Understanding Manufacturing Networks as Service Systems: An Ontological Approach

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Abstract. Continuously increasing market dynamics force manufacturing networks, more than ever, to innovate by not only focusing on the development of new goods but also on the design of additional value-creating services. In order to be able to properly analyze interdependencies and identify opportunities, it is therefore our proposition to understand manufacturing networks as service systems. For this purpose, based on experiences from a major European research project, this contribution discusses the fundamental elements of service systems as well as presents a formal ontology containing the most relevant concepts for analyzing manufacturing service systems.

Keywords: Business Networks, Design Science, Ontology, Manufacturing, Service Engineering, Service Systems.

1 Introduction

Although having different connotations and meanings in distinct disciplines such as industrial marketing or computer science, the term ‘service’ has extensively been used during the past years [1]. In this paper we adopt the definition of Vargo and Lusch [2], who understand the term as “the application of specialized competences (knowledge and skills) through deeds, processes, and performances for the benefit of another entity or the entity itself.” By that definition, almost any purposeful socio-technical system can be viewed as a service system because competences are being applied to produce something for someone [3].

Due to the effects of globalization as well as increased market dynamics, particularly the typical ‘product industries’ like the machine and equipment branch are expected to intensify their efforts on improving the service system they are engaged in as a stronger differentiation of organizational outputs is needed. Hence, the manufacturing industry of the future must evolve to a highly inter connected, dynamic, and often non-hierarchical business network [4].

With this paper we therefore present a first approach for understanding and analyzing manufacturing networks as service systems. In doing so, we try to answer the following research questions: (a) what elements characterize a (generic) service system, and (b) what are key constructs for building an ontology for manufacturing service systems?
For this purpose, the organization of this paper is as follows. After this short introduction, the second section describes the general characteristics of a service system. Then, in the third section, we discuss our proposition of an ontology for manufacturing service systems. Finally, in the last section, we present a conclusion and discuss further research implications.

2 Characterization of a Service System

As to Alter [3] a service system is the most fundamental unit for understanding, analyzing, and designing services. It can be described as “a system in which human participants or machines perform work using information, technology, and other resources to produce products and services for internal or external customers.” Transferring this idea to our initial definition of service, a wide range of possible instantiations of services are opened, that is for example tangible (products), and intangible services; automated, IT-reliant, and non-automated services; customized, semi-customized, and non-customized services; personal and impersonal services; repetitive and non-repetitive services; long-term and short-term services; and services with varying degrees of self-service responsibilities [3].

Based upon the before mentioned definition of service systems, nine common elements can be differentiated: Central to the concept of service systems are customers as they are the direct beneficiaries of the services produced by the particular service system. Customers can be internal (e.g. other business units, subsidiary company) as well as external (e.g. clients, partner company) to a specific organization.

In order to produce a particular service for a customer, sets of partially ordered and coordinated tasks (and thereof deduced atomic activities or functions), commonly referred to as processes, are needed. These often cross over organizational boundaries, as they occur across or between organizational units and generally are independent of formal organizational structures [5], [6]. However, to perform the activities for producing a specific service, almost always information and (human) participants are required. According to Alter [3], the term participants (not users) is included because important roles in a service system may be played by people, who are not direct users of IT. He also suggests separating the two terms ‘information’ and ‘technology’ since multiple technologies (not only IT) and different information sources (e.g. digital and analog information; structured, semi-structured, and unstructured information) may be relevant to a service system.

Indirectly the service system is impacted by the strategies of the firm (e.g. relating to customers, processes, financials, and innovation [7]), its infrastructure (e.g. human, information, and technical resources shared with other service systems and managed and controlled outside the service system [3]), and its environment (e.g. technological advance, regulations, policies, market structure, organizational and national culture [8]).
3 Ontology for Manufacturing Service Systems

In its most prevalent use in computer and information science, “an ontology refers to an engineering artifact, constituted by a specific vocabulary used to describe a certain reality, plus a set of explicit assumptions regarding the intended meaning of the vocabulary words” [9]. Often it is also referred to as “a formal, explicit specification of a shared conceptualization” [10]. Adopting this definition of ontology implies two important premises: (a) the ontology is specified in form (syntax) and content (semantics), and (b) the ontology is appropriate to represent a consolidated worldview of a delimited domain (pragmatics).

3.1 Principles for and approach to ontology engineering

Fundamental principles to develop an ontology are abstraction (i.e. simplify complexity by formulating general concepts), reuse (i.e. building on the existing knowledge base), and evolution (i.e. iterative development from simple to more complex vocabularies) [11].

The first two principles are addressed by substantiating the primal design of the ontology on the core business meta-model (CBM) developed by Österle et al. [12]. The CBM is a general and industry-independent approach to structure the (re-)engineering of businesses on a meta-level. It consists of forty-six design elements derived from models and methods related to change management, business and information systems engineering. As the phenomenon of manufacturing service systems is strongly influenced by organizational, technical, behavioral, environmental and strategic issues (cf. section 2), the CBM is seen as a good starting point for developing a domain specific vocabulary.

In order to foster an evolutionary and broadly accepted design of the ontology (the third principle), the collaborative ontology editor Knoodd was used [13]. This particular editor supports the conjoint development of ontologies based on the Web Ontology Language (OWL) and Resource Description Framework (RDF) as well as other textual and graphical specifications (see Fig. 1). As co-developer and ‘sparring partner’ for defining the ontology for manufacturing service systems, the members of the European Commission funded project inTime [14] as well as other interested parties from the manufacturing industry were involved.

3.2 Constructs of an ontology for manufacturing service systems

The resulting ontology consists of sixteen key constructs identified throughout the project as well as in the reviewed literature. For every construct a short description, exemplary instances or sub-classes, and the relations to other constructs is defined (see Table 1).
<table>
<thead>
<tr>
<th>Construct/class</th>
<th>Short description</th>
<th>Exemplary instances or sub-classes</th>
<th>Relations to other classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business area</td>
<td>A part of a company’s operations; that is the industry or sector, where an organization acts in</td>
<td>Automotives, electrical engineering, mechanical engineering, plant construction, plastics</td>
<td>Belongs to organization</td>
</tr>
<tr>
<td>Business function</td>
<td>Business functions represent collections of similar activities or processes in an organization</td>
<td>Facility management, human resources, procurement, production, R&amp;D, sales</td>
<td>Has business role, is part of organization</td>
</tr>
<tr>
<td>Business partner</td>
<td>A business partner is a commercial entity an organization is somehow related to (e.g. by contract or voluntary)</td>
<td>Customer, subsidiary, supplier</td>
<td>Is part of manufacturing network</td>
</tr>
<tr>
<td>Business role</td>
<td>Business roles represent collections of employees who perform similar functions in an organization</td>
<td>Assembler, buying agent, design engineer, logistician, plant manager, sales agent, scheduler</td>
<td>Belongs to business function</td>
</tr>
<tr>
<td>Critical success factor</td>
<td>A critical success factor is an element or activity required for an organization or project to achieve its goal system and thus vital for a strategy to be successful</td>
<td>Environmental factors, industry factors, strategic factors, temporal factors</td>
<td>Influences goal system</td>
</tr>
<tr>
<td>Goal system</td>
<td>A goal system of an organization consists of multiple targets or goals for which success factors can be derived, and which in turn can be measured by performance indicators</td>
<td>Client goal, financial goal, innovation goal, process goal</td>
<td>Is influenced by critical success factor, is influenced by incentive system, is measured by key performance indicator</td>
</tr>
<tr>
<td>Hardware</td>
<td>Hardware is a general term for the physical artifacts of technology such as the input and output devices (e.g. keyboard, display) of a computer</td>
<td>Data storage, input devices, network components, output devices</td>
<td>Is part of information system</td>
</tr>
<tr>
<td>Incentive system</td>
<td>An incentive system of an organization consists of multiple incentives or rewards conditionally offered to employees on certain goals being met</td>
<td>Coercive incentive, moral incentive, remunerative incentive</td>
<td>Influences goal system</td>
</tr>
<tr>
<td>Information system</td>
<td>Information systems consist of hard- and software components, using data and procedures to process and disseminate information</td>
<td>Analytical information system, collaborative information system, operational information system</td>
<td>Has hardware, has software, is part of organization, supports process is input for process</td>
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<td>-----------------------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Input (of service)</td>
<td>Resources employed to produce a particular service. They facilitate production but do not become part of the product (as with raw materials) or are significantly transformed by the production process (as with fuel used to power machinery).</td>
<td>Financial resources, human resources, physical resources</td>
<td></td>
</tr>
<tr>
<td>Manufacturing network</td>
<td>Manufacturing networks consists of firms that are geographically dispersed and do not belong to the same head company</td>
<td>Hierarchical manufacturing network, non-hierarchical manufacturing network</td>
<td>Has organization</td>
</tr>
<tr>
<td>Organization</td>
<td>Organizations, companies or enterprises are goal-directed, boundary-maintaining, activity systems</td>
<td>Large sized company, medium sized company, small sized company</td>
<td>Has business area, has business partner, has process, has information system, is part of manufacturing network</td>
</tr>
<tr>
<td>Output (of service)</td>
<td>Quantity of something (e.g. a product or service) that is created within a given period of time by given process</td>
<td>Product, service</td>
<td>Is output of process</td>
</tr>
<tr>
<td>Performance indicator</td>
<td>A performance indicator is a quantifiable measure of performance. Such measures are commonly used to help an organization define and evaluate how successful it is, typically in terms of making progress towards its long-term organizational goals</td>
<td>Client indicator, financial indicator, innovation indicator, process indicator</td>
<td>Is part of goal system</td>
</tr>
<tr>
<td>Process</td>
<td>A process can be defined as set of partially ordered and coordinated tasks, often cutting across functional boundaries within and across organizations to accomplish certain objectives</td>
<td>After sales, logistics, manufacturing, procurement, project management, sales</td>
<td>Is part of organization, is supported by information system, consumes input, produces output</td>
</tr>
</tbody>
</table>
Software is a general term primarily used for digitally stored data such as a written program used by the computer to instruct the hardware to perform certain tasks.

Application software, middleware, system software
Is part of information system

Fig. 1. Excerpt of ontology for manufacturing service systems specified with Knoold

4 Conclusion and future research

Within this paper it is argued that, in order to able to properly analyze interdependencies and identify opportunities, manufacturing networks should be perceived as service systems. In doing so, a first attempt was made to adopt this broader view of the service terminology by developing an ontology for manufacturing service systems.

Based upon the work of Österle et al. [12], sixteen key constructs were identified within a major European project and formalized using OWL and RDF.

As the ontology presented in this paper is still research in progress, future work should be directed at testing the proposed ontology regarding to validity, completeness and consistency. This exemplary can be conducted by means of in-
depth focus group discussions with selected thought leaders of the manufacturing industry. In addition, further effort should be undertaken in developing methods and tools to help practitioners to adopt the ontology.

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