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Aachen Digital Architecture Management (ADAM)

Your Guide to the Digitally Connected Enterprise

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fir at RWTH Aachen University

Impressum

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1 Executive Summary

Connected digitalization as an enabler for intelligent products and data-based business models presents companies with a whole range of diverse challenges on their path to digital transformation. To support these companies, various reference architecture models have been developed in recent years. A detailed analysis of these models, and their usage by companies in particular, has quickly shown that currently existing reference models have significant limitations when applied in practice. The Aachen Digital Architecture Management, ADAM for short, provides a framework that addresses the weaknesses of existing reference architectures while incorporating their strengths. As a holistic model specifically developed for practical usage, ADAM structures the digital transformation journey of businesses in the areas of digital infrastructure and business development based on customer requirements. It empowers companies to drive forward the design of their digital architecture under consideration of various fields of action. The description of the fields of action offers a detailed insight into the essential tasks on the path to becoming a digitally connected enterprise. The model not only serves as a structuring support, but also contains a toolbox that helps to configure the digital transformation process. The process differentiates between the development of a digitalization strategy and the implementation of a digital architecture. Three different case studies show how ADAM is used in practice, what structuring support it offers, and how the digital transformation process can be configured. The breadth and depth of ADAM enables companies to follow the path of digital transformation in a systematic and structured manner without losing sight of the value adding components of digitalization. This qualifies ADAM as a sustainability-oriented framework, especially as it places economic scalability, needs-based adaptation, and future-proof robustness of solution components at the heart of digital transformation.

2 Introduction

The digital transformation of companies represents one of the greatest technological and organizational challenges facing the German economy today. Not only do companies need to introduce new digital technologies, but also to use them for internal optimization and seamless connection with external customers and partners. This does not only apply to corporate processes and IT systems, but also to the products and services offered, the business model, and the company's strategic goals.

When approaching digital transformation, companies are confronted with a broad range of obstacles. On the one hand, politics and society increasingly require companies to be more ecologically friendly and to meet stringent sustainability targets; as a result, many businesses are adopting decarbonization strategies to achieve climate neutrality by 2030. On the other hand, customers increasingly demand highly customized offerings and more extensive scopes of service. This results in ever more complex products and services, which, due to a lack of customer integration, often do not meet the expected requirements. Instead of putting the product at the heart of all business activities, businesses need to achieve customer centricity - a strong focus on the customer and their needs becomes essential for gaining competitive advantage. Companies need to build new digital capabilities to better understand its customers and meet their needs in the long term. However, typically, companies do not start with a clean slate, following a greenfield approach: existing corporate structures must be taken into account and adapted. These are often characterized by an inward-looking focus as well as historically grown processes and IT systems. Those responsible for digitalization thus need to balance the tension between technological innovations based on legacy systems and corporate development with the aim of leveraging digital capabilities, a situation which places excessive demands on employees. The consequences are merely prototypical implementations or, at best, marketing-oriented innovation projects such as prestigious software implementations which, frequently fail to create the expected added value for the company or the customer.

Those responsible for digital transformation, from the top management team through to the operational innovation drivers in the specialist departments, need a systematic, structured approach that integrates the various digital transformation activities into a coherent overall picture. This comprehensive picture can then also be used as a basis for communication within the company. ADAM provides a framework with which to master and drive the digital transformation process at different levels of both business development and the digital infrastructure. An integrated consideration of the two development areas, business and IT, forms the basis of the management's and the specialist department's mutual understanding of all digitalization activities – from the concept phase through to synchronized implementation.

3 The Aachen Digital Architecture Management

Since the inception of the term *Industrie 4.0* in 2011 at the latest, the importance of digitally driven innovation, creativity, and interconnectedness in companies has never been greater. Although the drivers of digital transformation may differ from company to company, the contributions of all those involved in managing the deployment of technologically and organizationally oriented digitalization activities is more essential than ever, regardless of industrial sector. With unprecedented frequency, competitors push. Nevertheless, on closer inspection, it becomes clear that success stories like these are often isolated instances, and that the integration of such innovations throughout the company is often only partly successful.

ADAM offers a framework that gives shape to the digital transformation process by defining a digitalization strategy and by deriving measures for the successful implementation of a digital architecture. To this end, the business development and digital infrastructure perspectives must both be taken into account and holistically integrated.

ADAM (see Figure 1), considers two areas, digital infrastructure, which is subdivided into four design levels, and business development, which is subdivided into four development levels. The design and conceptualization of these levels, which is based on an analysis of internal and external customer requirements, provides the basis for building the digital architecture. The concept of the four design levels of the digital infrastructure is based on frameworks established in research and practice for the description of interconnected companies, systems, and products. The design of the digital infrastructure enables a company to develop its business with the support of technology.

Business development, represented by four development levels, can be actively driven from two directions: On the one hand, requirements can be derived from strategic business projects, which are to be technologically implemented using the digital infrastructure. Here, potential for technological improvement and support is formulated from the perspectives of value-added processes, connected products, and the company's

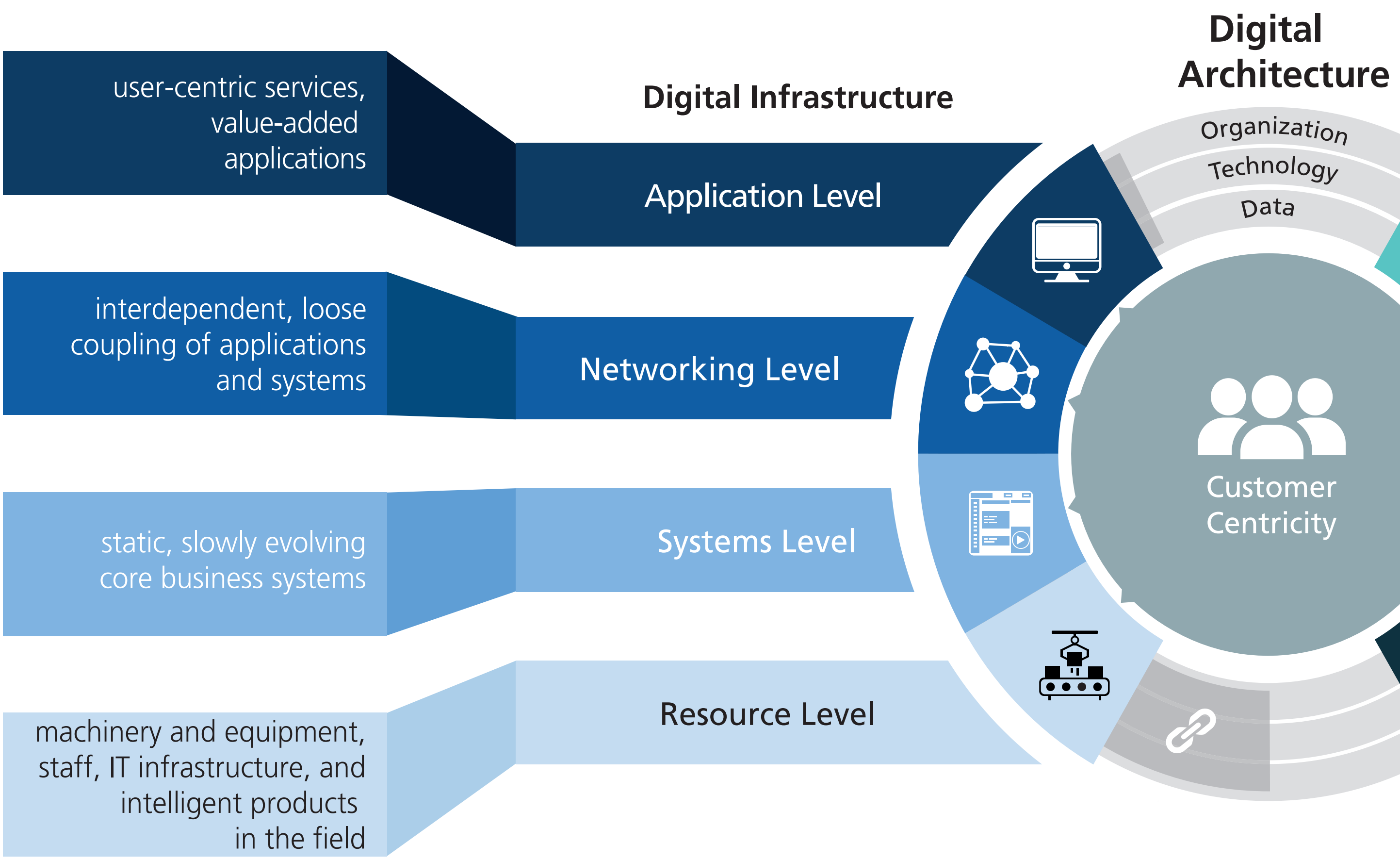
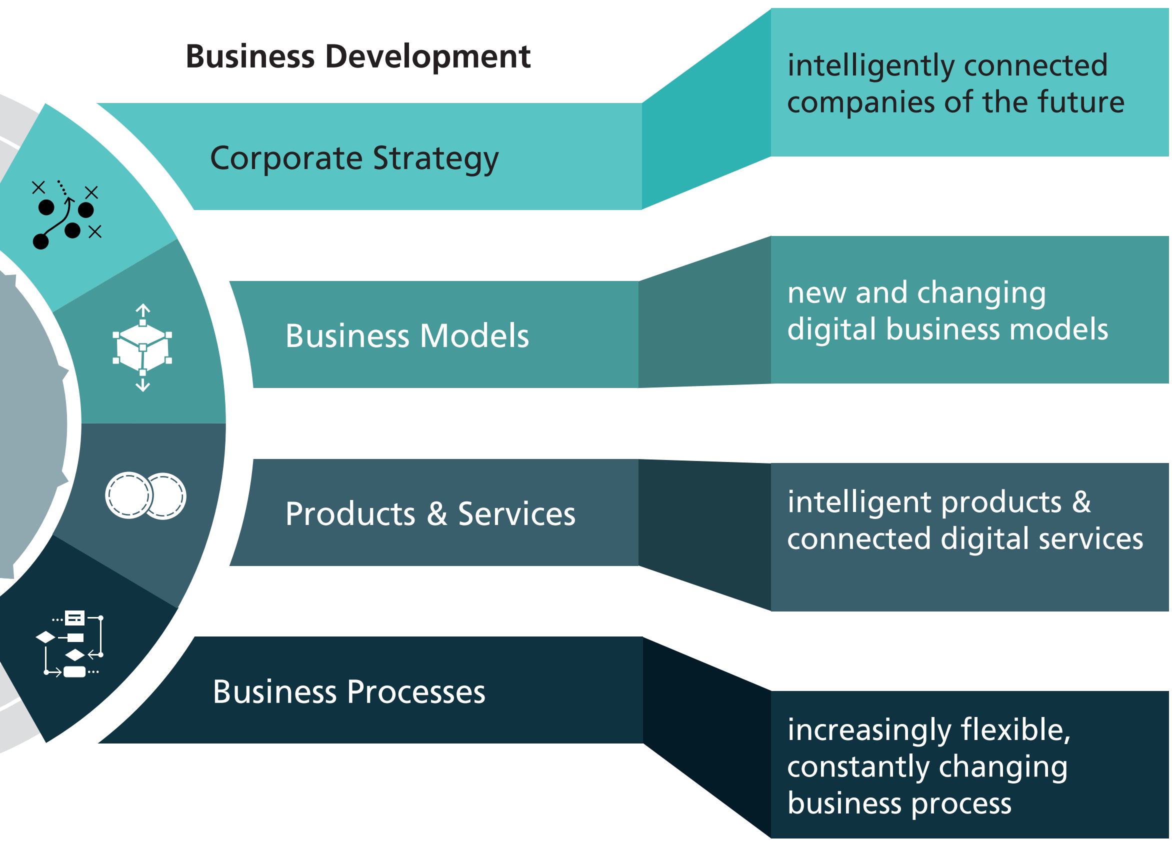


Figure 1: Aachen Digital Architecture Management (ADAM)

business model, whose outcomes contribute to satisfying customer needs. On the other hand, disruptive technological innovations open up a creative space that can be used for business development. For example, demand-oriented, scalable cloud infrastructures with pre-developed orchestration modules, such as user management, boost the establishment of start-ups or the implementation of prototypes. These two approaches reflect the traditional concepts of *IT follows business* and *IT enables business*, enriched by the perspective of technology management. In one case, technological innovation is brought into the organization as a push; in the other case, market needs are fulfilled by means of technology selection and design. Thus, ADAM embodies the harmonized interaction of business development and digital infrastructure design to build a digital architecture that forms the basis for digital transformation.

In the following sections, the individual components of ADAM are explained in order to illustrate its practical usage. In addition to the four design levels of the digital infrastructure and the four levels of business development, ADAM consists of further structuring elements. Three architectural views – *organization*, *technology*, and *data* – provide a comprehensive picture of all levels. Each architectural view sheds light light on each of the design levels and thus describes a room for action and design. In the area of digital infrastructure, these rooms are called *fields of action*. They describe concrete steps, tasks and methods for building the digital infrastructure.

The development levels, on the other hand, are not intersected, by the architectural views, but contain various business transformation fields, such as the development of digital products. The digital infrastructure is additionally framed by the cross-sectional topic of *information security*, which must be considered independently of the design levels.



3.1 ADAM: Putting the Customer at the Center

ADAM's focus is on the customer, whose needs and requirements are essential for the design of the digital architecture. It makes no difference whether it is an internal customer or a external for physical or digital goods and services. Not only does the digital infrastructure have to be aligned with the specific business transformation fields, but also has to consider the requirements of customers who are to reap the benefits it provides. Corporate executives must take internal and external interest groups into account in all important decisions.

All measures and implementation projects that contribute to digital transformation have an impact on internal interest groups, whose requirements, fears and desires must be cosidered. For example, the core message of the acatech *Industrie 4.0 Maturity Index* is that digital transformation can only succeed if the company's organizational structure and corporate culture are taken into account. This message is essential for the success of the project. The reasons for failed projects, for example in the construction industry, in aviation, or even in politics, are rarely technological in nature. Rather, it was lack of communication, lack of trust, or insufficient support that led to their failure.

Digital transformation has internal customers, who, in terms of process organization, are concerned with the primary activities of the value chain or engaged in support functions. One example is provided by digital integration between marketing, sales and production planning in a typical medium-sized company. Company-internal information is digitally transferred to marketing and sales via process planning. The sales department obtains and follows up leads from marketing campaigns and digitally records information on contact approaches and prospect meetings. This information is accessible to all interested parties. In this way, documented customer-specific requirements and desires are passed on to the process-planning department. The lead is converted into an opportunity and then into a customer, and all important lead-related information is tracked and transferred, so that the relevant customer-specific characteristics are known to all internal contact persons.

Many approaches focus on technical aspects and only consider organizational aspects after technology-related decisions have been made. But digital transformation is, above all, an organizational and cultural transformation. The design of the digital infrastructure can only be efficient if all relevant requirements have been recorded right from the beginning and have a defining influence beyond the conception phase. In this way, the digital infrastructure contributes to the achievement of recurring internal objectives of companies, such as to continuously improve business processes and increase process efficiency.

However, companies are not only concerned with internal, but also with external aspects of digital transformation. Positive effects such as transparency in order processing or digital value-added services should benefit existing and new customers alike. To this end, ADAM ensures a deep understanding of customers' key concerns and priorities, which makes it possible to support the customer's value creation activities, to deepen the relationship with the customer, and to better integrate customer requirements into the value-adding processes. In addition, the productivity of collaborative processes must be improved in order to strengthen the company's competitive position. Value-added structures are changing because industry and sector boundaries are becoming blurred and new digital competitors are emerging and competing for existing business. Thus, companies are confronted with increasing demands for transparency, customer orientation and high implementation speed. For ADAM, the consideration of internal and external customers is key, as their requirements provide important design principles for the digital infrastructure.

3.2 Digital Infrastructure

The structure and content of the digital infrastructure are defined on the basis of four design levels. The fields of action that represent the range of topics of the design levels contain tasks that cannot be addressed by traditional IT departments. They require capabilities beyond existing IT competency profiles and focus on digitalization tasks (see Figure 2, p. 9).

The first design level of the digital infrastructure, the application level, refers to all user-centric applications that allow a user to make benefit from the corporate resource "information" in a simple and intuitive way as part of their value-creating activities. Due to rapidly changing environments, enterprise dashboards are subject to constant change. In order for these dashboards to be valid at all times and to be used effectively in managing the company, they require agile and flexible adaptability. Ideally this adaptation can be carried out by the users themselves. Thus, at this level, task-specific applications for cross-domain decision support can be implemented in the shortest possible time.

The networking level enables a company to create interdependent, loose couplings of application and data-providing systems. It ensures the availability of all relevant data and orchestrates the distribution of data between the different levels. Technologically essential components include IoT platforms and suitable communication technologies. Data virtualization is the key enabler, ensuring the user- and developer-friendly provision of data in the long term. It enables companies to retrieve data from various source systems and modify them without the user having to have detailed information about the specific storage location or semantics.

The systems level contains static, slowly changing operational core systems that form the information technology backbone of a company as well as manage and support central value-added processes. In addition to operational core systems, the systems level also contains other, unique data storage solutions, such as databases on the shop floor. In addition, the systems level contains the business logic of a company. It thus represents the basic building block for making the application level more flexible, as the business logic elements and necessary data can be accessed via the networking level. Additionally to well-known systems such as ERP, ME, CRM, PLM, SCM, CAD and CAM systems, this level also includes systems for data analytics and interpretation, such as process mining systems.

The resource level is comprised of production and production-related machines, equipment and other physical assets, employees, including their skills and competencies, intelligent products in the field, and software and hardware infrastructure for IT operations. From an integrative point of view, the resources provide the physical basis for building a holistic and sustainable solution system, which is the basis of the Aachen Digital Architecture Management. Importantly employees are not exclusively perceived as a resource, but as key players in the digital transformation process taking place within the fields of action described below.

3.3 Business Development

The structure and content of business development are defined based on four development levels. Business development represents business activities in the well-known understanding of business-IT alignment.

The corporate strategy development level for business development determines the way in which the value of the company is increased in the long term. Based on clear corporate objectives, such as achieving a strategic position for success in the market, the company's corporate strategy, digitalization strategy, and IT strategy are formulated in a coordinated, integrated manner. Together, they build a framework for the further development of the business as part of the digital transformation of companies. A necessary prerequisite for the exploitation of the synergies and potentials resulting from this strategic alignment is a suitable digital infrastructure. In order to efficiently design this infrastructure from the existing one, strategic considerations are vital.

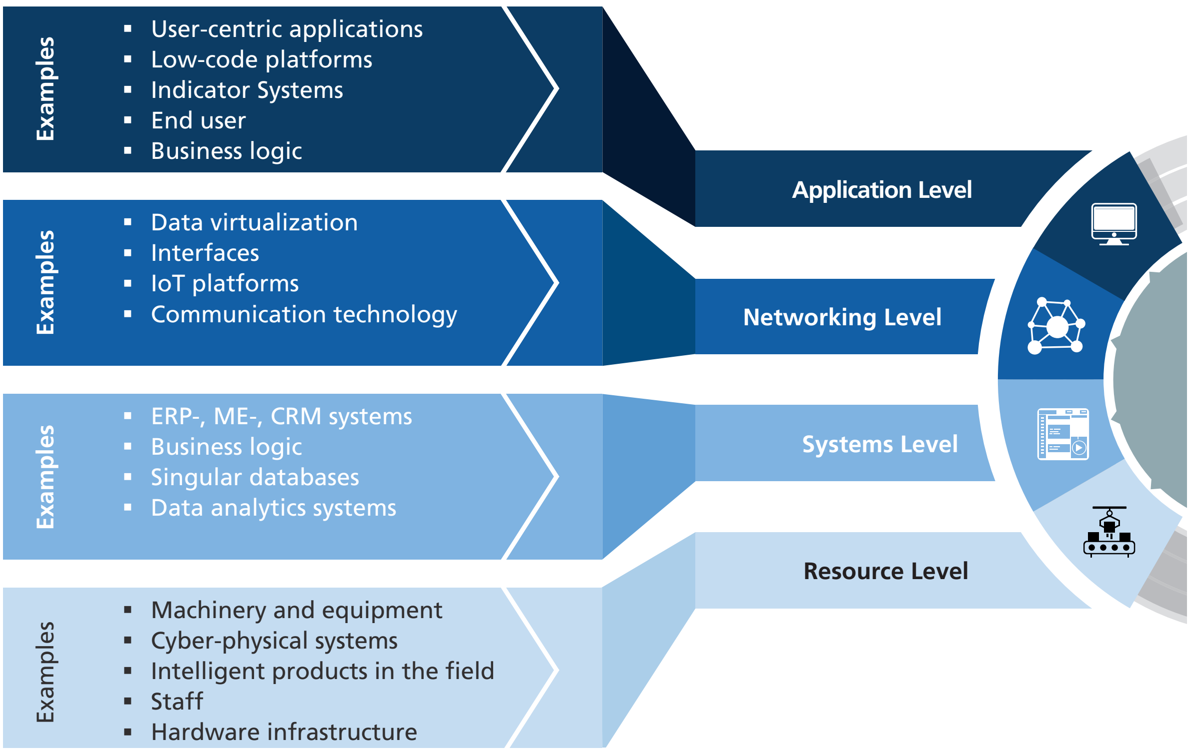


Figure 2: Design levels of the digital infrastructure in ADAM

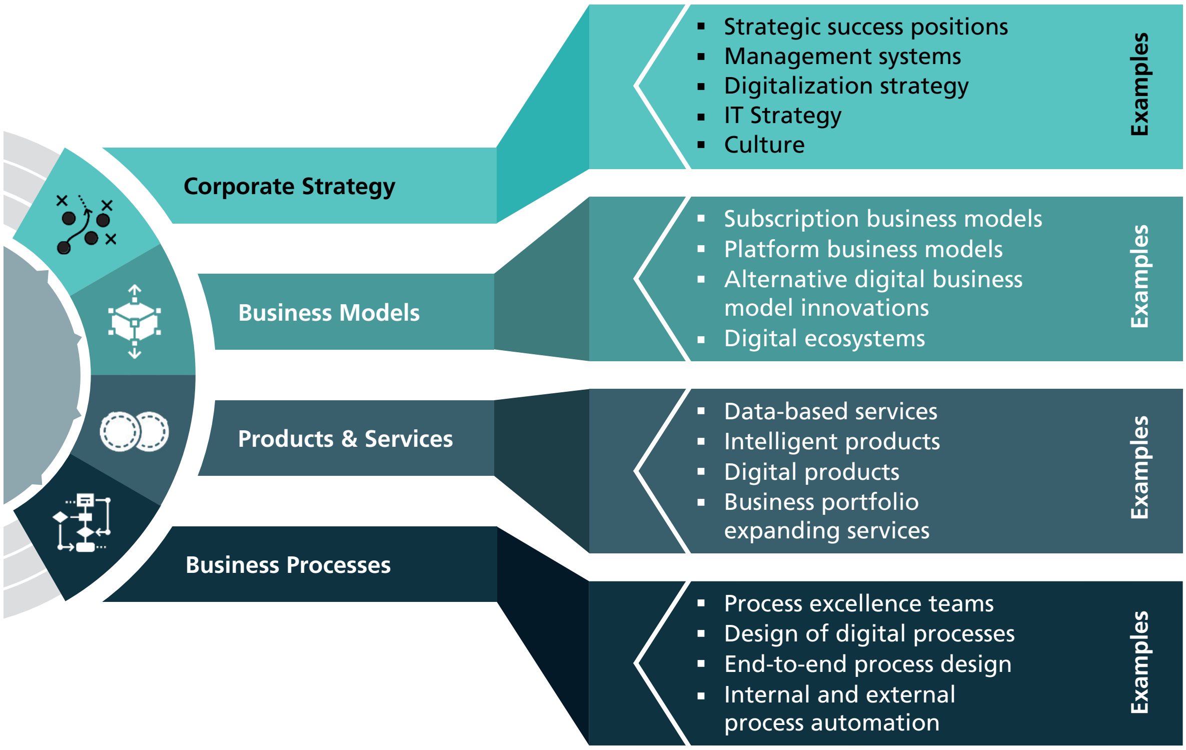


Figure 3: Development fields of business development in ADAM

The business models level determines how companies act on the market to implement their corporate strategy. In all sectors, there is a particular focus on digital business models which make it possible for companies to successfully exploit the potential of digital transformation and open up new business segments. At the heart of these business models are innovative value propositions for the customer with which all business activities are to be aligned. The data-based measurement and analysis of customer behavior, facilitated by a suitable digital infrastructure, is essential in order to continuously adapt and tailor the company's services to changing customer needs. This creates new forms of differentiation and flexibility for companies to better forecast future market developments and to be able to make appropriate provisions.

The products & services level deals with the actual design of the value creation process to achieve real competitive advantage. The basis for this are service systems consisting of intelligent, interconnected products, smart services, and digital components. The digital infrastructure drives integration and further development through the coordinated use of digital technologies such as 5G, artificial intelligence, or distributed ledger technologies. This provides the basis to build new digital ecosystems between customers, suppliers and vendors, whose data are aggregated and analyzed and then exploited by companies via digital business models.

The business processes level is concerned with the efficient design of business processes both internally within the company and with external process participants. For example, existing business processes must be optimized, designed end-to-end, and digitalized in order to scale digital transformation projects in the company. This is not limited to support processes but, in close connection with the resource level, also includes value-adding processes, such as the entire ordering process. Finally, interfaces to customer processes are to be integrated into the company with the help of digital technologies.

3.4 The Architectural Views and Fields of Action in ADAM

Three architectural views provide analytical perspectives on the design levels: The organizational view, the technology view, and the data view offer a comprehensive picture of the four design levels of the digital infrastructure.

The organizational view provides the framework for the design of the digital architecture. From a conceptual point of view, the focus is on the development of a suitable management and control system as well as of the structural and process organization. The organizational view describes how employees interact with each other, with corporate systems, and with digital solutions. The organizational view also defines rights of use, responsibilities, and organizational affiliations.
The technology view is characterized, by the selection of suitable technologies at the four design levels and their

integration. Concept development places particular emphasis on deriving the required technologies from the organizational framework conditions, such as existing competencies. Technologies to be implemented include information and communication technologies, e.g. hardware, the operating environment, or the technical implementation of interfaces. Requirements from the expert areas and from business development, in particular, serve as input for the activities of the technology view.

With the help of models across the different design levels, the data view offers a uniform perspective on the company's data. It describes the data structure, its components, and their relationships across the design levels. This ensures that the data and information required at the application level is available in sufficient quality and granularity and in the right structure. To this end, in the concept phase, a comprehensive information requirements analysis must be performed and specific data models down to the resource level must be developed. The data perspective uses various tools to differentiate between terms like data and information and ensures the standardization of the data used in the company.

The fields of action of the digital infrastructure are the basic building blocks of ADAM. Within and by using the fields of action, the individual projects are defined and structured. The fields of action describe interconnected areas in which typically the same questions and issues arise. A field of action is always assigned to an architectural view and is relevant to and thus "appears on" at least one design level. The fields of action are not strictly assigned to certain design levels, they only describe their primary focus of activity.

A field of action consists of typical questions and tasks that can be subsumed under a term with relevance to digital transformation. In addition, these tasks and questions can be assigned to methods that have proven particularly effective for their processing. With these tasks, *questions* and *methods*, the fields of action provide support at the strategic and operational level.

With the help of the fields of action, projects can be pre-structured and synergies between projects can be identified. At the operational level, the tasks and methods mentioned above support project planning and processing. The tasks and methods are outlined in detail in the following sections.

3.4.1 Fields of Action in the Organizational View

The organizational view describes general framework conditions as well as the interface between the departments and the IT organization. The overarching goal is to ensure a sustainable alignment of business and IT (see Figure 4, p.12)

IT Governance

IT governance consists of management and organizational structures as well as processes that ensure that business-IT alignment is successfully implemented. In this context, IT is not only understood in terms of resources, but also in terms of skills and competencies. The tasks of this field of action are the development and implementation of IT strategies. Input from other fields of action is integrated into the development of these strategies. The integration and orchestration of strategies to build a business-supporting vision for the infrastructure, the structural and process organization, and the management system are the focus of this field of action.

Change Management

Due to the nature of digital transformation as a change process, the field of action change management is highly relevant. In addition to formal corporate structures such as the structural and process organization, the corporate culture, i.e. informal long-term structures, plays an important role. Attitudes, values and informal rules are of great importance for achieving sustainable corporate success. This means that the adjustments derived from the business development process must be implemented taking into account the company's staff, its structures, and its corporate culture. Not only must companies provide employees with continuing education opportunities, but also foster positive attitudes and a spirit of collaboration, for example by providing information offerings, opportunities for participation, and guidance throughout the whole change process.

IT Controlling

The market requirements in the age of digitalization lead to increasing demands on the digital infrastructure of companies. Improved performance is offset by increasing cost pressures. The aim of IT controlling in this conflict of objectives is to approve the right investments, make IT projects a success, and provide transparency about the cost / benefit ratio of IT products and services. This includes calculating the *total cost of ownership* of licensed software, managing IT projects through portfolio analysis, and defining key performance indicators (KPIs) to objectively measure performance. To achieve cost transparency and obligations associated with digital technologies, a quantitative assessment of IT risks is also essential.

Low-Code Development

The digital infrastructure consists, among other components, of the application layer, which allows users to independently create value-adding apps and dashboards. The idea behind is that users know their requirements best. In this context, questions and

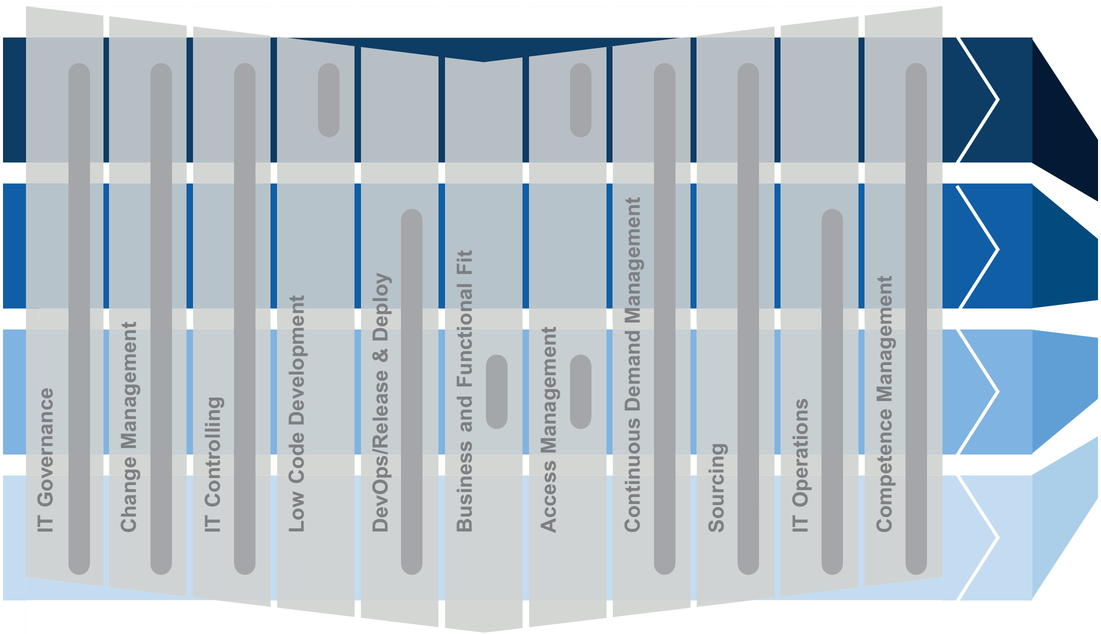


Figure 4: Fields of action in the organizational view

issues surrounding decentralized, i.e. distributed and non-standardized, development activities using low-code / no-code platforms are of great relevance. Mechanisms of quality control, standardization and transfer into applications managed by the IT organization are key tasks in this field of action.

DevOps / Release & Deploy

A modern digital infrastructure requires adapted software development processes. Trends such as the interdependent loose coupling of applications and systems or microservices open up new potential for *DevOps* and *Continuous Integration (CI)* as well as *Continuous Deployment (CD)*. But not every business is equipped to develop their own software, which requires a defined process for development and maintenance. The evaluation of the necessity and the development of relevant organizational structures (inclusive tool support) are part of this field of action. This also includes a tailored CI / CD pipeline and the establishment of DevOps principles in the organization.

Business and Functional Fit

The field of business- and functional fit is concerned with aligning the functionalities provided by the digital infrastructure with the requirements of the business processes. This includes both the adaptation and reorientation of IT systems *(customization)* as well as process adaptations to global requirements of the IT organization *(standardization)*. While business fit seeks to achieve optimal business support, technology fit considers the life cycle of the IT application, its connection to the digital architecture, and its fit with the IT competencies available to the company.

The short, medium and long-term planning of the IT system landscape is also situated in this field of action. Thus, it covers typical questions of *Enterprise Architecture Management (EAM).*

Access Management

The digital infrastructure must provide all stakeholders in the company with the data they need for their daily activities. At the same time, it is key for companies to protect their data and knowledge. The creativity of employees is also a factor in this context, as it can be leveraged to develop and improve corporate processes. Access management is concerned with these possibly conflicting goals. Due to the different levels in the digital infrastructure, consistent, comprehensive access rights are crucial to ensure that employees have access to the data they need to carry out their work in all applications.

Continuous Demand Management

Continuous demand management aims to integrate changing requirements from business processes into the planning and further development of the digital infrastructure. Particular emphasis is placed on the cross-departmental communication of requirements to the IT organization. Organizational roles such as key user or business architect are a way of breaking down possible barriers and of prioritizing and implementing requirements. Other important tasks include the procurement of software solutions and its approval by the IT organization.

Sourcing

The procurement of hardware and software is a complex, multi-dimensional task. The evaluation of the solution to be procured in terms of technological and infrastructural fit typically is a complex process, and the knowledge required is distributed among different corporate functions. Therefore, one of the tasks within this field of action is to involve and coordinate the dialogue between other departments, such as the purchasing or the legal department. Furthermore, a comprehensive IT sourcing strategy has to be developed.

IT Operations

IT operations include the provision of powerful hardware and software solutions with the aim of achieving operational excellence within the digital infrastructure. Key tasks of this field of action include the maintenance of daily operations, license management, as well as patch and upgrade management. Another important field of activity is incident and event management with the help of IT service desks, ticket systems, and well-defined ITIL®-compliant IT service management processes.

Competency Management

Key activities in this field of action are planning and coordination of IT and digitalization competencies within the IT organization. Therefore, it is important to know how many employees are necessary, what skills and competencies they need for solving which task at what cost. The strategic answer to these questions is closely linked to issues such as outsourcing or staff training and development. Aspects such as employee motivation, lifelong learning, and the management of explicit and implicit knowledge are also situated within this field of action.

3.4.2 Fields of Action in the Technology View

The selection and orchestration of suitable technologies (hardware and software) for the best possible IT alignment is a key consideration of the technology view. The organizational framework conditions are to be designed in the best possible way to meet the user's data and information requirements (see Figure 5, p. 14).

IT and Technology Management

The screening, assessment and planning of technologies are key elements of the IT and technology management field of action. This area examines the potential of disruptive new technologies with regard to digital processes, digital business processes, and new customer interactions. Relevant criteria for the use of technology are, in addition to professional aptitude, a firm's internal competencies ("Skills-Technology Fit") and corporate strategy ("Technology Strategy Fit"). In addition, the field of action is concerned with the development of strategies for technology exploitation, development and protection.

Internal Platforms

Internal software-defined platforms (low-code / no-code platforms) are the basis for the user-driven further development of the digital infrastructure. Activities such as the structured selection and operation of suitable workflow and business rule engines and visualization tools also belong to this field of action. Furthermore, self-service solutions for internal customers (e.g. hardware / software procurement, allocation of rights) are typical examples of internal platforms whose task is to delegate non-critical, high-frequency services to specific employee groups. The high level of personal responsibility of individual employees on such platforms must be placed on a sound organizational basis, which typically requires a simultaneous consideration of the fields of action of IT governance and access management.

External Platforms

The integration of external platforms is a particular challenge from a technological point of view, as additional requirements (e.g. information security) have to be met and specific standards have to be observed due to the data exchange with external systems. Interconnections along the entire value chain and new developments such as digital sovereignty of data contribute to the increasing importance of this field of action. Also addressed in this field of action are topics such as the integration of conventional external platforms such as EDI systems or online shops.

System Encapsulation and Access

Trends like containerization and virtualization have an impact on the digital infrastructure. Interdependent connected systems with close coupling through individually programmed interfaces are increasingly being replaced by encapsulated containers with defined APIs for data access. The loose coupling of these containers enables a reduction of complexity in the digital infrastructure and better unbundling in case of an IT system replacement. The standards required for encapsulation and API management as well as the development of an operational approach tailored to the application in question are key focuses of this field of action.

Communication and Orchestration

The transition to encapsulated systems increases the importance of the communication and orchestration field of action. Here, the focus is on internal standardization and use of communication paths. Decentralized architectures such as microservices require special attention to topics such as service recognition and orchestration. The development of company-specific solutions and selection of protocols and technologies are part of this field of action.

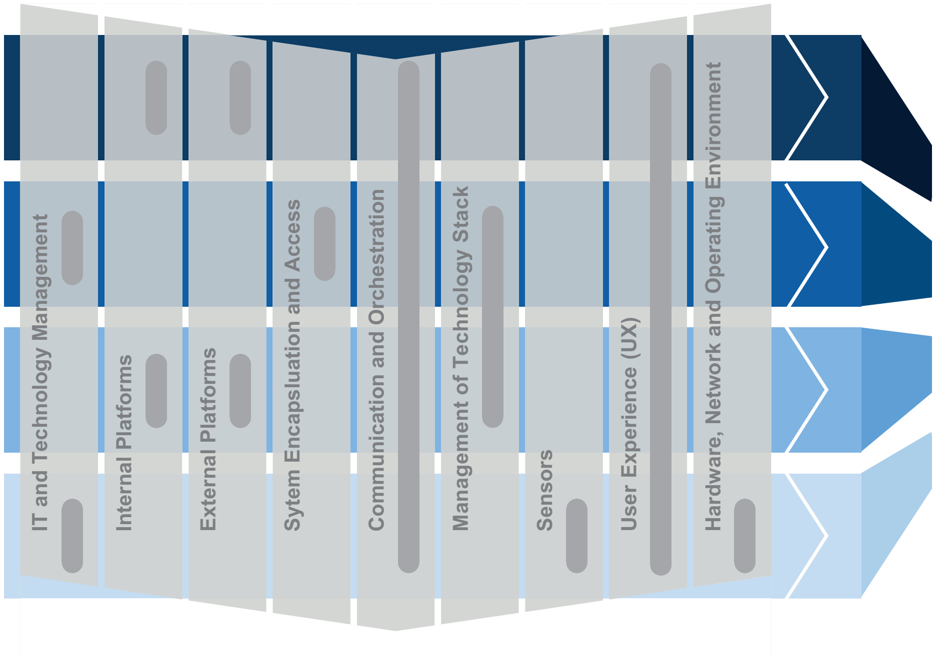


Figure 5: Fields of action in the technology view

Management of Technology Stacks

Technology stacks refer to the set of technology services used to create and run a single application. They consist of the programming languages, frameworks and tools. For example, modern web applications often combine at least three standard technology services: a database technology *(e.g. SQL)*, a backend server *(e.g. Apache)* and a frontend framework *(e.g. Angular)*. Active planning and control of the technology stacks used in companies and choices concerning the development and maintenance of applications are key to the realization of modern, functional applications. Focuses of this field of action include the monitoring and revision of standard technologies used for applications, from database to front-end, as well as the definition of company-wide standards for sub-components of the technology stack.

Sensors

The use of sensor technology enables the collection and integration of machinery and equipment data as well as data from other physical assets into the digital infrastructure. The focus here is on data acquisition and generation and on technological capabilities for decentralized data refinement (cloud / fog / edge computing). The evaluation, selection and design of suitable sensor solutions for individual applications are core tasks of this field of action.

User Experience (UX)

Humans are the key to business success. They generate data, make decisions, and create value. Therefore, it is essential to design the digital infrastructure in a user-centric way. Moreover, an efficient and effective design of the user interface has a great impact on the productivity and acceptance of IT systems. In this field of action, companies define and optimize the way users interact with IT systems. This involves the operational design and improvement of user interfaces and the definition of design standards. A core element is the provision of necessary information in a way that best meets the requirements.

Hardware, Network and Operating Environment

Depending on the company situation and project focus, the hardware, network and operating environment also constitute a field of action. The field of action is concerned with the goods which, in the form of hardware, firmware and operating systems, enable the operation of application software. Key activities include the efficient provision and operation of the required computing and storage capacities.

3.4.3 Fields of Action in the Data View

The data view is concerned with the data and information required for reliable and efficient business processes. In addition to the provision of data for a smooth basic operation, the focus is on the data-related design of an agile, adaptive company. In particular, artificial intelligence methods are applied, which enable learning from data and thus contribute to successful digital transformation and further development of the business.

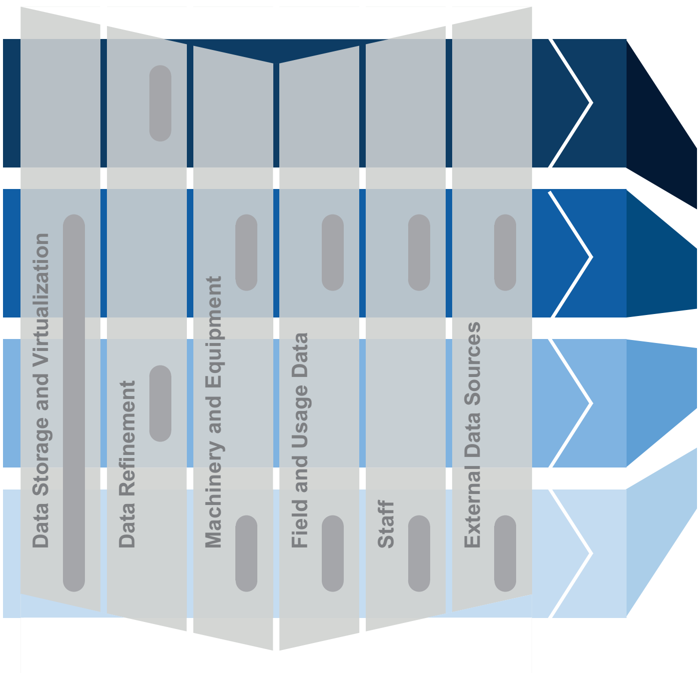


Figure 6: Fields of action in the data view

Data Management and Virtualization

The data management and virtualization field of action deals with planning and control of the company-wide data landscape. Here, the traditional concept of data storage is complemented by that of virtualization, since, in addition to the secure and cost-effective storage of data, there is an increased focus on accessibility across applications. The aim of virtualization is to enable data records to be read and modified without having to know their technical structure or full path. To create transparency over a company's entire data (Enterprise Data Catalogue) is a necessary prerequisite for the development of a data warehouse, a data lake, or a data space, as well as for the development and introduction of a middleware. Further aspects to be considered include the design of leading systems (standards), the creation of a virtual cross-system data model, as well as monitoring and management of data quality. In the context of data management, cloud strategies *(multi-cloud, XaaS)* and cloud transformations are also considered in this field of action.

Data Refinement

Data refinement deals with all the necessary steps to transform raw data into information that can be used within business processes and as a basis for decision-making. This includes data cleansing, contextualization through other data, information, and knowledge, as well as the use of statistical evaluation methods, if necessary in dedicated environments for data analytics and process mining applications. The task of identifying and designing use cases that use machine learning (or other areas of artificial intelligence) is of increasing economic importance.

Machinery and Equipment

In the context of machinery and equipment, the data view deals with the creation and management of digital twins in production. Relevant questions and issues include parameterization and real-time capability, as well as access to and programming of machine controllers (PLC). When creating and operating digital twins, it is essential to continuously ensure that information generated by the digital remains accurate and thus useful.

Field and Usage Data

Field and usage data have a number of special characteristics that company-internal data does not have. Here, field and usage data are understood as data that is under the control or influence of a third party. A machine that is operated on site at a customer's facility generates data whose ownership and access rights must be clarified. These relationships are becoming increasingly common, for example, as a result of use cases such as condition monitoring or subscription business models. In addition, questions of data sovereignty are addressed in this field of action.

Staff

A company's workforce is the key starting point for the generation and use of data. In the final analysis, in everyday business operations, it is almost always people who have to make and take responsibility for decisions.

Therefore, even from the perspective of the data and technology views, it must be ensured that the digital infrastructure is well aligned with user requirements. Implicit domain knowledge in the minds of employees is a data treasure within the company that must be systematically transformed into explicit knowledge (i.e. made available to all). The implementation of this topic, taking into account legally compliant behavior and performance monitoring, is the main task of this field of action.

External Data Sources

Successful companies do not only use the data they generate themselves, but also leverage data from external sources (data from value adding partners, environmental data, traffic data, etc.). Companies need to examine whether it is beneficial to procure and integrate external data into their own systems as well as to plan efforts and necessary measures for implementation. Furthermore, as part of the activities in this field of action, companies may consider to (commercially) share their own data on data marketplaces while considering the risks that this may pose.

3.5 A Cross-Cutting Topic: Information Security

When designing the digital architecture of an organization, it is necessary not only to consider the three architectural views and to work on the fields of action constituted by them, but also to consider overarching aspects. The cross-sectional topic of information security plays a major role for all measures and their management to ensure the security goals of *confidentiality, availability,* and *integrity*. Even if the long-standing basic principles of information security have not changed, due to the increasing interconnectedness within and between companies, the way in which they must be managed and dealt with has changed. The merging of business IT with shopfloor IT (OT) leads to a significant increase in the number of entry points for potential attackers and thus in the potential for damage. At the same time, companies are faced with the challenge of identifying efficient and pragmatic approaches to information security. On the one hand, it is necessary to be able to react to incidents more quickly and in a more targeted manner as well as to be able to communicate the required information to the Federal Office for Information Security (BSI), in accordance with existing legislation. However, first, management has to be convinced of the relevance of a high level of information security. ADAM provides support in this respect in a number of ways: For example, risks and weaknesses can be identified and evaluated along the different design levels in order to determine the required level of information security. Furthermore, the identification of concrete tasks and controls serves to sustainably establish the management of information security in clearly defined processes.

The cross-sectional topic of information security serves to clarify that a company's digitalization activities cannot take place in isolation, i.e. in a division, a functional area, or a department only. Rather, all controls put in place to achieve the required information security objectives must be well-coordinated and integrated in a holistic approach. ADAM makes it possible to identify relevant stakeholders whose commitment is essential for a successful digital transformation. By defining relevant controls and making their implementation part of a continuous improvement process, ADAM supports these individuals at both the operational and the strategic level.

3.6 Digitalization Managers: The Target Group of ADAM

Digitalization does not only affect processes, products and business models, but also corporate communication and collaboration. The digitalization process is not in the hands of a particular individual, but needs to be planned, developed and implemented top-down as well as bottom-up. Consequently, digitalization is driven by a broad range of topics, by different people, and, sometimes, by competing goals. This makes it difficult to assign all corporate digitalization activities to a specific business unit and to provide those responsible with the decision-making power that is required for a successful digital transformation. Some companies continue to entrust a *Chief Digital Officer* (CDO) with coordinating the digital transformation process. Companies tend to forget that in a heterogeneous organization, more than one individual feels responsible for digitalization. The CDO, as a functional role that does not directly contribute to value creation, inevitably gets into conflict with other members from the management level. The head of production has a similar interest in digitalization activities as the CFO. This also applies to the IT manager or the CIO, should responsibility be assigned to him or her. This decision is no less problematic, as an existing function is given even more responsibility; moreover, it is a function that, in recent years, has been faced with the demanding tasks of business-IT alignment. Another possibility is to launch digitally-focused spin-off companies, which assume responsibility for digital transformation of the parent company – a model that was considered highly attractive in the 2010s. This approach, however, has proven to be highly challenging as well. In terms of corporate culture, companies and their digital spin-offs drift apart faster than expected, so that the positive effects of quick and flexible solutions do not find their way back to the core of the parent company. These developments are reflected by the continuously decreasing number of new job openings for CDOs.

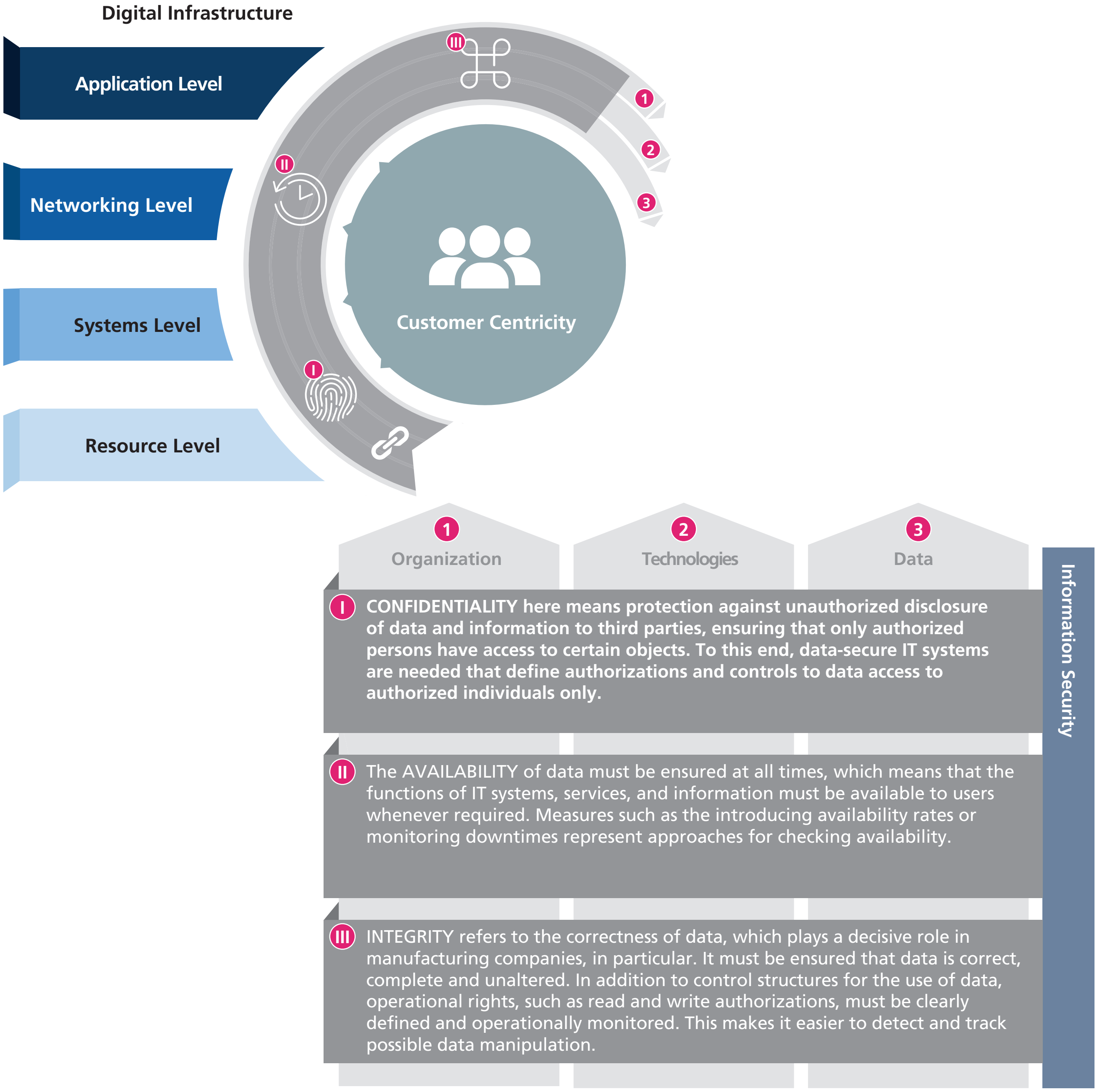


Figure 7: Architectural views and the cross-cutting topic of information security in ADAM

Moreover, there is an increasing number of reports that attempts to reintegrate independent *digital units* into the parent company are failing.

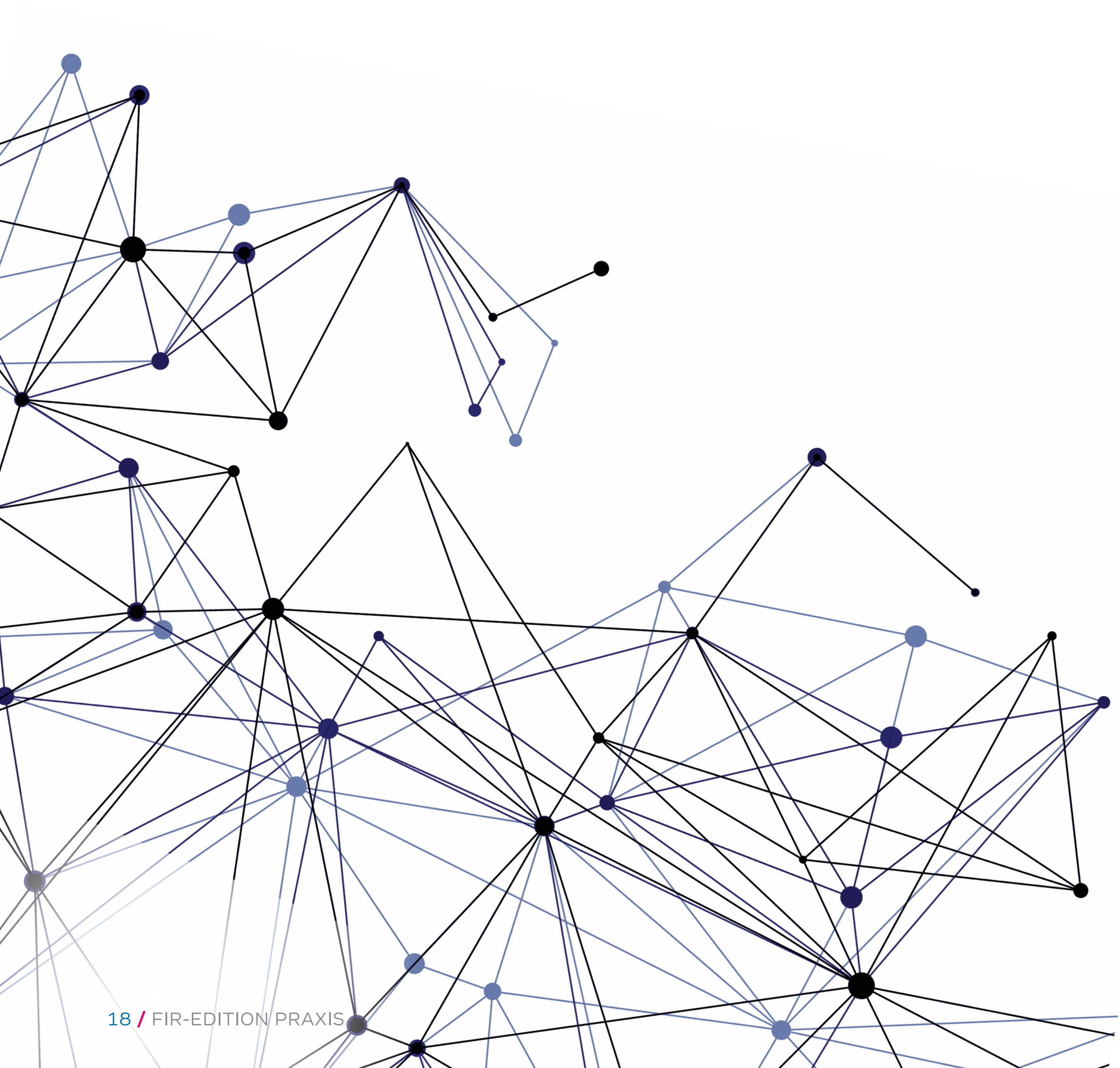
The top management team of a company must realize that digitalization is of major importance for all executives. In the age of digital transformation, therefore, it is essential that all board members fully support the digitalization agenda. Successful digital transformation is a key priority, which means that those responsible for digitalization must be provided with the necessary human, financial and time resources and endowed with far-reaching decision-making powers.

Numerous projects have shown that successful digital transformation requires the full support of top-level management to ensure that the necessary decisions and actions are taken. However, responsibility for implementing digital transformation is distributed throughout the entire company. Each staff member participating in the planning, design and implementation of the digitalization roadmap – an action plan for the company's digital transformation – is therefore responsible for the success of the company's digital transformation process.

ADAM supports these digitalization managers at the strategic and operational level. First, ADAM can be used to structure the entire project portfolio of the digitalization roadmap and to identify technical dependencies. On the other hand, with the help of the fields of action, ADAM enables them to detail individual projects and to formulate the task to be performed fully and accurately.

Thus, responsibility for digitalization does not have to be tied to a newly hired executive, but can be divided among several individuals in terms of content and responsibility. In order to achieve *top-down commitment*, it is essential that decision-making is carried out in close coordination with corporate management. If the latter is not fully committed to digital transformation, both externally and internally, success is a matter of luck rather than the logical outcome of a determined planning process.

In the following section, the usage of ADAM for strategic planning and operational implementation of digital transformation is generically described. ADAM is then applied in three different use cases with concrete case studies in manufacturing and service companies.



4 How to use ADAM

The challenges described in the introduction make it clear that a successful digital transformation requires drawing on a wide range of skills and capabilities within the entire company. Especially the scaling of prototypes into full-fledged solutions as well as project portfolio management often present, in the context of digitalization, hurdles that stand in the way of a successful digital transformation. On the one hand, it is necessary to centrally plan fundamental aspects such as new business models. On the other hand, untapped potential can only be unlocked by tapping the often implicit knowledge of employees across all corporate functions, which requires a necessary minimum of decentralization in planning. A fully decentralized approach, however, requires orchestration and often results in insufficient coordination, redundant work, and incompatibilities. When a decentralized approach is adopted, the relevance of cross-project coordination for leveraging synergies is obvious. By breaking down barriers between project silos, synergies between projects can be systematically exploited. Based on this understanding, a centrally defined digitalization strategy and its coordinated, decentralized implementation are necessary for a successful digital transformation. Targeted and transparent coordination in implementation ensures the exploitation of synergies across departments and projects.

ADAM takes up these ideas and provides a two-phase approach, consisting of the digitalization strategy and the implementation of the digital architecture, to guide companies on their digital transformation journey. In the following sections, the usage of ADAM within the two phases, i.e. development of a digitalization strategy and its subsequent, decentralized implementation will be outlined.

4.1 Developing the Digitalization Strategy

A company's digital transformation requires socio-cultural changes. These must be actively initiated as part of the strategic process, which requires the involvement of all organizational levels, from top management to every single employee. This provides the necessary impetus as well as a basis for planning the company's further development, while taking into account its current situation. The process of developing a digitalization strategy with ADAM is divided into four steps (see Figure 8).

In step 1, Identification of business transformation fields, the basic orientation of the company is defined based on the corporate strategy. This serves to identify the company-specific potential provided by digital transformation and helps clarify the question of how internal and external digitalization is to be implemented. In this step, the business transformation fields (BDF) are used to determine company-specific development paths. These serve as recommended – and partly necessary – building blocks which can be expanded in the course of planning.

The business transformation fields generically describe

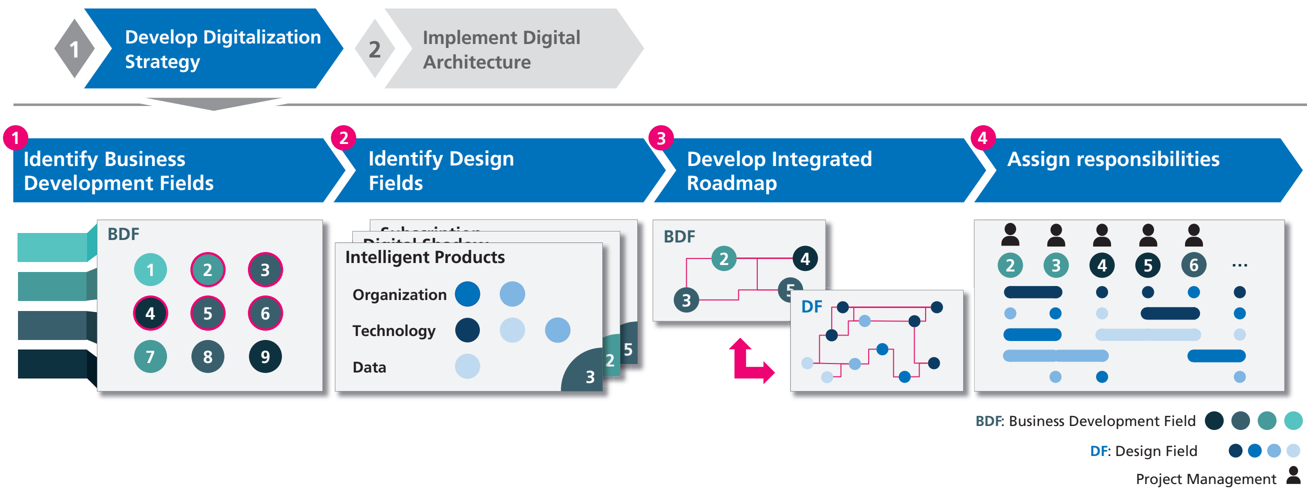


Figure 8: Developing a digitalization strategy

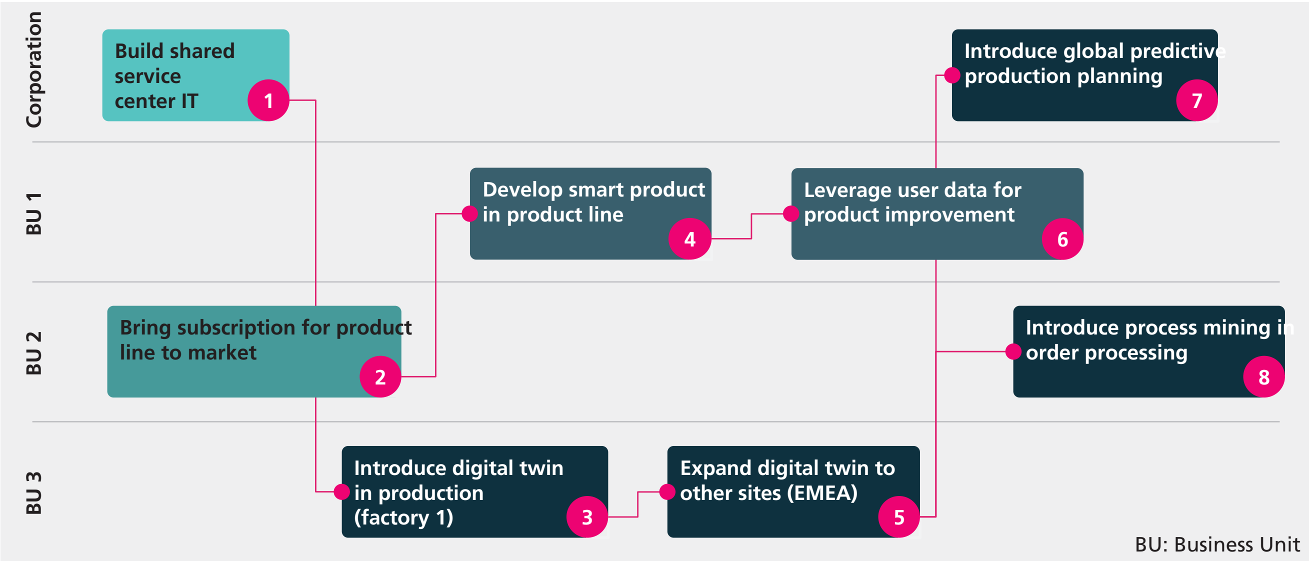


Figure 9: Digital transformation roadmap (Example)

all subject areas relevant to digital transformation. Thus, based on the organizational structure and the business model, the business transformation fields are to be applied to the company. A specific business transformation field may be relevant for and considered by several business units. In this case, synergies arise, which can be exploited depending on the company's organizational structure and corporate culture. As part of this step, which is initiated and shaped by the management, a decision must be made as to the degree of distribution and interconnection of the individual measures within the company.

Successful implementation of this initial step requires transparent communication throughout the company, avoiding isolated initiatives. Only in this way possible synergies can be exploited. However, top management must decide to what extent collaboration across business units and sites is desired and supported. The targeted management of synergies is a lever for cultural change and for breaking down departmental silos. Synergies, possible excessive demands on the organization, and cultural identity in the departments are all factors that have to be weighed up. Here, the engagement of executives is decisive, who act as gatekeepers and are responsible for ensuring that all activities are coordinated and synchronized across the departments involved.

In step 2, Identification of the fields of action, the business transformation fields identified in step 1 are developed and detailed. The focus here is on identifying the required skills and competencies as well as structuring the necessary expenditures in a realistic way, especially within departments that are critical to success. As part of these activities, the fields of action are determined based on the selected business transformation fields. This assignment of fields of action to business transformation fields is already generically defined in ADAM in the form of blueprints, but must be individually adapted to the company in this step. The resulting fields of action serve as a foundation for the next step of integrated planning.

In step 3, Development of an integrated roadmap (see Figure 9), the field of actions are to be detailed based on their descriptions and the company's digital infrastructure. Synergies between the business transformation fields are identified. Consequently, requirements for the sequence of implementation steps can be defined. As a result of this detailing process, companies are provided with an integrated roadmap, consisting of business transformation fields and fields of action, as well as a dependency matrix that describes interdependencies between the business transformation fields.

Step 4, as the final step, focuses on the Definition of responsibilities. The assignment of the projects from the roadmap defined in step 3 to the decentrally coordinated teams requires the allocation of project responsibilities. In this step, it is essential to ensure good communication and to situate the projects into the wider project context. In this step, the synergies and communication requirements described in the previous steps are further elaborated. Responsibility for implementation lies with those involved in planning, designing, and implementing the digitalization roadmap.

Step 4 completes the first phase of the development process and creates the basis for an optimized decentralized implementation. In the following sections, the second stage of ADAM, the implementation of the digital architecture, is described.

4.2 Implementing the Digital Architecture

The second project phase of ADAM describes the implementation of the digital architecture. This stage is divided into four successive steps which allow for an efficient project implementation (see Figure 10). The aim is to improve the quality of the defined digitalization projects. Additionally ADAM supports the planning and implementation of projects that are carried out independently of a digitalization strategy (the first phase). In the first step, Detailing of the fields of action, the fields of action identified in the first phase are examined more closely based on the identified requirements. At a higher level of detail and taking internal and external customer requirements into account, it is to be analyzed whether further fields of action must be considered to ensure an appropriate implementation of the business transformation field in question. Otherwise, the design areas already identified meet the requirements sufficiently.

After the fields of action have been reviewed and, if necessary, expanded, the next step, Task Selection, looks at the selected fields of action from the perspective of the digital infrastructure levels. Depending on these levels, different tasks are required in each field of action. The project managers must define these tasks with reference to the different levels so that the tasks required for the main project can be identified and addressed. The tasks located in the different fields of action provide a basis for discussion of the tasks assigned to a project. This allows projects to be pre-structured quickly and easily in terms of tasks to be addressed. The clear definition of tasks based on the fields of action and the resulting consistent view on the project as a holistic approach increase the feasibility of the project and the quality of its results.

Following the identification of the essential tasks within the fields of action, in step 3, the detailed fields of action are prioritized and scheduled in a project plan. The information previously collected serves as a basis for an efficient prioritization of the fields of action in order to exploit the synergy potential described above as efficiently as possible.

The final step in the implementation of the digital architecture deals with project implementation and project management. Existing project management methods such as SCRUM, Waterfall, or Agile Stage-Gate can be integrated into the project structure as support tools. ADAM supplements these methodologies in questions relating to digital transformation by providing a mindset and a content prestructuring approach. However, ADAM is not a substitute for frameworks such as ITIL®, COBIT® or TOGAF®; rather, it should be seen as

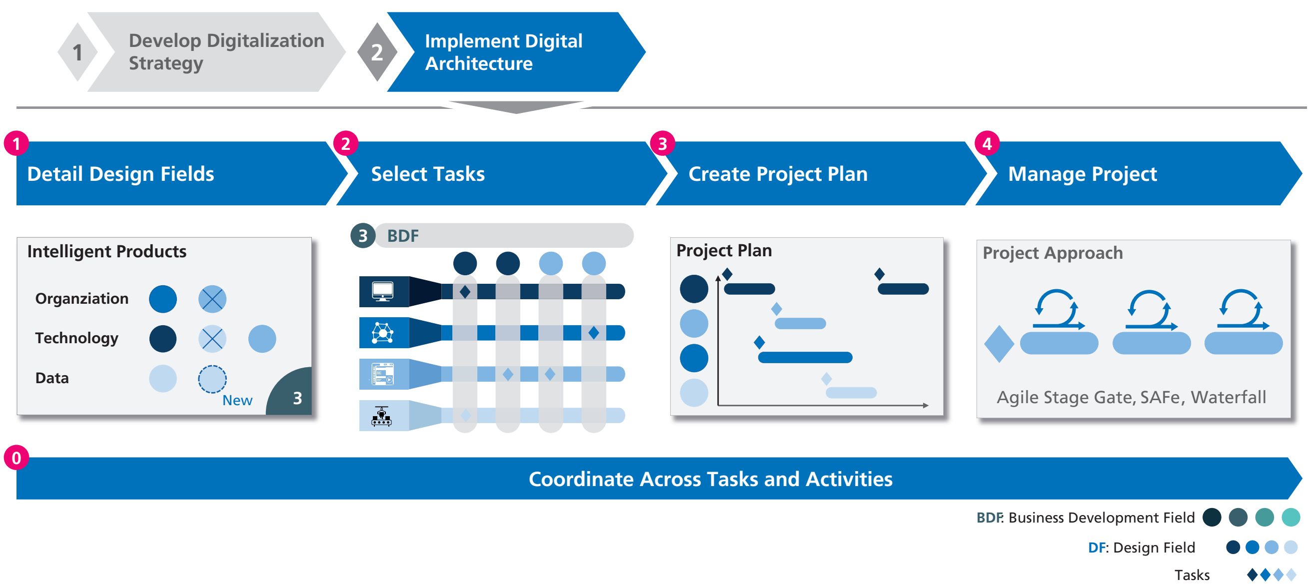
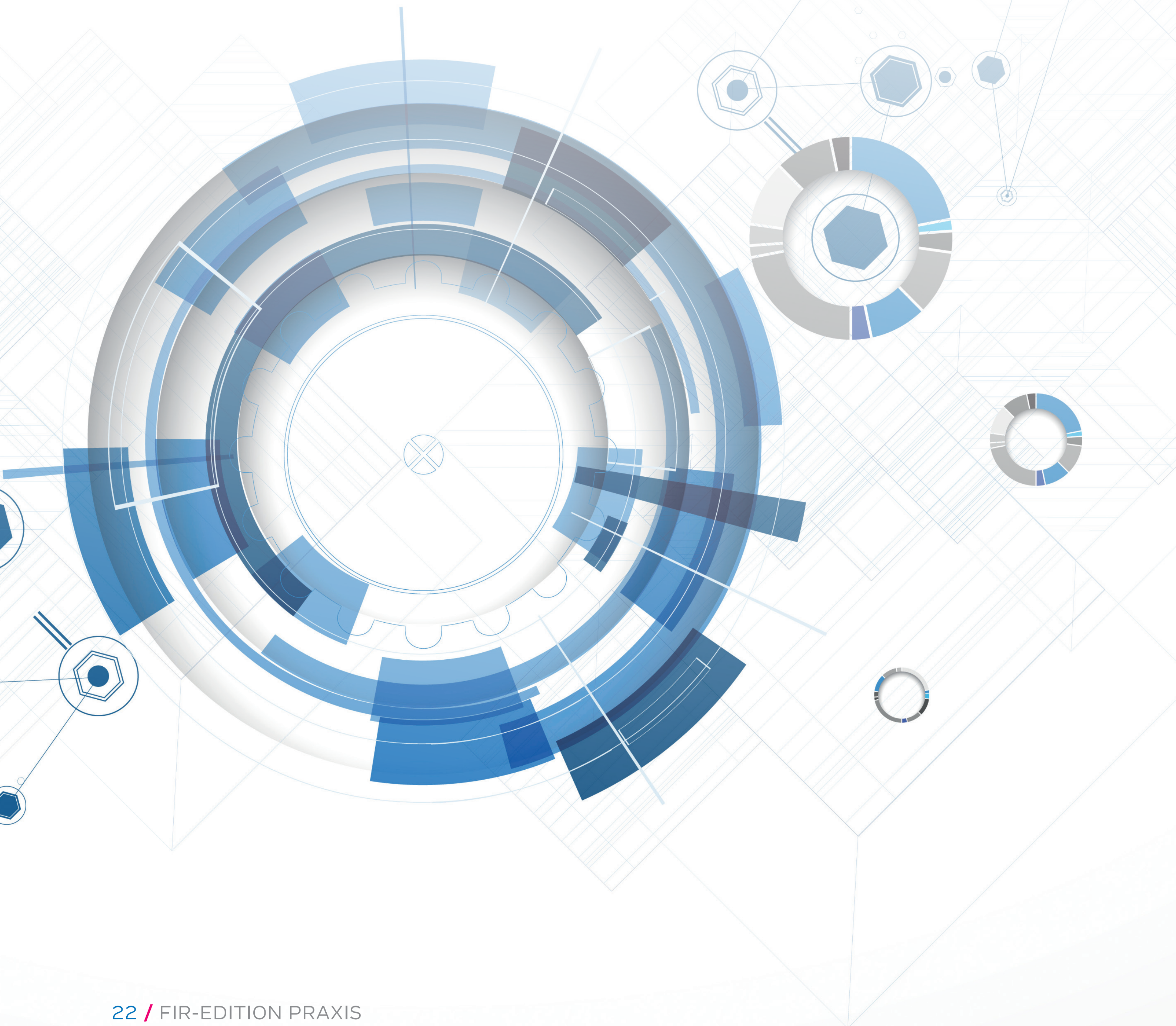


Figure 10: Implementing digitalization architectures

a useful complement to ensure acceptance beyond the IT department. Approaches such as BPM and EAM can also be applied in combination with ADAM. Throughout the entire implementation process, it is important to ensure cross-departmental communication and coordination by carrying out the project as transparently and as coordinated as possible.

As has become clear, the described approach is adaptable to different areas of application and companies, with their different structures, cultures, and industries. It is important, however, that the usage never takes place in isolation, but always taking company-specific circumstances into account.

This chapter has provided an overview of how ADAM is to be applied in principle. Its concrete usage in specific projects will be illustrated in the next chapter with the help of three potential use cases.



5 Case Study: IT Architecture Development for Digital Shadows

Initial Situation

As a supplier to the automotive industry, Batterie-Produktions GmbH produces battery cells, among other products. The manufacturing process covers the entire value chain, from the preparation of raw materials to final cell inspection and distribution. At project start, the manufacturing process resulted in a high number of cells being rejected. This was due to the special nature of the production process, which hardly allowed any conclusions to be drawn about the quality of the battery cell before completion of the product test phase, which took three weeks on average. The high reject rate led to increased costs and a poorer ecological balance, as the battery cells could only be disposed of as hazardous waste. In addition to producing the battery cells, the company has been conducting intense research on how to optimize the production process. These activities strongly affected production, as only small adjustments to parameters such as temperature or feed rate had a strong impact on the final result.

At the beginning of the project, only a few machines and systems at Batterie-Produktions GmbH were sufficiently interconnected to allow direct access to data that could provide insight into the current production status. Furthermore, there was no specific plan for the development of the IT architecture. Siloed solutions were implemented in isolation and without being coordinated with parallel activities. Furthermore, it was never examined whether the existing IT architecture allowed flexible and agile changes to the production process.

Objective

Consequently, *Batterie-Produktions GmbH* sought to drastically reduce the reject rate with the help of a digital shadow. A digital shadow is to be modelled at the right level of detail, depending on the application and objective, and the relevant data are to be interlinked and integrated depending on the question at hand. The goal was to obtain improved decision support to facilitate efficient adaptation of the production process. To this end, the production process had to be made sufficiently transparent through the collection, aggregation and analysis of relevant data. For each battery cell produced, the information had to be available in real time at all times. This required development of a suitable IT architecture, serving as an important link between the IT infrastructure and the added value generated through the digital shadows. It was necessary to capture the as-is-situation and to define key performance indicators for quality measurement. These indicators were then to be analyzed and the process continuously optimized in order to achieve better predictability of battery cell quality.

Approach

Figure 11 again shows the general approach to implementing the digital architecture in the form of a sub-project. The four steps are described in detail below.

As part of the development process for an IT architecture that is capable of realizing digital shadows, the fields of action were detailed and further requirements were defined. For the customers of the battery cells, it was particularly important to benefit from improved *customer integration* and stronger involvement in the production and *testing process.* Collaboration and trustworthiness were to be improved. In addition, the production line was to serve as a blueprint for further lines and thus had to represent a *scalable solution*. Regarding the IT architecture, for example, the process data of each machine needed to be linked to the identification numbers of the battery cells and automatically transmitted to the MES. This was impossible at the time of initial analysis. In Figure 12 (p. 24), the fields of action relevant to the development of an IT architecture for a digital shadow are shown and described below using three concrete tasks as examples.

ADAM helped identify design levels had to be taken into consideration. The networking and systems level turned to be particularly relevant. Based on the business development objectives, the tasks to be completed at the individual design levels were identified and specified by detailing the fields of action. The modular structure

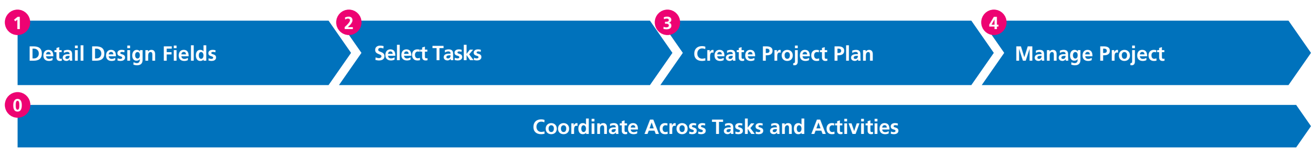


Figure 11: Approach to implementing the digital architecture

of the model made it possible to specifically select and develop the relevant fields of action.

At the resource level, the field of action *of machinery and equipment* was considered, as this is where the relevant raw data are generated. Furthermore, it is necessary to validate the identified cause-effect relationships in the real-world environment. Tasks to be addressed included, for example, *parameterization*, which sought to improve the production process and battery cell quality. At the systems level, the field of action of *data management and data virtualization* was particularly relevant. Tasks to be completed included *ensuring data consistency* and *management of master data* (identification, consolidation, harmonization, and integration of master data as well as subsequent data synchronization). As increasing the overall degree of automation was a secondary goal, the master data were also made part of the analysis. At the networking level, the field of action of *communication and orchestration* was identified. One of the tasks in this field of action was to identify *data transfer possibilities*. The aim was to ensure that all process-relevant data was available in real-time and with sufficient granularity. At the application level, a key objective was to ensure that the analyzed data and the information aggregated from it can be appropriately presented and visualized. This meant that user experience goals played an important role. For this reason, the task of *dashboard development* was given a high priority. The aim was to develop a modular dashboard that could be extended and adapted for each process step.

Based on a gap analysis, a project plan for the following six months was developed and supported by a classical waterfall project management approach. The roadmap focused on the flexible interconnection of the systems to allow easy and flexible adaptation of production to customer needs. This should also make it possible to implement the different measures independently of each other, to apply them quickly in the form of pilots, and simultaneously to implement a scalable solution.

Different teams worked on the project from different perspectives: One team dealt with the development and implementation of the IT architecture, while another

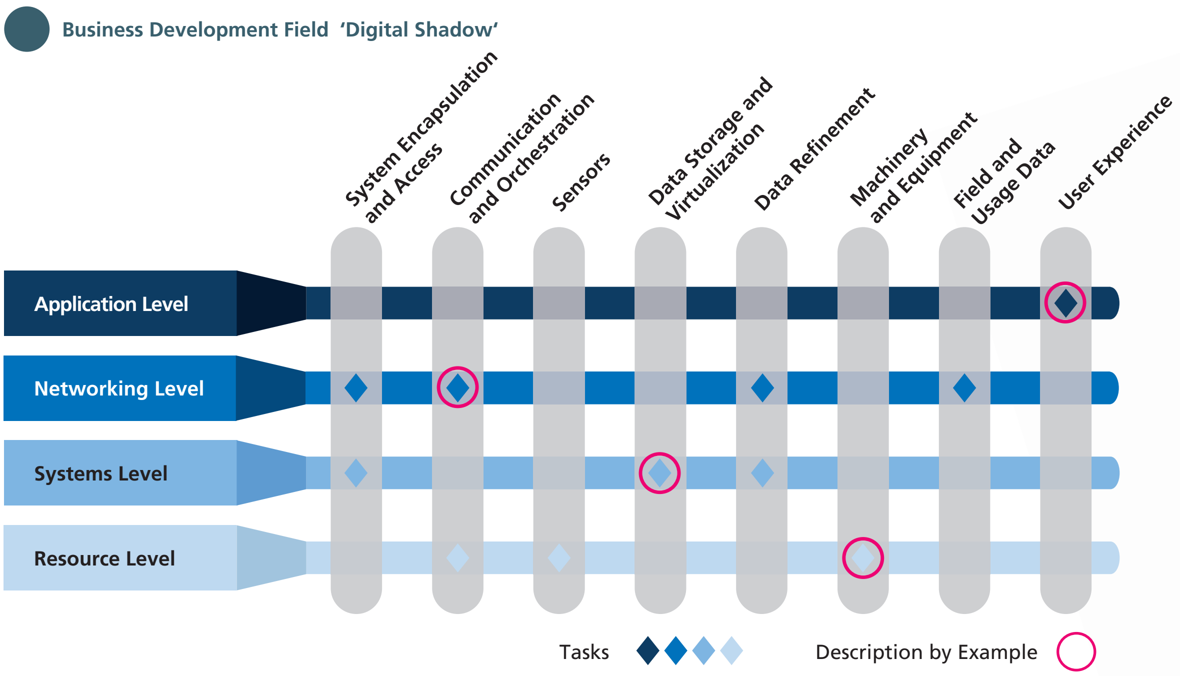


Figure 12: Relevant tasks for the development of an IT architecture for a digital shadow

team, equipped with the necessary domain knowledge, dealt with data analysis and process optimization. The project manager had overall responsibility for other sub-projects and coordinated the exchange with these projects. His main task was to make sure that standards for data transfer were established and that master data management was kept consistent.

Results

The rapid implementation of a digital shadow in a first production line, which served as a blueprint for further lines, generated immense added value for *Batterie-Produktions GmbH*. As tangible successes were achieved early on, other stakeholders could be convinced of the project's benefit. After further expansion of the first implementation and full realization of the digital shadow for the battery cell production process, it was possible transparently to present the relevant sub-processes as well as the battery cell characteristics. Thus, the key goals of data-based decision-making and reduction of the reject rate were brought within reach. It was possible to increase the yield by 16 percent. By reducing the reject rate, critical orders could be efficiently completed, resulting in higher delivery reliability and a reduction in waste. In addition, the newly available data provided a basis for the future optimization of products as well as internal business and external customer processes.

6 Case Study: Process Digitalization Through Tracking & Tracing

Initial Situation

At one of its assembly lines, a German gearbox manufacturer was spending too much time searching for gearboxes to be machined between individual process steps.

The reasons for these non-value-added search times were multi-layered: On the one hand, most gearboxes hardly differ visually from each other, which is why their serial numbers had to be manually checked by staff. On the other hand, between process steps, the gearboxes were kept in storage areas where their exact location could not be determined. The gearbox manufacturer had initiated an internal project to design a Tracking & Tracing solution with the aim of increasing process transparency. However, the existing assembly infrastructure presented the project with significant challenges. As both the assembly hall and the gearboxes themselves contained a high percentage of steel, many common tracking and tracing solutions had to be discarded right away.

Objective

The aim of the project was to develop a technology concept to allow tracking & tracing of the gearboxes within the assembly line in question. To this end, first, a systematic evaluation of possible technologies for tracking & tracing was carried out. The result was a list of all possible technologies or technology combinations that could solve the problem under the given conditions and requirements. In a second step, three different technology concepts were developed on the basis of the selected technologies. Then a first feasibility check was carried out on the basis of expert assessments. The last step was an economic assessment of the technology concepts. Relevant cost drivers were identified and potential benefits assessed. Finally, the individual concepts were compared in terms of cost-effectiveness.

Approach

In this project, particular focus was placed on the development level of business processes. The customer's explicit objective was to optimize the assembly processes. In the area of digital infrastructure, the project focused on the design of the resource and networking levels. Generally, the application and systems levels have to be considered as well when introducing an order tracking system. In this project, the customer already had systems in place for both the systems and application levels, which were to be used and interconnected for strategic reasons. The plan was to use the existing ERP system, which was the leading system within the plant. The following sections outline how the ADAM approach shown in Figure 13 was used to achieve the customer's objectives.

The first step was to define the fields of action to be considered. In the organizational view, the introduction of a tracking and tracing system requires the consideration of fields of action that have a direct impact on processes. In this case, access management, continuous demand management and sourcing are to be considered. In the technology view, early IT detection and technology management ensure that the latest technologies are considered for the application. In order for the employees to use the implemented system, their requirements must be taken into account in the design of the user experience. The feedback from customer data was essential to optimize the involved systems and to meet customer requirements. In the field of action of *communication and orchestration*, the interaction between system components and communication with adjacent IT systems are designed, as in an ERP system. Only by interlinking the data from different sources, for example combining the position data with the current production plan or the staff workload, can relevant information be generated and measurable added value

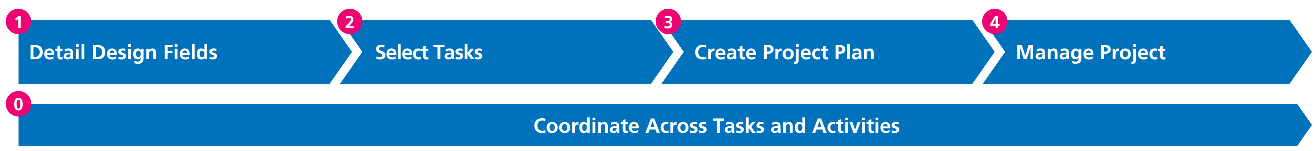


Figure 13: Approach to implementing the 'Tracking & Tracing' solution

delivered to the company. The hardware implementation will be successful if a suitable sensor technology was selected, the *technology stacks* are designed and bundled, and the existing hardware, network and operating environments are taken into account.

Within the data view, it must be decided, above all, how the resulting data is to be stored *(data management)*, how it is to be further processed and made available to the user *(data refinement)*, and which machines and plants are to provide feedback to the order tracking system.

The next step is to define tasks within the different fields of action. For structuring purposes, these tasks are assigned to the various design levels. The resulting distribution of tasks in the project under consideration is shown in Figure 14.

Based on the defined tasks, a project plan was developed, taking interdependencies between the tasks into account and prioritizing them in the event of capacity bottlenecks. The project schedule in the present case study was as follows: At the resource level, technologies for identification and localization were examined and selected. In the IT early detection field of action, possible technologies were identified via technology scouting. From the set of technologies, the most suitable ones were selected using three different filters: technical requirements, functional requirements, and customer priorities concerning expected generic benefits. Based on the remaining technologies, three different technology scenarios were identified: an end-to-end Real-Time Location System (RTLS), a combination of RTLS and RFID, as well as a combination of RFID, cameras, and QR codes. For the three technology scenarios, the necessary interfaces to existing systems and the corresponding transmission technologies were identified at the networking level. The subsequent analysis and comparison of the three solution variants resulted in a prioritization of the second technology scenario, the combination of RTLS and RFID. Combined use of these two technologies was shown to offer the greatest potential benefits in the present project.

Structured project management is essential to the success of a project like this one. In principle, traditional or agile project management methods such as waterfall or Scrum can be used. Which method is most suitable depends on the project's conditions and requirements. In the present project, it was the explicit wish of the customer to divide the project into sequential phases, which resulted in a structure that was mostly based on the waterfall model.

Results

As a result of the project, the company succeeded in eliminating gearbox search times. To achieve this goal, the developed technology concept, consisting of a combination of RTLS and RFID, was detailed and handed over to an implementation partner after a test phase. By introducing the 'Tracking & Tracing' system, it was possible to reduce the total error rate in production by 20 percent, and, as a result, to reduce the total throughput time of the gearboxes by 15 percent.

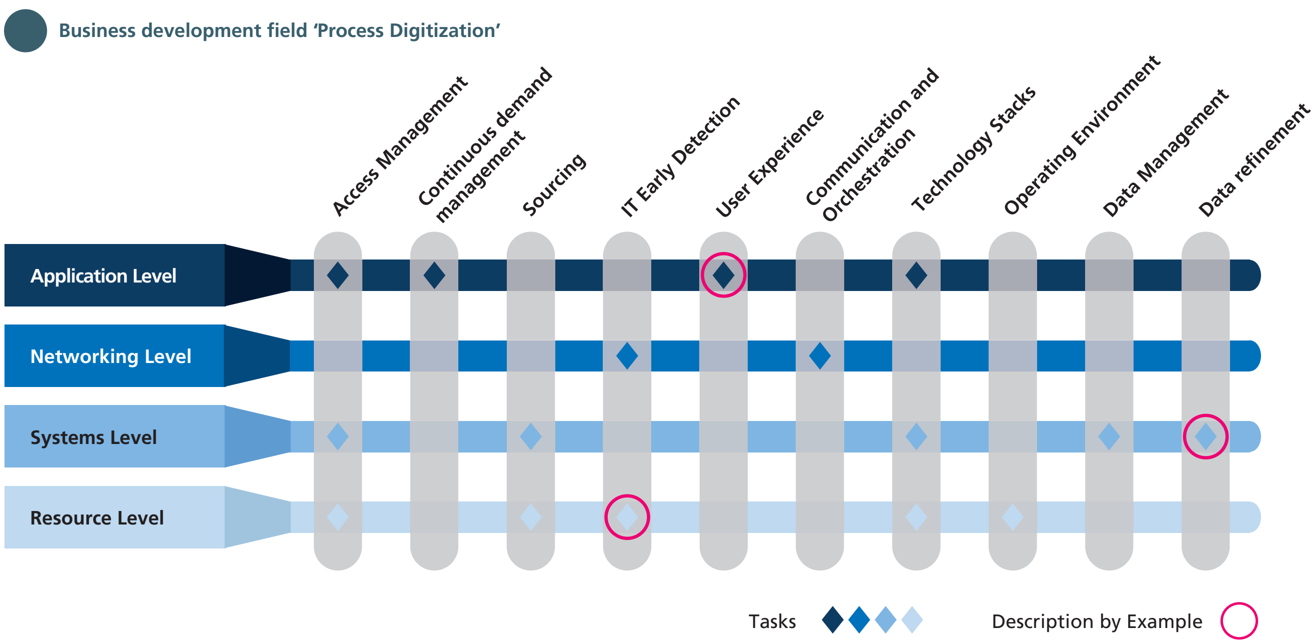


Figure 14: Relevant tasks for process digitalization through Tracking & Tracing

7 Case Study: Transparency in Production Processes Through Intelligent Machines

Initial Situation

A German manufacturer of button closure systems for the textile industry was faced with the problem that its punching machines occasionally produced faulty holes resulting in products which did not meet the customer's quality standards. The challenge for the manufacturer was to introduce suitable measures to reduce or avoid such quality defects and to increase the machine's processing quality in the long term. Due to a lack of transparency over machine usage in production, it was not possible to implement data-based measures to achieve these objectives. The machine was not capable of identifying mispunched holes and the production process did not provide any information about the frequency with which such quality defects occurred.

The implementation of a separate solution for automated data collection proved to be too complex, due to the confusing selection of numerous technological options and a lack of suitable IT systems. In addition, the manufacturer was not capable of designing and implementing the required IT infrastructure.

Objective

The aim of the project was to create a technological basis to enable the manufacturer to initiate precise, customer-centric product developments and thus consolidate its role as a leading supplier of high-quality closure systems in the textile market. It was therefore decided to further develop an existing machine product into an *Intelligent Product*, which is capable of providing insights into machine usage and production quality and, as a result, deliver a value-added service that creates customer loyalty and retention.

Approach

In the first step in the implementation of the digital architecture, the fields of action that belong to this business transformation field are detailed. Intelligent products, such as the intelligent punching machine developed in this project, are situated at the resource level of ADAM. However, in the implementation of intelligent products, all levels of ADAM have to be taken into consideration.

Business and functional fit was identified to be the key field of action at the application level. Its aim is to ensure that the IT infrastructure is capable of supporting the business objectives in the best possible way. This was particularly important in the realization of the intelligent punching machine, a project that served to ensure that the implemented applications succeed in creating added value for the manufacturer and its customers. For the customer, value is created through improved service and delivery performance, while the manufacturer gets added value by obtaining an improved, transparent picture of machine usage. In order to be able to offer tailored value-added services, it is essential to exactly identify the added value provided for those who are using the products. Only then can the functions of the IT infrastructure be optimally aligned with the products through the activities in the field of action.

At the networking level, the field of action of *field and usage data* was considered, among others. Here, it is key to create data models based on the identified use cases and thus to identify all data with relevance to implementing the planned value-added services, in the present case an analysis of the punching process. In this context, the field and usage data are to be specifically managed, since – in contrast to other data within the company – they have a different structure and are not always available immediately. Furthermore, decisions must be taken on how to refine these data to create maximum added value for the company and its customers.

In the data refinement field of action, data is extracted from various data sources within and outside the company. This is necessary to be able to analyze

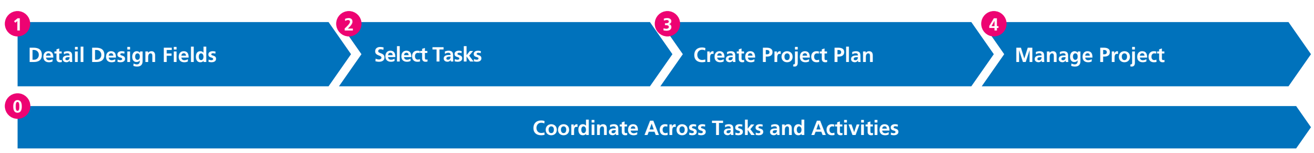


Figure 15: Approach to achieving transparency in manufacturing processes through intelligent products

the underlying cause of the mispunched holes and proactively to increase production quality by preventing such defects. This is achieved by establishing the necessary information flows between the different information sources. This makes it possible to identify which internal or external system can provide the data required for refinement and aggregation.

Subsequently, at the resource level, a suitable *sensor system* was selected with which to collect, the information identified in the other fields of action. With the help of *technology scouting,* the right measurement variables were identified at the machine. Using this data, the information required to analyze the causes of the defects in production and to assess overall production quality was generated.

Following the selection of tasks within the fields of action, a project plan for the realization of this business transformation field was drawn up. For this purpose, the tasks were prioritized and appropriately sequenced. In order to generate synergies in the execution of work packages, relevant interdependencies between the fields of action were taken into account.

For the realization of the project, an agile project management approach was chosen. The various tasks, especially in the areas of sensor technology, field and usage data, and data refinement, required a highly iterative development process. An agile approach within the chosen Agile-Stage-Gate process proved to be an ideal basis for successful project implementation. Modifications could be developed quickly and tested in the form of prototypes on the resulting intelligent punch machine. In addition, the gates were useful in achieving acceptance of deliverables and provided the necessary structure for the project.

Results

By using ADAM, it was possible to develop an intelligent punching machine in a highly targeted manner. The machine was equipped with the appropriate sensor technology to detect faulty punched holes and to be able to initiate quality assurance measures. The data acquired in the field was transferred to a platform of the manufacturer and connected with the necessary data from other systems. This platform was implemented by an external service provider as it was not possible to adequately implement the required functions using the existing IT infrastructure. This gives the manufacturer transparent insight to the performance of their systems and the quality level currently achieved. This information was made available to the client in dashboards integrated into the web-based platform. This also enabled the client to track the stock of blanks in the punch machines. The value-added service developed with the help of ADAM made it possible to automatically order new material should the stock fall below a certain level. In summary, the project enabled the manufacturer to perform a data-based analysis of the usage of its products and, as a result, to derive improvements to existing or new products on the basis of this information.

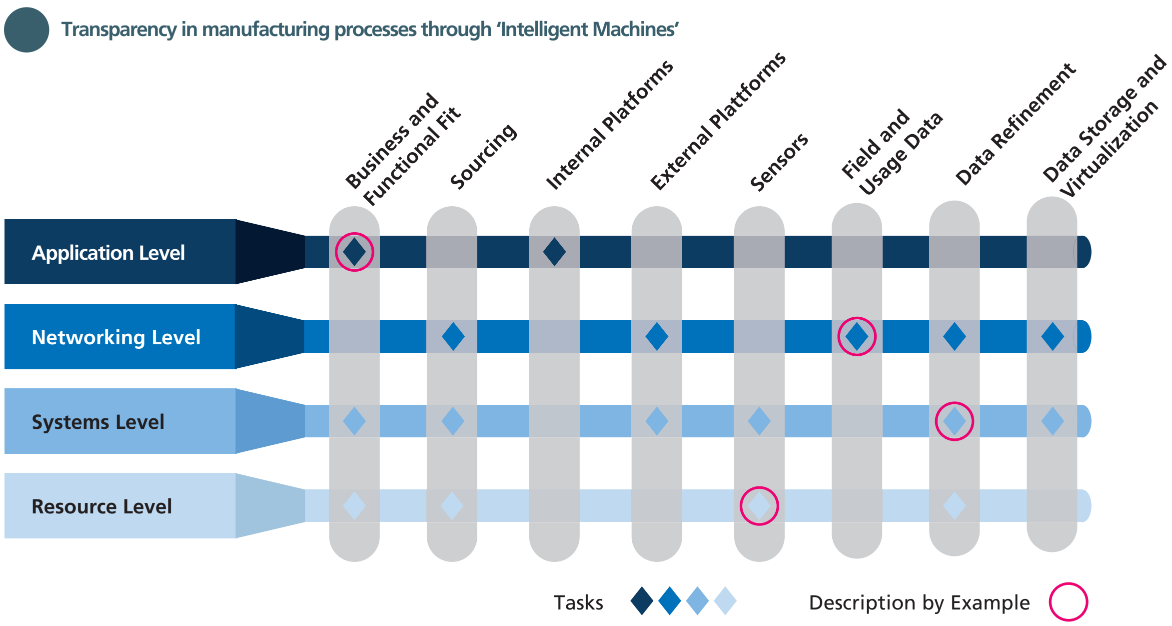


Figure 16: Relevant tasks for achieving transparency in manufacturing processes through intelligent products

8 Summary

Businesses today are fully aware of the significance of digital transformation, although not all sectors have been impacted by the changes that come with it to the same extent. The alignment of business processes and business activities with customer needs and requirements represents a decisive cultural and organizational change within companies. it is not sufficient, that executives embrace and employees and reflected in business activities, it must also be supported by a company's digital architecture. Those responsible for its design and implementation frequently lack the support they need, resulting in prototypical implementations only and fail to embrace a more holistic perspective. The reason for this is that the established reference architectures do not provide the necessary level of detail that is required for a more comprehensive approach.

The Aachen Digital Architecture Management framework was developed as a holistic framework especially for digitalization managers facing the challenges outlined above. Its main objective is to support the digital transformation of companies in a structured approach. The central elements of the model, the three architectural *views of organization, technology and data*, the fields of action of the digital infrastructure, the business transformation fields, and the cross-sectional topic of *information security*, provide those responsible for digitalization in companies with a hands-on approach to developing a digitalization strategy and to implementing the digital architecture. With ADAM, the needs of internal and external customers are always at the center of activities. The combination of digital infrastructure, business development, and customer-centricity constitutes a company's holistically conceived digital architecture, which in turn provides the basis for a successful and sustainable digital transformation.

To ensure that digitalization managers are provided with the right level of detail, the design levels of the digital infrastructure are based on an understanding that is widely accepted in science and practice. However, the detailing of the underlying fields of action provides a further depth and a granularity of description that demonstrates ADAM's practical applicability. This also applies to the area of business transformation. Taking customer needs into account, this model represents a modern approach to alignment. ADAM enables the value-creating interaction of customer centricity, business development, and digital infrastructure for building a digital architecture that forms the basis of the digital transformation of companies.

ADAM thus provides those responsible for corporate digitalization projects with the systematic support they need for managing digital transformation.

9 FIR – A Competent Partner in Practice

The Institute for Industrial Management, *FIR* for short, is a non-profit, intersectoral research and educational institution at RWTH Aachen University concerned with business organization and corporate development with the aim to establish the organizational basis for the digitally connected enterprise of the future. The institute supports companies and provides research, qualification programs and training in the fields of services management, business transformation, information management, and production management. As a member of the German Federation of Industrial Research Associations, FIR promotes research and development for the benefit of small, medium-sized and large enterprises. Since 2010, the managing director of FIR, Professor Volker Stich, has also been heading the *Smart Logistics Cluster on RWTH Aachen Campus*. The Smart Logistics Cluster is one of six initial clusters on the Aachen Melaten campus. More than 350 employees from academia and industry develop solutions on how products and information can be optimally connected in the digital world of tomorrow. In a completely novel form of collaboration between research and industry, the complex interrelationships in real-world production and IT environments can now be experienced.

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