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Procedia CIRP 69 (2018) 25 – 30

www.elsevier.com/locate/procedia

25th CIRP Life Cycle Engineering (LCE) Conference, 30 April – 2 May 2018, Copenhagen, Denmark

Product life cycle design for sustainable value creation: methods of sustainable product development in the context of high value engineering

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Abstract

This study proposed a framework for sustainable product development in the context of high value engineering, using life cycle based approaches combined with methods of sustainable value modeling and analysis. A Sustainable Value model was proposed based on the understanding of Value from economic, social and environmental perspectives. Then, a QFD-based approach of life cycle scheming driven by sustainable value requirements was proposed for generating product concepts and life cycle plans of total high value, while Life Cycle Simulation was employed for modeling complicated close-loop type product life cycles and evaluation of sustainable values. The proposed framework may help bring experts in fields of product and process engineering, industrial management and ecological assessments to a common vision, and therefore accelerate design convergence for more sustainable products, processes and business.

Peer-review under responsibility of the scientific committee of the 25th CIRP Life Cycle Engineering (LCE) Conference

Keywords: Sustainable Value, Life Cycle Engineering, QFD, Discrete Event Simulation

1. Introduction

Competition in the modern global economy relies on gaining superior engineering capabilities to create high value added products and services rather than focusing solely on the output of manufacturing. This leads to a new knowledge area of increasing importance-high value engineering, which is focused on how to effectively create value through engineering excellence in the current business environments and for the future. With growing demands for sustainable products, there are clear implications for developing high value engineering capabilities from the perspectives of industrial sustainability. There is an urgent need to develop process and tools to better integrate sustainability into global value chain [1]. Sustainable value implies profits, improved environmental performance and safety amongst other parameters in an organization. The aim of a value-based managed organization is to create value, manage value and measure value to create more value based on the identified improvement potential [2]. However, the question arises as existing value concept and definitions sufficient when viewing values form broader perspectives of sustainability. Just to quote: Long-term thinking has to be instilled; old fashioned value perspectives have to be refreshed so that a sustainable growth and survival becomes realistic [3]. Thus, a broad view of what makes product and services “valuable” and competitive in the market with growing concerns of sustainability should address all the significant ways in which attributes of the product impact interests of involved partners.

Sustainable Value refers to a broad set of benefits derived by a stakeholder from an exchange, which, in the context of sustainability, do not only include monetary profit, but also include social and environmental aspects [4, 5]. In the research of Henriques and Catarino[6], a Sustainable Value concept was proposed using the synergies between tools from Value Management, Value Analysis and from Eco-efficiency, Cleaner Production, resulting in an indicator that integrates the three aspects of Sustainability: economic, environment and social and enables the monitoring of the evolution of those aspects in

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doi:10.1016/j.procir.2017.11.099

a company. The philosophy behind this concept is the delivery of products and services that satisfy human needs at lower costs while reducing the ecological impacts and resource intensity. Study of Baldassarre et al [7] was focused on the business model innovation for achieving sustainable development. Their research aims to develop more successful, radical and user-centred sustainable value propositions, which is the core of a sustainable business model, by combining principles from both sustainable business model innovation and user-driven innovation. It is inevitable that some judgements and decisions must be based on hard numbers and quantitative assessments. This naturally leads to a question that "how can the sustainable value be evaluated and compared in order to reach a decision". Figge and Hahn [8] proposed a Sustainable Value model aims at the quantitative assessment of the value-creating use of environmental, economic and social resources. The approach can be used to answer the financial-economic question of "where environmental and social resources should be allocated in order to achieve an optimal overall return". Mastre and Vogtlander [9] proposed an indicator for eco-efficient value creation, which is the Eco-cost/value ratio (EVR). In their study, eco-costs was used as a single indicator in LCA for the environmental burden of a product, while market price is used as value for existing products and the Willingness to Pay(WTP) for products not yet on the market. The EVR was developed to link production side of the environmental problems (i.e. make products with lower eco-costs) to the consumer side (i.e. give green products a higher value so that customers will buy it). Then, eco-efficient value creation for the product system was addressed by analysis and reduction of EVR. However, the common disadvantage of the above mentioned two studies is lacking of value perspectives of various involved stakeholders throughout the value chain. That is, to maximize the overall value of the value chain, it is important to identify, in the first place, what is value to different stakeholders involved in the business.

It is found that sustainable value and/or sustainable value creation are generally studied from managerial perspectives such as business strategy making and business model innovation. Business strategies and models need to be continuously cross-linked to engineering activities to adapt to the ever changing market environment and vice versa. The awareness of sustainability concepts and applying these concepts to products, processes and services holistically require engineering capabilities. That is, instead of looking at the implementation of single elements, engineers must be aware of multiple interactions among value creation factors (i.e. product, process, service), life-cycle stages (i.e. design, manufacturing, use and EoL), and sustainable principles of engineering practices (i.e. reduce, recycle, remanufacturing). It is important that engineering activities bring value, and engineers should properly comprehend value demands and integrate them into their daily work. Given the existing researches, we found there are still needs for 1) better conceptualities of sustainable value that taking both the desires of involved partners throughout the value chain and equally important the interests of the environment and 2) approaches and tools that translates sustainable value demands into terms that are immediately meaningful to design engineers. To address the above problem, this study proposes a novel approach to guide engineers on how to achieve sustainable solutions that respond to both requirements of high value creation and environmental concerns by sustainable innovation.

2. Development of Sustainable Value Model with multi-view of sustainability and perspectives of different stakeholders throughout product life cycles

Sustainable value requires performance on multiple dimensions:

Sustainable value=total satisfaction of value requirements from perspectives of economic, social and environment

$$V_{sus.} = f_{eco.}(vr_{eco.}, S_{LC}) + f_{soc.}(vr_{soc.}, S_{LC}) + f_{env}(vr_{env}, S_{LC}) \quad (1)$$

where,

$V_{sus.}$: Sustainable value ;

S_{LC}: Sustainable product life cycle solution;

$vr_{eco.}$: Economic value requirements;

$vr_{soc.}$: Social value requirements;

vr_{env}: Environmental value requirements;

$f_{eco.}$: Evaluation function of economic value requirement satisfaction ;

$f_{soc.}$: Evaluation function of social value requirement satisfaction;

$f_{env.}$: Evaluation function of environmental value requirement satisfaction.

$$f(vr, S_{LC}) = g(\Delta\left(vr_{target}(S_{LC}), vr_{estimate}(S_{LC})\right)) \quad (2)$$

in which,

$vr_{target}(S_{LC})$: Target value settings of value requirement indicators;

$vr_{estimate}(S_{LC})$: Estimated (or evaluated) value of value requirement indicators;

Δ: Difference between the estimated and target value of VR indicators;

g: Evaluation function based on Δ.

The keys to understand and make use of the proposed sustainable value model include the concept of Sustainable Value Requirement (SVR) and value requirement satisfaction. First, value can be economic and/or social and/or environmental demanded by customers and/or businesses to fulfil the customer's requirements and/or to achieve strategic goals. Value requirements are the demands for the value by both customers and businesses. These requirements are related to sustainable value based on it dynamics in the sustainable value frame (i.e. Ref[[10]).

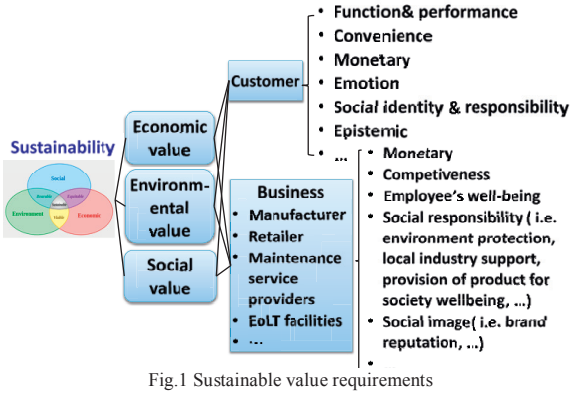

Fig.1 Sustainable value requirements

Therefore, combining the multi-views of sustainability and perspectives of different stakeholders, SVRs can be