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Framework To Design Compliance Rules For Digital Technologies In Manufacturing Companies

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Abstract

Digital technologies such as 5G, augmented reality, and artificial intelligence (AI) are currently being used in various ways by manufacturing companies. As the fourth industrial revolution progresses, it has become apparent that reckless use and inadequate regulation of these technologies have a detrimental effect on the environment in which they are utilized. Therefore, regulation of digital technologies is imperative today to ensure more responsible and sustainable use. While governments usually establish regulations, progress is not keeping pace with the demands and hazards of employing digital technologies. The European AI law serves as an example of the considerable distance yet to be covered before binding guidelines are established. Consequently, companies must take proactive measures today to ensure that they use digital technologies responsibly in their environments. In this context, identifying which digital technologies are pertinent to manufacturing companies in terms of regulation is crucial. Furthermore, a comprehensive approach is required to design compliance holistically for digital technologies and to systematically derive the corresponding guidelines. This paper introduces a set of models that not only determine the importance of compliance in the application of different technologies but also present a framework for methodically designing compliance. Furthermore, the paper contributes to the development of an AI platform in the German research project PAIRS by investigating the compliance relevance of applications such as artificial intelligence.

Keywords: digital technologies; industry 4.0; compliance; regulation; 5G

1. Introduction

Legislators and regulators today have significantly heightened expectations of companies in terms of compliance and governance. There is a clear trend towards mandatory and comprehensive corporate transparency and trust. The discussions on this topic were triggered in the 1990s by the bankruptcies of companies such as Bearings Bank and Enron, which resulted in stricter requirements being imposed on auditing companies in order to restore public confidence [1]. A critical aspect of this is the information and information technology (IT) used, for which companies must also establish compliance rules [2]. This takes into account the growing significance of operational resource information as a production and competitive factor [3]. Furthermore, it is anticipated that legal and regulatory requirements for IT in the European Union and globally will continue to increase in the future [4]. In addition to traditional IT, new digital technologies such as artificial intelligence (AI) or edge computing are also among the key building blocks of digital transformation [5]. Manufacturing companies, in particular, are increasingly using digital technologies to gain a competitive advantage, such as within the context of Industry 4.0 [6]. These need to be taken into account in manufacturing companies' future compliance efforts. In the case of AI, regulators and legislators in the European Union are also for the first time considering the development of compliance regarding the use of digital technologies. In the last several years, the EU Commission has published a regulation on AI, with the aim of using technology

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in a manner consistent with the values, fundamental rights, and principles of the European Union [7].

In recent years, the case of AI has underscored the necessity for compliance in the utilization of digital technologies in business. As a result, companies must tackle compliance for digital technologies and require assistance in systematically generating compliance guidelines for a range of digital technologies used in manufacturing companies. This article introduces a series of four models that facilitate the establishment of compliance for digital technologies in manufacturing companies at an early stage. The models are also presented in Fig. 1.

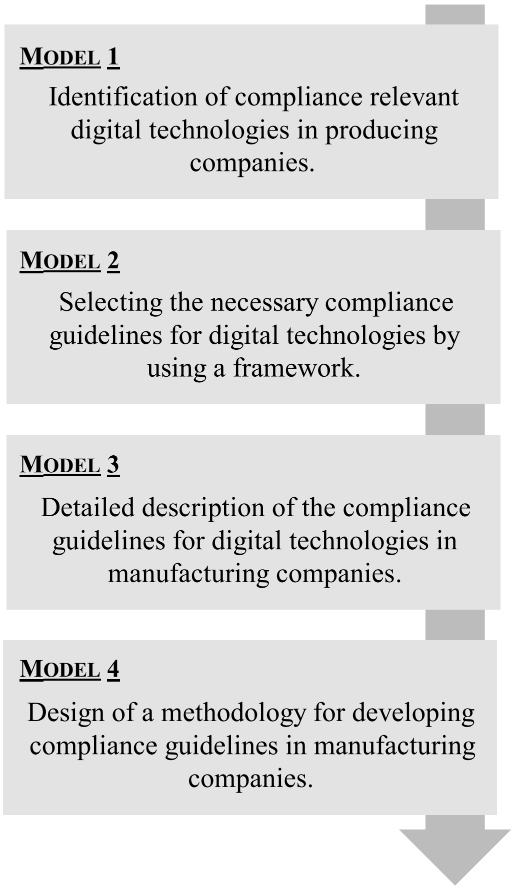

Fig. 1 Sequence of models to design compliance rules for digital technologies

The objective of this approach is to facilitate manufacturing companies in systematically regulating the digital technologies they use. The first model introduces a method to identify digital technologies that require compliance. It also offers a status quo assessment of the compliance relevance of existing digital technologies, which can be used as a guide by companies. The second model, which is the main focus of this paper, proposes a comprehensive approach to enable the systematic derivation of compliance rules in the subsequent models. This model addresses the gap created by the lack of a structured, holistic approach to identifying compliance guidelines for manufacturing companies. The subsequent model three provides the necessary content of compliance guidelines for manufacturing companies. For the first time, a collection of compliance aspects of digital technologies that need to be considered is developed scientifically. To ensure applicability by manufacturing companies, the final model four outlines a comprehensive methodology in the form of a guideline, which allows companies to customize the framework developed in model two with the content from model three. This guarantees practical implementation.

The structure of this paper is outlined as follows. Section 2.1 offers an overview of the literature and current state of research on compliance of digital technologies, while Section 2.2 discusses existing frameworks utilized for the implementation of digital technologies within the context of the fourth industrial revolution. In Section 3, the paper presents a discussion of the frameworks in terms of designing compliance policies for digital technologies used in manufacturing companies. Additionally, Section 4 outlines the approach for identifying compliance guidelines. Section 5 illustrates the practical application of the method through the example of 5G communication technology. Finally, Section 6 provides a conclusion.

2. Related work

This section summarizes the important previous activities in the field of compliance of digital technologies. On the one hand, the literature on compliance of digital technology is presented, and on the other hand, frameworks for digitization and the use of digital technologies are presented. These frameworks will be discussed in section 3.

2.1. Compliance of digital technologies

The international literature presents a two-fold understanding of compliance for digital technologies. On the one hand, digital technologies can aid in detecting compliance violations in companies to mitigate compliance risks. This view is often referred to as digital compliance in legal literature. For instance, Mozzarelli [8] provides an exemplary article in this regard. On the other hand, the use of digital technologies in companies must be subject to defined rules. [9] This paper adheres to the second view of compliance for digital technologies. The increasing digitization of business and production processes through new technologies necessitates adjustments to compliance. [10] Despite extensive research, the authors could not find significant scientific literature, especially frameworks and procedures, for developing guidelines for digital technologies. However, there is some grey literature on the internet that describes the current status quo. For instance, Bräutigam et al. [9], in cooperation with the Technical University of Munich, note that the use of digital tools is widespread despite compliance concerns. Legal risks are often underestimated, especially when using new technologies. Many companies do not have specific positions for dealing with digital compliance risks, with approximately 70% stating that they have no such position. In recent years, European legislators have become significantly more active in the field of digital regulation, and the case law of the European Court of Justice has increased the complexity of the situation. [9]

The EU Commission's AI Act serves as an example of efforts to ensure the safety, transparency, ethics, impartiality, and human control of AI. The EU has introduced a classification system for AI applications based on their level of risk, and corresponding rules and regulations have been established. For instance, the use of social scoring is prohibited due to its high risk, while low-risk chatbots are only required to comply with transparency obligations. Despite the importance of compliance in the context of digital technologies, there is currently a lack of comprehensive scientific approaches and attention from both legal and digital technology experts. As a result, AI remains the only prominent example where these issues have been investigated by the European legislature.

2.2. Frameworks for digitization and use of digital technologies

There exist various established and practical scientific frameworks that are utilized in digital transformation projects of companies. In the subsequent discussion, a distinction is drawn between maturity and reference models. Due to the vast number of available frameworks, this paper is limited to the ones that are particularly relevant to the research project.

A well-known maturity model is the Industry 4.0 Maturity Index, which was developed as part of a study by German Acatec. The overarching objective of this model is to determine the current Industry 4.0 maturity level of a company and identify specific measures for its enhancement to reap the economic benefits of Industry 4.0 and digitization. The maturity-based approach is implemented in four developmental stages (visibility, transparency, predictability, adaptability) and aids companies from establishing the fundamental requirements for Industry 4.0 to complete implementation. The target state to be achieved is unique to each company and is dependent on its corporate strategy. [6]

Another reference model that can be utilized in managing digital transformation is the new St. Gallen Management Model. It is used to systematically categorize issues, challenges, decision-making, and action areas in the management context. The model can be considered as a search grid and a useful "map" for a company's own orientation and should aid in comprehending important terms and concepts in the overall management context. [11]

Based on the St. Gallen Management Model, a comprehensive regulatory framework for production and management has been developed, which includes information systems as a supporting factor for all other processes in the framework, owing to its significance for manufacturing companies [12].

Appelfeller and Feldmann have published a particularly extensive reference model of digital transformation, with the aim of organizing the many individual elements of digital transformation, clarifying the cause-effect relationships between them, and creating a consistent terminology. To this end, ten elements, such as digitized processes and digitally connected customers, have been defined, and development stages have been added to the reference model to create a maturity model [13].

Another reference model is the Reference Architecture Model Industry 4.0 (RAMI 4.0), which consists of a three-dimensional coordinate system that incorporates the essential aspects of Industry 4.0. The first horizontal axis of the system arranges hierarchy levels from the international series of standards on the integration of enterprise EDP and control systems, representing the different functionalities within the factory or plant. The second horizontal axis depicts the life cycle of plants and products, based on the IEC 62890 standard on life cycle management. On the vertical axis of the model, six layers are utilized to describe the IT, such as the digital image of a machine, in a structured manner [14].

The Aachen Digital Architecture Management Model (ADAM) is a framework that uses a structured approach to align the technology infrastructure with business development during digital transformation. ADAM comprises the digital infrastructure, divided into four design levels, and business development, divided into four development levels, as shown in Figure 2. The design and development of all levels are guided by the requirements of internal and external customers, leading to the digital architecture. The description of the four design levels of the digital infrastructure is based on established frameworks in science and practice for describing networked companies, systems, and products. Furthermore, the layers are encompassed by three architecture views, namely the organization view, the technology view, and the data view.

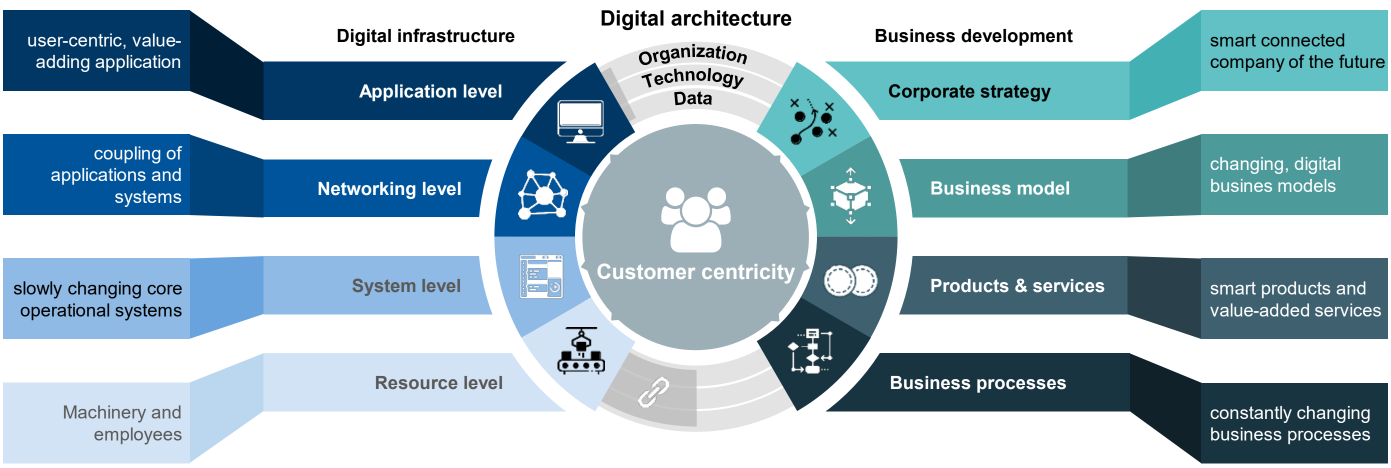

Fig. 2 Aachen Digital Architecture Management Model (ADAM) [15]

These views provide a comprehensive perspective on the layers. [15]

3. Discussion of frameworks

In order to achieve the goal outlined in this paper, which is to enable companies to establish guidelines for compliance-related digital technologies, a series of four models has been developed. These models, as illustrated in Fig. 1, are arranged in sequence and build upon each other. The first model employs a Delphi study to identify digital technologies that are relevant for compliance. This method is particularly well-suited for this purpose, given the uncertainty surrounding the subject matter and the need to consult a large number of experts from both academia and practice. The most pertinent technologies that were identified include 5G, conversational interfaces, and artificial intelligence applications. Detailed results and the entire process can be found in Schuh et al. [16].

For the next step in Model two, a suitable practical framework is required to systematically examine the identified compliance-relevant digital technologies with regards to compliance guidelines. The development of such a framework is the main focus of this paper. As a starting point, Section 2.2 provides an overview of common frameworks for the use of digital technologies and the implementation of digital transformation.

There are two specific requirements for a framework to determine compliance rules for digital technologies. First, it is crucial to use a holistic framework that takes into account both enterprise IT aspects and business needs. Digital technologies are used at various levels in companies, meaning that they are applied in traditional business processes, products and services, as well as on the shop floor through sensors or in the network through communication technologies. Second, the framework must be applicable in and by companies. It should be easily understood and accessible to manufacturing companies, while having a low level of complexity to facilitate application in practice.

When evaluating the frameworks presented in Section 2.2 with respect to the two requirements, it is evident that the holistic view of both business elements and IT areas of a company is not provided in the Industry 4.0 Maturity Index, the Sankt Gallen Management Model, and the model from Appelfeller and Feldmann. While Appelfeller and Feldmann's model and the Industry 4.0 Maturity Index do not consider business aspects such as the digitization of products and business processes, the Sankt Gallen Management Model has a strong focus on the business area but does not cover the required levels of a company's IT infrastructure. In contrast, the RAMI 4.0 and ADAM models satisfy the holistic requirement. RAMI 4.0 covers various business levels within the company as well as the IT utilized throughout the company via three specified axes. ADAM differentiates between levels for business development and levels for digital architecture, thereby fulfilling the requirement for holism.

After analyzing the first requirement, the two remaining frameworks are examined with regard to the second requirement of applicability in companies, with complexity and accessibility being the decisive factors. RAMI 4.0 employs three axes, creating a holistic approach, but also leads to increased complexity due to its multidimensionality, which impairs fast comprehensibility and results in increased application costs for enterprises. In contrast, ADAM uses only two views, resulting in less complexity, and employs terminology that corresponds to the common terminology used in manufacturing companies, ensuring good accessibility in application.

In summary, RAMI 4.0 and ADAM meet the holistic requirement, but ADAM is easier for companies to understand and access. Based on this reasoning, the authors have chosen to use ADAM as the fundamental framework for the intended development of compliance guidelines.

4. Methodology

To identify the guidelines necessary for complying with digital technologies, the six levels of ADAM were utilized. These levels include product and service, business process, applications, networking, systems, and resources. The guidelines and compliance rules are established through the business strategy and business model levels. Additionally, the three architecture views, namely organization, technology, and data, are incorporated. These efforts culminate in the creation of a 6x3 matrix, as illustrated in Fig. 3.

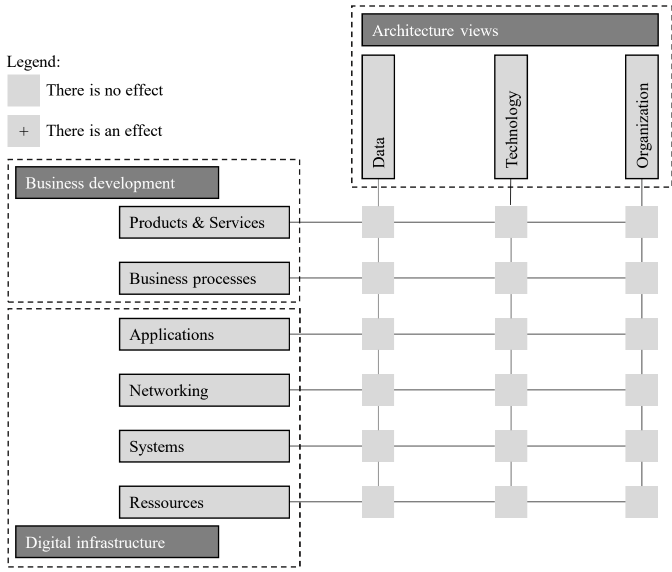

Fig. 3 Matrix for the identification of compliance rules

The six levels of ADAM, namely product and service, business process, applications, networking, systems, and resources, have been utilized to identify the necessary guidelines for ensuring compliance with digital technologies. The guidelines and compliance rules are established by the business strategy and business model levels. Additionally, the three architecture views, namely organization, technology, and data, are employed, resulting in a 6x3 matrix as illustrated in Figure 3. This matrix forms the complete framework for defining compliance rules for digital technologies.

Cause-effect relationships are used to determine the required compliance guidelines for each technology individually within this framework. Specifically, these relationships are described using the intensities of "There is an effect" and "There is no effect". In order to determine the effect intensities, a structured literature review in conjunction with expert interviews can be conducted. The literature review begins with a simplified search for relevant papers using suitable search strings in an appropriate literature database, followed by further reduction of the number of relevant papers through an abstract analysis. The remaining papers are then subjected to an in-depth analysis to assess their contributions to the evaluation of the compliance guidelines of a technology. These relevant papers form the basis for filling the matrix. In addition to scientific aspects, practical experience is also incorporated in the selection of guidelines to ensure a comprehensive view. To this end, technology experts are interviewed regarding standardization, regulation, and compliance relevant aspects of the technologies. The interviews are conducted in a semi-structured manner using a guideline to foster a natural discussion situation.

5. Result

Initially, five distinct search strings were scrutinized in Scopus. Scopus was preferred as the literature database due to its incorporation of various sub-databases such as ACM, Springer, IEE, and Wiley. The summary of the outcomes is presented in Table 1.

Table 1. Results literature research for 5G

Number of papers title analysis	Number of papers abstract analysis	Number of papers in-depth analysis
(TITLE(5g) AND TITLE(transmission) AND TITLE(data))		
58	18	5
(TITLE(5g) AND TITLE(technology) AND TITLE(challenges))		
81	36	12
(TITLE(5g) AND TITLE(acceptance)		
8	6	2
(TITLE(5g) AND TITLE(product) AND TITLE(business AND service))		
22	9	5
(TITLE(5g) AND TITLE(process))		
90	9	4
Total		
259	78	28

Based on the analysis of 28 papers in-depth, the impact relationships for 5G technology were established using the matrix framework presented in Section 3. Four interviews were conducted with experienced 5G experts for this purpose. Two experts, A and B, have particular knowledge of deploying first 5G campus networks, and are from the academic context. Another expert, C, is a technology developer driving the development and expansion of 5G technology globally. A representative from a manufacturing company, D, who applies 5G in first use cases in production, was also interviewed. For instance, embedding 5G in the structural and process organization in manufacturing companies requires particular regulation. The interviews revealed that there is a high level of unawareness and bias towards 5G on the shopfloor. Complexity is a significant barrier to the use of 5G in organizations. Regulation based on existing terms from the Wi-Fi standard (IEEE802.11) could promote the use of 5G. Experts also see the need for informative rules to reduce barriers to 5G. These views are also reflected in the literature, particularly in the work of Al Maroof et al. [17], which focuses on developing skills to drive the adoption and use of 5G.

In summary, the literature review and expert interviews complement each other well and enable a complete filling of the 6x3 matrix. Scientific papers provide information on standardization aspects, model-based assumptions, and legal aspects, while expert interviews reveal challenges and barriers in practice that should be addressed by compliance guidelines.

6. Conclusion

In the introduction, the authors established that there are currently no comprehensive scientific approaches to developing and describing compliance for digital technologies. Both legal professionals and digital technology experts have thus far given little attention to this topic. The purpose of this paper is to present a series of models that allow manufacturing companies to identify and design compliance guidelines for digital technologies. To achieve this goal, four models were introduced and a framework was developed. Models two and three of the framework enable companies to search for relevant guidelines for digital technologies on both the digital infrastructure side and in the business levels. To identify the relevant guidelines, a structured literature review and expert interviews can be utilized.

The framework was applied to the example of 5G to illustrate how the method works and the conditions required for success. In the future, comprehensive validations of the entire project will be undertaken to further examine its application in manufacturing companies. Currently, the framework can only be used to make statements regarding the necessity of compliance guidelines. Further work is necessary to remove this limitation. Subsequent models will provide more detailed information on the content of the compliance guidelines and develop guidelines for implementation in manufacturing companies. This will be an essential step towards ensuring that the framework is practical and effectively transferred into practice.

Acknowledgements

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