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Enterprise Architecture Management (EAM) as a fundamental approach for the digital transformation of the German road infrastructure management

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Abstract

Enterprise Architecture Management (EAM) could play a key role in keeping up with and driving the digital transformation of the German road infrastructure management. With digital engineering technologies advancing and being deployed more widespread, information systems and information technology should be structured in a strategic manner to facilitate interorganizational cooperation and data flows. Established EAM frameworks are complex and generic and not apt for ad hoc application. In order to make EAM more accessible for road infrastructure management initial steps towards the development of a tailored approach are presented. Finally, outlining EAM's possible future relevance in enabling digital transformation, examples for areas in which it is applicable or already being applied are presented and put into context.

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Keywords: Enterprise Architecture Management; Digital transformation in public sector; IT portfolio management; Integration of networks and services; Intelligent asset management systems

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1. Introduction

Digitalisation has an enormous impact across the different areas of the societal, political and economic system of a country. Examples of affected sectors are the road sector, public authorities and administrative organs, the field of research as well as commercial enterprises. In the medium to long term, digitalisation will bring profound changes and challenges to the status quo. Enterprises, defined in a broad sense as any collection of organizations with a common set of goals (The Open Group, 2018), have to adapt to this increasingly complex and everchanging environment. For many companies and organizations this means fundamentally dealing with the company's grown structures and processes and at the same time examining to what extent a strategic adaptation and further development can take place. In the public sector, IT landscapes are often complex and heterogeneous. One of the reasons for this is that the public sector has lots of different and very specific tasks. Frequently, individual decisions are taken regarding IT applications which are specific to one field. Furthermore, IT requirements such as security, transparency and efficiency encompass additional costs and complex governance structures. The private sector deals with these challenges, among others, by implementing an enterprise architecture management (EAM) and by strategically planning information systems (IS) and information technology (IT). Ward and Peppard (2002) suggest building IS and IT in a way that they best support business goals and processes. In this context, they propose the analysis of applications into four categories based on an assessment of the current and future business importance. The four categories are strategic applications, key operational applications, applications that support operations and applications that have high potential. IT portfolio management thereupon is considered by the authors of this paper to be an important part of EAM.

A study by Johannsen (2012) shows that enterprise architecture frameworks are still hardly implemented by German public administration, although they bear great potential for the public sector. Existing EAM frameworks such as TOGAF† and COBIT‡ are complex, generic and address the entire life cycle of an EA. Although numerous steps are provided for deriving a concrete EA, there is still a very high level of abstraction that does not allow for ad hoc application – an adaptation to the respective individual strategic goals of a company is indispensable.

Caldera et al. (2021) provide a literature review on the extent of available digital engineering technologies, such as Building Information Modeling (BIM) and Geographic Information Systems (GIS) and their infrastructure asset management requirements. The result is a comprehensive overview on the available tools and their suitability for the difference phases of the life cycle of an infrastructure object. Caldera et al. (2021) suggest further research on enablers for the application of digital engineering in infrastructure management. The authors of this paper consider EAM to be such an enabler.

This paper seeks to elaborate on the relevance of EAM as an enabler for innovation in the German public sector in general, and road infrastructure management in particular. It lays the groundwork for a tailored approach of the general business practice of EAM by providing steps for its development and implementation. The aim is to illustrate how established frameworks can be more accessible and operational for the German road infrastructure management. In addition, as one of the steps to be taken when initiating EAM in such a context, the description and analysis of the portfolio of specialised IT applications are introduced.

This paper outlines EAM's possible future importance, both for research on infrastructure and transport as well as for infrastructure management. This is done by reviewing its main features and demonstrating the need for a structured approach to strategy, data, applications and technology in infrastructure management in order to best deal with the amount of data to be collected, stored, exchanged and analysed in the future.

It is important to make a remark on the role of the Federal Highway Research Institute (BASt) as a relatively small German federal research institute. Although it performs some tasks for the German Federal Ministry for Digital and Transport (BMDV) with regard to the operation of the federal trunk roads, its focus lies on research activities, consulting and the developing of methods and concepts for further possible use. This paper and its results should be regarded in reference thereto. In relation to data and their exchange, BASt can be considered a data supplier as well as

† TOGAF = Acronym for "The Open Group Architecture Framework"
‡ COBIT= Acronym for "Control Objectives for Information and Related Technology"

a data user. Furthermore, BASt utilizes external data for research purposes and thus relies on interfaces connecting its IT applications to external IT applications.

For this analysis, two main EAM frameworks, COBIT and TOGAF and their features are presented. Regarding COBIT, this paper makes reference to COBIT 5, which was published in 2012 and offers guidelines for improving governance and management. Regarding TOGAG, The TOGAF Standard 9.2 is referenced, which was launched in 2018. Subsequently, initial steps for a tailored EAM approach to the German road infrastructure management are provided. Finally, the potential of and the need for EAM as an enabler for digital transformation will be demonstrated.

2. An overview of established EAM frameworks

EAM is part of the field of Business Informatics, more specifically Information Management as Winter (2009) points out. A few works have been published on EAM in the German public administration, among those Obermeier (2014), Johannsen (2012), Grönert et al. (2014) and Santesson et al. (2016). Trindade and Almeida (2018) shared Portuguese experiences through a study undertaken regarding digitalisation and digital strategy for asset-intensive organizations such as public infrastructure organizations. They conclude that asset-intensive "[…] need to manage their transformational adaptation to better fit with emerging strategic priorities" (Trindade and Almeida 2018: 17), however do not offer a concrete vehicle for tackling this. EAM seems like an appropriate tool to address the challenges ahead.

2.1. COBIT

COBIT (ISACA 2012) is a popular IT governance and management framework that divides IT tasks into processes and so-called control objectives. According to COBIT, "governance ensures that stakeholder needs, conditions and options are evaluated to determine balanced, agreed-on enterprise objectives to be achieved; setting directions through prioritization and decision making; and monitoring performance and compliance against agreed-on direction and objections" (ISACA 2012). It aids in ensuring that IT activities are aligned with business goals and objectives. Its primary focus lies on what is to be implemented, rather than how the requirements should be implemented.

COBIT evolves around five key principles (see. Fig. 1 (a)). Furthermore, the framework contains detailed descriptions of each IT process. The processes are divided into process domains, namely one governance domain ("evaluate, direct and monitor") and four management domains ("align, plan and organize", "build, acquire and implement", "deliver, service and support" and "monitor, evaluate and assess").

COBIT considers seven enablers to further the implementation of sustainable IT governance – each on their own as well together (see. Fig 1 (b)). The enablers are key components in achieving business and IT goals and can be measured with the help of different dimensions, e.g. the stakeholder dimension, which prompts asking "Are the stakeholders' needs addressed?".

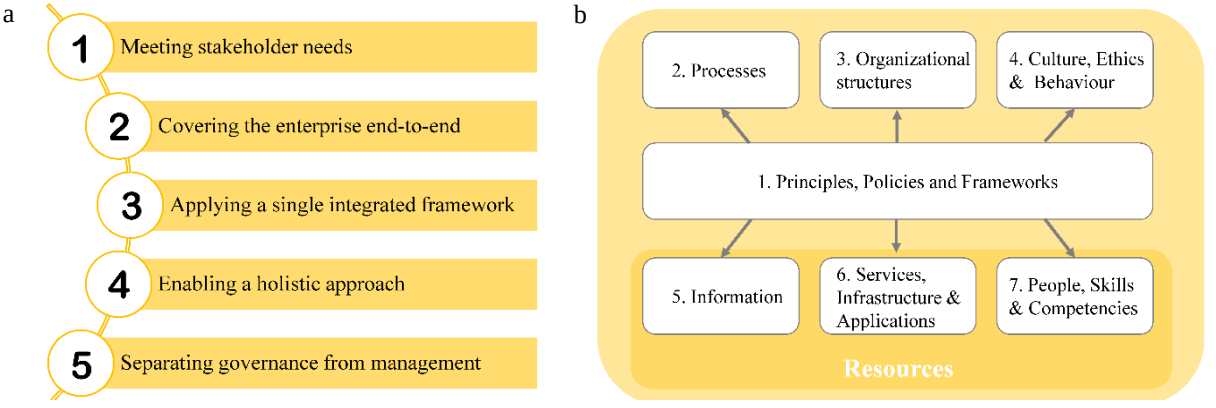

Figure 1. (a) COBIT's five key principles; (b) Enablers for a sustainable IT governance. Based on ISACA, 2012.

2.2. TOGAF

TOGAF (The Open Group, 2018) is a best-practice framework that aims at facilitating effective enterprise architecture for organizations through a set of documents, guides and reference architectures. Enterprise architecture, according to TOGAF, provides a strategic context for digital capabilities, which is needed in an ever-changing environment while providing an integrated strategy which concern all sectors of an organization. In contrast to COBIT, TOGAF focuses more on how the requirements are to be implemented.

Four architecture domains are considered, namely (1) business architecture which describes strategy, governance, organization and key business processes; (2) data architecture which details the structure of data assets and data management resources; (3) application architecture which provides a layout for the applications, their interactions and their relations to the core business processes; and finally (4) technology architecture which defines the software and hardware capabilities needed to support the formerly mentioned architectures.

TOGAF offers a step-by-step implementation manual, the so-called Architecture Development Method (ADM). The ADM can be utilized once for a specific task or can be used in iteration continuously. The procedure produces a series of documents, catalogues and diagrams, e.g. stakeholder map matrices, business capability maps and process flow diagrams. What output an organization choses to produce with the ADM depends heavily on the stakeholders invested in the architecture work. In some cases, high level illustrations seem more appropriate than rather technical lists or complicated matrices; if, however, the technician who will be implementing new IT systems is to work based on an architectural output, specifications are in need. Other than concerning work products, decisions regarding the level of detail, the time period as well as the architecture domains considered are taken by the organization deploying the ADM. This clearly shows that TOGAF thus, can be tailored according to the needs of the enterprise. In overview, the procedure of developing an architecture can be divided into the following four phases (see Fig. 2):

1. In the phase “Architecture Context” the objectives and principles are decided upon; the scope, time frame and the vision of the architecture work are set and the stakeholders involved are specified.
2. “Architecture Delivery” refers to the phase in which the current (“baseline architecture”) and the desired (“target architecture”) architectures are described and developed covering the four domains.
3. “Transition Planning” encompasses the identification of the necessary changes and evaluates them. This phase serves as a basis for decision-making and leads to a roadmap for implementation projects.

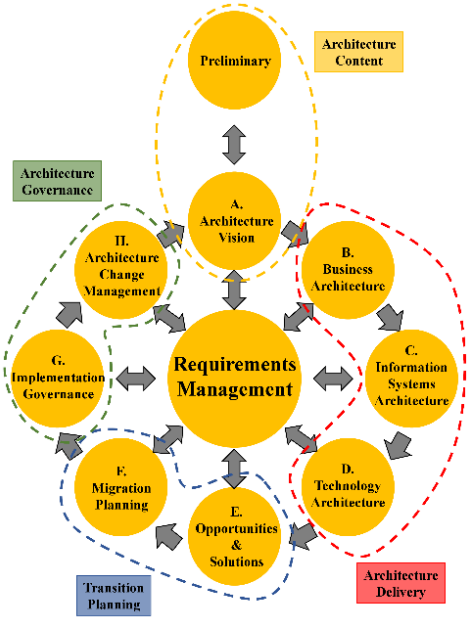

Figure 2. The TOGAF Architecture Development Method. Based on The Open Group, 2018.

4. Although depicted as being the last of the four phases, “Architecture Governance”, which is the steering of the implementation projects, occurs – together with the ongoing task of “Requirements Management” – parallel to the development of architecture. This governance is to ensure that the developed solutions and systems correspond to the outlined target architecture.

3. Development of a tailored EAM approach to the German road infrastructure management

The German federal government suggests that frameworks such as TOGAF and COBIT should be adapted before being applied (Beauftragte der Bundesregierung für Informationstechnik 2020). The Open Group (2018) recommend such an adaptation, too: “Organizations that are new to the TOGAF approach and wish to incrementally adopt TOGAF concepts are expected to focus on particular parts of the specification for initial adoption, with other areas tabled for later consideration” (The Open Group 2018: 3). Smaller organizations as BASt as well as those that do not yet develop and manage enterprise architecture need to choose feasible options that maximise output while considering resources.

As the COBIT framework describes what should be considered rather than offering guidelines on how to develop and manage enterprise architecture, it can provide an overarching structure. Moreover, it can embed enterprise architecture processes that are performed according to TOGAF into the bigger picture of IT processes. Especially, the principle “Meeting stakeholder needs” as well as the emphasis on the importance of the alignment of business and IT can be useful when creating the architecture vision. TOGAF offers a number of tools, templates and manuals. A possibility is to tailor the ADM to consist of the first phase (architecture vision, definition of scope and time frame) and the second phase, considering one architecture domain solely, for example, application architecture, thus analysing the IT portfolio. Figure 3 provides a simplified overview on the frameworks and methods introduced and applied. One should focus on the most important topics that evidently benefit most from enterprise architecture development. IT architecture should only be described and planned where necessary and useful.

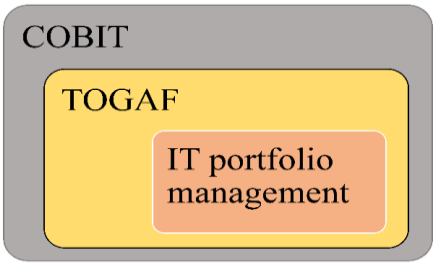

Figure 3. A simplified illustration of the interrelation of COBIT, TOGAF and IT portfolio

Regardless of which framework is applied for the development of an EAM, the description of the baseline architecture is necessary groundwork. In the BASt, the first step was to assess the current application portfolio, the baseline application architecture. With reference to TOGAF, this is part of the second phase of “Architecture Delivery”, more specifically the information systems architecture. For this purpose, a survey of all relevant IT applications and projects was carried out. Relevant IT applications in this context are applications that provide general information on an asset such as a road or infrastructure, however, in particular, applications that provide information on the condition or condition development of the infrastructure. BISStra can be mentioned here as an example. BISStra is a geographical information system consisting of databases with GIS as well as a core system integrated in a software application and various specialised systems. BISStra supports the BMDV and the BASt in solving a wide range of planning, administrative and research tasks. The core system stores alphanumeric and geometric road network data of the federal trunk roads. Specialist systems are operated for various tasks such as traffic data, condition data, international road networks, accident analyses or traffic control systems, in future, also risk management.

In addition to documenting the goals to be obtained through their use, underlying methods, data and informational content, as well as responsibilities and roles were described. Furthermore, the resources and the technical infrastructure required to operate the applications were compiled. Additionally, it was determined how the applications are linked to other internal applications and how they fit into the external environment of the BASt, e.g. by listing data flows and

interfaces. This analysis represents the foundation for the gradual further development of the in-house architecture as well as the integration of the BASt into the superordinate development of the IT architecture of the entire road infrastructure management in Germany.

4. EAM as an enabler of digital transformation

The German road infrastructure sector has various different stakeholders and actors of which some are rather new. The recent so-called "Autobahn reform" led to the foundation of a new state-owned infrastructure company, the *Autobahn GmbH des Bundes*, as well as well as the creation of Federal Trunk Road Authority (FBA). Since the beginning of 2021 the Autobahn GmbH is solely responsible for planning, construction, operation, maintenance and also asset management of the federal motorways in Germany (Autobahn GmbH des Bundes, 2022). The FBA has legal and technical supervision over this. Before the reform, German federal states managed the federal motorways and their infrastructure. This recent past has resulted in a heterogeneous situation regarding data availability and data interoperability as well as a varying degree of digitalisation of the road infrastructure sector. IT has a cross-cutting function that can be used to bridge disparities and enhance cooperation. It is advisable for organizations in the road infrastructure sector to set themselves up in such a way that they can work together – digitally transforming the whole sector.

The cornerstone of the digital transformation is digital infrastructure as well as technologies that continue to develop at an ever-faster pace while simultaneously triggering new digital innovations. Examples include Building Information Modeling (BIM), Digital Twins and the Internet of Things. The key is a targeted development of digital, data-based applications for Mobility 4.0 that is aligned with the interests of all stakeholders.

The German Federal Ministry of Transport and Digital Infrastructure aims to have fully introduced and established the BIM method as a standard procedure for the planning and construction of Federal trunk roads by 2025 (BMDV, 2021). This will serve as the foundation for the operation of infrastructure structures on the basis of fully integrated digital twins which in turn demands an encompassing data and information management in order to make efficient and optimal use of BIM and digital twins. The overall objective of a digital asset management system can only be met if all the necessary information can be integrated across all assets and all life cycle phases. In view of the large amounts of data that will accompany digitalisation in the future, there will be an increasing need for data management systems, innovative applications and procedures for data processing, analysis and evaluation. AI-based methods offer promising approaches here. Equally fundamental is a uniform database, but also a secure and shareable data environment - these elementary infrastructural foundations must be created.

A major challenge is that the digital transformation not only requires the adaptation of one's own organization regarding strategy and structure, however, it leads to changes in external factors, actors and requirements, too. This makes it difficult to define one's target architecture. Since the exchange of information will take on a much more central role than before, it is necessary to shed more light on processes in the overall context and thus build architectures for them.

At BASt, a pilot has been launched to work towards a unified data base. In a first step, case-specific data requirements are identified based on a series of use cases. These are combined to form a data architecture, which in turn is mirrored by an IT architecture. The required data is catalogued and described by metadata. The metadata are stored in a database set up for this purpose. Finally, based on the use cases, specific needs for regulation for the handling of data is identified and rules are agreed upon. One of the use cases is the IT-ZEB server, an information system on German federal motorways' and highways' pavement conditions that was developed in 2008. The pavement condition of German federal motorways and highways is monitored with the help of the procedure Pavement Condition Monitoring and Assessment ("Zustandserfassung und -bewertung", in short ZEB). Due to an increasing number of users of the data gathered by the ZEB the IT-ZEB server was developed. It contains current and historical ZEB data since 1997, grid data, geometry data as well as route and surface images. The BDMV, BASt, German federal states' road administrations as well as the Autobahn GmbH have access to ZEB data. Through further integration with data from other information systems considerable synergy effects could be achieved. Moreover, a concept to test the feasibility of a common working environment (CDE) is being developed at BASt. In this way, the BASt is actively involved in the development of infrastructure, which will have a strong influence on the future way of working, while

at the same time, being able to take this into account, when describing BASt's target architectures. Another field in which EAM is applicable in order to enable digital transformation is that of satellite data and services. The EU's earth observation programme Copernicus provides huge daily amounts of data that can enhance research and services in the road infrastructure sector. BASt is only one of its users, thus data format and access are determined externally. To ensure efficient data interfaces that enable users to stream large volumes of data, possibly real-time data, is an objective that would need architecture work in preparation.

5. Conclusions

In this work, commonly used EAM frameworks were described. It was shown that one, COBIT, focuses on governance while providing an overview of the enterprise, while the other, TOGAF, offers a step-by-step implementation guide for enterprise architecture. Both, as well as IT portfolio management, consider organizational strategy and goals to be at the core of IT strategy and development. IT should be effectively used to achieve the desired organizational outcomes and objectives.

At BASt initial steps towards the digital transformation were taken, frameworks were analysed and a staff unit that occupies itself with the digitalisation was established. The latter ensures that the digital transformation can be accompanied in a centralised and target-oriented manner. The steps taken at BASt towards an EAM were outlined in this paper, in order to provide an approach to tailoring EAM to the parameters and needs of a public research institute within the German road infrastructure sector. A short introduction and prediction of areas in which parts of EAM are currently being applied, or possibly could be applied in the future were given to show the opportunities and range of research topics and fields of applicability.

Structuring the increasing need for information and the simultaneously increasing demands on data procurement, EAM can provide great added value to the German road infrastructure management. The integration of processes, applications, data, and technology allows enterprises, whether they be road operators or research institutes, to operate as smoothly and efficiently as possible while pursuing their strategic objectives. EAM for the public sector in general, and the German road infrastructure management in particular, seems like an appropriate means to an unavoidable end – as the challenges posed by digitalisation are already being met.

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