

ОБЩЕСТВЕНИ КОМУНИКАЦИИ И ИНФОРМАЦИОННИ НАУКИ
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**ANALYSIS OF THE SUITABILITY OF RELEVANT FRAMEWORKS
FOR DIGITALIZATION IN CONNECTION WITH CYBER-PHYSICAL SYSTEMS**

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Abstract: *Digitalization is the key drive of innovation and growth for companies and economies. The focus is on efficiency gains, flexibilisation and better use of resources. Digitalization is increasingly associated with cyber-physical systems, and this represents a considerable challenge in terms of implementation. Studies indicate that the implementation success of this type of project is stagnating, which leads to the conclusion that new implementation approaches are needed. The following questions therefore need to be researched:*

- *Which fundamental, implementation-relevant dimensions need to be considered in digitalization projects with cyber-physical systems?*
- *Which frameworks exist to support the implementation of digitalization projects with cyber-physical systems, which dimensions do they offer and how high is the coverage with the required, implementation-relevant dimensions?*

In the first step, all dimensions were identified that are related to digitalization in a business context. In the second step, digitalisation-related frameworks were analysed and evaluated in the third step. "Systems Engineering GfSE/INCOSE – ISO/IEC 15288" emerged as a convincing framework.

This theoretical research forms the basis for subsequent empirical research to create a framework for implementation recommendations for digitalization with cyber-physical systems.

Keywords: *Digitalization; Cyber-physical Systems; Implementation; Frameworks*

INTRODUCTION

Digitalization and digital transformation is a growth driver in the economy. According to a survey, the business benefits and the goals and expectations that companies associate with digitalization are improvements in strategic competitive position, fulfilment of customer wishes, redesign of work processes, redesign/redefinition of business models, stronger customer loyalty, cost savings and enabling new forms of collaboration (cf. Wintermann et al. 2020, p. 56).

Digitization basically has two perspectives. Firstly, the purely technical view of how analogue signals are converted and stored into machine-readable data and information as well as data processing and transmission processes with the help of control devices, computers, software and more (cf. Müller-Brehm/Otto/Puntschuh 2020, p. 4). The second view of digitalization concerns how we as individuals and society deal with digitalization in our everyday lives. In other words, the effectiveness of the interaction with and through people, the corresponding technologies and the design and use of applications (cf. Müller-Brehm/Otto/Puntschuh 2020, p. 5). In addition, digitalization is increasingly being linked to cyber-physical systems. Cyber-physical systems (CPS) are systems in which information and software technology is connected to mechanical components, with data transfer and exchange as well as monitoring and control taking place in real time via a network such as the internet. Key components are mobile and movable equipment, devices and machines (including robots), embedded systems and networked objects (Internet of Things) (cf. Bendel 2021). This poses a challenge in terms of implementation.

When it comes to the success rate of digitalization projects, studies have shown that, depending on the question, over 40% (cf. NTT DATA Business Solutions 2024, p. 48) of digital transformation objectives are not achieved and up to 70% of digitalization projects fail (cf. Forth/Reichert/de Laubier/Chakraborty 2020).

RESEARCH METHODOLOGY

The following questions therefore need to be explored:

- Which fundamental, implementation-relevant dimensions need to be considered in digitalization projects with cyber-physical systems?
- Which frameworks exist to support the implementation of digitalization projects with cyber-physical systems, which dimensions do they offer and how high is the coverage with the required, implementation-relevant dimensions?

Theoretical research will be carried out to answer this question. Based on existing specialized literature, relevant facts will be developed using methods of concentric circles and keyword searches.

Only the part of the theoretical research that forms the basis for the subsequent empirical research is presented in this publication.

RESULTS

Identification of dimensions from the business context:

The first step was therefore to identify all relevant dimensions that come into contact with digitalization in a business context.

Here is an excerpt of identified dimensions:

In principle, all concepts of *business economics* must be considered during digitalization. Here, the focus is not only on the current, operational business, but also on the future. Strategic, planning and design issues are also part of business economics (cf. Hofmann A. 2016). *Innovation management* is also a core activity. This involves the design of new products, new processes in the sense of a technical procedure, new services and the design of a combination of the aforementioned. In addition, these approaches are supported by the use, provision and further development of technology-oriented approaches (cf. Möhrle 2018). *Organizational management* is also an instrument and core element of business administration for corporate management and serves to achieve corporate goals and their value creation (cf. Bach et al. 2017, p. 1). A wide variety of *project management* methods are available for the operational implementation of digital projects. The field of tension of business-IT alignment encompasses organization, business processes and IT (cf. Masak 2006, p. 10). *Interoperability* is another specific feature of digitalization. Interoperability refers to the ability of a system to work together with other systems (cf. Johner 2023). *Digital leadership* is about specific knowledge and the associated expertise relating to digital value creation. In addition to technical and social skills, digital skills will also be essential in the future (cf. Kollmann 2022, p. 10). The *skills of social competence* include communication skills, conflict behaviour, empathy, cooperation skills, assertiveness, flexibility of action and self-control (cf. Kanning 2002). Due to the lack of emphasis, many players do not realize that the digital transformation requires compliance with many *legal regulations, provisions and standards*, especially in connection with cyber-physical systems. *Safety, security and privacy* are often equated in terms of terminology. However, they differ extensively in their meaning in terms of definition and environment as well as possible threats, risks, attack scenarios, avoidance and defence strategies (cf. Schmid/IAS 2018) and always go hand in hand with ensuring protection against undesirable behaviour. Using and coordinating the dimensions mentioned so far already gives an idea of the complexity of digitalization. *Complexity* generally defines the totality of all interdependent features and elements that are part of a diverse but holistic relationship structure (system). Complexity is understood to mean the variety of possible behaviours of the elements and the variability of the courses of action (cf. Feess 2018).

Identification of relevant frameworks

The second step was to examine frameworks that are related to digitalisation or cyber-physical systems to identify further dimensions. Enterprise architectures (EA) are a special type of framework for optimizing a company regarding the alignment of digital approaches, from design to implementation and integration of digitalization. EA frameworks are defined as a logical structure for classifying and organizing complex information. Enterprise architecture frameworks help to implement the business strategy, considering IT strategies, technology deployment and business requirements across all the company's specialist departments. The presentation on the developments and interrelationships of EAFs (see Matthes 2011, p.

56) was used as a basis and supplemented with further developments.

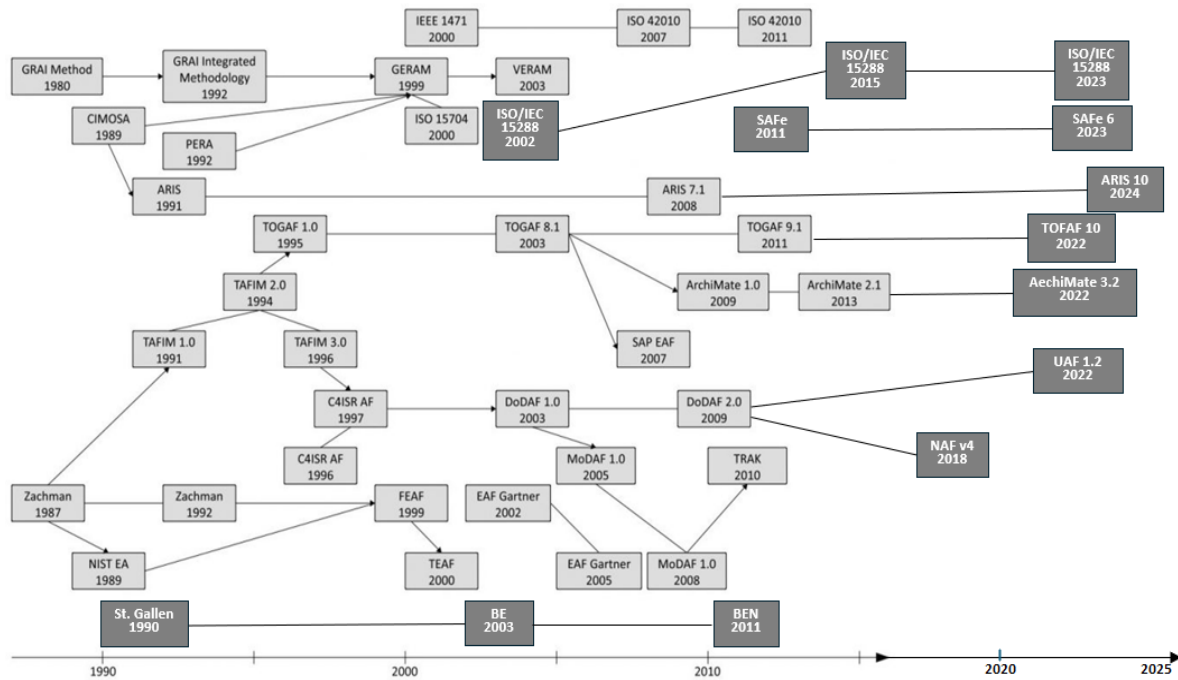


Fig. 1. Development of EA frameworks (own illustration based on Matthes 2011)

The presentation does not claim to be exhaustive. Each framework focuses on specific aspects of the transformation and uses different methods to achieve its goal. Trend-setting, newer or very different EA frameworks (FW) were used for the analysis:

FW 1 = St. Gallen Business Engineering Framework / Navigator BEN

Business engineering is understood as “business engineering”, i.e. the approach provides models and methods for the development mode “change the business”. Fundamental changes are often triggered by technological innovations, primarily in the field of information and communication technology (see Österle/Winter/Brenner 2011, p. 2).

FW 2 = Systems Engineering GfSE/INCOSE – ISO/IEC 15288

Systems Engineering (SE) is an interdisciplinary team approach to the realization of complex systems. SE focusses on product development. The aim is to define, implement and verify customer requirements and functionalities as early as possible in the development process to obtain registration, i.e. product approval for the market from the relevant authorities (cf. GfSE 2017, p. 2).

FW 3= Scaled Agile Framework (SAFe)

The scaling agile framework, an agile concept for the methodical organization of software development. As a framework, SAFe provides methodological knowledge in the form of a documented process model and tried-and-tested process patterns (cf. Block 2023, p. 60).

FW 4 = Digital Transformation Management Frameworks DTMF

DTM framework is representative of one of many that are created and promoted by consulting firms. This takes a holistic perspective and places digital innovations at the centre. Transformation strategies are used to consider ideas for new products and processes as well as the adaptation of structures, systems and cultures in the context of the financial framework and technological possibilities (cf. Hess 2022, p. 6).

FW 5 = Zachman framework

One of the oldest representatives of enterprise architecture frameworks is the Zachman Framework.

Zachman recognized that information systems entailed a complexity that had to be mapped through clear classifications and interfaces, which should be represented by a kind of architecture of the IT components. The approach is that the questions “what”, “how”, “when”, “who”, “where” and “why” must be answered (see Schweda C. 2024, p. 243).

FW 6 = TOGAF (The Open Group Architecture Framework)

The core task of “TOGAF” is to shape transformation. The core element of TOGAF is the Architecture Development Method (ADM), a model consisting of 10 phases for architecture planning, architecture development, architecture implementation and, if necessary, adjustments (cf. The Open Group 2022, p. 17).

FW 7 = HISA Health Information System Architecture – ISO 12967 and **FW 8 = WHO Guideline** are industry-specific frameworks from the healthcare sector and are representative of regulated domains, as this was the subject of the research.

Identification and evaluation of dimensions from relevant frameworks:

In the third step, a matrix was created with all the dimensions identified from the previous analysis of the respective fields of action considered in the framework. These fields of action were given the generic term dimensions. A total of 36 dimensions were identified in the context of digitalization with cyber-physical systems and clustered into the following perspectives:

Table 1. Comparison and evaluation of different frameworks

	Dimension	FW to be evaluated							
Business Perspective	Strategy / business model								
	Business economics								
	Organizational management								
	Innovation management								
	Process management								
	Contractual arrangements								
	Value chain/ecosystem								
	System/product concept								
	Purchasing, production, handover, operation								
	Resource management								
	Knowledge management								
	Information management								
	Transformation options/areas								
	Evaluation of the benefit								
	Business IT alignment								
Technical Perspective.	Workflow management								
	Technologies as enablers								
	Information systems								
	IT infrastructure								
	Interoperability								
	Safety, security and privacy								
	System of Systems Challenge								
	Operational system/product development								
	System development regulations								

Project-		Project management								
		Portfolio management								
		Stakeholder Needs								
		Risk assessment								
		Decision management								
		Complexity reduction								
Human		Digital Leadership								
		People, soft skills & social competences								
		Change management								
		Interface communication								
		Industry-specific regulations								
		Industry specifics								

Strong focus was marked with “x”, included in the framework marked with “!”.

ISO/IEC 15288 Systems Engineering GfSE/INCOSE covers 26 dimensions that offer methods and approaches for implementing digitalization with cyber-physical systems. In systems engineering, the focus is very much on system/product development, i.e. on the necessary technical issues. All required activities and their dependencies and sequences are explained in an application-oriented manner. This promotes improved communication and more efficient collaboration, as well as an improved understanding of the system.

FW 3 = SAFe, FW 4 = DTMF and FW 6 = TOGAF are rated the same and have a strong business management focus. Nevertheless, they differ greatly in terms of details and approaches.

SAFe focuses on agile methodologies and the organizational planning and implementation of software-driven projects. SAFe combines proven frameworks such as Scrum, Kanban, DevOps and Lean Start-up, promotes collaboration between many teams by defining roles and hierarchy levels and focuses on accelerated time-to-market and customer focus.

The DTM framework strongly emphasizes the impact of corporate culture and therefore focuses on involving every employee in change management. Another focus is the development of a clear strategy for digital transformation.

The focus of TOGAF is on the modular approach including roles, result types and practical tips for planning, developing and deploying enterprise architectures, as well as focusing on digital transformation and also taking agility into account.

If the results of the study are presented in relation to the dimensions covered and the clusters of business, technical, human, industry-specific and project-specific perspectives, the focus of the content can be recognized.

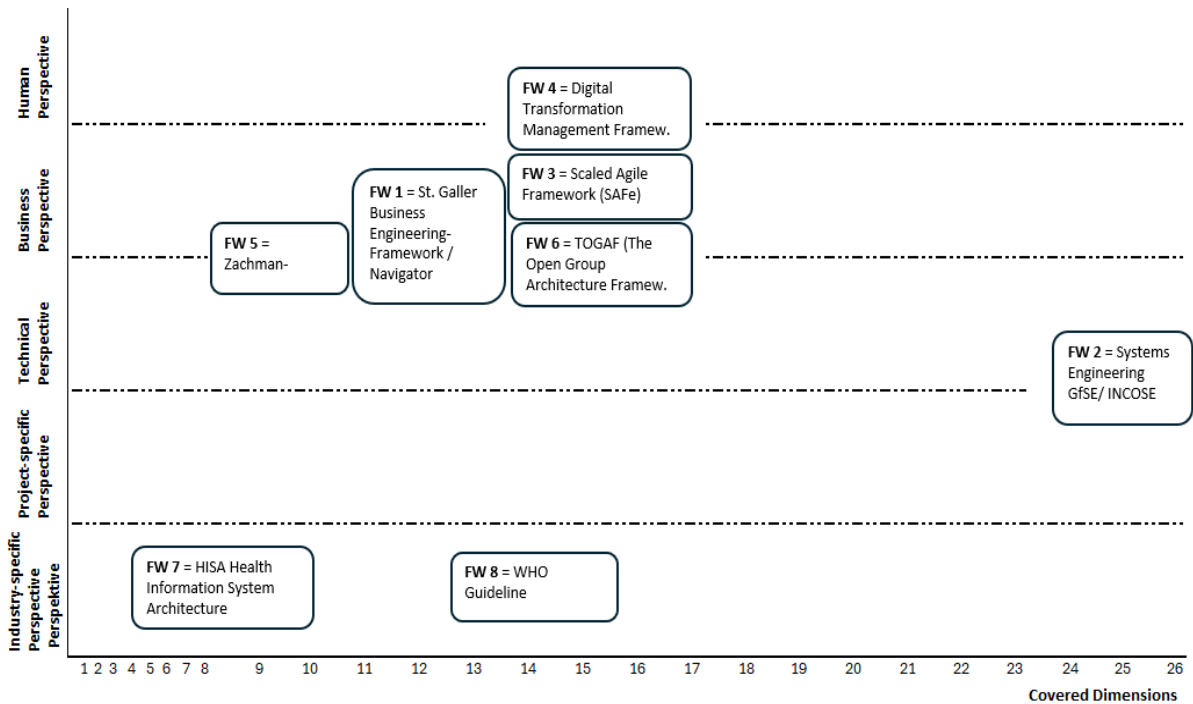


Fig. 2. Frameworks depending on the dimensions covered

CONCLUSION

As in all analyses, there are advantages and disadvantages, strengths and weaknesses of the frameworks. The decisive factor in each case is the perspective from which the assessment is made. What all frameworks have in common is that none of them covers all the necessary fields of action for the successful implementation of a digital transformation with cyber-physical systems. These were basic findings for subsequent empirical research to generate further documented, analysable data and information. Ultimately, the aim is to create a guideline for action in the form of a framework that supports digitalization with cyber-physical systems.

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АНАЛИЗ НА ПРИГОДНОСТТА НА СЪОТВЕТНИТЕ РАМКИ ЗА ЦИФРОВИЗАЦИЯ ВЪВ ВРЪЗКА С КИБЕРФИЗИЧНИТЕ СИСТЕМИ

Резюме: *Цифровизацията е основен двигател на иновациите и растежа на компаниите и икономиките. Фокусът е върху повишаването на ефективността, гъвкавостта и по-доброто използване на ресурсите. Цифровизацията все повече се свързва с киберфизични системи, а това представлява значително предизвикателство по отношение на внедряването. Проучванията показват, че успехът на изпълнението на този тип проекти е в застой, което води до заключението, че са необходими нови подходи за изпълнение. Поради това е необходимо да се изследват следните въпроси:*

- *Кои фундаментални измерения, свързани с изпълнението, трябва да се вземат предвид в проектите за цифровизация с киберфизични системи?*

- *Какви рамки съществуват в подкрепа на изпълнението на проекти за цифровизация с киберфизични системи, какви измерения предлагат и колко високо е покритието с необходимите свързани с изпълнението измерения*

В първата стъпка бяха идентифицирани всички измерения, свързани с цифровизацията в бизнес контекст. Във втората стъпка бяха анализирани свързаните с цифровизацията рамки, които бяха оценени в третата стъпка. Systems Engineering GfSE/INCOSE – ISO/IEC 15288 се очерта като убедителна рамка.

Това теоретично изследване формира основата за последващо емпирично изследване за създаване на рамка за препоръки за прилагане на цифровизацията с киберфизични системи.

Ключови думи: *цифровизация; киберфизични системи; внедряване; рамки*

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