Building win-win value networks for product-service systems' delivery

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Abstract: Product-service systems (PSS) are complex bundles of products and services aimed at fulfilling customers' needs. The key challenges of designing a new PSS include establishing the underlying value network supporting PSS delivery. The success of a PSS business model relies heavily on establishing a win-win value network that ensures fairly shared value capture and creation among the PSS stakeholders. This paper investigates the underlying challenges of establishing such value networks, and proposes a novel framework for building win-win value networks for PSS delivery. A case study illustrates the applicability and usefulness of the proposed framework in designing and assessing the possible value networks and associated value capture for the delivery of an innovative smart PSS in the cheese industry.

Keywords: product-service systems; PSS; business model; value network; value capture; economic assessment.

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1 Introduction

Product-service systems (PSS) are innovative bundles of products and services with the objective to fulfil customers' needs. PSS provide companies with strategic benefits, including continuous revenue streams, increased customer loyalty, better product differentiation, strategic barriers to lock-out competition, as well as new ways of value creation (Agrawal and Bellos, 2017; Liu et al., 2019). In a PSS context, value can be most effectively delivered by networks of collaborating firms. By integrating their products and services, these new eco-systems can create the value customers seek (Pawar et al., 2009). Therefore, creating value requires the simultaneous design of products, services, and the associated organisational eco-system. Hence, the network of firms involved in defining, designing, and delivering value through the PSS must be carefully considered (Pawar et al., 2009). The successful design of the supply network entails the transparent and clear definition of the roles and expectations of all partners, incl. the focal company and additional external partners. This can be considered as an early stage of the PSS delivery process (Brax and Visintin, 2017; Saccani et al., 2014).

In PSS networks, value co-creation can lead to value capture. Value capture refers to the outcomes that the partners within the PSS networks can achieve together when retaining value. Monetary or economic value reflects the overall financial benefits derived from a PSS offering (Garcia Martin et al., 2019; Sakao and Lindahl, 2015). To support economic value sharing, the financial benefits must be assessed transparently and communicated within the trusted network, as well as for each network partner individually.

In order to ensure successful PSS development and scale-up, profitable business models must be identified. Profitable business models in this context are expected to lead to win-win value co-creation and capture (Garcia Martin et al., 2019). However, these endeavours face several challenges, such as a poorly addressed multi-actor perspective in PSS design and delivery, as well as lack of guidance in assessing PSS value (Pawar et al., 2009; Datta and Roy, 2010; Saccani et al., 2014; Rodríguez et al., 2020). Addressing PSS transition projects and supporting decision-making through qualitative and quantitative models are among the dominant avenues for dealing with these challenges (Kjaer et al., 2018; Chiu et al., 2019). To-date, the challenges have not been analysed and structured comprehensively.

The objective of this paper is to close this pressing research gap by investigating the underlying challenges of developing an appropriate value network for PSS delivery. The identified challenges serve as the foundation for proposing a novel framework to design win-win value networks for PSS delivery. A case study illustrates the applicability and usefulness of the proposed framework in designing and assessing the possible value networks, as well as associated value capture for the delivery of an innovative smart PSS in the cheese industry.

The remainder of the paper is structured as follows. First, we present the conceptual background which relates to value networks and value capture within PSS business models. Section 3 introduces the proposed framework, which adopts a cost-engineering approach. Section 4 presents a case study illustrating the use of the proposed framework to solve a given problem instance. The paper ends with discussions and research outlooks in Section 5 and a conclusion in Section 6.

2 Conceptual background

2.1 PSS business models

In essence, a business model describes how organisations create, deliver, and capture value. It explains the value architecture, which comprises the value creation, delivery, and capture processes and their underlying components and mechanisms (Teece, 2010). A business model is the representation of a firm's underlying core logic and strategic choices for creating and capturing value within a value network (Shafer et al., 2005).

The topic of business models is a major research theme within the PSS literature (Li et al., 2020). The service transformation of industrial firms is associated with new and innovative business models (Adrodegari and Saccani, 2017; Brax and Visintin, 2017; Lightfoot et al., 2013; Mont, 2002; Tukker, 2004); and PSS have been described as 'an innovative business model integrating products, services, and supporting infrastructure' [Chiu et al., (2019), p.6452]. Tukker (2004) considers three main types of PSS business models:

- *Product-oriented PSS:* the product is sold in traditional manner and the service is added, e.g., in form of after-sales services.
- *Use-oriented PSS:* the provider does not sell the product but the use or availability of it and therefore he keeps the ownership. Products are leased, rented or shared.
- *Result-oriented PSS:* the result or capability is sold instead of a product.

The first type of PSS relies on the traditional product-centric approach, whereas the use-oriented and the result-oriented PSS rely on an outcome-based perspective where the company no longer sells pure products, but delivers (product) functionality (Rodríguez et al., 2020). They are generally perceived as more sophisticated and innovative business models.

PSS business models deliver superior value propositions while achieving better results for business organisations (Moro et al., 2022). At the same time, only few studies address the necessary support activities during the transition of an organisation towards PSS (Chiu et al., 2019). Furthermore, there is a lack of quantitative studies that assist decision-making (Kjaer et al., 2018). Integrating a PSS scheme into a viable and profitable business model remains a challenge for many enterprises (Chiu et al., 2019).

2.2 Value networks in PSS business models

Successful PSS require the design of proper business models and associated value networks. The value network is comprised of the actors who share responsibilities and jointly generate values through the new product-service offering (Adrodegari and Saccani, 2017).

The organisational implications of PSS extend beyond the boundaries of a single company. Developing a PSS requires competencies, resources, and capabilities which may be new to the company and thus require collaboration, often dynamic, with other partners (Pawar et al., 2009). A PSS requires the orchestration of a complex network of stakeholders, both in-and outside of the company, in order to deliver an augmented product to the customer in a satisfactory manner. The delivery of PSS requires manufacturers to access and coordinate a network of external suppliers and partners throughout the system’s life cycle (Brax and Visintin, 2017).

This is especially true for small and medium-sized enterprises (SMEs), which generally lack the necessary resources, (e.g., staff, competences, facilities, and finances) to provide comprehensive PSS. SMEs heavily depend on additional actors in their business network and need to establish ‘value constellations’, either vertically, (i.e., collaborating with firms in the upstream or downstream of supply chain) or horizontally, (i.e., collaborating with firms in the same level of supply chain) (Kowalkowski et al., 2013).

In these networks or constellations, value is co-created and emerges as an outcome of interactions among the different stakeholders. Value co-creation has been defined as a process of resource integration activities, when firms interact with various actors in their business network, resulting in benefits for all business actors involved (Chowdhury et al., 2016). Whilst a number of studies have highlighted the benefits of value co-creation, researchers often fail to consider its potentially negative consequences, especially in the context of business networks. Chowdhury et al. (2016) suggest that a perception of harmonious co-creation of values can be considered as naïve and simplistic. The complexity of inter-firm relationships is often neglected within a B2B context. In addition, value co-creation encompasses negative aspects, such as role conflicts and ambiguity, opportunism, and power plays (Chowdhury et al., 2016; Pathak et al., 2020).

Most studies argue that servitisation creates value for all network actors. Realistically, in many cases the collaboration results in one firm appropriating value from other actors, thus creating tensions within the network (Burton et al., 2016). In order to successfully offer a sustainable PSS on the marketplace, manufacturers must initiate changes in their activities and processes, both internally and externally. These changes may include adjustments of how activities, and the value associated with them, are allocated. These adjustments can reshape relationships between network actors, and create relational tensions that may limit or destroy the value created and captured by a PSS offering. Manufacturers undertaking servitisation must anticipate, identify, and respond to these tensions. Polova and Thomas (2020), for instance, underline the critical importance of clarity in the repartition of roles in which actors collaboratively co-create value, as well as in the repartition of value captured among them.

The goal of value co-creation is value capture. Value capture refers to the outcomes that the partners within the PSS networks can achieve when retaining value, including monetary and non-monetary value. Monetary or economic value refers specifically to the overall financial benefits derived from the PSS offerings (Garcia Martin et al., 2019).

In PSS networks, value co-creation and capture processes should result in win-win situations where financial benefits as well as risks are fairly distributed among the partners. To support the economic value sharing, the financial benefits must therefore be assessed for the network as a whole as well as for each individual partner.

2.3 Value capture in PSS business models

Value capture refers to the revenue model and costs structure (Paiola and Gebauer, 2020). Profits generated by a business model depend on how the revenue model and the cost structure are defined. Therefore, it is necessary to define pricing and revenue sources, volumes, and margins (Adrodegari et al., 2016).

The revenue model determining the suppliers' pricing scheme is of particular importance for contractual design (Richter et al., 2010). With the shift from ownership to access, the revenue model evolves from one-off transactions (product-oriented PSS), to continuous payment over time (use-oriented PSS), or even to outcome-or output-based (result-oriented PSS) (Adrodegari and Saccani, 2017).

Traditionally, the literature distinguishes between cost-based pricing (company determines price on basis of cost plus desired profit margin), competition-based pricing (market pressures influence prices which vary in consideration of competitors' behaviour), and value-based pricing (prices commensurate with value created for customers). However, the first approach still dominates both the manufacturing and service industries today (Rapaccini, 2015). Moreover, Guerreiro and Ventura Amaral (2018) showed that, in B2B contexts, companies set prices based on value while simultaneously preserving the simplicity of cost plus margin formulas.

Cost assessment is therefore critical to define the revenue model. This turns out to be a complex undertaking in a PSS context, because of the difficulty of properly estimating the costs of activities during the long-lasting contracts (Datta and Roy, 2010). Consequently, specific cost modelling techniques have been proposed, especially in the context of availability-based contracts (Datta and Roy, 2010; Settanni et al., 2014).

Datta and Roy (2010) identify five main cost estimation techniques that fit the PSS context: parametric, analogy, analytical, activity-based costing (ABC), and expert judgement. Each technique has merits and demerits with regard to PSS costing. They conclude that the best practice choice should be guided by four criteria: purpose of costing (feasibility study or bidding for a contract); type and complexity of the service (type of offering); he precision required; and data availability. Settanni et al. (2014) analyse to what extent through-life costing (TLC) is methodologically appropriate for costing the provision of advanced services, particularly availability, through a PSS. They suggest a novel methodology for TLC addressing the challenges of PSS cost assessment with regard to 'what?' (cost object), 'why/to what extent?' (scope and boundaries), and 'how?' (computations). Rodríguez et al. (2020) propose a broader PSS cost estimation process, as an iterative sequence of five main activities:

1 Definition of cost estimation viewpoint (to guide and bind decision making across the estimation process towards a defined objective).

2 Characterisation of the cost estimate (to define the attributes of the estimate and to outline the baseline conditions on which it is built).

3 Conceptualisation of PSS (to identify significant technical and operational parameters and their mathematical relationship with the cost estimate).

4 Computation and assessment of the estimate (to measure the cost estimate impacts of a given set of parameters' values).

5 Adjustment and definition of the estimate baseline (to define the cost estimate baseline and to make the relevant adjustments for the compliance of its purpose).

Accurate costing methodologies incorporating a multi-actor dimension are generally deemed important, yet the literature suggests a clear research gap in this area. The complexity of required value network of collaborating partners is a key missing element from existing perspectives (Pawar et al., 2009). Studies generally consider the development and delivery of a solution as an effort of a single firm, or completely neglect the role of suppliers altogether. Although managing upstream relationships is particularly critical in servitised contexts, theory development on this topic is still at an early stage (Saccani et al., 2014).

Based on the previous analysis, this paper introduces a framework for building win-win value networks for PSS delivery involving a multi-actor perspective and a quantitative approach for cost and revenue calculation. The framework is rooted in the scientific literature of PSS engineering and management. Especially, Baines et al. (2017, p.268) identified the 'dynamics of value propositions, co-creation of processes in broader networks' among the undeveloped topics that needs to be addressed in servitisation research. The framework we propose aims at addressing this issue b:

1 taking in consideration not a focal or dyadic but a network point of view

2 allowing trade-offs between stakeholders that could lead to improvements in value co-creation and value sharing.

3 A framework for building win-win value networks for PSS delivery

3.1 Overall methodology

The methodology behind our framework is based on propositions from Datta and Roy (2010), Rodríguez et al. (2020), and Settanni et al. (2014).

The cost estimation viewpoint (Rodríguez et al., 2020) or purpose of costing (Datta and Roy, 2010) relates to a feasibility study in the context of innovative PSS. The aim is to support decision-makers in their approach to establish appropriate value networks and value capture, by conceiving and assessing different possible scenarios. The objective is to provide a quantitative assessment of the value networks to support decision-making. Cost and revenues are key criteria for the stakeholders to decide on a value network's viability.

Consequently, the precision required (Datta and Roy, 2010) is medium, given that the goal is not to bid for a contract, but to give higher-level estimates allowing for a comparison of different scenarios. The scope of the analysis (Settanni et al., 2014) relates to the activities that are undertaken within the value network providing the PSS.

The conceptualisation of the PSS (Rodríguez et al., 2020) refers to the type and complexity of the offering (Datta and Roy, 2010). The framework we propose suits all three types of PSS, namely product-, use-, and result-oriented. The differences between each PSS are reflected in the revenue model. The revenue model includes one-off transaction (product-oriented PSS), continuous payment over time (use-oriented PSS), or to outcome-based (result-oriented PSS) (Adrodegari and Saccani, 2017).

The cost objects (Settanni et al., 2014) are stand-alone instances of product and service exhibiting certain characteristics (e.g., an assembled robot, a maintenance service). Specifically, services in this case refer to life-cycle services, and can either be 'spot' services such as installation, or 'repeated' services such as maintenance.

The computation and assessment of the estimate (Rodríguez et al., 2020), the 'how?' (Settanni et al., 2014), rely on ABC, on extrapolation based on expert opinion, and on an algorithmic approach for computation. In bottom-up approaches such as ABC, resource utilisation is recorded at the individual service level, and service level utilisation data is aggregated to identify the type of resources used and to measure resource utilisation in order to calculate the costs of specific services (Settanni et al., 2014). The choice of this approach is related to the data availability (Datta and Roy, 2010), since a bottom-up approach is useful when cost data are not available from other reliable sources (Settanni et al., 2014). In innovation projects, where the PSS does not exist yet, very few data points are available, and expert opinion is needed to complement the missing data insights.

The computation process which applies to both revenues and costs is further detailed in the next section. The contracts are consistent with a cost-plus fixed-fee model allowing to ensure PSS profitability for the stakeholders. This model avoids to consider risk related costs which may lead to higher PSS selling price for the customer. This model is also widely used in the business sectors as it helps defining reasonable prices for products (Marn et al., 2003).

3.2 Computation process

The proposed framework integrates ABC with an algorithmic approach to assign costs to stakeholders considering the PSS life cycle. Contracts serve as the trigger of cost and revenue calculation, and extend the notion of functional unit for cost calculation (Settanni et al., 2014). The main benefit is the adequacy with the life cycle context, as it allows to simulate PSS operations based on ongoing contracts. Each contract specifies PSS content in terms of products and services, service duration, underlying revenue model, and obligations of contract parties (Meier et al., 2010).

Costs are aggregated into roles, (i.e., aggregate cost for given role is sum of activities' costs related to role) and assigned to associated stakeholders (playing these roles) for a given value network [equations (1)–(3)]. Roles represent a responsibility associated to a sub-set of activities to be conducted for realising and delivering the PSS. Typical roles include equipment provider p, service provider q, and customer r. A stakeholder can play multiple roles in a given value network. For a PSS specified in a contract c during a given period t, the cost for a stakeholder l is calculated according to equation (1), where C_l^c are the costs assumed by l in the contract c. C_l^c is calculated according to equation (2), where $\propto_i^c$ is the cost driver of activity i (required frequency) and β_{ij}^c is the cost driver of resource j (required amount) to realise activity i, c_j^t refers to total cost of resource j during period t and v_j^t refers to total volume of resource j. Costs incurred by a customer r are calculated according to equation (3). They equal the share of revenues of stakeholder l generated by sales to customer r in a contract c, referred to by $R_l^{r,c}$.

$$C_{l\in\{p,q\}} = \sum\nolimits_c C_l^c \tag{1}$$

$$C_{l\in\{p,q\}}^c = \sum\nolimits_i \propto_i^c \times \sum\nolimits_j \beta_{ij}^c \times \frac{c_j^t}{v_j^t} \tag{2}$$

$$C_r = \sum\nolimits_c R_l^{r,c} \tag{3}$$

Revenues are calculated according to a fixed pricing strategy that applies a pre-defined margin rate to the total cost. Consistent with previous research (Medini et al., 2021), a straight-line depreciation is applied to equipment as shown in equation (4), where a_e, s_e, and d_e refer to the acquisition cost, salvage value, and lifetime duration of equipment e. For a PSS specified in a contract c during period t, the revenue for stakeholder l is calculated according to equation (5), where C_l^c refers to costs incurred by stakeholder l in the contract c, γ_e is a binary variable which equals 1 if equipment e is rented in contract c, and r refers to margin rate.

$$D_e = \frac{a_e - s_e}{d_e} \tag{4}$$

$$R_l = \sum\nolimits_c \left(C_l^c + \gamma_e \times \sum\nolimits_e D_e \right) \times (1 + r) \tag{5}$$

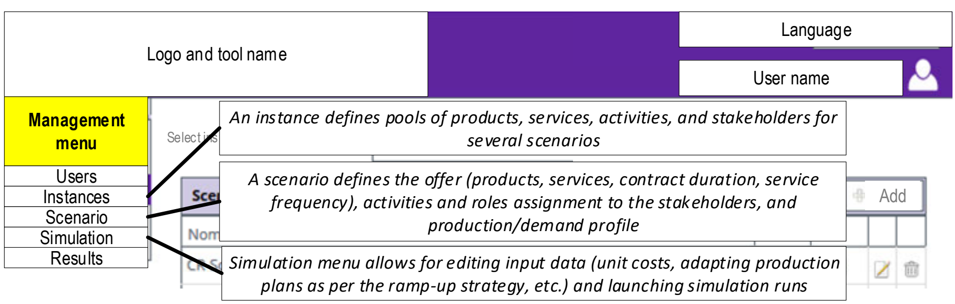
Cost and revenue calculation are triggered by contracts and driven by demand profiles. The latter defines the share of each PSS contract c in the portfolio of stakeholder l, referred to by u_l^c, and planned contracts for each period t during a specified time horizon H, referred to as v_l^t. Portfolio (u_l^c) and planned contracts (v_l^t) should be compliant with constraints shown in equation (6) and equation (7), where S refers to the set of stakeholders, d_t is the demand forecast in number of contracts at period t, and C refers to the set of contracts.

$$\sum_{c \in C} u_l^c = 1, \forall l \in S \tag{6}$$

$$v_l^t \leq d_t, \forall t \in H \tag{7}$$

The algorithmic approach simulates the PSS realisation and operation, and calculates the cost and revenues for each stakeholder in different possible value networks. First, the portfolio of contracts (u_l^c) and planned contracts (v_l^t) are specified. Then the contract management algorithm proceeds as follows: updating contract status allowing to launch new contracts, closing contracts coming to an end, and updating the lifetime of still ongoing contracts. Contract management enables the following operations: executing services and component replacement, calculating material requirements, and updating cost and revenue indicators (Medini et al., 2018, 2021). The algorithm and the whole model are implemented in a web platform in PHP (Hypertext Pre-processor) (Figure 1).

Figure 1 Excerpt from the web platform for PSS value capture assessment (see online version for colours)



A meta-model is implemented in the platform which specifies how a value network instance can be modelled. The platform allows therefore to model different possible value networks. The resulting model is then populated with real case data about cost, contracts, etc.

Algorithm Contract management

for each $t < H$ do

    for each $c \in C$ **do**

    update contract status

    manage contract

$t \leftarrow t + 1$

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4 Case study of an innovative PSS for the cheese industry

As depicted in the methodology section, the developed framework was tested and validated through case study research. The selected case study is the result of a research project that aimed at designing an innovative solution to improve traceability in the cheese production process. In this industry, cheese traceability is currently performed based on casein chips (casein is a milk protein which is food grade), that are printed with traceability information (production date, lot number, etc.) and affixed manually on cheese wheels (Emmental or Cheddar for instance) at the beginning of the production process. Later in the process, they are collected manually at the end of the production process. In the proposed solution, the traceability system is improved in two ways:

1. RFID sensors are integrated on casein chips to ensure a more accurate monitoring of cheese wheels throughout the production process (information can be read and added anytime through mobile RFID readers).
2. The placing and collection of these RFID identifiers are robotised.

The project team involved four different companies: the three providers of the products and services to be integrated in the solution (R, S, and I), a cheese producer (C), and a group of researchers in industrial management; two of the researchers are co-authors of the paper. The project team was in charge to define the possible PSS that could be designed to support the new traceability solution. Table 1 summarises the products and services that encompass the possible PSS.

Table 1 Products and services encompassed in the PSS

Stakeholder	*Products*	*Services*
R	Placing and collecting robots	Commissioning, training, and maintenance of robots
S	RFID tags, fixed and mobile RFID readers	Commissioning, training, and maintenance of RFID
I	RFID identifiers (RFID tags integrated in casein chips)	Customer interface

4.1 Value networks for PSS delivery

The PSS includes a technical system and several associated services. The technical system is comprised of the following components:

- RFID tags (RFID sensors) that are integrated on chips made from casein to form RFID identifiers. S provides the RFID tags; I integrate them to produce RFID identifiers.
- Robotic systems for placing the identifiers on the cheese wheels at the beginning of the production process, and retrieving them at the end of the process. They are provided by R.
- RFID readers to encode/read the identifiers, which are either integrated in the robotic systems, (i.e., provided to R) or mobile devices used by the cheese production staff.

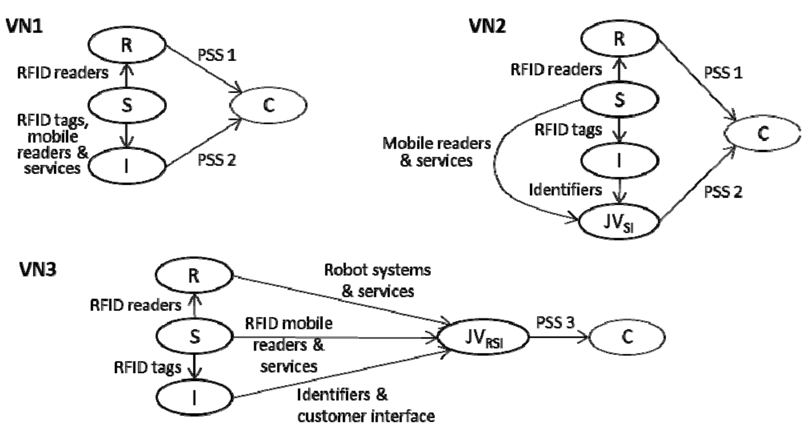
- The PSS also encompasses a set of services, namely commissioning, training, and maintenance of the robot system (assumed by R) and the RFID system (assumed by S), as well as a customer interface which refers to the assistance provided to the customer throughout the life cycle of the solution (assumed by I).

The collaborative work of the project team on the PSS design led to consider three PSS options:

- PSS 1: a PSS relying on the robot system, which includes the provision of the placing and collecting robots, and of the related services (commissioning, training, and maintenance of the robot system).
- PSS 2: a PSS relying on the RFID system, which includes the provision of the RFID identifiers and readers, the related services (commissioning, training, and maintenance of the RFID system), and the customer interface.
- PSS 3: a comprehensive PSS which includes the robot and the RFID systems, and all the services (commissioning, training, and maintenance of both systems, and the customer interface).

All three PSS options are use-oriented, i.e., products and services are provided to the customer for a 2, 3, or 5 year period in exchange for a yearly fee. Whereas the framework is suited to all types of PSS (product-, use-, and result-oriented), we chose to focus only on use-oriented PSS at this point. Indeed, these three PSS options are the most preferred ones by the stakeholders within the framework of the case study.

Figure 2 Value networks for PSS delivery



The stakeholders are three SMEs: the provider of the RFID system and related services (S), the provider of the casein chips who is also in charge of integrating the RFID tags to form RFID identifiers for cheese wheels (I), the provider of the robot system and related services (R). The PSS customers are cheese producers (C).

Three main value networks were considered, VN1, VN2, and VN3 (Figure 2).

- In VN1, S sells the RFID readers to be integrated in the robot system to R, and the tags to be integrated on casein chips, and the mobile RFID readers to I. R sells PSS 1 to C; I sell PSS 2 to C.

- In VN2, S sells the RFID readers to be integrated in the robot system to R, and the tags to be integrated on casein chips to I. A joint-venture is created between S and I (JV_{SI}), which buys the RFID identifiers from I and the mobile readers from S, and sells PSS 2 to C. PSS 1 is still sold by R to C.
- In VN3, a joint-venture is created between the three providers (JV_{RSI}); each provider R, S, and I sells their products and/or services to JV_{RSI} which sells PSS 3 to C.

4.2 Value capture in networks

Data was collected through interviews with CEOs and employees from the participating providers R, S, and I. This allowed to identify and calculates the costs of the products and services, as well as the revenues stemming from the yearly fees of the three PSS. Basic yearly fees were calculated based on the product and service costs, a standard quantity of identifiers (four batches/year), basic margin rates on products and services defined by the companies' CEOs, and contract durations. Unit costs and yearly fees are shown in Table 2 and Table 3, respectively.

Table 2 Products and services' unit costs

Stakeholder	*Products and services*	*Unit costs*
R	Placing robot	180 k€
	Collecting robot	200 k€
	Installation, commissioning and training	2 k€
	Maintenance	9 k€/year
S	RFID tags (batch of 100,000)	60 k€
	Readers	6 k€
	Mobile readers	5 k€
	Installation, commissioning and training	7 k€
	Maintenance	9 k€/year
I	RFID Identifiers (batch of 100,000)	150 k€
	Customer interface	17 k€/year

Table 3 PSS yearly fees

	Two years contract	*Three years contract*	*Five years contract*
PSS 1	200 k€/year	135 k€/year	85 k€/year
PSS 2	960 k€/year	950 k€/year	940 k€/year
PSS 3	1,500 k€/year	1,400 k€/year	1,300 k€/year

Three demand profiles, (i.e., the total number of PSS contracts sold each year) were considered (pessimistic, optimistic, and medium) (Figure 3). Simulations were run over a ten year timeframe, which is considered realistic given the investment and industry. Overall, nine simulations were run providing costs and revenues for each stakeholder, each year, each value network (x3) and demand profile (x3).

The results allowed for comparing the revenues and costs, and thus the margins for each value network and each stakeholder. Figure 4 shows the average cumulative margins over the three demand profiles for the value network stakeholders. The simulations show that VN1, VN2, and VN3 are all equally pertinent to S given its role in the PSS network. The joint-venture JV_{SI} margins increased tremendously in VN3 given its key role as a focal company in the PSS network compared to VN2 where it is limited to customer relationships management services. The subsequent analysis will not specifically focus on the joint-venture since risk and opportunities will be equally shared among the stakeholders of the project who will be involved as shareholders.

Figure 3 Demand profiles (number of PSS contracts sold/year) (see online version for colours)

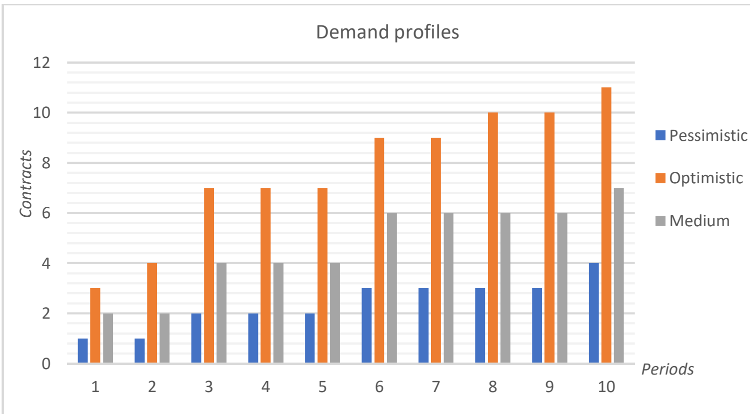
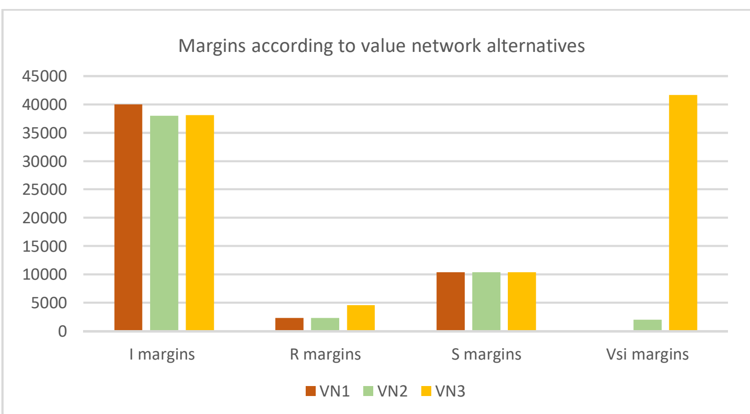


Figure 4 Stakeholders' cumulative margins in each value network (see online version for colours)

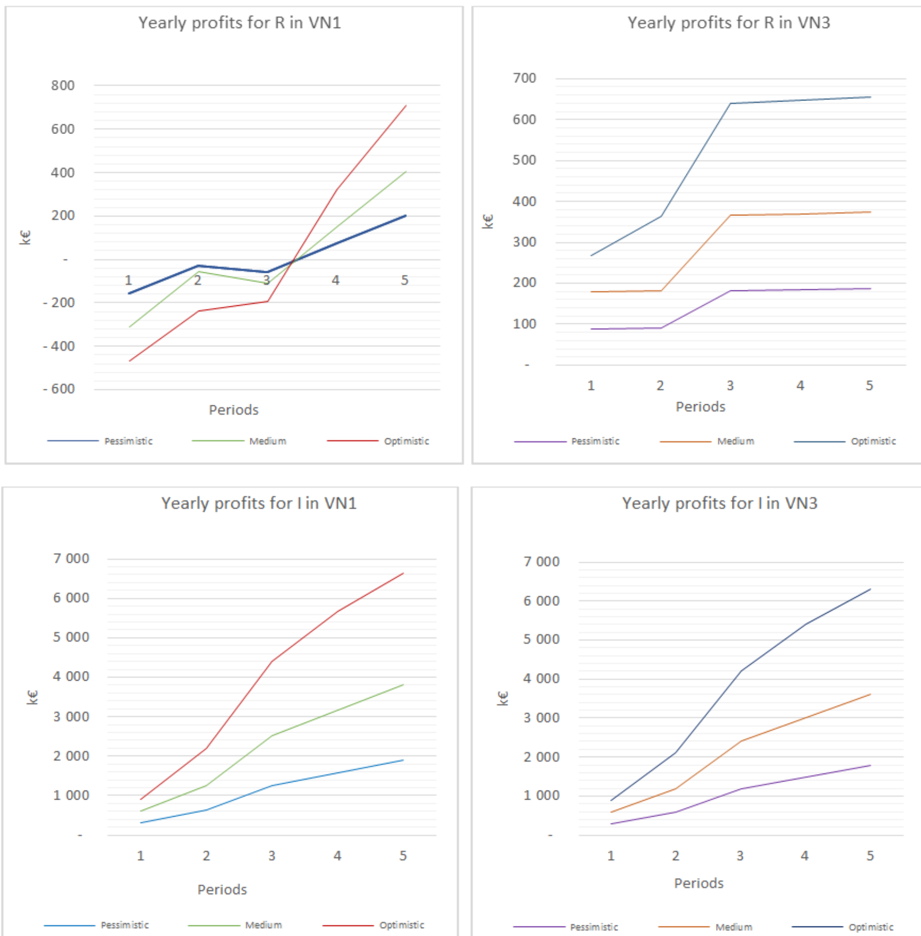


VN3 is the most beneficial scenario for R, since it leads to an increase in associated revenues and profitability, and to a decrease of its short-term financing needs, whereas VN1 is the most favourable scenario for I. Although VN3 allows to double cumulative margins of R, it induces a 5% decrease in I margins compared to VN1.

Figure 5 shows the yearly margins over the first five years for R and I considering the three demand profiles. Looking at R yearly margins in VN1, a negative margin can be noted over the three first years regardless of the demand profile. This means that VN3 is still the most beneficial for R.

It can also be inferred from Figure 5 that financial needs of R tend to be higher when adopting the optimistic demand profile. In this case, the margin remains in the range of 486 k€–192 k€ during the first three years. However, this strategy pays off in the long run, with a cumulative margin of 3,682 k€ against 2,187 k€ and 1,016 k€ in medium and pessimistic demand profiles.

Figure 5 Yearly margins over the first five years of PSS introduction into the market according to the demand profiles (see online version for colours)



These financial implications go hand in hand with risks incurred by each of the stakeholders. VN1 implies higher risk for R since the negative margins persist for the first three years. VN3 seems to be the most suitable scenario for both R and I since the risk is shared with JV_{RSI}.

Combining the general insights (Figure 4) and the analysis of individual results (Figure 5) allows for well-informed decisions on the PSS value networks, as well as on their consequences on value capture for each stakeholder. This is likely to help engaging stakeholders in subsequent steps of the project.

The results confirm that use-oriented PSS, leading to a spread of revenues over the length of the contract, engenders a lengthening of the pay-back period, and consequently gives rise to financing needs at least in the short run. This provides valuable insights that can support negotiating the value network selection. By the time this research was conducted, the selection of the value network for the case study was not determined yet. The case study's results provided valuable insights into each of the scenarios and paved the ground for further assessment.

It should be noted that the proposed framework aims first at an economic evaluation, based on generated margins, while also supports a financial evaluation, with margins serving as a basis for calculating cash-flows.

5 Discussion

The design and inception of new PSS remain a critical challenge for manufacturers today. Methodological guidance and operational tools are needed to support decision-making in order to bridge this gap. This paper presents a novel framework for supporting the building of value networks for PSS delivery. The supporting case study illustrates how the developed framework can be applied and how it provides value by uncovering improvement potentials in a real industrial setting. The work contributes to the growing body of knowledge focussed on operationalising PSS.

Pezzotta et al. (2018) consider the PSS design process to consist of four phases:

1. customer analysis (identify customers' needs)
2. solution concept designs (identify, evaluate, and select PSS solutions)
3. solution final design (final definition of the PSS solution)
4. offering analysis (launch the PSS in the market and monitor it).

The proposed framework can be inserted between the third and the fourth phase: once the solution is finalised, and before it is launched in the market. We recommend to use it as a collaborative tool by the stakeholders in order to increase their awareness of the trade-offs of the possible value networks and foster an ongoing discussion. In this sense, identified value networks coupled with revenue, cost, and value capture analysis provide the foundation for a collaborative endeavour for successful negotiation to reach a consensus on the suitable value network (Zhang, et al., 2022). Furthermore, it helps overcoming the uncertainty and reluctance with regard to PSS and innovative offers development often stemming from the inability to quantify different scenarios.

Such framework can be very valuable for companies considering the offering of PSS, especially for SMEs. Business model design is a topic of fundamental importance for SMEs (Viswanadham, 2018). At the same time, SMEs often remain hesitant when implementing such strategic change (Kambanou and Sakao, 2020). The proposed framework supports transparency and discussion among the partners, and favours trust and a true collaborative environment, which is considered as an antecedent condition of multi-actor servitisation (Polova and Thomas, 2020). Hence it can be used by designers in order to ease the process of PSS value network creation and value capture assessment.

While the proposed framework was tested with SME stakeholders, and the presented case study focuses on use-oriented PSS, its scope is much wider. Indeed, this framework is suited to a variety of PSS offerings (product-, use-, and result oriented), and to every business context (SMEs and large companies, B2B and B2C contexts).

The framework contributes to the existing literature in several ways. For instance, it integrates the multi-stakeholder perspective through a structured approach for cost engineering during PSS design. This is line with previously highlighted requirements for PSS development underlying for instance the critical importance of clarity in the allocation of the roles of different stakeholders (Aurich et al., 2010; Polova and Thomas, 2020). The framework extends the literature on PSS costing by operationalising the existing recommendations and models and integrating both the multi-stakeholder and life-cycle perspectives (Medini et al., 2021; Rodríguez et al., 2020; Settanni et al., 2014).

This research offers guidance to practitioners facing uncertainty and concern regarding the value creation and capture through PSS by providing a new method to explore, prioritise, and work out concrete PSS value network creation and value capture assessment. As such, this research extends the literature addressing strategic decision horizons for PSS development (Chiu et al., 2019; Mitake et al., 2020). It provides quantitative decision-making support for assessing alternative value creation scenarios, in line with the requirements highlighted by previous works (Chiu et al., 2019; Kjaer et al., 2018). While much of the existing research is focused predominantly on economic value assessment, this research is consistent with the intrinsic PSS characteristics suggesting that collaboration is perquisite for successful PSS development (Meier et al., 2010; Zhang et al., 2022).

The limitations of this research study include decisions taken in the design of the model as well as the case study. First, the proposed framework is based on a cost-based pricing, whereas firms undergoing servitisation are suggested to shift from cost-based to value-based pricing strategies. Therefore, the proposed framework could be refined to integrate a value-based pricing approach in the future.

Another current limitation and material for future work of the proposed framework is the integration of uncertainty and risk management. This area is only partially covered when defining the value networks and risks are discussed at a high-level during the interviews and brainstorming meetings at this point. Research in this direction is ongoing and the aim is to provide a structured approach for risk identification and quantification as an inherent part of the framework. The cost and revenue calculation model will need to be updated accordingly to cover additional costs and revenues related to negative and positive risks. Further pricing models will be explored as an alternative of the currently used cost-plus model. The model presented in this paper could also be extended by considering evolving interactions among PSS stakeholders over time and influence on generated margins. This also implies questioning the pricing model and updating it accordingly. The results analysis can be extended through sensitivity analysis in order to pinpoint improvement drivers of the economic performance of each of the stakeholders. From a technical point of view this can be implemented through a combination with existing frameworks using Monte Carlo simulation for instance (Boucher et al., 2019).

Moreover, while PSS are widely considered as a driver to reduce the harmful environmental impact of consumption and to support environmental sustainability (Vezzoli et al., 2012), our framework focuses on monetary value and does not integrate non-monetary value such as reduced impacts and environmental benefits.

6 Conclusions

The success of PSS business models relies heavily on a win-win value network that ensures that value capture and creation is shared fairly among the PSS stakeholders. In this paper, we investigate the underlying challenges of establishing such value networks, and propose a novel framework for building win-win value networks for PSS delivery. This framework extends the current literature on PSS costing by operationalising the existing recommendations and models and integrating both the multi-stakeholder and life-cycle perspectives. The research also offers guidance to practitioners by providing a method to explore, prioritise, and work out concrete PSS value network and value capture assessment.

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