Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 61 (2017) 104 – 109
www.elsevier.com/locate/procedia

The 24th CIRP Conference on Life Cycle Engineering

Complexity in a Life Cycle Perspective

Christoph J. Velte[a,*], Anja Wilfahrt[b], Robert Müller[a], Rolf Steinhilper[a,b]

[a]*Fraunhofer IPA - Project Group Regenerative Production, Universitaetsstr. 9, Bayreuth D-95447, Germany*
[b]*Chair Manufacturing and Remanufacturing Technology, University of Bayreuth, Universitaetsstr. 30, Bayreuth D-95447, Germany*

* Corresponding author. Tel.: +49-921-78516-422; fax: +49-921-78516-105. *E-mail address:* christoph.velte@ipa.fraunhofer.de

Abstract

Transforming linear businesses to circular economies is anticipated by industry and policy as a way to conciliate economic, societal and environmental interests in a life cycle perspective. This integration of aspects however comes at the price of complexity in manifold facets. In this paper, we suggest a conclusive categorization of complexity through a literature review and collect drivers of complexity. Through coding the literature for weighted interdependencies, we are able to show how drivers and categories interrelate in a contingency matrix. The results help companies to better leverage existing means of complexity planning and management for developing circular economies.

© 2017 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering

Keywords: Complexity; Production Systems; System Theory; Qualitative Data Analysis; Complexity Management; Interdependency

1. Introduction

Complexity is a very complex thing. It is often talked about, while the very meaning can differ from one source to another, from one field of application to the next [1]. In fact, complexity can be seen as an umbrella term that subsumes different phenomena. Those aspects of complexity will be presented in section 2 of this paper. A problem that arises from the ambiguous meaning of complexity on the one hand, and the limited meaningfulness of talking about complexity without detailing the real problem on the other hand, is the fact that researchers as well as practitioners struggle to find the right measures to effectively deal with the complexity-induced problems that are described.

This is especially important when taking into account that complexity is not a singular event, but, when thinking about complexity as a system property as done in various disciplines such as “philosophy, the physical sciences, engineering and management” [2, p.13], complexity is present in a system’s elements and their connections [3]. This results in non-obvious, dynamic effects throughout systems, where local differ from global, and short-run differ from long-run phenomena [3]. In the light of a discrepancy of how complexity is dealt with today and the role of complexity towards a circular economy [4], analyzing drivers is an important start to the control of interdependencies in a life cycle perspective.

To help foresee causes and effects better, this paper presents a number of complexity drivers as they are described in the literature and analyzes them for their interrelations through an extensive data analysis. Thus it can be shown how, through these interrelations, changes in one area of a company (e.g. the process complexity) trigger changes in other, connected areas of the same company (e.g. order fulfillment).

To reach this goal, this paper will introduce the state of the art concerning systems and models, complexity and qualitative data analysis in engineering in section 2.

Section 3 will present the analyzed complexity driver data and result in a list of complexity drivers, categorized for their area of origin and nature. Section 4 will present how those drivers are analyzed for their interdependencies and result in a contingency matrix that presents the weighted mutual influences of the drivers. The results will show how the drivers and categories interrelate. Finally, section 5 will summarize the findings and give an outlook on forthcoming research based on the results presented in this paper.

2212-8271 © 2017 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.11.253

2. Complexity and systems

In this section, we introduce the state of the art in systems thinking and models, the definition of complexity and the use of qualitative data analysis techniques to clarify the framework used in this paper.

2.1. Systems and models

To think of production as a system is a good way to make something that is intangible understandable and describable. In this vein, to familiarize with the term complexity and dealing with complexity in companies, the two schools of systems theory and cybernetics have proven to be capable [6]. For an ease of understanding, systems can be pictured as networks that, in their most basic appearance, have at least two elements that are connected by one relation [7]. A system's model is a simplification of the very system analyzed, limited to the elements and relations that are to be investigated through this model [8], the subjective view of the modeler and the point in time when it is created [9,10].

Systems theory aims at describing such systems using consistent definitions and well described tools in order to understand the basic interrelations and principles of the system on an abstract level [11].

To frame the necessary understanding of a system as it is relevant in the context of this paper, it is furthermore necessary to state that systems and their elements have some distinct properties that define them. Firstly, a system is always limited by a system boundary, separating the elements that are system-internal from those, that are external to the system. Here we talk about system endogenous and exogenous areas [5] or, meaning the same differentiation, the system area versus a system's environment [11].

Secondly, elements of the system may influence each other in various constellations. The simplest of those is a cause and effect relationship, where an action or change in one element directly causes a change in another element [5]. In reaction to this stimulus, the affected element may affect another element again. If this reaction from the affected element directly feeds back to the element that sent out the initial stimulus, the relationship between those elements is called a (direct) feedback loop [12].

The third class of properties that define a system, besides the fact that it has boundaries and the described elements and relations within these, are quantity and kind of inputs to the system and outputs of the system that pass through these boundaries. The system is influenced by its environment and might influence back surpassing its own boundaries [5]. This is also the case if the system imagined is a subsystem that communicates with the rest of the bigger system.

An overview based on a systems understanding as it is taken up in this work based on [5] can be found in Fig. 1.

Though due to the scope of this paper, we will not apply the results presented in system dynamics already, it is important to have this understanding of systems and relations within systems to understand the main motivation for the analyses presented. Thinking in systems makes it necessary to analyze sources of complexity in this spirit in order to create results that can be further applied with and deepened through e.g. system dynamics models.

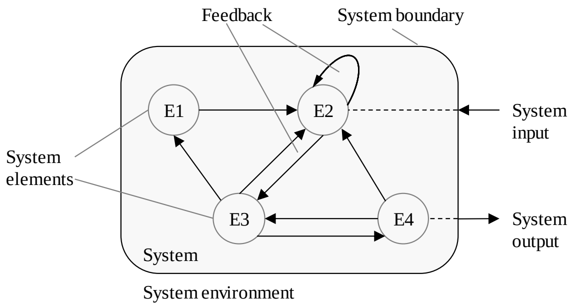

Fig. 1. Main terms and elements of a system based on [5]

2.2. Complexity

Having gained an understanding of a system and a system's model, it is easy to understand what is meant when talked about complexity. Building on complexity as defined e.g. by Wildemann, a first delineation can be drawn between structural complexity and dynamics [13,14]. While structural complexity origins from quantity of elements and connections together with the degree of difference between elements as well as connections (compare also [15]), the dynamic aspect of complexity covers the fact that this structure changes over time interdependently and is unpredictable and indeterminable [16]. Different opinions prevail on whether insecurity and opacity belong to the dynamic component of complexity or are a separate category (compare [16–19]), while in this paper we subsume those elements under dynamics and describe complexity as consisting of the static elements quantity and variety and the dynamic elements dynamics and interdependency (compare [18]).

Depending on the degree of structural and dynamic complexity, and transferring this idea of complexity to systems thinking, systems can be classified to be simple systems if both structural and dynamic complexity are low, complicated systems if only the structural complexity is high, dynamic systems if only the dynamic complexity is high, and complex systems if they are determined both by a high structural and dynamic complexity [20].

2.3. Qualitative data analysis, inter-rater-reliability and contingency matrix

To be able to analyze qualitative data, such as written text, social sciences know a technique called qualitative data analysis. This technique enables the structured analysis of written text as to its content in order to interpret the meaning of a text and make sense out of it rather than repeating it [21]. Coming from e.g. interview interpretation and bottom-up-coding, this technique is nowadays applied in different fields of research with all kinds of documents [22] and has also been applied to analyze product development data in the engineering sciences [23]. According to Yin, qualitative research is structured into five phases called compilation of data, disassembly of data, reassembly of data, interpretation

Download English Version:

https://daneshyari.com/en/article/5470488

Download Persian Version:

https://daneshyari.com/article/5470488

Daneshyari.com