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Defining value creation in the context of circular PSS

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Abstract

The concept of a circular economy (CE) can be regarded as a way to operationalise the aim of accomplishing sustainable development (SD) on a macro level. Product-Service Sytems (PSS), business models (BM) that combine tangible products with intangible services to jointly satisfy a customer's needs, are well suited to align with CE principles. Whether applying CE principles leads to value creation for a broader group of stakeholders, however, is not yet sufficiently proven. The study presents CE principles, elements that govern the decision-making process of a firm and uses the example of PSS to demonstrate how these principles are applied in the design of the supply chain network. A definition of value creation for multiple stakeholders is presented, and the example of mobility as a service used to highlight the importance of system and life cycle (LC) thinking to prevent rebound-effects and fully understand the trade-offs of a circular PSS.

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Keywords: Product-Service System; Servitization; Rebound Effect; Trade-Off; Circular Economy

1. Introduction

In recent years, circular economy (CE) has gained attention in both academia and industry as a means to shift towards a waste-free society and a more resilient and fair, nevertheless growing, economic system. Originating from different schools of thoughts (such as Industrial Ecology, Cradle to Cradle, Natural Capital), CE can be regarded what Hirsch and Levin call an 'umbrella construct' to combine otherwise unrelated findings in order understand the bigger picture. The emergence of CE creates a platform on which different strategies for the extension of resource-life can be discussed [1] but does as well lead to inconsistencies and variations of definitions [2].

These inconsistencies become evident reviewing different author's opinions on what a CE defines, using terms such as principles, attributes, strategies, BM or values. In this study, we define CE principles as a moral rule or code of conduct governing behaviour and decision making in the chain of reasoning with the aim to stepwise transform from a linear to a CE. A CE is a free, industrial system, designed to maintain, protect and restore environmental quality, increase the economic prosperity and guarantee social equality to the benefit of current and future generations. The aim of CE can be defined as accomplishing sustainable development (SD) [2]. Using CE principles to accomplish SD must be done with caution, as following CE principles inconsiderately on a micro level may lead to adverse effects on a macro level.

The study presents a set of guiding principles derived from the literature and describes how these principles apply to Product-Service Systems (PSS) and how that may lead to the SD mentioned above through integral value creation. By proposing a definition for value creation for multiple stakeholders, the study suggests an alternative way of examining the value created in a system. It not only focuses on the benefits of business models (BM) but as well shows how unintentional rebound effects that diminish the overall value created may be spotted.

2. Circular economy principles

A challenge in collating and defining CE principles is to find the balance between abstraction and detail and varies from 3

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[3] to 15 [4] principles in the reviewed literature. The terminology used can be misleading as authors interchangeably use the words aims, principles and activities to describe the concept of CE. The CE principles synthesised from the literature are considered as guidelines governing the decision-making process of organisations to accomplish SD.

To minimise the use of primary resources, the "3R-principles" of reducing, reusing and recycling (some authors add recovery to these principles) on a micro- (enterprise), meso- (industrial park) and macro- (regional) level are a fundamental principle. As a primary guideline, efficiency reduces the requirement for more raw materials, prolonging life through repair and remanufacturing helps to reuse products to a maximum capability, recycling reduces the consumption of virgin materials for part production. In the last instance, recovery of energy such as incineration aims to extract energy stored within the material. For the highest impact, these steps are hierarchically ordered to preserve more of a product's value as it keeps and restores its integrity, complexity and embedded labour and energy. [2–6].

To accomplish SD the use of scarce and finite resources must be minimised, energy must be produced from renewable sources, and natural capital has to be used in a regenerative way. The biological material should be allowed to re-enter the biosphere safely for decomposition and to regenerate into new value. [2,4,5,7].

In a CE, waste does not exist. Waste should be turned into wealth by re-entering it as "food" into the supply chain using new technologies and materials. Products can be cascaded across multiple diverse applications along the value chain to avoid leakage of material and destruction of value through loss. By doing so, negative external effects such as landfilling can be turned into possible benefits for both technical components and materials as well as biological nutrients. [4–6].

Regenerative biological and restorative technical nutrients must be free of toxic chemicals, strictly segregated and kept pure to increase the collection and redistribution efficiency as well as the material productivity. [5,8,9].

Products and processes must be designed so they not only do less harm but do good and have an optimal product life scenario. Waste is designed out to keep products, components and materials at the highest utility and value for as long as possible. Such a design can be achieved by determining the end of life strategies not when products have technically failed, but as a precautionary process for disassembly, reuse and recycling to increase the number of the possible life cycle (LC) and optimise the use of the components of a product. Maximising the number of consecutive cycles and extending the utilisation period of products slows down the flow of material through the economic system by avoiding material and energy consumption. This reduced flow of resources can be achieved when companies recognise the responsibility and take on the product stewardship and the accountability for their products and end-of-life and continually innovate to achieve efficiency and effectiveness in their products and operations [4–6,9–11].

System- and network-thinking is widely applied in CE as organisations, society and the environment are complex systems. These systems are rich in feedback loops and often strongly interlinked with other actors in their system and affected by decisions made by an organisation. These links must be taken into consideration all the time across the entire value chain when planning supply chain networks. Actors in the system collaborate internally and externally through formal and informal arrangements to optimise the economic system and create mutual value. [4,5,8,11].

CE aims for diversity as a critical driver of versatility and resilience within the systems. Building up robustness through diversity is not only necessary for living systems but as well for economies to recover quickly from various disturbances and crises. Production in CE should be local and decentralised to reduce the pollution and resource consumption during the transport and create self-sustaining communities and ventures. By doing so, residues and waste from production stay where they have been extracted, processed and transformed [2–4].

Circular BM must be economically viable and follow the law to ensure economic growth and prosperity is maintained, protected and strengthened. Prices should reflect real costs of a product and all negative externalities must be considered as the price builds a feedback loop and message to the market. Companies should strive for strongly sustainable BM which creates positive environmental, social, and economic value throughout its value creating system without substituting one with another. To be sustainable, organisations must be transparent about their decisions and activities and communicate them in a clear, accurate, timely, honest and complete manner. [2,4,5,7,11]

3. The rationale for circular PSS

The principles described in the previous section are not restricted to a specific BM. However, the barriers to infuse CE principles differ among BM. Different sustainable BM to realise an industry driven transformation towards a CE have been identified [12] with PSS as a prominent example. Apparently, the potential is big enough for the United Nations Environment Program to call them 'a win-win solution for the producer, user and the environment for both developed and developing countries'.

A PSS supply chain can be described as 'a platform that integrates and utilises the resources of suppliers and customers to co-create the customised and flexible bundling of products and services throughout its life cycle'[13]. Complementing this definition with the idea of taking over a stewardship role, LC thinking seeks to identify possible solutions to improve goods and services by reducing resource use and environmental impacts throughout the entire product LC.

The supply chain networks that support servitized products throughout their LC stages are in the academic literature often described as complex adaptive systems and are discussed from a systems perspective. These stages consist of Beginning of Life (BoL; concept, design, plan, source, manufacturing, delivery and installation phase), Mid of Life (MoL; use phase with monitoring and maintenance) and the End of Life (EoL; collection, recovery strategy, redistribution, disposal phase or the introduction into a secondary market) and highlight the potential of the PSS provider's stewardship role [13–15].

It is the designers' and engineers' obligation in the BoL to make sure that they consider the resource consumption throughout all the different LC stages and choose material and energy from renewable sources. Taking a systems perspective is especially compiling for PSS as the supply chain network is governed by the provider which allows taking a fresh look at the entire system to create integral value for various stakeholders in the ecosystem. In these networks, products and processes are, potentially in collaboration with third-party system integrators, designed to integrate with the customer's operations fully. In these integrated solutions, the possibility of multiple LC and the EoL strategies to maximise material longevity are discussed during the design phase and not just when the product has functionally failed. This LC thinking makes clear that closing the supply chain loop in CE is more than just harvesting parts when products are not working any longer [10,16].

In use and result oriented PSS, the company providing the service may retain ownership over the products involved in providing the service. By doing so, the provider takes on the responsibility for the EoL strategies such as disposal, recovery or the introduction into a secondary market [17]. After the service is provided, reverse logistics return the product from the customer to the service provider or a third-party company which decides on the most suitable recovery strategy [18]. State of the art literature in this field suggest three to five hierarchically ordered recovery strategies for servitised goods which are [5,15,18,19]: (I) Maintain, Clean, Refill, (II) Repair, Refurbish, Upgrade, Reuse, (III) Remanufacturing and part harvesting, Material recycling (IV) and (V) Scrap and energy recovery. By executing these recovery strategies, and following CE principles in all phases of the product's LC, the supply chain loop is closed as depicted in Figure 1.

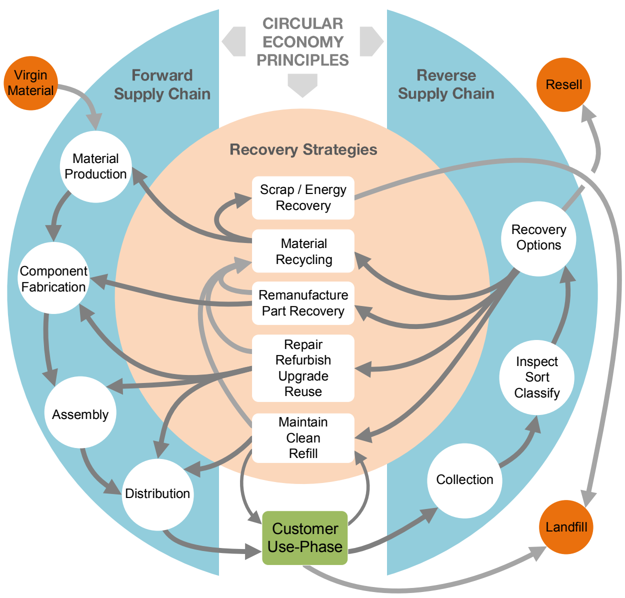

Fig. 1: Circular PSS supply chain

The supply chain network to support the different recovery activities is ideally decentralised to keep the transportation costs and emissions low and process residues locally. Such decentralised supply chain networks are more resilient and diverse as external effects only affect the supply chain locally rather than disturb it globally. The academic literature PSS emphasises on closed-loop supply chains. However, open supply chains may occur if a third party performs the product recovery and the artefact is resold, cascaded into a different market or if there is simply no aftermarket [18].

Although the PSS literature predominantly discusses CE principles related to technical products, biological materials are equally important, considering new materials in the production, consumables during the use phase and separability in the recovery operations.

4. Value creation in circular PSS

Novel business models, the abstraction of 'how a firm does business, capturing the heuristic logic of how a firm creates, delivers, and captures value through its activity and transaction system architectures, in concert with its boundary-spanning relationship network' [20] have caught the attention of both academics and practitioners. Such BM may in combination with the application of CE lead to a more sustainable and a harmonious society through integral value creation. This form of value creation covers multiple types of business value, opportunity creation, risk reduction and impact reduction for the focal firm, primary and secondary stakeholders [21]. However, create, deliver and capture value describes the activities of a focal firm and the dyadic relationship with the customer predominantly and only to a limited extent suitable to do justice to the LC and multi-stakeholder thinking required in CE and to accomplish SD.

In discussions around BM and CE the term value is often over- and misused, and authors tend not to define what they mean by value explicitly. In this study, we use and adopt the definition from the marketing literature, which defines value as the overall assessment of trade-off between benefits and sacrifices (see Zeithaml, 1988) of an economic transaction [22]. The *Value* of a PSS can, therefore, be defined as the ratio between the *Benefits* and *Sacrifices* involved in the provision of the products and services [23], as described in Formula 1.

$$Value = \frac{Benefits}{Sacrifices} \quad (1)$$

The literature on PSS is predominantly, but not exclusively, discussing mutual value in the buyer-supplier relationships, the trade-off in what is given and the perception on what is received [22,24–26]. In CE however, a more holistic view of value creation, interests and responsibilities of the extended value creating system has to be taken into consideration. This expanded view is demonstrated by taking the external impact on the natural environment and society at large into consideration as depicted in Figure 2 [27].

To identify and measure value for the different stakeholders that are affected by the achievement of an organisation's objective, the horizon has to be expanded, and more stakeholders have to be integrated, namely non-supply chain actor s [21].

The focal firm is viewed as a separate stakeholder group, encompassing employees, investors and shareholders. It creates value for or with its primary stakeholders which include customers who receive perceived value in use and suppliers, service providers, distributors and leasing companies who more likely receive transactional value. The secondary stakeholders are embedding the primary stakeholders and are groups that are influenced by the activities of the focal company without being involved in the transactions. These secondary stakeholders such as natural environment, governmental and non-governmental organisations, future generations or the society at large are the hardest to identify as they do not have bi-directional interaction with the focal firm and may receive potential beneficial value, but most likely negative impacts [21,28,29].

Both benefits and sacrifices entail intangible components and are, therefore, subject to perception [23] and evolve and manifest over the different stages of the product's LC [30]. We define the benefits as *Potential Value* that is generated by using the functionality, consuming the emotional attribute, experiencing the availability of a product or the capability to satisfy the performance specification required [23]. With the emergence of a service-dominant logic [25] which advocates the value in use as a process, value is always contextual and requires both customer's and firm's resources. This value in use is derived from the solution quality [22], happens locally, can most effectively be done by networks of collaborating firms that simultaneously and is ultimately the determining factor for the pricing.

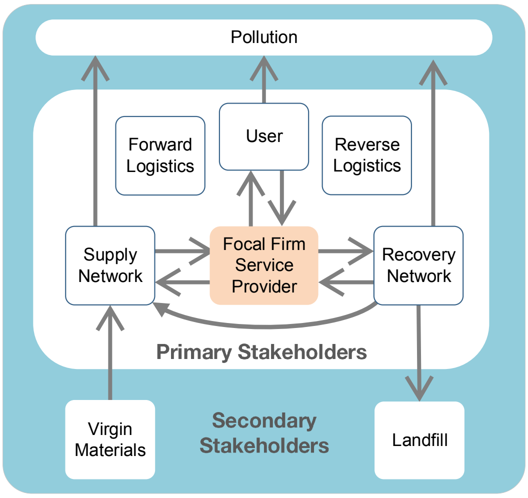

Fig. 2: Stakeholders in a circular PSS

The potential sacrifices identified in the literature cover two major topics, *Risk* and (negative) *Impact*. Perceived risk in PSS manifests in many ways and has been identified to be related to the availability, use, process or the environment of a product or service and are the result of commercial, affordability, performance, training and engineering related factors [23,30].

To increase the value created in the PSS, firms try to reduce risks and impacts. Mitigating risks, however, proves to be difficult as they not only result from mistakes in decision making but may derive from outside the firm and, therefore, are beyond the company's direct control [31]. One way to mitigate external risks it to internalise them what manufacturers do by accepting the risk related to the performance of the PSS by stepping into the provision of outcome-based contracts [16]. Identifying and quantifying the impact of PSS on the different stakeholders during the LC of its products [14,21] is probably the most challenging because of the lack of direct interaction, but as well the one with the most significant effects on the broader group of stakeholders [27].

The *Expected Value* of a PSS can be described as the ratio between the *Potential Value* and the sum of *Potential Risk and Potential Impact*, described in Formula 2 (the denominator of equation 2 is set equal to 1+(Potential Risk+ Potential Impact) to avoid Expected value in use increasing indefinitely when risk and impact is close to zero) [23]. These three components, value, risk and impact, are all 'potential' as they are experiential and derive from the observer.

$$Expected\ Value = \frac{Potential\ value}{1+(Potential\ risk+Potential\ Impact)} \quad (2)$$

Although established literature predominantly discusses financially quantifiable value manifestations, it is important to highlight that the benefits might be the creation of opportunities, improved efficiency, increased customer interaction, higher resource utilisation, less pollution or local infrastructure development [21].

However, what might be beneficial for one stakeholder might be harming another, intentionally as the result of a decision-making process, or unintentionally. By using formula 2, the value created is the ratio between benefits and sacrifices and the trade-off thereof which allows assessing the value for multiple stakeholders.

Blindly and thoughtlessly applying CE principles to business processes without considering the broader systemic effects, all stakeholders and the different LC of a product holds the risk that that reduction of overall resource consumption is not achieved. Rebound effects describe the phenomenon of eco-efficiency strategies at a micro level that leads to increased resource consumption at a macro level. For example, using bioethanol requires astounding amounts of water and land which otherwise could be used for the local food production and the production of solar panels requires rare earth metals and complex toxic processes [32].

For the provider of a PSS, it is both challenging and encouraging, as the orchestrator of the supply chain network, the firm must decide which recovery strategy to choose and by doing so significantly influence the value creation in the value creating system. Whether the offering leads to a decrease in environmental impact depends on the design of the supply chain and the products itself. Refurbishing and remanufacturing, for example, may require many additional kilometres of transport and still require new parts as well and as these activities rarely take place at the same locality as sales, the benefits are likely to be externalised as well [32].

Individual transport is an example often used for circular PSS as it entails huge potential to reduce structural waste in private cars as they are most often parked or almost empty while driven. A circular mobility system based on mobility as a service for individuals would lead to fewer and better-utilised cars and less pollution and resource consumption during the different LC stages.

However, such a BM may become more circular in the case that the pricing is based on performance rather than exchange to embrace fuel-efficient driving styles. Otherwise, the resources saved by reducing structural wastes are foiled by the increased consumption during the use. Furthermore, the consideration of the entire LC highlighted, as a recent study showed that new diesel engines might be preferred over remanufactured ones as the older engine produces significant exhaust emissions and 85% of the energy consumption and pollution occurs during the use phase. A remanufactured diesel engine could, therefore, consume more net-resources and pollute more than a new one, produced from recycled material but on the latest state of the art. Choosing a new over a remanufactured engine is somewhat contradictory as CE promotes to 'reduce-reuse-recycle' hierarchically, hence may lead to rebound effects if taken at face value [32–34].

To address this issue, the UK based company Riversimple tries to disrupt mobility by only offer their hydrogen fuel cell cars on a subscription basis and pay by the mile rather than owing the car. By doing so, the company aims to align the different stakeholder's interest by optimising the system as a whole from the production to the use phase and the recovery strategies.

5. Conclusion

The study presented was set out to further develop the body of knowledge on circular economy and Product-Service Systems. It did so by synthesising the literature to define CE principles, moral rules to follow in the decision making to shift towards a more sustainable and resilient future. Work on CE in both academia and industry is at a critical point as the validity of the concept is challenged, and rigour in definitions and research is crucial to result in coherence rather than a passing fashion, especially considering the relation to competing concepts for SD [1,2].

The principles presented in secion 2 add to the body of knowledge as they set clear guidance to accomplish SD and differ from more intangible high-level definitions and aims of CE. In accordance to some of the principles presented, a discussion on a general shift of mindset is deemed essential as non-material related CE principles such as stewardship are as crucial as the more quantifiable 3R principles.

The article used the BM of a PSS to demonstrate how these principles can be applied in the supply chain and develops a definition of value creation and the different stakeholders involved. Based on this definition, trade-offs and rebound effects are discussed, and the example of mobility as a service is presented to foster CE thinking.

A systematic literature review the authors recently conducted investigated the value creation in result oriented circular PSS and revealed that PSS research addressing sustainability issues lacks in investigating more complex technical B2B solutions (most of the research has been done on rather simple or standardized products such as bikes, prams, washing machines). Work on servitization, on the other hand, investigated predominantly customised complex products and discussed the dyadic customer-provider relationship, but not the extended supply chain network and encompassing value creating system. The review has further shown that sacrifices outweigh the benefits for the upstream suppliers and that unconsidered applying CE principles might lead to rebound effects that decrease the overall environmental performance.
To identify the stakeholders and their role in the value creation system, it is deemed useful to differentiate between the focal firm, the primary stakeholders such as the customer and the supply- and recovery network and the secondary stakeholders such as the natural environment and society at large. G, the stakeholders can be identified by defining who is involved in a bidirectional relationship with the focal form and who is unilaterally affected by the focal firm's activities [21,27,28].
It is found that the concept of CE is not yet at a stage where it is broadly applicable in an industrial context for low quantity high-value goods but rather developed for fast moving consumer goods. For companies to successfully integrate CE principles, an understanding of the value creation over the LC stages of the products and the involved actors is required. The study suggests that non-material related CE principles such as system thinking and the application of network methodologies are not only favourable but essential to achieving SD [11].

In this study, the authors propose an alternative definition of how value is created using the ratio of value and the sum of risks and impacts. The commonly used definition of value creation in BM of value creation, delivery and capture is unsatisfactory as it is derived from a transactional and dyadic mode of value creation, rather than an experiential integral view. This alternative approach to assess value creation as the trade-off between benefits and sacrifices allows the analysis of 'value created' in a PSS over the entire LC for multiple stakeholders, which allows to maximise the value in the system rather than optimising locally. The clear distinction between value for multiple stakeholders in the construct of integral value creation is supported by the aim to strive for strong sustainability. In contrast to weak sustainability, strong sustainability assumes that man-made and natural capital is complementary, but not limitlessly interchangeable. This view allows to create a clear link between CE, PSS and SD.

The illustrative example of mobility demonstrates that for actual value creation, system thinking is indispensable and that CE principles may not be applied arbitrarily as it suits best, but systemically considering the entire, potentially multiple, LC of a servitized good. This need calls for new frameworks and tools that are required to depict innovative circular PSS and identify the benefits and sacrifices of all stakeholders over the multiple LC to evaluate trade-offs and prevent rebound effects. Further, the example of the diesel engine presented stretches the importance of the design of products and a scenario-based LC assessment and renders upgradability and modulatory of products in a PSS crucial for circular value creation.
The academic community has so far found no consensus on how value in PSS, especially non-transactional experiential and subjective value, can be measured, quantified and assessed. By using the suggested definition of value, it is further possible to assess the value concerning multiple stakeholders and therefore as well evaluate on how the business model adds to the accomplishment of SD. The study in this way suggests how the accomplishment of SD thought the BM of PSS and CE could be operationalised.

The challenges identified set the scene for future research. The true cost of PSS is still unknown, and the trade-offs are widely unresearched. Although theoretically, PSS may lead to the promised win-win situation, real industry case studies involving multiple stakeholders are scarce.

We suggest that the CE principles must be refined and be more workable such as the BSI standards [11]. Rather than conceptual work, solutions are required on how business strategy and operation can be tangibly aligned with CE principles to strengthen the supply chain network and gain competitive advantage. Once such principles for an industrial context are developed, it would be of great interest to see empirical work that investigates the effect such on high-value low volume products in the context of servitization.

Suggested are systemic modelling approaches that investigate how the different configurations in the supply chain network affect the value creation for the different stakeholders. Mixed methods have been proved useful in the investigations of a causal relationship in the creation of value as they allow to quantify and rank otherwise intangible value constructs [22].

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