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A System Dynamics Model for the Evaluation of the Productivity of Knowledge-intensive Services

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ABSTRACT

This paper presents an approach to develop a system dynamics model for the evaluation of the productivity of knowledge-intensive services. This model is based on the results of a case study as well as on literature research. At first, this paper gives a short introduction about knowledge-intensive services and the system dynamics method. The identified variables as well as their causal relationships will be presented in the following sections. A recapitulation of the findings and a prospect on further research conclude the paper.

Keywords: System Dynamics; Productivity; Knowledge-intensive Services

1. Introduction

For manufacturing companies it has become a priority to offer a range of services along with their tangible products. In a growing number of industries services account for a significant share of turnover and often generate a higher margin. These services can often be considered as knowledge-intensive, as they require frequent interaction with the customer and the processing of a large amount of information and knowledge (e.g. for consulting services). Due to their complexity and the high level of customization, these services are difficult to standardize, and consequently, it is somewhat difficult to evaluate their productivity.

In accordance with Djellal and Gallouj, the authors claim that determining productivity requires a flexible evaluation system that integrates multiple criteria instead of using a single productivity ratio [1]. To develop such an evaluation system, it is necessary to identify the essential variables affecting productivity as well as to find out how these variables interact with each other. As there are certainly many variables that impact service provision, the illustration of the interactions would be of immense value for both academics and practitioners. In 2012 the authors investigated the case of the implementtation of a performance measurement model in the ‘2nd level technical support unit’ of a multinational company [2]. This technical support service can be considered as rather knowledge-intensive, as it solves rather complex problems that occur at the customer’s site which cannot be solved by the customers themselves or the field service of the company. Based on the results of the case study supplemented by a literature research the authors set up a company-specific system dynamics model [2].

Grounding on this specific model, additional studies and further literature research, the authors have developed a general system dynamics model for the evaluation of the productivity of knowledge-intensive services. This general model includes variables of the company-specific model. Other variables had to be universalized and extended to transfer them. This model will be presented in the following.

2. Developing a System Dynamics Model

2.1. System Dynamics

System dynamics models are used to depict and analyze dynamic systems. These models were originally developed at the Massachusetts Institute of Technology in the 1950s and published in the article ‘Industrial Dynamics: A Major Breakthrough for Decision Makers’ by Jay W. Forrester in 1958. He analyzed relationships and processes in industry [3] and in cities [4]. In the meantime, system dynamics models have been built and applied in many disciplines and in many contexts.

Dependencies in a dynamic system can be described by using single or multiple feedback loops. A feedback loop is a fixed path, which connects the decision that controls an action, the condition of the system and all information regarding to the condition, being reported at the decision point [5]. Therefore, system dynamics models are suitable to identify the effects of a single action in the course of a process, allowing the detection of delays within processes, caused by a badly designed flow of information. Therefore, a reshaping of the information flows is possible [6].

To depict feedback loops, so-called Causal Loop Diagrams are used to describe the causal dependencies between system elements, as well as the polarity of the dependencies. The polarity of the feedback loop may be either reinforcing (positive polarity) or balancing (negative polarity). Hence nonlinear feedback systems can be generated. The systematic variation of information relationships, interaction loops and dependencies in system dynamics models help to clarify the performance of a system in its entirety.

2.2. Structure of the System Dynamics Model

The system dynamics model presented in **Figure 1** shows all variables influencing the productivity of knowledge-intensive services. Connections between variables depict, which ones are influencing other variables. The spearhead indicates the direction of the influence. In addition, the spearhead shows the kind of influence as a '+' for proportional influence and a '–' for inversely proportional influence. The evaluation, whether the influence is proportional or inversely proportional, requires the simplified assumption that all other variables stay constant, even though this is actually impossible due to the feedback. The dotted variables are *input variables*. These variables are not influenced by any other variables. The blank variables are the so called *state variables*. All state variables combined are characterizing the current state of the complete system. The presented system dynamics model can be divided into four feedback loops. The notation of these loops is defined in the legend of **Figure 1**.

2.3. Variables of the System Dynamics Model

The *service capacity* is an existential potential of a service company to be able to provide their services. Increasing the two input variables *number of employees* and *average working time* causes a positive service capacity. *Knowledge management* (i.e. the creation, sharing, capturing and distribution of knowledge) is one of the main input variables on the productivity of knowledge-intensive services. The most important resource for these services is, of course, knowledge [7]. Providing more knowledge management increases the level of *qualification* of each employee [8] and effectively reduces service capacity [9] at the same time. Because knowledge management is not influenced by any other variable, it can be seen as an input variable for the service provider. The number of *trainings* is another significant input variable, which can be influenced by the service provider. On the one hand trainings reduce service capacity, but on the other hand they increase the qualification of the employees. Knowledge-intensive employees should frequently attend trainings to improve their qualification [10,11]. So only a reasonable level of qualification enables employees to perform their work (*working ability*) sufficiently.

Another input variable which can be influenced by the company is *equipment.* Equipment is obviously necessary to provide any kind of service. If there is no functional equipment, the employees need more time to perform their tasks properly. In addition, using the right equipment increases the working ability of the employees [12].

The *autonomy* of the employees is another input variable. It signifies that employees are allowed to manage their work by themselves (e.g. autonomous sequencing of tasks). A higher degree of autonomy may have a positive effect on their *motivation* [13]. Motivated employees have a higher *performance readiness* and a lower *absence* [14]. Combining the performance readiness with the working ability leads to the *performance* [10,15]. The performance is the ability of a service provider to perform a service matching the customer's requirements on a specific level [16]. The performance contains the ability of the service provider as well as the willingness to perform the service. The *customer performance* as an input variable describes the performance or the activities that a customer is supplying in order to achieve a specified service outcome.

The performance on the one hand combined with the service capacity on the other hand influence the *service rate* in a proportional way. The service rate is the average number of orders that can be served in a specific time.

The difference between service capacity and *demand for services* is the so called *quantity gap*. Consequently, the service provider always attempts to keep the quantity gap small. When there is not enough demand for the given service capacity, a service is not profitable [17]. The bigger the quantity gap is, the more the *workload* of the employees and the *orders in process* rise. The workload has a main influence on the *employee satisfaction*. Additionally, more orders in process lead to more *completed orders*, which extend the *experience*. *Queued orders* are those orders, which cannot be started immediately, because the demand is higher than the service rate. Unfortunately, queued orders increase the *waiting time* and therefore lower the *perceived process quality*.

In addition to the quantity gap there is also a *quality gap*. Comparing the *expected outcome quality* with the *perceived outcome quality* the customer will normally have a mismatch. Secondary this gap is generated by the

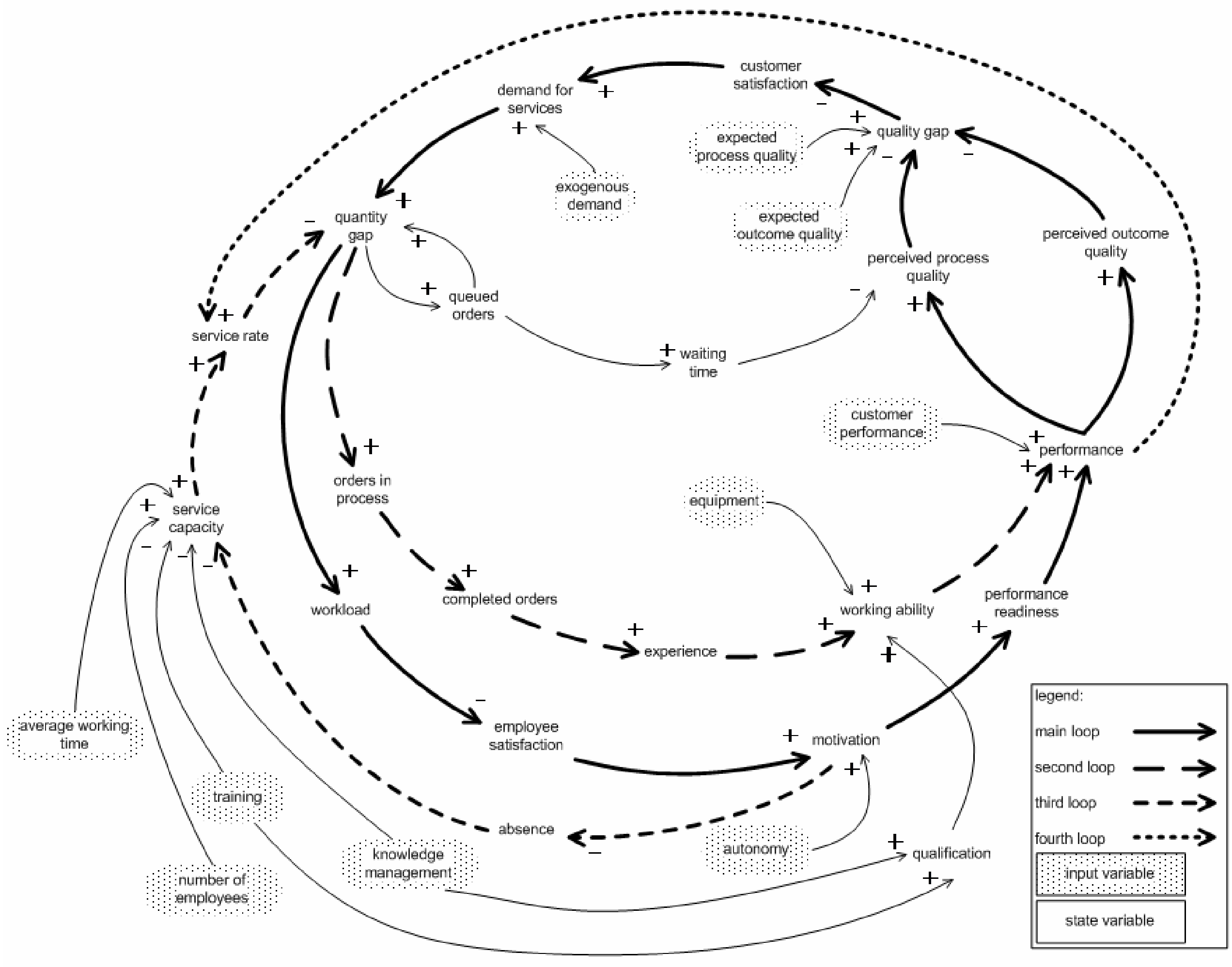

Figure 1. System dynamics model for the evaluation of the productivity of knowledge-intensive services.

difference between the *expected process quality* and the perceived process quality [18]. Mostly the customer's initial expectation on the quality is higher than the received one. Because of this, there is a quality gap. When the gap increases, the *customer satisfaction* is getting worse. It is necessary for a company to have satisfied customers, as customer retention will create new demand for services in the long run. Also the *exogenous demand* depending on the market share has an influence on the demand for services.

To sum up, the system dynamics model, which is shown in **Figure 1**, is not finalized, but it is a first step to decompose the service provision process and to identify the main drivers and barriers for service productivity.

3. Conclusions and Further Research

Measuring the productivity of knowledge-intensive services is an intricate problem because the process and the outcome of knowledge-intensive services are to a certain degree unpredictable.

A first step towards finding ways to deal with the complexity of knowledge-intensive services is to uncover the main cause-effect relationships. This paper presented an attempt to develop a general system dynamics model for the evaluation of the productivity of knowledge-intensive services. Due to the complexity and diversity of knowledge-intensive services the presented model is just qualitative. Nevertheless, it offers a good starting point to select a well-balanced set of variables for measuring the productivity of knowledge-intensive services. More studies are required to improve the quality of the model and to generalize the findings.

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