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Qualitative System Dynamics Cycle Network of the Innovation Process of Product Service Systems

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Abstract

The innovation process of Product Service Systems (PSS) is affected by a vast number of internal and external influences. Especially the management of timely or structurally repeating influences, so called cycles, shows a great potential for improving the innovation process. Thereby two types of cycles can be differentiated. Firstly, internal cycles during the innovation process itself going from engineering change cycles, to manufacturing resource cycles or even team building processes. Secondly, the external, environmental cycles that have an impact on the innovation process, i.e. government- and customer-related demands and dependencies. A lot of these dependencies, most likely external ones, contain uncertainties, that have to be handled for successful innovation of PSS.

To cope with these struggles, methods and tools have to be developed, to allow analysis and forecast of the cycles in the innovation process. Especially the high degree of cross-linking between the different cycles indicates the need of integrated modeling and analysis. An interdisciplinary cycle network of 30 relevant cycles and external influences as well as 51 interconnections so far, was set up in a System Dynamics environment. Though not all influences can be determined yet, the created causal loop diagram can already serve as a framework for analyzing the innovation process of PSSs and support deeper understanding of the interdisciplinary interdependencies.

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Keywords: Product Service Systems; Cycle Management; Cyclic Influences; System Dynamics; Interdisciplinary Interconnection;

1. Introduction

Internal and external context factors have a vast impact on the innovation processes. Companies have to handle the customer demand for innovations, challenging laws and regulations, incremental and radical innovations of product and production technologies. These context factors often have a cyclic character, meaning they are (temporally or structurally) reoccurring. Nevertheless their anticipation while planning the innovation processes is becoming more challenging, as these cycles can be very complex. [1,2].

In addition to shortened innovation cycles, due to high pressure concerning time, cost, competition etc., companies have to satisfy the customers needs for integral combinations of products and services, the so-called product-service systems (PSS) [3].

PSS further complicate the innovation process, as new disciplines have to be involved. In addition to traditional domains like mechanical, electrical and software development, new service oriented fields have to be considered.

To maintain the competitive capability as well as the capacity for innovation, manufacturing companies have to optimize their innovation processes by integrating the internal and external cycles in their prevision. Cycles have been discussed individually across multiple disciplines: Schumpeters business cycles [4], cycles of the S-shaped technology curve [5] or Tuckmans stages of team development [6].

Besides their dynamics, ambiguity and uncertainty, these internal and external cycles depend on each other and influence themselves temporally and with regards to content. Problems result from the unawareness and lack of manageability of these cycles, their interdependencies and effects.

To ensure efficient and effective innovation, an interdisciplinary approach is needed, which considers not only the discipline-specific cycles and their internal dynamic behavior but also their interconnections on a global level.

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The work in this paper was developed within the research collaboration 'SFB 768 Managing cycles in innovation processes Integrated development of product-service-systems based on technical products'. The research team consists of 14 research groups within 7 organizational units out of 4 disciplines (mechanical engineering, psychology, economics and computer science). Relevant cycles were collected during interviews within this research collaboration. The different aspects of the innovation process of PSSs, researched by these disciplines, were collected and broken down to into interconnected cycles. Finally, a cycle network considering of 30 cycles and external influences together with 51 interconnections was worked out in a qualitative System Dynamics model. By this, a novel, interdisciplinary, cycle-oriented view of the innovation process was developed with means of qualitative System Dynamics modeling.

System Dynamics has also been proven useful to model cycles in other works i.e. [7–9]. With this perspective, System Dynamics promises to be a plain and adequate modeling environment for both qualitative and quantitative approaches to the innovation process of PSSs.

This paper presents the resulting model, describes the cycles and interconnections and gives an example of how the model is supposed to be used.

2. Introduction to System Dynamics

System Dynamics is a methodology, developed by J. Forrester in the mid-1950s at the Massachusetts Institute of Technology (MIT), with purpose to analyze and simulate complex dynamic systems [10]. With a focus on socioeconomic behavior, it provides a universal approach, based on feedback loops. There is a qualitative and a quantitative method, which serve for particular requirements. The qualitative approach is mainly used to analyze and visualize dependencies and to identify reinforcing and balancing loops. It can be used without simulation and data to create influence diagrams, which allow making decisions. Especially the knowledge about balancing and reinforcing loops gives an important clue about the stability of a system [11].

The quantitative method uses stocks and flows to discretize the qualitative model. It is recommended to verify decisions based on qualitative models with this method. This paper will give an overview to a qualitative approach, to prepare a quantitative analysis.

3. Modelling cycle networks with System Dynamics

The goal of the collaboration is to support the integrated development of PSSs based on technical products [12]. Within the last eight years of research various cycles and influences were modeled, which try to cover as many aspects of the innovation process as reasonably possible.

To manage the complexity of the network, it was clustered into 8 top-level cycles as illustrated in Fig. 1 in a directed graph. The top-level cycles are further refined by subnetworks.

The nodes of the graph illustrate cycles, the edges represent dependencies. The impact of the interconnections varies, starting from light influences like wear and tear, to strong effects, like triggering a new iteration of a cycle.

From the point of view of PSS developing companies, the cycles can be differentiated into internal cycles regarding the

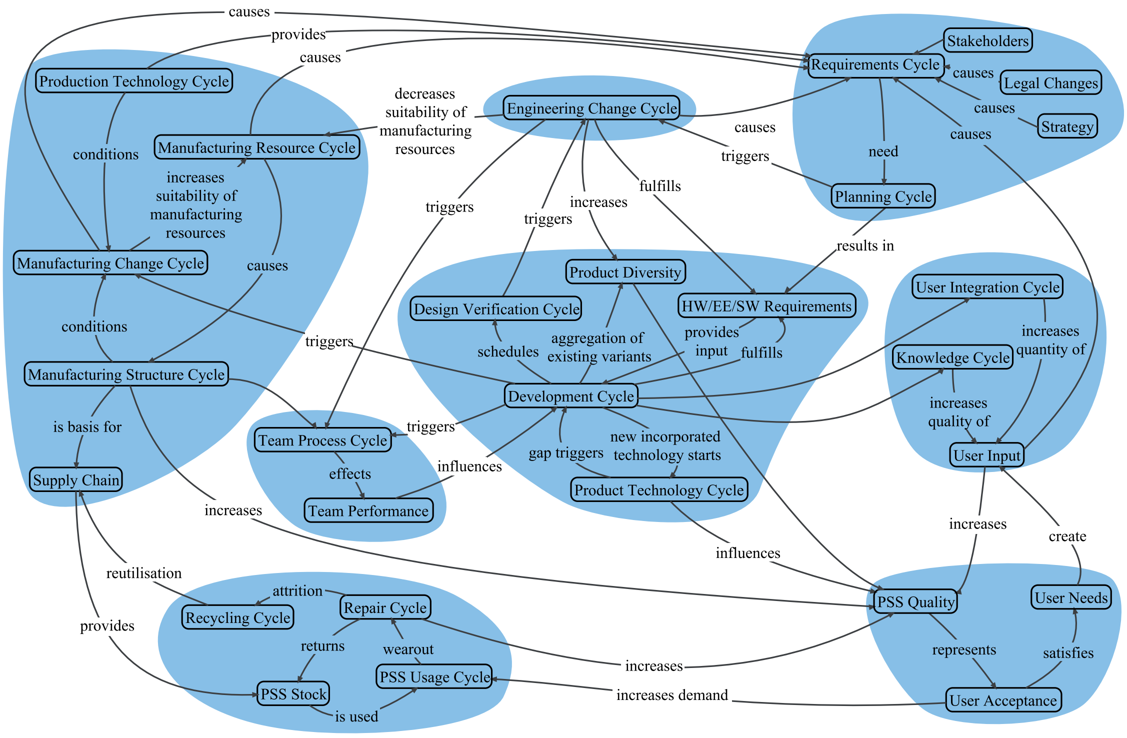

Fig. 1. Cycle network of the innovation process of PSSs