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Quantified economic and environmental values through Functional Productization - A simulation approach

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ABSTRACT

Industrial companies rely on hardware and services from external providers to deliver functions that are critical to their operations, increasingly demanding solutions that not only meet technical and availability requirements but are sustainable too. Traditionally, industrial companies choose and purchase hardware and maintenance support to fulfil their functional requirements. An alternative arrangement, known as Functional Product (FP), involves external providers supplying customers with the functionality they require through contracts that specify guaranteed functional availability whilst giving providers freedom to choose and retain ownership of the supplied hardware and services. This paper describes an innovative simulation modelling and optimization approach to quantitatively compare economic and environmental values resulting from transition from traditional to FP arrangements. The approach is demonstrated through the analysis of a scenario involving a hydraulic drive system provider and set of customers in Sweden, with the results exhibiting simultaneous improvement in economic and environmental values at each stage of the transition.

1. Introduction

The earth is facing an increasing population (United Nations, 2013) who, by following the same consumption pattern as historically, will require increased resource extraction (Wiedmann et al., 2015). In addition, it is expected that growth will be sustainable such that the global mean welfare will continue to increase and that the global environment will not be deteriorated to a hazardous level. Since natural resources are limited, these conditions cannot be simultaneously fulfilled meaning that actions need to be taken to change the resource extraction and the environmental impact. A substantial amount of research has been conducted to address sustainability challenges from different perspectives (Arena et al., 2009; Delai and Takahashi, 2011; Morlet et al., 2016; Bratt et al., 2011). In particular Bond et al. (2012) conducted a state-of-art analysis regarding sustainability assessment. They found that since the early 1990s the amount of research has increased rapidly and claim that sustainability assessment is one of the most important factors to actually increase sustainability.

Many of the current mega trends of globalization, informatization, move toward a network economy, lean and "just in time" production, concentration of core business, shift to two income families, more single-person households, more time pressure on citizens and individualization inherently lead to a greater demand on product-service solutions rather than products. A customer often does not have the time, knowledge or resources necessary to evaluate all available solutions from all vendors. Therefore if the customer chooses the product constituents to purchase (as a solution to their functional requirements) the risk is high that the sustainability of the solution will be suboptimal (Tukker and Tischner, 2006).

Research has further indicated that transformations into Performance Based Contracts (from resource based contracts) has the potential to improve sustainability through increased resource efficiency (Bakshi et al., 2015) and lead to improved hardware availability (Guajardo et al., 2012; Kim et al., 2017). On the other hand, by comparing leasing and servicizing contracts with pure sales, research has shown that environmental impact depends on different assumptions and context and can even be an environmentally inferior alternative (Agrawal et al., 2012; Agrawal and Bellos, 2017).

It has been shown that industry is one important stakeholder affecting the sustainability development (Lindahl et al., 2014). Therefore, different aspects of how industries can contribute to sustainability have been studied (Joung et al., 2012; Lindahl et al., 2014). One such aspect regards transformation from traditional product provision to performance based innovations such as Product Service Systems (PSS) (Mont,

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2002), Through-life Engineering Services (TES) (Roy et al., 2013) and Functional Products (FP) (Alonso-Rasgado et al., 2004) – the latter of which is targeted in the research presented in this paper. Amongst these business concepts, a defining feature of FP is its total care guarantee, incentivizing and empowering the provider to consider the whole value-chain in a life cycle perspective when developing solutions. Within the area of life cycle simulation, there exist some pioneering work regarding evaluation of environmental and economic impact e.g. Johansen et al. (1997) and Umeda et al. (2000). However, in these examples the flexibility and level of detail of the support system is limited. In addition, Fujimoto et al. (2003) illustrated, through simulations, the potential of service oriented products in terms of both environmental load and business opportunities. Simulation has been widely used to model the environmental performance of product lifecycles, for example in cement manufacturing (Gäbel et al., 2004), due to its flexibility and ability to perform detailed analysis. Garetti et al. (2012) proposed a reference architecture for life cycle simulation for PSS which included both a product model and a service model instance. They concluded "the use of simulation for the virtual emulation of a service network could offer strong support to engineers to develop a comprehensive PSS." Tukker (2004) performed a qualitative evaluation of the economic and environmental sustainability characteristics of eight types of PSS. The conclusion was that most PSS types will likely result in marginal environmental improvements at best and that the idea that PSS development will automatically result in an environmental-economic win-win situation seems to be a myth. The exception was the PSS type known as functional results, where the result rather than product is sold by the provider, which Tukker deemed most promising in environmental terms primarily due to the greater freedom for the provider to design a low-impact system. FP is most closely related to functional results PSS (also known as result-oriented PSS), however FP is constituted by a specifically developed integration of hardware, software, service support system and management of operation (Lindström et al., 2012) and places greater focus on the delivered function rather than enabling constituents (Lindström et al., 2014). Under FP, customers enter a contract that gives the provider freedom to choose the appropriate solution to achieve the agreed upon functionality for the customer industrial applications. The provider retains ownership of all constituents and the contracts stipulate performance-based guarantees (e.g. functional availability) to incentivize the provider to meet the functional performance levels required by the customer. On the other hand, under traditional product provision, customers themselves choose and take ownership of the product constituents, by purchasing them from the third-party providers, to provide the required functionality for their industrial applications.

Retention of ownership of all product constituents by the provider under FP, and hence the responsibility for them throughout the product lifecycle, also generates new incentives and possibilities, which has also been shown in servicizing contracts (Reiskin et al., 1999). In contrast to traditional business models, income in FP businesses is generated only through the provision of functionality leading to incentives for the provider to be as resource efficient as possible (Alonso-Rasgado et al., 2004), for example by sharing resources across multiple customers. Further, by retaining ownership the provider has the possibility to upgrade, reuse, remanufacture, down cycle and recycle the constituents to remain resource efficient over the life cycle (Mont, 2001). These efficiency improvements can then be shared within the FP value chain. In addition, other tangible and in-tangible values are typically generated through FP innovations (risk sharing, partnerships, even cash flows etc.) which hence promotes sustainable value chain win-win over the life cycle (Lindström et al., 2014).

Although qualitative research exists indicating sustainability advantages by transformations into FP businesses (Functional Productization) there is still a lack of quantified results (Markeset and Kumar, 2005; Brännström et al., 2001). One reason for this is that very few FP businesses exist (i.e. where the constituents have been specifically developed for FP provision) that could generate real data as evidence. In addition, many contributions utilize quite general sustainability impact assumptions (e.g. assumed differences in durability between products when leased or sold (Agrawal et al., 2012)), hence the relationships to the physical events vanish, resulting in limited validity. However, a possible strategy to quantify sustainability gains is to explicitly model the functional provision events that occur when FP and alternatives are implemented and then measure the resultant differences in economic and environmental impact. To make a fair comparison, the different scenarios should all be optimized and evaluated at the same level of production and with equal boundary conditions. Such a fair comparison is lacking in existing literature. Research has previously been published on modelling and simulation FP constituents to predict measures other than sustainability e.g. hardware availability (Löfstrand et al., 2014) and service support system costs (Kyösti and Reed, 2015), and also on how to integrate constituents in simulation models to assess and optimize these metrics (Löfstrand et al., 2011). However, despite the existence of these prediction strategies, there still exist no results quantifying the sustainability improvements, if any, that result from Functional Productization. Therefore, the hypothesis for this research is that:

Transformation from traditional product trade to FP can simultaneously improve economic and environmental sustainability.

Thus, the objective for this paper is to provide evidence to justify this hypothesis. The study is limited to one scenario based on a real industrial situation and excludes the social sustainability dimension.

2. Research approach

To provide quantitative evidence of sustainability improvement through Functional Productization a hypothesis testing approach was applied (Spector, 1981). To test the hypothesis, the characteristics of business cases representing the transition from traditional to FP must be identified and indicators of economic and environmental sustainability performance must be measured for each. These measures can then be compared between the cases to detect whether Functional Productization leads to economic and environmental sustainability improvements. Industrial situations that would enable direct and fair comparison between functional provision and traditional product trade do not currently exist. This could possibly be solved by developing FP at some existing industry, which could then be studied when provided to customers to obtain empirical evidence. This strategy was considered as infeasible due to time limitations, complexity of establishing comparable situations and lack of possibilities to control the study. Therefore, a model approach based on an existing industry situation was selected for the research presented in this paper.

Aligned with previous research presented (Kyösti and Reed, 2015), a hydraulic drive business-to-business (B2B) value chain including a fleet of process industry customers and applications were selected for the common scenario. The data needed to set up the scenario was collected by a systematic analysis of existing information regarding value chains in manufacturing and process industry from previous research projects carried out within VINNOVA Excellence Centre the Faste Laboratory since 2007. In particular, material from interviews and workshops with personnel at a hydraulic drive manufacturer in Sweden as well as with personnel at some of their customers was considered. To further ensure scenario relevance, the current hydraulic value chain was thoroughly analyzed. For confidentiality reasons, a tentative value chain was developed based on current hydraulic drive value chains.

Several intermediate business models exist between the extreme traditional and FP cases outlined in the introduction, representing the transition in responsibility, choice and ownership of the functional provision constituents from the customer to the provider. It was decided that four cases representing different progression steps toward provision of FP should be modelled. Three existing business cases, which will