Chapter 10
Architecting Digital Products and Services

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Abstract Enterprises are currently transforming their strategy, processes, and their information systems to extend their degree of digitalization. The potential of the Internet and related digital technologies, like Internet of Things, services computing, cloud computing, artificial intelligence, big data with analytics, mobile systems, collaboration networks, and cyber physical systems both drives and enables new business designs. Digitalization deeply disrupts existing businesses, technologies and economies and fosters the architecture of digital environments with many rather small and distributed structures. This has a strong impact for new value producing opportunities and architecting digital services and products guiding their design through exploiting a Service-Dominant Logic. The main result of the book chapter extends methods for integral digital strategies with value-oriented models for digital products and services which are defined in the framework of a multi-perspective digital enterprise architecture reference model.

Keywords Digital transformation · Digital products and services · Service-dominant logic · Value modeling · Digital architecture

10.1 Introduction

Data, information and knowledge are fundamental core concepts of our everyday activities and are driving the digital transformation of today's global society [12]. New services and smart connected products expand physical components by adding

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information and connectivity services using the Internet. Influenced by the transition to digitalization many enterprises are presently transforming their strategy, culture, processes, and their information systems.

Digitalization [24] defines the process of digital transformation, which is promoted by important technological trends: Internet of Things, artificial intelligence, cloud, edge and fog computing, services computing, big data, mobile systems, and social networks. The disruptive change of current business interacts with all information systems that are important business enablers for the digital transformation. Digital services and products amplify the basic value and capabilities, which offer exponentially expanding opportunities. Digitalization enables human beings and autonomous objects to collaborate beyond their local context using digital technologies. The exchange of information enables better decisions of humans, as well as of intelligent objects. Furthermore, social networks, smart devices, and intelligent cars are part of a wave of digital economy with digital products, services, and processes, which call for an information-driven vision [6].

The digital transformation deeply disrupts existing enterprises and economies. Digitalization fosters the development of IT systems with many, globally available and diverse rather small and distributed structures, like Internet of Things or mobile systems. Since years a lot of new business opportunities appeared using the potential of the Internet and related digital technologies, like Internet of Things, services computing, cloud computing, big data with analytics, mobile systems, collaboration networks, and cyber physical systems. This has a strong impact for architecting digital services and products integrating high distributed systems and services.

Unfortunately, the current state of art in research and practice of enterprise architecture lacks an integral understanding of an integral value and service perspective of design models connecting a digital strategy with a digital enterprise architecture for the digitalization of products and services. Our goal is to extend previous quite static approaches of enterprise architecture to fit for a flexible and adaptive digitalization of intelligent products and services. This goal shall be achieved by introducing new mechanisms for an integral design of digital products and services, considering a service-dominant logic perspective, for a value-oriented modeling approach as part of an effective digital architecture.

Our chapter focuses on a fundamental research question:

> How can a value-oriented digital architecture for digital products and services be modeled to support the open-world integration and management for a huge amount of dynamically growing micro-granular intelligent systems and services?

We will proceed as follows. First, we are setting the fundamental architectural context for digital transformation introducing digital products and services. We integrate fundamental perspectives and principles of the service-dominant logic for architecting digital products and services. Then we present our digital modeling approach for systematically defining value-oriented digital products and services in order to map digital business operating to digital composition models and digital architectures. Based on the target of digital architectures we are focusing on modeling micro-granular digital systems and services and provide insides to our methods and mechanisms for architectural decision management for multi-perspective digital architectures. Finally, we conclude in the last section our research findings mentioning also our future work.

10.2 Digital Transformation

New high-performance IT technologies are strategic drivers of the digital transformation. Digital transformation [21, 25] primarily concerns the formulation of a digital strategy and new digital business models geared to disruption. The most important transformations concern the transition from analog to digital platforms in a way that is focused on customer value.

For years we have been experiencing a hype about Digitalization, in which the terms digitization, digitalization and digital transformation are often confusingly used. The origin of the term digitalization is the concept of digitization. According to [8], there are four stages of digitization (Fig. 10.1). At the basic level of substitution, analog media are replaced by digital media, which is called digitization. Digitization doesn't replace the original analog information, but provides a digital copy of it. This first transformation level essentially represents the digital substitution of original analog representations, such as paperwork, in computer-based media in order to

Digitalization Level	Description	Transformation Type	Example
1. Substitution	Technology as a direct tool substitute, with no functional change	Digital Enhancement (1)	Scientific paper as pdf file
2. Augmentation	Technology as a direct tool substitute, with functional improvements	Digital Enhancement (2)	Enhanced pdf file with direct connectors to processes / tools
3. Modification	Technology allows significant task redesign	Digital Transformation (1)	Paper submission automatically triggers the subsequent review process
4. Redefinition	Technology allows creation of new tasks, previously inconceivable	Digital Transformation (2)	Digital platform and ecosystem of living scientific conferences, journals, and other assets with co-creating people and intelligent services

Fig. 10.1 Levels of digitalization: digital enhancement versus digital transformation

store, process and transmit them digitally. In this way, only the static information is digitized without functional change, while the process in this first transformation step remains the same as in the analog world.

The next stage of digital improvement is augmentation, where the digitized information consists of a combination of basic information and is complemented by functional improvements such as menus to activate associated processing steps. In a further transformative step, the modification of the processes opens up new possibilities for exchange and communication. The aspect of digital transformation by modification is based on functional extensions, which enables significant transformations of processing, e.g. process automation with digital technologies and reduced user interaction.

Digital transformation is broader than digitalization and usually involves a digital strategy at the beginning. Digitalization of business leads to digital business. This transformation of business is an important topic of digital change management enabling the digital transformation. Digitalization is the use of digital technologies and data to enable digital value propositions for customers and to improve business while expanding the revenue.

Finally, at the level of the highest redefinition (digitalization) completely new forms of interaction and structures become possible. At the highest level, the transformative redefinition enables new digital perspectives, e.g. through digital platforms and ecosystems, which were previously not possible. Many domains of social life are redefined by digital communication and social media platforms. Digitalization enables changes to new digital business models with expanded value perspectives for customers and improved revenue opportunities. Digitalization is therefore more about shifting processes to attractive high automated digital business operations and not just communication by using the Internet. The digital redefinition usually causes disruptive effects on business. Going beyond the value-oriented perspective of digitalization, digital business requires a careful adoption of human, ethical and social principles.

Considering close related concepts of digitization, digitalization and digital transformation [5] we conclude: Digitization and digitalization is about digital technology, while digital transformation is about the changing role of digital customers and the digital change process. We digitize information, we digitalize processes and roles for extended platform-based business operations, and we digitally transform the business by promoting a digital strategy, customer-centric and value-oriented digital business models, and an architecture-driven digital change.

Digital technologies change the way we communicate and collaborate for value co-creation with customers and other stakeholders, even with competitors. Digital technologies have changed our view on how to analyze and understand a magnitude of real-time accessible data from multiple perspectives. Digital transformation has also changed our understanding on how to innovate in global processes to architect and develop digital products and services faster than ever approaching for the best available digital technology and quality. Digitalization force us to look differently on value creation for and together with customers.

Five strategic domains define the focus of a digital transformation in [21]: customers, competition, data, innovation, and value. Most important strategical changes of customers in a digital business are: customers as dynamic network, two-way communication for co-creation, customers are key influencers, marketing to inspire purchase and loyalty, reciprocal value flows, and economies of value. Strategic changes also affect competitors, as: competition across fluid industries, blurred differentiation between partners and competitors, competitors cooperate in key areas (coopetition), key assets reside in outside networks, platforms and ecosystems with partners who exchange value, and winner-takes-all due to network effects. The strategic perspective on data in digital business can be described as: data is generated and processed in real-time, data provides valuable information, unstructured data is increasingly processable and valuable, value of data results from connected data across silos, data is a key asset for value creation. Digital innovation is promoted by: decisions based on testing and validating, testing of ideas is cheap and easy, experiments are conducted constantly by everyone, challenge of innovation is to solve the right problem, early and cheaply failures, focus on minimum viable prototype and fast iterations. Finally, the improved digital value perspective results from: value proposition defined by changing customer needs, uncover the next opportunity for customer value, evolve before you must to stay ahead, judge change by how it could create your next business, and stay always active and not looking for complacency.

10.3 Digital Products and Services

The digital transformation is the current dominant type of business transformation having IT both as a technology enabler and as a strategic driver. Digitized services and associated products are software-intensive [24] and therefore malleable and usually service-oriented [35]. Digital products are able to increase their capabilities via accessing cloud-services and change their current behavior.

In the beginning, digitization was considered a primarily technical term [32]. Thus, a number of technologies is often associated with digitization [35]: cloud computing, big data often combined with advanced analytics, social software, and the Internet of Things. New technologies such as deep learning are strategic enablers and strong related with advances in digitalization. They allow computing to be applied to activities that were considered as exclusive to human beings. Therefore, the present emphasis on digitalization become an important area of research.

New ways of interaction with the customer are enabled [14] by combining a product consisting of hardware and software with cloud-provided services. Current research suggests that different customers will use such devices for different use cases enabling new ways of triggering and interaction with business processes. An example is Amazon Alexa, in [30] and Fig. 10.2, that consists of a physical device with microphone and speaker e.g. Echo Dot, and services, called “Alexa skills”. The

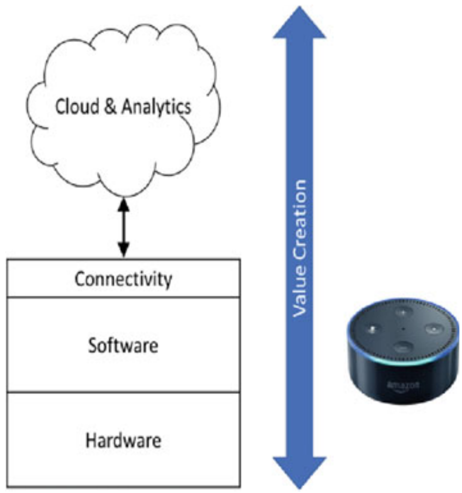

Fig. 10.2 Hybrid value creation for digital products

set of Alexa skills is dynamic and can be tailored to the customer's requirements during run-time. The lifecycle of digitized products is extended by the acquisition and decommissioning of services.

Our thesis is, that digitalization embraces both a product and a value-creation [24] perspective. Digitized products and services support the co-creation of value together with the customer and other stakeholders in different ways. First, there is a permanent feedback to the provider of the product. The internet connection of the digitized product allows to collect permanently data on the usage of the product by the customer. Second, the data provided by a large number of digitized products are able to provide new insights, which are not possible with data from a single device. Current research argues that digital products and services are offering disruptive opportunities [12] for new business solutions, having new smart connected functionalities.

Classical industrial products are static [24]. You can only change them to a limited extent, if at all. On the contrary, digitized products are dynamic. They contain both hardware, software and (cloud-)services. They can be upgraded via network connections. In addition, their functionality can be extended or adapted using external services. Therefore, the functionality of products is dynamic and can be adapted to changing requirements and hitherto unknown customer needs. In particular, it is possible to create digitized products and services step-by-step or provide temporarily unlockable functionalities. So, customers whose requirements are changing can add and modify service functionality without hardware modification.

Digital products [12] are able to capture their own state and submit this information into linked contexts. This is the basis for the so called servitization of products. Not a physical product, but a service is sold to the customer. The service usage is measured and lays the foundation for usage-based billing models. The provider can remotely determine, whether the product is still functional and trigger, where appropriate, maintenance and repairs. Evaluation of status information and analysis of the history of use of the product can be predicted when a malfunction of the product is probable. A maintenance or replacement of the product is performed before predicted data of failure. The data collected also provide information for a repair on the spot, so that a high first-time solution rate can be achieved. At the same time, storage can be improved in this way of spare parts. By this means, preventive maintenance can be implemented. Unscheduled stoppages can this way be significantly reduced.

Digital products also enable network effects [12] that grow exponentially with the number of participating devices. An increase in the number of digitized products increases the incentive for providers of add-on services and complementary skills. At the same time this increase the attractiveness for further digitized products. In summary, an exponential growth can be achieved. Therefore, significant first-mover advantages exist. Network effects emerge not only for the functionality but also for the analytical exploitation of data collected by the digitized products. These effects are called network intelligence [12]. By bringing together data from many devices and not only single devices, trends can be detected much earlier and more accurately. Further improvements can be achieved by linking data from different sources, also external ones. In this way, it is possible to establish correlations that would not have been possible considering data from a single device. This effect increases with the number of devices.

Digital products and services [24, 14] become part of an information system, which accelerates the learning and knowledge processes across all products. The manufacturer can win genuine information about the use of the product. Important information for the development of new products can be obtained in this way. Therefore, a number of other beneficial effects can be achieved as network optimization, maintenance optimization, improved restore capabilities, and additional evidence against the consideration of individual systems.

Traditional products were created with a tayloristic view in mind, that emphasized the separation of production and consumer in order to enable centralized production and thus scaling effects. Now, the co-creation approach of service-dominant logic [28, 29] can be implemented because of a persisting continuous connectivity of digital products with the manufacturer. The consumer converts dynamically to be co-producer. Platforms are complementary to products, which cooperate via standardized interfaces.

10.4 Principles of Service-Dominant Design

The Service-Dominant (S-D) logic [28, 29] is a fundamental service-centered approach and to some extend opposite to the traditional goods-centered paradigm for large parts of the traditional business. The principal idea is that all economic exchanges can be defined as service-to-service exchanges considering also associated real or digital products. The origin of the service-dominant logic relies on ten fundamental axioms [28] for defining service businesses, including digital services and products. The origin of service-dominant logic was slightly extended through modifications and additional premises [29] to a body of five axioms and eleven foundational premises.

Fundamental premises of the S-D logic [28, 29] promote a clear service perspective and above all the exchange of services based on a network-centered actor for actor generalization, predicating the first axiom: a service is the fundamental basis of exchange, and deriving the indirect exchange as fundamental basis of exchange. S-D logic relies on decoupling of information from related physical forms. Goals provide just distribution mechanisms for service provisioning, which implies that all economies are service economies. Operant resources, like knowledge and people, are the fundamental source of strategic benefit.

The second axiom is that the value is co-created by several actors, including the beneficiary, e.g. the customer, but also the service provider. The next fundamental understanding of S-D logic in the third axiom is that actors are resource integrators, but cannot deliver value by themselves, but can participate in the creation of value propositions, and promoting that a service-centered view should be beneficiary-oriented. All social and economic actors are resource integrators, not only by providing a service but also integrating various even external resources.

The last two axioms postulate that value is always determined by the beneficiary, and value co-creation is coordinated through actor-generated institutions and institutional arrangements. Institutions are in this sense human-defined rules, norms, and beliefs that enable and constrain actions.

Through exploiting the base of service-dominant logic and by means of design research a focused set of four design principles for business-model-based management methods was elaborated in [3]. This service-dominant perspective of inspiring design principles motivates and sets the base for our digital service-oriented design methodology. These design principles not only apply to capture the general guidance and methods for designing digital services and products, but also to illustrate their organizational implications.

The first principle defines the proactive base for an ecosystem-oriented management by positioning the orchestration tasks for specific actors in a service ecosystem, defining an organization's role as focal orchestrator in the service ecosystem, and for sharing the risks, costs, and revenues among multiple actors.

The second principle about a technology-based management defines responsibilities for using digital infrastructures, for decoupling informational assets from products and facilitate product exchange, and for driving value creation through digital channels.

Principle three about mobilization-oriented management postulate the mobilization of operand resources, like knowledge and capabilities, which are the fundamental source of strategic benefit, and further uncovering and utilizing internal knowledge.

The last principle about co-creation-oriented management demands for customer involvement, to reflect on co-creation through customer journey as dynamic interaction, and for recalibrating service bundles to optimize customer's experience.

In addition to methods for digital business modelling, we also cover theoretical principles for the design of a digital infrastructure, which are part of a theoretical framework [4]: structural integrity, elasticity, ambidexterity, connectivity, generativity, and modularity.

Structural integrity of the digital infrastructure is the fundamental basis for control and stability. The digital infrastructure aims at stabilization in order to use the actor-to-actor network. Elasticity of a digital infrastructure supports autonomy and change. The digital infrastructure is looking for dynamism to open new ways of resource integration that adapt to external stimuli. Different ways of organizing actors should be suitable for innovation opportunities.

The ambidexterity of the digital infrastructure is the basis for reconciling integrity and elasticity, seeking a balance between structural integrity and elasticity. A digital infrastructure should enable both control and stability as well as autonomy and change. The connectivity base is the fundamental mechanism of the structural integrity of the digital infrastructure. The connectivity of the digital infrastructure reduces communication costs and increases its speed and reach. Generativity is the basic mechanism for the elasticity of the infrastructure, generating new results, structures and behaviors. Modularity is the basic mechanism of ambidexterity of the digital infrastructure to increase the separation and recombination of digital components.

10.5 Value-Oriented Architecture

The business and technological impact of digitalization [12] has multiple aspects, which directly affect digital architectures of service-dominant digital products and services. Unfortunately, our current modeling approach for designing proper digital service and product models suffers from having many uncontrolled diverse modeling approaches and structures, where value-orientation of integral composed services and systems is only partially fulfilled. High quality digital models should follow a clear value and service perspective.

But today, we currently have no sound value relationship from digital strategies, to the resulting digital business modeling, and subsequently to a value-oriented enterprise architecture, which today often has seldom proper aligned service and product model representations. The core idea of the present contribution and current paper is to present and discuss a new introduced integral value-oriented model composition approach by linking digital strategies with digital business models for digital services and close aligned products by means of an extended multi-perspective digital enterprise architecture model.

Value is commonly associated with worth and aggregates potentially required categories like worth, importance, desirability and usefulness. The concept of value is important in designing adequate digital services with their associated digital products, and to align their digital business models with value-oriented enterprise architectures. From a financial perspective the value of the integrated resources and the price defines the main parts of the monetary worth.

A current conceptualization of value as a service-based view is offered by [27, 18] considering a conceptual framework of service-dominant (S-D) logic [28, 29] and its service-ecosystem perspective. The distinction between the concepts of value-in-use and value-in-exchange dates back to the antiquity and continue to influence our today's value view. Since the work of Adam Smith and the development of economic science the value-in-exchange as a measure for price a person is willing to pay for a service or a product moved to the forefront. Smith recognized the value-in-use as the real value and value-in-exchange as the nominal value.

We present our view of an integrated value perspective combined with a service perspective in Fig. 10.3. Today, we are experiencing a starting set of now not well consolidated digital strategy frameworks, like in [6, 23] which are loosely associated with traditional strategy frameworks.

The digital marketing discipline nowadays shifted to a nominal use of the value perspective [27] considering customer experience and customer satisfaction as important value-related concepts. Characteristics of value modeling for a service ecosystem were elaborated by [3]. Value has important characteristics: value is phenomenological, co-created, multidimensional, and emergent. Value is phenomenological means that value is perceived experimentally and differently by various stakeholders in the varying context within a service ecosystem. Value is co-created though the integration and exchange of resources between multiple stakeholders and related organizations.

Value is also multidimensional, which means that value is aggregated up of individual, social, technological and cultural components. Value results as emergent value from specific manifestations of relationships between resources and resource combinations. Therefore, the resulting real value cannot be determined ex-ante. Value propositions are value promises for a typical, but not exactly known customer at design time and should be realized later when using these digital services and associated products.

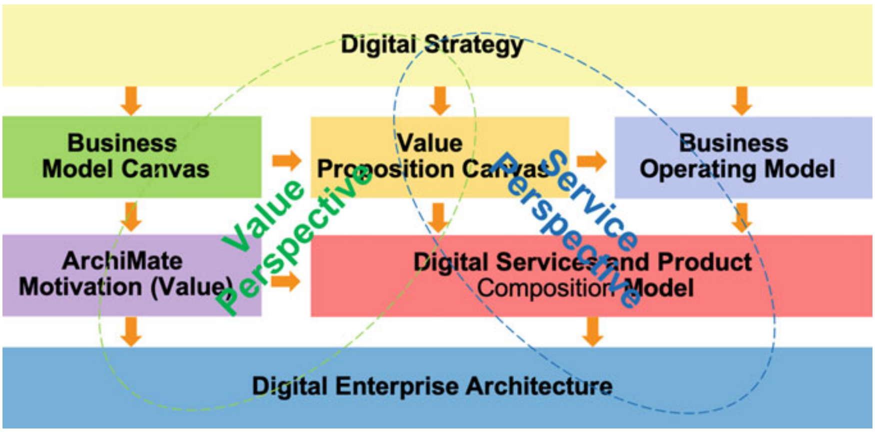

Fig. 10.3 Value and service perspective of service-dominant logic

Our starting point is a model of the digital strategy, which gives the digital modeling direction and sets the base and a value-oriented framing for the business definition models, with the business model canvas [19], and the value proposition canvas [20]. Having the base models for a value-oriented digital business we map these base service and product models to a digital business operating model. An operating model [22] strategically defines the necessary level of business integration and standardization for delivering services and products to customers. From the value perspective of the business model canvas [19] results suitable mappings to enterprise architecture value models [13] with ArchiMate [17]. Finally, we are setting the frame for the systematic definition of digital services and associated products by modeling digital services and product compositions following semantically related composite patterns.

We have integrated the Business Model Canvas [19] into our comprehensive digital modeling framework to uniformly describe the digital business model respectively to enable a first conceptual modeling of digital products and services as well as a firm's or product's value proposition, infrastructure, customers, and finances. The Business Model Canvas was initially proposed by Alexander Osterwalder [19] and is based on his PhD-Thesis on Business Model Ontology. Central part of the Business Model Canvas [19] is the description of offerings based on value propositions. First, the Business Model Canvas indirectly describes offerings giving priority to the value propositions to meet the needs of its customers. A company's value proposition is what distinguishes it from its competitors.

The value proposition provides value through various elements such as newness, performance, customization, "getting the job done", design, brand/status, price, cost reduction, risk reduction, accessibility, and convenience/usability. The value propositions may contain demanded or supposed business requirements which can be related to qualitative or quantitative descriptions. The Value Proposition Canvas [20] extends the Business Model Canvas [19] to conceptualize and exactly define digital services and products for customers which are connected to the perceived value of digital products or services, and the potential product/market context. The value proposition from the Business Model Canvas [19] is projected to the Value Proposition Canvas [20] and divided into three perspectives as products and services, creators of profit and painkillers, which are associated to the customer segment aspects, as customers jobs, profits, and pain.

The primary motivation of successful organizations is to provide value to one or more stakeholders, typically considering value for clients at first. This includes the modeling of value creation, capturing, and value delivery by using discrete value producing tasks. Classical concepts of value chains and value networks are seminal for lean value streams and for applying the current fundamental TOGAF [16] series guide on value streams [18]. Value chain modeling focuses on an economic perspective while value networks primarily shows participants involved in creating value.

Value streams, as in [18], model an end-to-end value view of value-adding activities as value stream stages from the customer's or stakeholder's perspective. Therefore, value streams enable digital business models which are closer to the definition and not the implementation of organizational core activities. Value streams are defined as compositions of value stages from the value-perspective for the addressed stakeholders.

From using value stream models and mappings we can summarize important benefits. Value stream models are the base for decision making helping to envision and prioritize the impact from strategic plans, for managing the stakeholders' engagement, and supporting the deployment of new business solutions. Business capabilities enable value stages and value streams, which are focused to the viewpoint of customers. Value streams provide a framework for better requirement analysis, case management, and supports modeling of digital services. Finally, value streams are focused on how business value is achieved for specific stakeholders, particularly for customers.

10.6 Digital Enterprise Architecture

Enterprise Architecture Management [11], as today defined by several standards like [16] and [17] uses a quite large set of different views and perspectives for managing current IT. An effective architecture management approach for digital enterprises should additionally support the digitalization of products and services [24] and be both holistic and easily adaptable [35]. Furthermore, a digital architecture sets the base for the digital transformation enabling new digital business models and technologies that are based on a large number of micro-structured digital systems with their own micro-granular architectures [34], like IoT [26, 1, 33] mobile devices, or with Microservices [2, 15].

We are extending our service-oriented enterprise architecture reference model for the context of digital transformation with micro-granular structures and considering associated multi-perspective architectural decision-making [9] models, which are supported by viewpoints and functions of an architecture management cockpit. DEA - Digital Enterprise Architecture Reference Cube provides an architectural reference model [35] for bottom-up integrating dynamically composed micro-granular architectural models [34] (Fig. 10.4). DEA for architecting digital products and services is more specific than existing architectural standards of architecture management, like in [16, 17]. The bottom-up composition of living architectural models fundamentally extends existing quite static frameworks from practice.

DEA provides today with our current research ten integral architectural domains for a holistic architectural classification model, which is well aligned to embed also mirco-granular architectures for different digital services and products. DEA abstracts from a concrete business scenario or technologies, because it is applicable for concrete architectural instantiations to support digital transformations independent of different domains. The Open Group Architecture Framework TOGAF

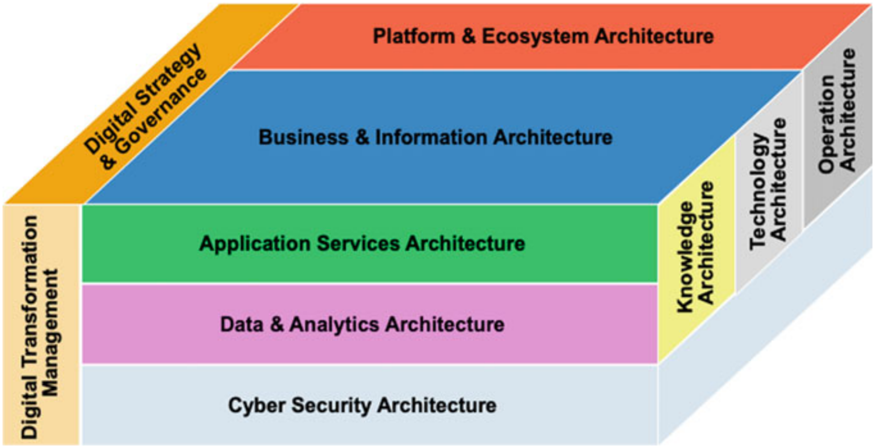

Fig. 10.4 Digital enterprise architecture reference cube

[16] provides the basic blueprint and structure for extended service-oriented enterprise architecture domains. Metamodel extensions are additionally provided by considering and integrating ArchiMate Layer models from [17].

DEA extends by a holistic view the metamodel-based extraction and bottom-up integration for micro-granular viewpoints, models, standards, frameworks and tools of a digital enterprise architecture model. DEA frames these multiple elements of a digital architecture into integral configurations of a digital architecture by providing an ordered base of architectural artifacts for associated multi-perspective decision processes.

Metamodels and their architectural data are the core part of the enterprise architecture. Enterprise architecture metamodels [11, 17] should enable decision making [10] as well as the strategic and IT/business alignment. Three quality perspectives are important for an adequate IT/business alignment and are differentiated as: (i) IT system qualities: performance, interoperability, availability, usability, accuracy, maintainability, and suitability; (ii) business qualities: flexibility, efficiency, effectiveness, integration and coordination, decision support, control and follow up, and organizational culture; and finally (iii) governance qualities: plan and organize, acquire and implement deliver and support, monitor and evaluate (e.g., [31]).

Digitalization promotes massively distributed systems, which are based on the development of IT systems with many rather small and distributed structures, like Internet of Things, mobile systems, cyber physical systems, etc. Additionally, we have to support digitalization by a dense and diverse amount of different service types, like microservices, REST services, etc. and put them in a close relationship with distributed systems, like Internet of Things. The change from a closed-world modeling perspective to more flexible open-world composition and evolution of system architectures defines the moving context for adaptable systems, which are essential to enable the digital transformation. This has a strong impact for architecting digital services and products. The implication of architecting micro-granular systems and services considering an open-world approach fundamentally changes modeling contexts, which are classical and well defined by quite static closed-world and all-times consistent and less complex models.

The Internet of Things (IoT) [1, 26, 33] connects a large number of physical devices to each other using wireless data communication and interaction based on the Internet as a global communication environment. Additionally, we have to consider challenging aspects of the overall software and systems architecture to integrate base technologies and systems, like cyber-physical systems, social networks, big data with analytics, services, and cloud computing.

The Internet of Things, supports smart products as well as their production enables enterprises to create customer-oriented products in a flexible manner. Devices, as well as human and software agents, interact and transmit data to perform specific tasks as parts of sophisticated business or technical processes. The Internet of Things embraces not only a things-oriented vision [1] but also an Internet-oriented and a Semantic-oriented one. A cloud-centric vision for architectural thinking of a ubiquitous sensing environment is provided by [26].

Microservices and Microservices Architectures (MSA), as in [2, 15], is considered to be an important enabler for the digital enterprise and the digital transformation. Software developing enterprises have switched to integrate Microservice architectures to handle the increase velocity. Therefore, applications built this way consist of several fine-grained services that are independently scalable and deployable. The fast-moving process of digitalization demands flexibility to adapt to rapidly changing business requirements and newly emerging business opportunities.

Microservices addresses our second fundamental use-case for micro-granular architectures, which are developed and operated in an open-world. The fundamental concept of architecture is defined as structure of components, their inter-relationships, together with principles and guidelines for governing their design and evolution. The open-world approach fundamentally changes the rules of engineering and management by following a high distributed and globally metaphor for the new setting of a digital business operating model. This bottom-up tailored digital operating model changes the perspective of a classical top-down oriented enterprise architecture.

Microservices should be designed to be self-contained by integrating with specific needed platform and infrastructural elements. Microservices does not require a large pre-existing infrastructure. As exemplified by DevOps [15], Microservices support processes of Continuous Development (CD) in small environments and Continuous Integration (CI). Additionally, Microservices should also naturally support resiliency and scalability in both cloud and on-premise environments.

Architecture governance, as in [31], defines the base for well aligned management practices through specifying management activities: plan, define, enable, measure, and control. Digital governance should additionally set the frame for digital strategies, digital innovation management, and Design Thinking methodologies. The second aim of governance is to set rules for a value-oriented architectural compliance based on internal and external standards, as well as regulations and laws. Architecture governance for digital transformation changes some of the fundamental laws of

Fig. 10.5 Example: enterprise architecture cockpit

traditional governance models to be able to manage and openly integrate a plenty of diverse micro-granular structures, like Internet of Things or Microservices.

To effectively support architecture managers for navigation, interaction and decision support during knowledge intensive management activities in a complex architectural space we have adopted the idea of a Decision Support System (DSS) [10], as in Fig. 10.5, which gives the idea of managing decisions by navigating using an enterprise architecture cockpit [9, 7].

A cockpit presents a facility or device via which multiple viewpoints on the system under consideration can be consulted simultaneously. Each stakeholder who attends a cockpit meeting can utilize a viewpoint that displays relevant information. Stakeholders can leverage views that fit the particular role, like application architect, process owner or infrastructure architect.

The viewpoints are applied simultaneously and are linked to each other showing multi-perspective architectural dependencies and the impact of change. Changes in one view are pointing to updates and dependencies in other views as well.

Jugel et al. [10] have elaborated a collaborative approach for decision-making for EA management. They identify decision making in such architectural exploration environments as a complex knowledge-intensive process, which strongly depends on the participating stakeholders. Therefore, the collaborative approach presented is based on the methods and techniques of adaptive case management (ACM).

10.7 Conclusion

Based on our fundamental research question we have first set the context proceeding from digital transformation to a systematic value-oriented digital product and service modeling according the service-dominant logic. To be able to support the dynamics of digital transformation with flexible software and systems compositions we have leveraged an adaptive architecture approach for open-world integrations of globally accessed systems and services with their local architecture models.

We contribute to the literature in different ways. Looking to our results, we have identified the need and solution mechanisms for a value-oriented integration of digital strategy models through suitable digital business models up to models for service-dominant products as part of a value-based digital enterprise architecture. To integrate micro-granular architecture models from an open-world we have extended traditional enterprise architecture reference models and enhanced them with state of art elements from agile architectural engineering to support the digitalization of products, services, and processes. This is a major extension of our seminal work on reference enterprise architectures, to be able to openly integrate through a continuously bottom-up approach a huge amount of global available and heterogeneous micro-granular systems, having their own local architectures.

Strength of our research results from our novel approach of integrating a digital strategy with digital business operating models for architecting flexible compositions of digital products and services. Limits are still resulting from an ongoing validation of our research and open issues in managing inconsistencies and semantic dependencies.

Future research will cover mechanisms for flexible and adaptable integration of digital architectures. We are working to extend human-controlled dashboard-based decision making by AI-based intelligent systems for decision support, as well as for architectural data and model analytics with semantic representations combined with deep learning mechanisms.

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