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Product-Service Systems across Life Cycle

Requirements for product-service description at e-marketplaces in the manufacturing domain

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Abstract

Industrial procurement is exposed to an increased service-oriented supplier market. However, industrial e-marketplaces for product-services that are accepted by buying experts are rare. Possible buyer benefits of e-markets such as access to a wider range of markets, accumulation of required information, and increase of market transparency cannot be utilized. Currently, product-services are at best traded within closed silos that offer mainly manual search and comparison capabilities through a web storefront. A lack of existing "generic" industry-sector-specific concepts for service description is a main problem that the potential of e-commerce is not utilized for product-services. This article analyzes the requirements for service representation at e-markets regarding the manufacturing domain. State-of-the-art concepts of business service description are considered at the beginning of this research. Because of the heterogeneity of product-services, a case study was conducted in order to identify relevant product-services in the manufacturing domain. In order to study a real case scenario, a "first-tier supplier" in the automotive industry was used in this research study. This company is specialized in systems engineering and systems serial assembly. Typical product-services of this company source are manufactured products needed for serial production, for example, casting, milling, turning, or injecting molding parts, alongside a wide range of services. Investigating the professional purchasing department was necessary to analyze the requirements in service description throughout the complete buying process, commencing with the conceptual product design stage until the serial product delivery.

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Keywords: product-service description, product-service advertisements, manufacturing services, service capability description, manufacturing service, USDL, service marketplace, electronic marketplace

1. Introduction

Industrialized countries are subject to structural change toward a service society, while the industrial sector drifts to emerging and developing countries [1]. Because of the increased competitive pressure resulted from the globalization of markets, manufacturing companies of industrial countries are forced to add service offerings to their product portfolio to differentiate their portfolio from the competitors. Manufacturing companies try to keep their competitiveness by shifting to more service-oriented businesses [2]. Another reason for the increased service orientation in the manufacturing domain is the concentration toward core competencies and outsourcing of activities, which was an important management focus within the last decades. Last but not least, market requirements force industrial corporations to provide customized solutions rather than simple mass products, which imply the need to add service offerings to products [3,4]. Since the industrial revolution, the research focus has been mainly upon the manufacturing of goods rather than on the provision of services. The importance of service provision increased in industrial countries and leads to a lack of research because of the essential differences in the nature of services compared with products [5]. In most economies,

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the service sector is growing; however, the productivity in this sector is typically much lower than that in the industry sector. Service science tries to understand services to improve the efficiency of creating new services and to improve the productivity in this sector [6]. Despite the fundamental change of paradigm, the current state of research regarding the integration of products and services is insufficient, certainly because of the novelty of the topic [7]. Research in product-service systems (PSSs) is one specialism of service science, because of the importance of the combination of products with services. The term "product–service systems" has been defined as "a marketable set of products and services capable of jointly fulfilling a user's need" [4]. The expression PSS is mainly used in B2C context while "industrial product-service systems" (IPSS) is rather used in the B2B environment. This article focusses on IPSS.

2. Problem description

Industrial procurement is already exposed to an increased service-oriented supplier market. However, no appropriate public e-marketplace for product-services could be identified, that is, both well-known to buying experts and widely accepted by them. Neither the supplier search and evaluation process nor the order execution process is supported by e-marketplaces appropriately, considering industrial services [8]. Dorloff et al. [9] claim that industrial procurement does not utilize possible benefits given by the use of electronic marketplaces at sourcing of services and service-enhanced products. Possible buyer benefits of e-markets exemplarily mentioned by Stockdale and Standing [10] are access to a wider range of markets, accumulation of required information, reduction of transaction costs, or increase of market transparency cannot be utilized. Only sell-side systems are currently used for description-complex offerings as product-services imply. Services are at best traded within closed silos that mainly offer manual search and comparison capabilities through a web storefront [8]. This proprietary approach leads to deficient information to service offerings and a poor comparability.

A main problem that the potential of e-commerce is not utilized for IPSS is a lack of existing "generic" industry-sector-specific or intersectoral concepts for service description [9]. Services are compared with products that are more difficult to describe because of manifold reasons. A service is the process of doing something, transforming provider's resources and even input of the consumer to an individualized outcome. Hence, service description needs to specify the service provision process besides the service result. Product description only needs to specify the outcome/result, thus the product. Another reason that makes service very difficult to describe is its heterogeneity. The emergence of Internet marketplaces for business services is driving the need to describe services, not only from a technical level as web service requires, but also from a business and operational perspective [11].

3. Methodology

This article commences with a view into the literature to the state-of-the-art concepts to service description. Services are very heterogeneous, and hence, subsequently a case study was chosen to identify IPSS with a set of relevant product-enhancing services in the manufacturing domain (automotive domain). The identified services are analyzed according to their specific characteristics, in order to understand their specificities compared with other service domains. Industrial e-markets are used within industrial buying departments. Hence, the observation of the real case took place in the purchasing department. Last but not least, expert interviews with these purchasers were conducted, so that a discovery of the purchasers' requirements for service representation in e-markets could be completed.

4. State of the art

One of the most cited articles at the beginning of service science was written by Vargo and Lusch in 2004 [12], "Evolving to a New Dominant Logic for Marketing," which sees service as the process of doing something—for and with another party. This concept of "value co-creation" moves the view from the producer to a collaborative process. Value is co-created with the customer in the service provision process. The basic abstraction is the service system, a configuration of people, technologies, and other resources that interact with other service systems to create mutual value. Many systems can be viewed as service systems, including families, cities, and companies, among many others [5].

4.1. Non-functional properties

O'Sullivan [13] describes non-functional properties (NFPs) of services aiming to represent all types of services domain independable, that is, conventional, electronic, and web services. He made extensive use of object-role modeling (ORM) to develop a taxonomy that includes derivation rules. He describes a comprehensive set of NFPs consisting of temporal and locative information to describe the availability of a service. He specifies service obligations, such as price or payment and models discounts and penalties. Also, service "Rights" are described only to mention the access to a service, a recourse, suspension, termination, privacy, refusal, disclosure, extension, or the warranty rights of a service. A further descriptive NFP is the language that is used for interaction between service stakeholders. Properties that describe trust, quality, and security are also part of this taxonomy.

The taxonomy of O'Sullivan gives a very comprehensive understandable overview of NFPs even if some described properties are very abstract such as the quality of services. In the approach of NFP, the area of capability, the functional perspective to services, is seen as the boundary of the taxonomy.

4.2. Service capabilities

The discovery of services, either web services or business services in manufacturing, is the first crucial step of interaction with a service or service provider, although the stages of evaluation, selection, negotiation, execution, and monitoring are also important. The ability to automatically locate a suitable service is a goal of both the sematic web and web service [14]. The difficulty to realize even manual discovery of services is that informal description of what the service can do is found in “documentation” elements, often text fields. The users first manually search for services and read the documentation to see what the service can do. To enable dynamic discovery of services, a mechanism is required to describe the behavioral aspects of services systematically, that is, what services do. A sematic description should include the capabilities that a service can provide, under what circumstances the capabilities can be provided, what the service requires to provide the capability, and what results can be delivered [14]. According Oaks et al. [14], a capability language should include the ability to (i) declare what action a service performs, (ii) allow different set of inputs, (iii) declare preconditions and effects in named rule definition language, (iv) describe objects that are not input but are used or affected by the capability, (v) refer to ontological descriptions of the terms used in the descriptions, (vi) make the domain or context in which the service operates explicit, and (vii) enabling exact or partial matches between required and provided capability descriptions.

4.3. Manufacturing service description language

Manufacturing service capability (MSC) representation mostly relies on the manufacturers’ own text-based or semi-structured capability specifications. Moreover, the mapping of manufacturers’ capability specifications to the capability models that e-sourcing portals currently utilize typically causes loss of semantics and limited expressiveness when representing manufacturing capabilities [15].

Manufacturing Service Description Language (MSDL) is an ontology developed by Ameri and McArthur [16] for formal representation of manufacturing services capabilities in the mechanical manufacturing domain. It was initially designed to enable automated supplier discovery in distributed environments. The ontology modeling language of MSDL is OWL-DL. It describes the manufacturing service capabilities with a model of four different capability levels: the supplier, shop, machine, and the process capability of the provider. In this perspective, the four levels contain all required information for searching a manufacturing service. The “supplier-level capability” describes, for example, machining skills, years of experience, industry focus, product focus, and quality assurance standards. The “shop-level capability” describes supporting systems of the manufacturing facilities, for example, control systems. The “machine-level capability” derives its capabilities, for example, speed or length of movement from the machine components. The “process-level capability” describes the machining process.

This representation of manufacturing services describes a solution for service discovery according to functional parameters, by describing capabilities. This approach includes some NFPs as it describes some trust properties. MSDL describes manufacturing capabilities and its capability limitations. The problem of this approach is that it is assigned to a concrete technology; Ameri and McArthur [16] developed this language for machining services.

4.4. USDL

USDL is claimed as a unified description of business, operational, and technical aspects of services [17]. USDL consists of three main UML-class packages. The technical perspective has its roots at the description of web services and contains descriptions for messaging protocols, metadata exchange protocols, security protocols, and so on. The business perspective of USDL incorporates information to service participants, service level, service marketing, or legal aspects. The operational perspective is the functional capability description, and it consists of UML packages such as operations, classification, functionality, phases and milestones, consumer process, and interaction channel. The operation module describes the flow of activities as a process, the input, the process activities, and the output referring to the required stakeholders [11].

The consideration of USDL in more detail would go beyond the scope of this article. USDL is the most comprehensive attempt in unified service description, but it has received limited adoption because of its complexity, while it also exhibited limitations with respect to the level of extensibility [8].

5. Case study

The heterogenity of service causes an even greater diversity of IPSS, which is the combination of a product with several services. For the exploration of the ideal manufacturing service representation at e-markets, we studied a real case to ensure the relevance of our research. On the one hand, we wanted to look at IPSS that are relevant to the industrial purchasing department, and on the other hand, we decided to study a real case in the automotive domain because of its significant share within the industrial production and its service intensity. Furthermore, the case study is used to study requirements in manufacturing service representation for e-markets caused by the purchasing process.

5.1. Introduction to the business case

The used company to study a real case scenario is a “first-tier supplier” in the automotive industry. This company is delivering systems to OEM car manufacturers. The examined company’s specialization is systems engineering and systems serial production. It is offering all activities of the system development process, which are according to Gentner’s [18] conceptual design, component development, construction, component integration, prototyping, testing, and industrialization for serial production. Typical component supplier ("second-tier supplier") are companies that provide manufacturing services such as casting, milling, turning, injection molding, and so on.

All information gathered for this case study was observed within an industrial procurement department. The complete procurement process was observed, from the first contact to a supplier until issuing a long-term agreement for the serial delivery of specific products. Although, we studied several relevant IPSS sourcing cases of this company, the restriction of this article allows us only to present one IPSS. Hence, we look at all services required at the sourcing process of only one product, which is the casting part for serial production.

5.2. Identified IPSS services

Simultaneous engineering services. Each system development process commences with a conceptual stage. In this early stage, the supplier's expertise is required to confirm the manufacturability of a product according to conceptual drawings. Furthermore, the supplier's expertise is needed to optimize the part's design according to qualitative and economic aspects. Topics for the optimization process of the casting part are material qualities, geometric details, or even the choice of the appropriate manufacturing technology, for example, die-casting versus sandcasting.

Engineering services. During the development stage, a casting simulation is requested from the component supplier, aiming to identify critical areas of the part, for example, in terms of the solidification process. Early prototypes produced by specific methods such as rapid-prototyping or milling the part from solid material is another identified product-enhancing service. Also, manufacturing engineering is required to process technical documentation for specific manufacturing technologies. For example, the supplier adds draft angels to the 3D construction of the product design.

Manufacturing services. Furthermore, the second-tier supplier provides the construction and manufacturing of the required casting tooling. Besides the casting mold, tooling for leakage tests and deburring tools for serial production are also required. Casting suppliers have to have the competency to supply the tools with a third party, or they have the capability to make an in-house production. A long-term maintenance service of these tools has to be included, which could be classified as typical "after sales service". Additionally, the supplier offers vertical integration of manufacturing processes, like machining of the raw casting part. Further manufacturing processing services are the industrial cleaning of the part or the hardening of the surface of the part.

Product quality testing services. A lot of different quality testing services are demanded from suppliers. The casting part provider has to deliver x-ray documentation, computed tomography scans, grinding patterns with the analysis of cavities, 3D scans to verify geometry, leakage proofing data, chemical analysis of the specified material, stress-deformation testing, or hardness test results. Also, a cleanness check, provided by certified labors, is a requirement. Not to mention, that it needs several optimizing stages at the supplier to deliver a product that conforms to the technical specification of the customer. A very important product-enhancing service is to provide measurement engineering capabilities and technology in order to verify part geometries.

Process quality testing services. Besides the product quality services, process quality services are also demanded from the product supplier. Mostly, these services are summarized in a Quality Assurance Agreement. The supplier has to be certified according to the management norms, such as ISO9001 or ISO/TS16401, which imply that the supplier has to organize its internal processes according to the specified rules. A process for product identification and traceability is such a service only to mention an example. The casting part supplier has to provide following further services: failure mode and effects analysis (FMEA) of the production process, auditing of sub-suppliers, technical modification services, providing a control plan, documentation of part history, providing sampling parts according to the VDA automotive norm, or providing a so-called IMDS entry, which specifies exactly the material composition of the product delivered.

Logistic services. Packaging and conservation of the product are important logistics issues to provide protection against corrosion and transport damage. Managing safety stock levels for serial production or providing transport services are further concerns.

5.3. Characteristics of identified services

After identifying a relevant set of product-enhancing services, we examined their service characteristics. Only with this more detailed view, we can understand why specific descriptive properties mentioned in state-of-the-art concepts have more or less relevance in the manufacturing domain. For a first illustration we assign the identified services to the approach of Lovelock et al. [19], which categorizes services according to service process attributes. It answers two fundamental questions: (a) At whom (or what) is the service activity directed? (b) Is the activity tangible or intangible? [19] Classifying the identified services to this approach shows that manufacturing services are not directed to peoples' bodies. The service provision and consumption of manufacturing services are often not simultaneous, which means that the description of the location of service performance is one of the most important descriptive properties if you are looking for the next available hair dresser, but it is of minor importance considering manufacturing services. Most identified services do show rather a sequential character than impose a simultaneous processing, characterized by the inseparability of production and consumption of a service. Looking at an example of a cleanness analysis of a casted part, first its sequential steps are bringing the tangible part and the intangible cleanness specification to the disposal of the service provider. After that, the provider executes the service process and delivers the outcome at the end, the result of the cleanness analysis with the tested part. The service provider could schedule its services according to first in, first out principles. Therefore, "throughput-time" of the service would rather be an appropriate descriptive property than the exact date and the time of the service availability required for example at people processing services and described by the state-of-the-art approaches. The main part of the identified services are "possession processing" services; hence, the provision of the services is completely separated from their subsequent consumption. Lusch and Vargo [20] say that goods are used as a distribution mechanism in service-dominant logic (SDL). The service is delivered on the product. The consideration of the identified services demonstrates that a big part of these services has tangible aspects. These aspects have impact on their description. It is an easier way to assess and describe the quality of services with material results. For example, the quality of the provision of a casting service can be evaluated using approved test methods, such as 3D scans, CT scans, or leakage tests. By contrast, assessing the quality of immaterial results is not straightforward. The success of a consultation service to optimize a part design cannot be validated easily, because the compared "bad" design probably will not be realized.

At the major group of the observed services, the service provision process can be determined after an initial reception of customer data. Hence, the service price cannot be advertised until this interaction happened. A small group of identified services has its specificity that prices are always difficult to estimate, because of a frequent customer interaction and multiple variation points during the service provision process, which is typically for consultancy activities. We conclude that the description of the price of the service that is proposed in the state of the art (USDL, NFP) is mainly not relevant in the manufacturing domain.

It is notable that all "services directed to possessions" do require a certain extend of machine resources that have to be accessible for service provision. This is very specific for manufacturing services, not only parts processing services such as machining, cleaning, or hardening, but also the quality testing services require defined machine resources, besides the availability of competencies. Performing a supplier search and evaluation of manufacturing services implies alongside the evaluation of the required human competence, also the assessment of the provided machinery or technology resources.

6. Requirements for service representation in the manufacturing domain

During the time of the case study, additional expert interviews were conducted within the purchasing department. A main finding is that the discovery, evaluation, and the selection process of services is a manual activity done by professional purchasers. These manual activities will not be replaced by automated technology because of the required professional buyer experiences needed to evaluate highly heterogenic and very complex technological services. Industrial companies perceive increased risks at service purchasing, so that only the experienced buyer can assess the trustiness of the service provider, the service offering, and the level of risk that the company is willing to take. According to these interviews, service representation at e-markets requires not only the completeness of the required information but also the structure of information.

Therefore, these marketplaces would require a high-level description that supports the purchaser at a rapid decision-making process, to decide whether an offered service or rather an offered IPSS could match to the demands or not. Thus, the first description to be answered is what a provider is capable of. When the purchaser finds a match to his or her needs, the second discovery step is to evaluate the trustiness of the offered capability. Therefore, data of the provider is also part of this high-level representation. It is remarkable that this trust evaluation can be structured into two parts. First, the purchaser checks whether the offered capability can be provided with the resources the provider has. Second, the trustiness of the provider itself can be analyzed. Following **capability trust properties** were identified: reference customers and projects, branch experiences, other services or products offered, existing business relationships, proof of required competences (description of experience and education of involved persons), additional resource descriptions (machinery, know-how, control systems , etc.), company certificates (ISO 9001, etc.), and interaction standards such as engineering and construction standards (for technical drawings, material description, metrics, etc.). Following **provider trust properties** were used in the case study: company name, legal status of company, company registration no., VAT no., address of head office and subsidiaries, information to contact persons (technical/commercial/quality), interaction language, location of service provision, year of foundation, company ownership, board members/CEO/CFO, organizational structure, number of employees, financial data (turnover, profit, cash, liquidity, etc.), turnover assigned to product/service portfolio, declaration of confidentiality, and website address.

Table 1. Illustration for IPSS high-level description

Product: Casted Part	Capability Boundary	Provider Information
Manufacturing Capabilities - Sand casting - Dye casting - Machining services - Prototyping services	Max. size: 60×60×60 Only metal alloy XY Machining only in combination with casting Machined from solid	Casting experience in automotive since X years; reference customers: BMW, Audi, Ford; casting batch size XY; manufacturing location: Italy; in-house labor cleanness check available in 24 h; exiting 5-axe milling machines: …; ISO 9001, 16949
Engineering Capabilities - Feasibility study - Production of tooling - Casting simulation	In-house production of sand casting tooling; simulation, & dye casting tooling by third party	
Quality Capabilities - Leakage tests - Industrial cleaning - 3D measurement	Min. particle size; Zeiss machine no. XY, restrictions regarding geometry of part, etc.	

Not until this first discovery step is finished, a "low-level" description of the provider is needed to answer the question of *how* the provision of the IPSS takes place. On the one hand, this low-level description includes a detailed capability description with the functional process that applies including the necessary customer input, interaction procedure, acceptance criteria, delivered outcome, or additional services that can be added. Also non-functional commercial data are required for low-level service discovery. According to the case study, following **commercial data** were requested: price and price split, currency, quantity, payment terms, delivery time/throughput time, incoterms, tax, sales terms, validity/availability of offer, payment method and belonging properties: bank transfer → bank name, bank account no., IBAN code/bank account no., name of account owner.

7. Conclusions and outlook

Manufacturing services differ to other services, which has effects on their descriptive properties. For example, sales prices are rarely part of service advertisements; the price is rather represented after an initial interaction step, after consumer's input took place. The identified manufacturing services serve the product development, its production, the delivery, and quality verification process of products. We recommend representing manufacturing services associated to its product categories. Furthermore, we assume that adequate service catalogues and service classification are also required to provide appropriate search functionality and propose additional research on these issues.

Existing state-of-the-art models lack either in generality, as MSDL is usable only for machining services, or they are extremely comprehensive including properties that are not required, as USDL aims to represent web services with an identical framework as manufacturing services. A main aim of the existing service description models is to enable automated discovery of services.

The evaluation, the negotiation, and the selection of IPSS in the manufacturing industry are supposed to remain on manual or semi-automatic activities done by professional purchasers, because of high perceived risks at service purchasing. One reason therefore is that a certain unpredictability of the quality of the service outcome exists, which demands an evaluation of trustiness of the provider. Inappropriate service performance could result in high follow-up costs. Imagine a bad quality of a casting part runs into serial production of a car manufacturer. The costs of all services required during the product development and industrialization process could be less worth than the costs occurred because of a line stoppage at the OEM car manufacturer caused by poor quality services delivered by the component supplier. These are the reasons why the manufacturing domain demands electronic support for the discovery, the evaluation, the negotiation, or the selection of services, rather than automated technology.

Hence, one main challenge for manufacturing service representation at e-markets is, that information has to be structured supporting the purchasing process. It requires a structured high-level capability description that includes the capability that is offered by a provider and its boundaries. Industrial purchasers compare the full set of capabilities a provider has, to find the most suitable solution to their need. Another finding of the case study is, that the evaluation of trust information plays a major role at the service discovery and evaluation process, and thus, it is also a part of a high-level service representation that is required for the purchaser to decide whether her/she has interest to explore the low-level details. We recommend further research in representing the trustiness of an offered service and its' provider, because this important issue is not sufficient described in existing models.

An integrated recommender system could support the search procedure as a semi-automatic approach. Possible needs for representing feedback data or rankings gathered by consumer experiences cause the requirement for supplementary description of performance indicators [21] proposes KPI to evaluate the IPSS that could be used as basis framework to realize a required customer rating.

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