, which control and manage traffic in a collective manner,
- private navigation providers, which align their services primarily to "paying" customers in the context of the generation of profits.

According to Schneider (1995), institutions are differentiated between ruling institutions (regulations) and acting institutions (organisations), cf. Fig. 6.

- Examples for ruling institutions are legal frameworks, behavioural norms and practices in markets and in other organisations. Organisations that create ruling institutions undertake ruling ITS roles.
- Acting institutions encompass acting organisations and always require acting persons. This property separates the acting institution from the ruling institution.

*Importance of the institutional ITS role model for the ITS architect*

For the ITS architect, the institutional role model approach is of great advantage for the establishment of concrete ITS value chains because he can rely on institutionalised roles (actor stereotypes), which can not only be expected to behave politically, economically, operationally and technically institutionalised (behavioural stereotype), but can also be expected to be equipped with corresponding institutionalised capabilities in terms of their personal, technical and financial resources as well as their skills (capability stereotypes).

*3.2. ITS Architecture Development Method*

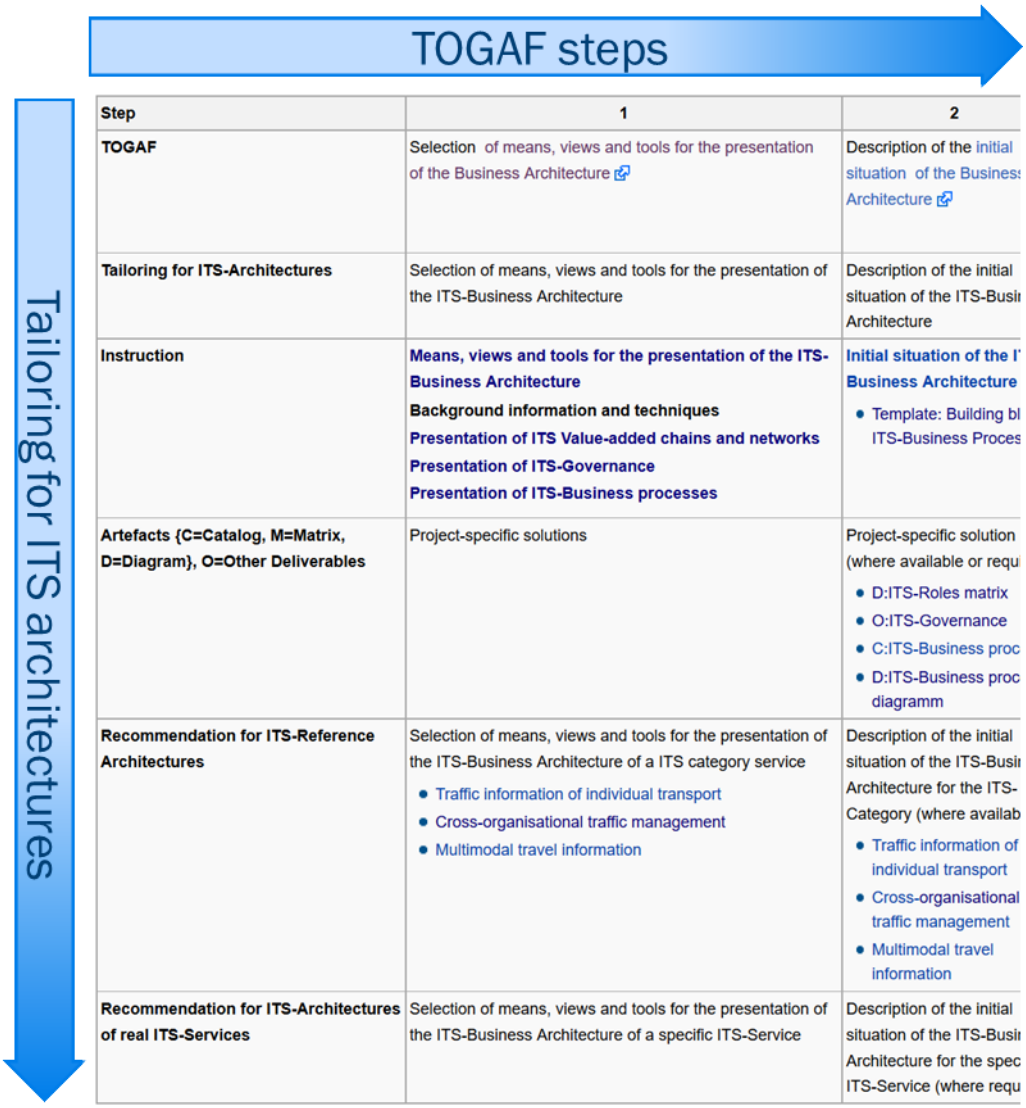
The TOGAF Architecture Development Method ADM was used as process model to develop ITS architectures. As it has been defined and developed as a method for the development of enterprise architectures within a single

company, a tailoring model has been developed in order to adapt to an ITS architecture which always involves several organisations. Fig. 7 exemplarily shows the tailoring of the first steps of the business architecture (TOGAF phase B). In the overview table, links to explaining pages and templates for building blocks offer comprehensive guidance for each step to the ITS architect.

The five rows under each TOGAF step explain and guide in the following topics:

1. **Tailoring for ITS architecture**: This row describes the steps of a phase for ITS architecture provided in TOGAF.
2. **Instruction**: The purpose of this row is to provide explanations of the meaning and procedure for the step and, where possible, to give examples.
3. **Artefacts**: This row provides suitable templates for the documentation of the results provided with the step in the form of catalogues, matrices, diagrams other formats.
4. **Recommendations for ITS reference architecture**: This row provides specific sample artefacts of various ITS reference architectures for download.
5. **Recommendations for ITS reference architectures of real ITS Services**: This row is used to provide sample artefacts for ITS architectures of real ITS services.

The tailoring was generally carried out for all phases of the TOGAF ADM. However, it should be noted that not all of the steps foreseen by TOGAF have been evaluated as relevant for the development of an ITS framework and reference architecture. In such cases, the user is free to develop a project-specific solution.




| Step | 1 | 2 |
|---|---|---|
| **TOGAF** | Selection of means, views and tools for the presentation of the Business Architecture | Description of the initial situation of the Business Architecture |
| **Tailoring for ITS-Architectures** | Selection of means, views and tools for the presentation of the ITS-Business Architecture | Description of the initial situation of the ITS-Busi Architecture |
| **Instruction** | **Means, views and tools for the presentation of the ITS-Business Architecture**<br>**Background information and techniques**<br>**Presentation of ITS Value-added chains and networks**<br>**Presentation of ITS-Governance**<br>**Presentation of ITS-Business processes** | **Initial situation of the I' Business Architecture**<br>• Template: Building bl ITS-Business Proces |
| **Artefacts {C=Catalog, M=Matrix, D=Diagram}, O=Other Deliverables** | Project-specific solutions | Project-specific solution (where available or requ<br>• D:ITS-Roles matrix<br>• O:ITS-Governance<br>• C:ITS-Business proc<br>• D:ITS-Business proc diagramm |
| **Recommendation for ITS-Reference Architectures** | Selection of means, views and tools for the presentation of the ITS-Business Architecture of a ITS category service<br>• Traffic information of individual transport<br>• Cross-organisational traffic management<br>• Multimodal travel information | Description of the initial situation of the ITS-Busi Architecture for the ITS-Category (where availab<br>• Traffic information of individual transport<br>• Cross-organisational traffic management<br>• Multimodal travel information |
| **Recommendation for ITS-Architectures of real ITS-Services** | Selection of means, views and tools for the presentation of the ITS-Business Architecture of a specific ITS-Service | Description of the initial situation of the ITS-Busi Architecture for the spec ITS-Service (where requ |

Fig. 7 Tailored TOGAF step model applied for the development of an ITS business architecture (detail)

## 4. Conclusion and Outlook

The German ITS Architecture Framework is in the final project phase. The project will end in May 2018 and will result in a comprehensive deliverable. With the ITS architecture pyramid and the instantiation concept, the basic pillars have been described. These fundamental concepts are of high significance and unique for the ITS architecture. It was shown how TOGAF was used and tailored for ITS architecture and how the ADM gives step-by-step guidance for the development of ITS reference architectures or architectures of real ITS. In the remaining project period, the focus will be on the necessary maintenance and implementation processes. These will be essential elements since the architecture framework is not seen as a static framework, but rather as a first release of a living flexible and dynamic guidance for ITS architecture in Germany.

The results of the novel approaches of the German ITS Architecture will be fed into the pan-European ITS architecture activities. With the Programme and Support Action FRAME NEXT, the European Commission has funded a programme to update, evolve and extend FRAME. The German ITS Architecture will provide all its experiences of the project in order to create an encompassing European architecture framework.

## Acknowledgements

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