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► **To cite this version:**

David Görzig, Thomas Bauernhansl. Service Capability Ontology. IFIP International Conference on Advances in Production Management Systems (APMS), Sep 2021, Nantes, France. pp.361-368, 10.1007/978-3-030-85914-5_38 . hal-03897846

HAL Id: hal-03897846

<https://inria.hal.science/hal-03897846>

Submitted on 14 Dec 2022

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Service Capability Ontology

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Abstract. Digitization is transforming previously physical products into holistic product-service systems which open up opportunities for new business models. But to achieve an excellent customer experience with them, a use case-specific configuration of the extensive product-service systems is necessary. One possible approach for the efficient implementation is to modularize the systems. In digital product-service systems, these modules require a holistic view that includes physical and digital resources as well as processes and people. The construct of capability might be a suitable framework to define such modules purpose-based and to manage the configuration. However, capabilities are not sufficiently defined in the literature and are, therefore, hardly ever used in practice. The aim of this paper is to create a common understanding of the term capability in the context of product-service systems with the help of an ontology.

Keywords: Product-service systems, digitization, capabilities.

1 Introduction

For several years now, digitization has been extensively changing industries. With a simplified access to information, the focus of business models is shifting from products towards customized services that maximize customer experience and open up new sources of revenue for mechanical engineering. [1] However, due to their deep integration into customer processes, the resulting product-service systems are much more extensive and dynamic. With each new business relationship, providers need to reconfigure the product-service systems to customer requirements. In order to manage the required changes efficiently, service-based business models could be designed modularly. In addition to software, such a module should include also physical resources such as people and machines as well as processes. Capabilities can provide a starting point for this by encapsulating enterprise components as a purpose-driven system [2]. Although capabilities are becoming increasingly important, there is no uniform definition of the term in the literature [3]. Thus, capabilities are not applicable in business practice today. The aim of this paper is to present an approach for the flexible design and adaption of service-based, digital business models with the help of capabilities. Therefore, a common understanding of capabilities by means of an ontology is needed. As a framework for this paper, the Knowledge Engineering Methodology of Noy and McGuinness has been selected. [4] Accordingly, the domain digital product-service systems is determined in Chapter 2. In Chapter 3, existing capabilities definitions are

examined and important components of capabilities are derived. In Chapter 4, classes for service capabilities are defined and assigned relations.

2 Domain of Digital Product-Service Systems

Starting point of digital product-service systems is the development towards smart and worldwide connected products that enable new data-driven business models [1]. Digitization thus adds an information-based service component to previously purely physical products and creates product-service systems. However, services are fundamentally different in their nature from physical products. Services can be defined as the application of resources through deeds, processes, and performances for the benefit of others or oneself [5]. They are much broader in scope and more dynamic than physical products. To better understand the resulting changes in business models and to derive what is necessary for their modular description, a deeper examination of service-based business model components is necessary. According to Gassmann, a business model consists of the four views “who”, “what”, “how“ and “value” [6].

First step is the analysis of the “who”. A service is a cooperative process in which value is created through consistent orientation and adaptation to a specific context of use. [7] The term cooperative indicates the emergence of ecosystems. These contain a task-oriented and in consequence short-term joint value creation of provider, customer und additional partners via common institutional logics. Technically, the required rapid adaption of the ecosystem to a specific task and context is based on the application of platforms that provide standards for cross-company collaboration [8]. In summary, the question of "who" becomes far more short-term and encompasses actors, context, their common goal and how they interact. The second question focuses on what is the value proposition. Customers no longer purchase goods but rather solutions to problems in their individual context. Physical goods are just tools or distribution mechanisms for a service. Companies are not exchanging outputs anymore but performance. Providing the appropriate resources embedded in processes is the key to generate performance. [8] As customers become part of the value chain, their resource base rapidly changes. In addition, new technologies such as smart sensors, interfaces and platforms need to be taken into account. Thus, the "how" includes the resources of the actors and the processes in which they are applied. A particularly important issue is the transfer of value. By shifting to services, value is measured in a new way. Instead of focusing on pure output, the focus is on performance, which leads to an improved customer experience. It is no longer charged per product, but per customer benefit in pay-per-x models. For this purpose, it is necessary to be able to measure the customer benefit.

3 State of the Art in Capabilities Research

Following the identification of the relevant properties of digital service systems, the concept of capability is examined from five different perspectives. Based on this, the relevant elements of a capability are derived.

3.1 Concept of Capability in Common Language and Philosophy

According to the Oxford English Dictionary, the term capability can be defined as the ability to do something [9]. To be capable originates from the Latin word *capabilis* which means to be susceptible to something [10]. The FrameNet project offers a semantic description of the capability concept [11]. It defines capabilities as the preconditions that an entity has to meet in order to participate in an event. Further features for the characterization of capabilities are external circumstances, the degree and frequency of fulfillment of the preconditions, the status of the capability, the explanations for the existence of the capability, the relevant features and roles of the entity as well as the temporal determination of the event. Historically, Aristotle analyzed the concept in his ninth book of *Metaphysics* [12]. He refers to capabilities as the principle for measurably changing something else or oneself. Thus, they form the starting point of a causal chain. The basis for the emergence of capabilities are the characteristics of their carriers which produce certain effects under certain external circumstances. It can be distinguished between an active capability – being able to change something – and a passive capability – being able to be changed. While Aristotle focuses on the process of change and its results, FrameNet concentrates on the properties of the entities. Both approaches complement each other well and show overlaps in the consideration of boundary conditions.

3.2 Capabilities in Military

In the field of military planning, capabilities are applied as a reaction to the increasingly dynamic threat situation. By helping to overcome the need to consider fixed scenarios and instead focus on the objectives, they increase the flexibility of the armed forces in unexpected situations [13]. Capabilities are defined as the ability to achieve a desired operational effect in a specified context for a certain time frame during a mission [14]. The operational effect represents the target state that has to be achieved to successfully encounter a threat and complete a mission [15]. The previously defined context includes the entire spectrum of possible situations and is described by scenarios, conditions, locations and threats. [13] The time frame defines how quickly capabilities should be ready and how long they should be sustained. Capabilities are generated by combining building blocks such as personnel, material, training, infrastructure, and management into an interlocking system. [14] The building blocks differ by country.

3.3 Capabilities in Information Systems

Capabilities in enterprise architecture (EA) are based on military capabilities. EA defines capabilities as the ability and capacity of a company to achieve a specific purpose or outcome in a certain context. Ability refers to the available individual competencies to achieve a goal. Capacity refers to the availability of resources such as people, money and tools. [16] Capabilities describe what a company does to create customer value [17]. Therefore, they encapsulate resources, roles, processes, context and information. Moreover, capabilities are described as non-redundant, stable over time, hier-

archical and combinable [3]. The CaaS project identifies three groups of capability elements [16]. Enterprise and capability modeling contains business goals, KPI, processes and resources in order to develop generic solutions that can be reconfigured according to the context. Secondly, the context represents the situations in which the solutions are used. Capability delivery patterns are the third area. They describe best practice solutions for achieving business goals in a defined context.

The Capability Maturity Model Integration (CMMI) presents another way of applying capabilities [18]. CMMI is a framework that supports the development of software and products. For this purpose, it has five maturity levels that contain several predefined process areas. The progress in each process areas is tracked based on specific goals with the help of the four capability levels incomplete, performed, managed and defined. In contrast to the other approaches presented, CMMI is much more specific and focused on development processes.

3.4 Strategic Business Planning

The concept of organizational capability is deeply rooted in the resource-based view of strategic business planning. The aim of this concept is to explain competitive advantages [19]. Organizational capabilities enable an organization to repeatedly perform an activity according to an intended and specific purpose [20]. They represent a tool for organizations to configure their resources [21]. Organizational capabilities can be divided into operational and dynamic capabilities. Operational capabilities enable an organization to solve current operative problems without change [20]. Therefore, they encapsulate routines and resources company-specific [21]. Routines are activities that are executed in a reproducible and reliable manner [20]. Resources are everything to which a company has direct or indirect access. They are divided in tangible (machines, tools, ...) and intangible (knowledge, leadership, skill, brands, ...) resources [21]. Dynamic capabilities enable a company to change its operational capabilities [20]. Through these capabilities, companies can integrate, build and reconfigure internal and external competencies to adapt themselves to a rapidly changing environment. This results in innovative competitive advantages [22].

3.5 Manufacturing

Operations management uses capabilities to plan manufacturing systems in an automated manner. Contributions in this field of research usually use the term skill. These are elementary, solution-neutral functionalities of resources which are described by parameters and which are independent of hardware and operating principles [23]. By linking several skills so-called composite capabilities are created [24]. The BaSys project adds the goal to the capability definition in order to trigger an effect in the physical or virtual world. This effect is described as the change of property values of objects by the resource [25]. Composite capabilities can be described by different components. At their core, they consist of a sequence of elementary skills that are steered by a control flow. The overall composite capability system communicates with its environment via input and output parameters and uses transformation functions to convert them into an

understandable form for the elementary capabilities. Templates allow the elementary capabilities to be assigned to resources. Mechanical connections describe physical and spatial relationships [23].

Further capability types in operations management are the machine and the process capability in quality management. A machine capability describes the ability of a machine to continuously produce a certain product quality. Process capability extends the term to the entire manufacturing process.

3.6 Discussion of the Relevant Capability Classes

All presented disciplines use capabilities in slightly different ways. However, there are great similarities in the definitions. Capabilities are hierarchical, stable over time, and non-overlapping. As illustrated in table 1, they have very similar building blocks.

Table 1. Elements of Capabilities

Approach	Purpose	Effect (Change)	Resources act. / pass.	Process	Context	Time	Inter- faces
3.1 FrameNet	-	-	x / -	x	x	x	-
3.1 Aristotle	x	x (x)	x / x	-	x	-	-
3.2 Military cap.	x	x (x)	x / x	x	x	x	x
3.3 EA cap.	x	x	x / -	x	x	-	x
3.3 CMMI	x	-	- / -	x	-	-	-
3.4 Res.-based view	x	x	x / -	x	-	-	-
3.5 Manufacturing	-	x (x)	x / x	x	-	-	x
3.5 Machine cap.	-	x	x / -	x	-	-	-

First element of most capabilities is the purpose. This is a superior goal to be achieved through the application of one or more capabilities. In military, for example, a mission is accomplished with the help of capabilities. In strategic planning, competitive advantages are generated. The purpose is achieved by attaining effects. An effect is a measurable change of the target object. Aristotle describes e.g. the healing of a patient with the help of a doctor's capabilities. In manufacturing, the properties of an object are changed. To achieve the effect, resources are applied in processes. Resources are tangible and intangible assets that are limited. A distinction can be made between active resources, which create change, and passive resources, which are changed. The changes are carried out in a specific context and time period. The context includes everything the provider of the capability cannot influence like the place or external conditions. The basis for the correct execution of a capability is the provision of the required information through interfaces. In the further course, capabilities will be defined as the ability of a system of resources to change itself or another system of resources in a defined context and timeframe in order to achieve a superior objective.

4 Structure of a Service Capability Model

In their basic definition, services and capabilities are very similar. While services are about the use of resources for the benefit of oneself or someone else, capabilities focus on changing the resource base of oneself or someone else for a higher objective. Due to the high degree of congruence, it seems possible to apply capabilities as a framework for the description of services and the business models associated with them. Due to the hierarchical structure and long-term orientation of capabilities, business models can be built up modularly. To map the capability components to the requirements of services as well as to uncover gaps, the classification according to Gassmann is applied again [6].

In order to assign service-based business model and possible capabilities, the question of "who" is asked first. Capabilities are deployed between at least two actors. The first actor uses its resource system to change the resource system of the second actor. Characteristic features to describe the who are the underlying purpose as well as the interfaces between the actors provided for its realization. Furthermore, the context and time frame of the change need to be mapped. The context consists of different context elements, each of which can be described by a measured value. The what is the starting point for the modularization of business models. By using the construct effect, capabilities allow the purpose to be decomposed into solution-neutral building blocks. An effect can be achieved through different capabilities. Effects can be described as measurable and repeatable changes of a resource base in a specific context and time frame. A maturity level for each effect can be tracked. The how includes the specific solution and is described by the resources applied in processes. Resources might be people, software, hardware, information, materials, energy, infrastructure or intangible assets. Resources are described by their names, properties, interfaces, and capacity. Ultimately, however, the specific properties of these resources are responsible for the execution of processes and thus for the application of a capability. Each property is applicable through one or more interfaces that might be physical, digital or a human-machine interface. Adjustments to effects are initially made by replacing full capabilities. If no suitable capability is available in the ecosystem, the resources and processes of existing capabilities can be adapted. The result is a new capability with a lower maturity level. The last field is the description of values. So far, capabilities are not associated with costs and a benefit in the literature. Because capabilities define a resource system in a purpose-oriented way. This is generally possible. During the execution of processes, costs are incurred that are offset by the benefits to the benefiting actor. These benefits are also the key performance indicator for the billing of pay-per-x business models. Alternatively, single effects may be used. Figure 1 summarizes the characteristics of capabilities in an ontology. It shows the most important elements of capabilities and assigns them to the areas of a business model. By proceeding step-by-step through the four phases, it becomes possible to identify the relevant capabilities of a provider and to determine the adjustments that may be necessary.

For the practical use of capabilities, it is advantageous to be able to express capabilities in a sentence. Based on the analysis, the following form can be used: *Who* (active

actor) wants to change *what* (resources of beneficiary actor) from *whom* (beneficiary actor) with what *effect* and *purpose* in which *context* and in which *time frame*.

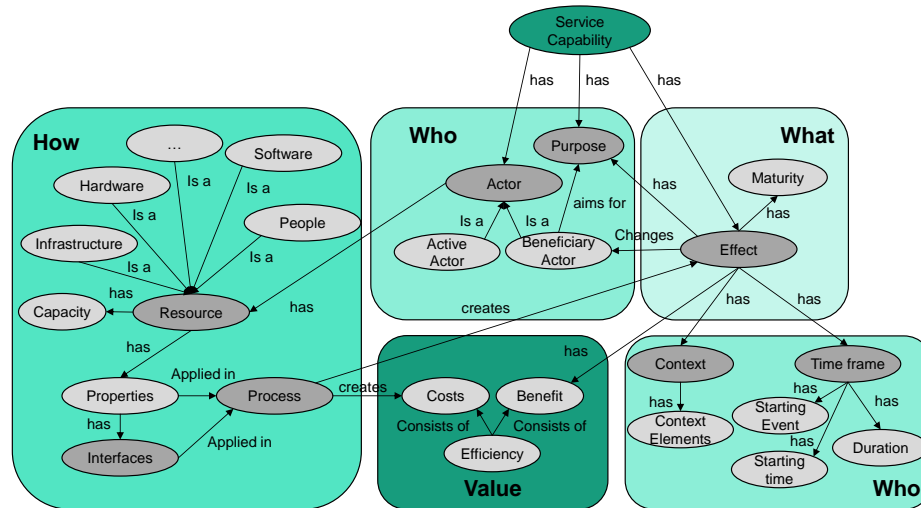


Fig. 1. Service Capability Ontology

5 Summary and Outlook

The aim of this paper is to analyze the term capability in a cross-domain view and to derive a uniform understanding for its use in the area of service description. For this purpose, the domains of general usage, military, business informatics, economics and manufacturing were examined. From this basis, classes were derived and a model was developed. Modeling an ontology is an interactive process. The goal of this paper is to generate a first draft that can be further refined in subsequent steps. In the further elaboration of the model, a system for automated matching of capabilities and customer requirements will be brought into practical use. Moreover, the capability model will be further refined by mapping the capability base of individual companies.

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