INSTANTIATING A GENERIC PROCESS MODEL FOR EARLY-STAGE PRODUCT-SERVICE SYSTEM (PSS) DESIGN IN TWO CAPITAL GOODS MANUFACTURING COMPANIES

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ABSTRACT

Product-Service Systems (PSS) are seen as key enablers of circularity. However, better sustainability performance of PSS when compared to transactional business models is not given and it must be carefully considered in the design process. The early-stage PSS design is considered crucial because it determines most of the future offerings' impact. Nevertheless, manufacturing companies struggle with PSS design and often rely on ad hoc intuitive approaches with low success rates. Current PSS design approaches have been dispersed in literature until a recent systematic literature review by the authors proposed a comprehensive generic process model to enable the inclusion of sustainability considerations in the early stages. This paper takes the generic process model as a starting point and instantiates it to the context of two manufacturing companies, seeking to (i) explore the instantiation process from a generic to company-specific process models to support manufacturing companies; and (ii) reflect upon and prepare an evaluation of the generic process model concerning eight predefined criteria. The study reveals a number of potential areas for improving both generic and instantiated process models.

Keywords: Product-Service Systems (PSS), Sustainability, Early design phases, Process modelling, Capital good manufacturers

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1 INTRODUCTION

The transition of manufacturing companies towards a circular way of production and consumption is considered pivotal to enabling sustainable development (Lieder and Rashid, 2016; Morales *et al.*, 2021). A Circular Economy (CE) advocates the elimination of waste through a superior economic system in which resource consumption can be decoupled from economic growth, hence eliminating the current linear ('take-make-use-dispose') economic system (Lewandowski, 2016; Morales *et al.*, 2021). CE has become one of the pivotal paradigms to propel Europe towards the 2030 sustainability targets (European Commission, 2015, 2019).

Product-Service Systems (PSS), as one of the CE strategies (Blomsma *et al.*, 2019) (e.g., rethink, reduce), are considered the primary means of changing the current economic systems towards a more circular system (Kjaer *et al.*, 2019; Pieroni *et al.*, 2018). PSS can be defined as offerings focused on the complete life cycle, composed of products and services that are supported by the infrastructure and the actor-network, designed concurrently to deliver more value than traditional transactional offerings (Mont, 2004; Sarancic *et al.*, 2022). PSS business models show great potential in positively impacting the triple-bottom-line (TBL) of sustainability (Chiu et al., 2018), but are not by default more sustainable in any dimension than pure product sales (Bech *et al.*, 2019; Pigosso and McAloone, 2015).

Despite the immense opportunities that PSS offers, many manufacturing companies struggle to transition from product- to service-centric offering development (Bertoni and Bertoni, 2019; Vezzoli *et al.*, 2015). The biggest struggle typically occurs in early-stage PSS design, which is a highly uncertain period where the available knowledge is the weakest and most inconsistent across the academic fields that explore PSS (Barravecchia *et al.*, 2020; Peruzzini and Wiesner, 2020). Nonetheless, early-stage PSS design plays a key role in the whole design process as it is where the majority of PSS impact is determined in the TBL (Alonso-Rasgado *et al.*, 2004; Sousa-Zomer and Miguel, 2017). The early stage of PSS design encompasses the planning and conceptualisation stages, as commonly referred to in product development literature, which results in an assessable PSS concept (Welp and Sadek, 2008).

Manufacturing companies today primarily rely on intuitive and ad hoc approaches in designing PSS, where research shows that structured processes could yield more timely and consistently fruitful offerings (Aurich *et al.*, 2006; Bertoni *et al.*, 2019). One such highly structured process is a generic process model for early-stage PSS design (Sarancic et al. 2023, forthcoming).

This study adopts the generic process model for early-stage PSS design and instantiates it in two case studies to support manufacturing companies in developing company-specific and structured processes for early-stage PSS design. The case studies involve two Danish capital goods manufacturing companies in the food processing and medical device industries, respectively. The goal of the paper is twofold:

1. to answer the following research question: How to instantiate the generic process model for early-stage PSS design to the context of a specific manufacturing company? (RQ1)
2. to conduct a reflection and preparation for an evaluation of the generic process model for early-stage PSS design with respect to a set of eight predefined criteria.

The following sections of the article introduce the generic process model for early-stage PSS design (Section 2), explain the research methodology (Section 3), present the instantiated process models in the two case companies (Section 4), discuss the key insights from the process of instantiation and evaluation of the generic process model (Section 5), and present conclusions and future research steps (Section 6).

2 BACKGROUND

The generic process model for early-stage PSS design (Figure 1) was devised by the authors in previous research building on a comprehensive systematic literature review of 96 relevant approaches (Sarancic et al. 2023, forthcoming). The generic process model is structured in a stage-gate form based on the Rational Unified Process (RUP) and the functional modelling language IDEF0 to ensure wide adoption in industrial companies. The generic process model consists of:

- A temporal dimension split into three distinct stages (Strategic planning, Exploring opportunities and PSS concept development) with four gates (a-d); and
- A content dimension grouped into seven clusters (business model, the network of actors, requirements, functions, offerings, structure, and the plan for implementation), each containing several entities (objects of design or consideration which can be grouped in a cluster) which can

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be designed following a workflow of five activities (identification, analysis, definition, evaluation, selection, and refinement) to yield an assessable concept.

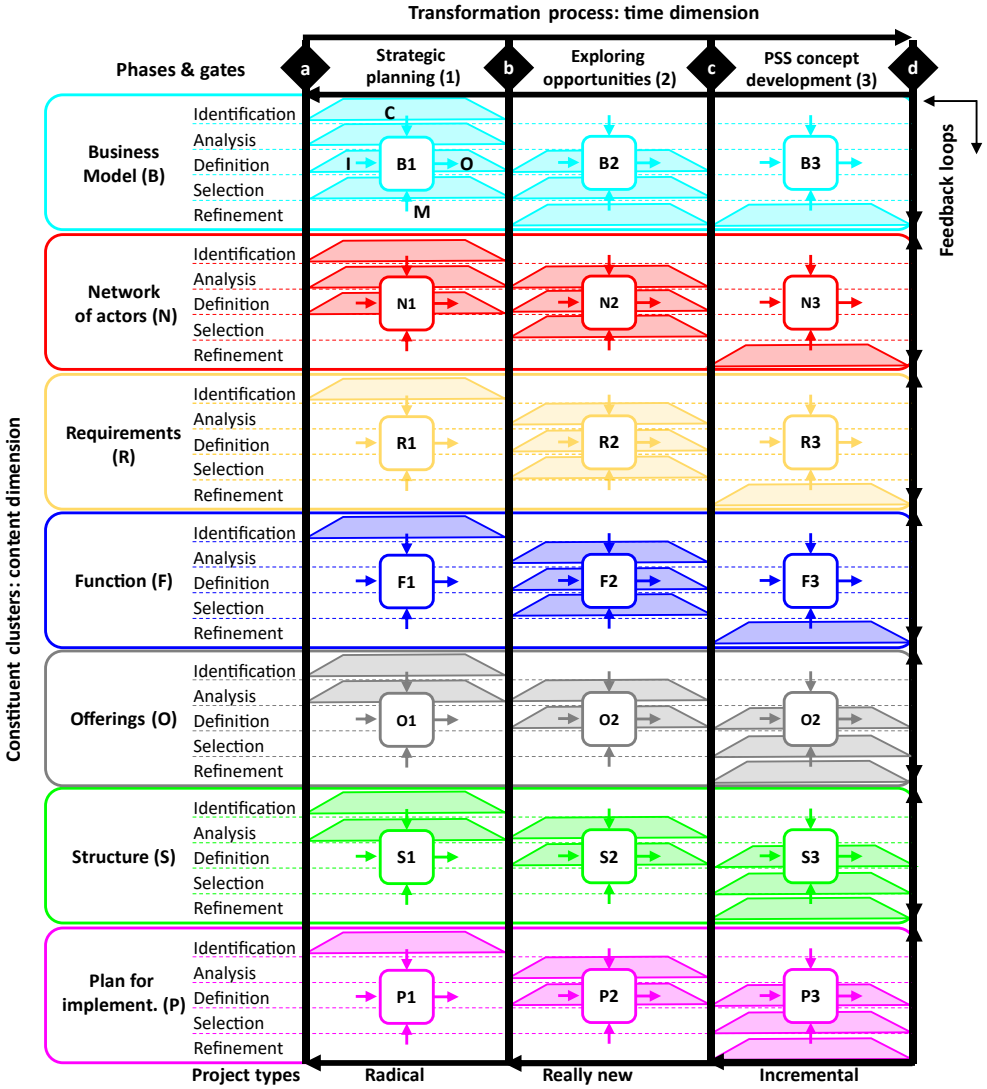

Figure 1. A generic process model for early-stage PSS design, adopted from Sarancic et al. (2023, forthcoming*).*

The generic process model's structure, a comprehensive collection of entities and a temporal perspective furthermore enable the incorporation of sustainability considerations, therefore, increasing the chances of developing a more sustainable offering while using the process model.

The trapezoids indicate the temporal sequence of the activities and entities where most of the focus is required from a manufacturing company in every stage of the process model to develop a PSS concept. Each of the stages is more focused on certain entities, which can be seen by the number of trapezoids. E.g. the business model (e.g. value proposition) and the actor-network (e.g. customers, partners, competitors, suppliers, institutions) are of particular interest in the first stage (Strategic planning).

Although the clusters are shown independent of each other, they are in reality interconnected, and numerous iterations and feedback loops are to be expected when using the process model. However, a stage-gate form was consciously selected in favour of industrial usability and easier management of the PSS design process. The gates, therefore, serve as stage reviews where the decision-makers examine the quality of execution of the previous stage and decide on the continuation to the next stage.

3 METHODOLOGY

The instantiations of the generic process model were carried out in the context of two case studies (Yin, 2003) in two capital goods manufacturing companies.

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Company 1 is a mid-sized Danish machinery manufacturer in the food processing industry (Sarancic *et al.*, 2021, 2022). At the time of the study, the company was in the early stages of the PSS development journey that was initiated to contribute to a holistic triple-bottom-line (TBL) focused strategy and increased service revenue. Despite being an engineering-to-order company with ample experience in product development, the company realised the lack of structured processes for front-end business development, i.e., the development of PSS offerings with greater service content. The company had hitherto only been developing product-oriented PSS offerings in an ad hoc manner.
Company 2 is a large Danish equipment manufacturer in the medical device industry. At the time of the study, the company had already been experimenting with a number of different PSS types, from purely financial motivation. However, the experimentation was limited to product-oriented PSS offerings. Despite the gathered experience in PSS design and operation, the company's processes were still intuition-driven and dependent on individuals' capabilities, without the support of a formalised process. Therefore, the company wished to introduce a more structured way of conceiving new PSS offerings and at the same time, challenge its purely financial motivation.
The steps conducted in the case studies mimic action research (AR) (Coughlan and Coghlan, 2002) but without the direct involvement of the companies in the process of instantiation. Steps resembling AR were adopted due to the method being successfully used in the PSS design context in the past (Sarancic *et al.*, 2022; Tonelli *et al.*, 2009). The method, therefore, consisted of a pre-step and four basic steps: diagnosing; planning action; taking action and evaluating action.

3.1 Pre-step - context and purpose

The pre-step served to gain access to the two companies and get an understanding of their respective organisations. Further, this step served to determine the scope of the case studies, as well as to gather data about the companies' motivation to pursue the systematic development of PSS offerings. The contextual introduction to the two companies described above was derived from this pre-stage.

3.2 Step 1 - Diagnosing

The first step implies the articulation of the theoretical foundation for the case study. The theoretical foundation is based on a systematic literature review of early-stage PSS design approaches previously conducted by the authors (Sarancic et al., 2023, forthcoming) and introduced in Section 2 as the background of this study. Moreover, this step includes data gathering from the case companies related to their current product/service development processes to make them available for analysis, understand the vocabulary and identify the key departments involved in their development and execution.

3.3 Step 2 - Planning action

The second step serves to elaborate and plan how the instantiation is going to be executed. This step is crucial for determining the scope of the study, i.e., the level of required intervention to adapt the generic process model to the companies' contexts and needs, and the parts of the organisation to involve. The key people identified in the organisation were subject to face-to-face semi-structured interviews to clarify their needs with the tailored process models for early-stage PSS design.

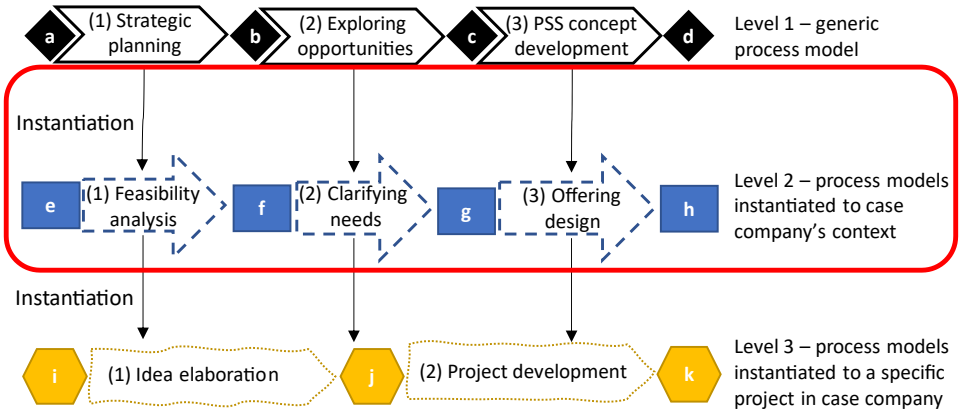

Figure 2. Scope of this paper (marked red). Focus is placed on the instantiation of the generic process model (Level 1) into case companies' contexts (Level 2).

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Figure 2 presents the scope of this study by showcasing the level of process model instantiation interventions. The goal is to instantiate the generic process models to fit case companies' needs, which might influence e.g., the number and names of stages and gate or their contents and activities.

3.4 Step 3 - Taking action

The third step aims to instantiate the generic process model and adapt it to the contexts of the two manufacturing companies. The first versions of the instantiated process models were generated in two four-hour long workshops involving the authors, based on the data gathered in the previous steps from the two respective companies. The workshops involved mapping the entities and activities between the generic process model and the existing product development processes of the two case companies. A particular focus was placed on retaining as much of the existing process models and transforming and enriching them with additional entities and activities needed for the early-stage PSS design according to the generic process model.

3.5 Step 4 - Evaluating action

The fourth step involved reflection on the resulting instantiated process models and the process to create them. Based on that process, an initial descriptive evaluation of the generic process model was conducted, encompassing questions related to utility, consistency, completeness, scope, broadness, precision, simplicity, and clarity, adapted from Pigosso, (2012) and Vernadat (1996).

4 RESULTS

The process of instantiation began by studying the terminology of the product development process models brought forward by the case companies in order to identify similarities and differences, compared to the generic process model. Subsequently, the focus was placed on examining the main stages of the process models and studying their contents to delimit the instantiation to the early stages, to be able to compare it to the generic process model.

It has been noticed that the workflows in the companies' respective process models mirror the distinct departments, rather than entities that need to be cross-functionally designed as in the generic process model. Although such organisation of the workflows might hinder cross-collaboration, it remains the most pragmatic way for the case companies to track the process and responsibilities. However, in order to design PSS rather than just a product, numerous other departments must be involved, due to the breadth of the design object (PSS). Therefore, insight was needed into companies' organigrams to map all the other departments (resources) the companies had, as well as which were necessary for PSS design. Both companies already had most of the departments that should be involved in PSS design, but by nature, they were not all involved in product design directly (e.g. after-sales department). Some desired capabilities, such as partnerships management, were not found in the case companies; these would need to be acquired to ensure greater success rates with PSS design.

Following these examinations, activities from the company-specific process models were mapped onto the generic PSS process model to identify the entities and activities not covered by the existing models. A challenge arose in this step as both the existing product development process models in the case companies were at a relatively high level, when compared to the generic process model, therefore leaving some room for interpretation of the contents of the activities they devised. A further round of dialogue (to ensure correct interpretation) was carried out, to ensure a sound understanding. Thereafter, a backwards mapping was conducted from the generic process model onto the company-specific process models to expand the existing product development models and adjust the terms from the generic to the company-specific terminology.

After the mapping, the two instantiated process models were generated, as presented in the following sub-sections, utilising the findings obtained through forward and backward mapping of the generic and company-specific process models. In both models, a clear link to the generic process models is showcased with colour-coding relating to the generic process model (e.g. a yellow rectangle marked with 'R' next to a workflow in the instantiated process model indicates its connection to the "Requirements" cluster entity in the generic process model).

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4.1 Case company 1

The instantiated process model in case company 1 can be seen in Figure 3. Given that the existing product development process at the company had a similar scope to the generic process model, three stages of the process model were retained, although renamed to fit the company's vocabulary and adjusted in their duration in relation to each other. Therefore, the resulting idea (strategic planning) and analysis (exploring opportunities) stages are noticeably shorter than the project (PSS concept development) stage.

The content dimension (vertical axis) has been split into three main tracks: 1. commercial or outbound headed by a chief commercial officer (CCO); 2. technical headed by a chief technology officer (CTO); and 3. operational or inbound headed by chief financial/operations officers (CFO/COO). The three tracks were further split into departments relevant to early-stage PSS design. The entities and activities related to them have then been assigned to responsible departments (bolded), and other departments that should be involved in the design of a particular entity. It can be noticed that the activities (identification, analysis, definition, evaluation, selection, and refinement) and the IDEF0 notation have not been explicitly included to accommodate the higher level of process models used at the company.

The gates were retained as per the existing process model in the company, where only gate 'a' as indicated in the generic process model was omitted as that gate serves for strategy alignment purposes in the generic process model, but it was considered that this alignment has to be adjusted and monitored throughout the whole process since the motivation for PSS design in the company is stemming from TBL sustainability improvements as indicated in the lowest flow arrow in Figure 3.

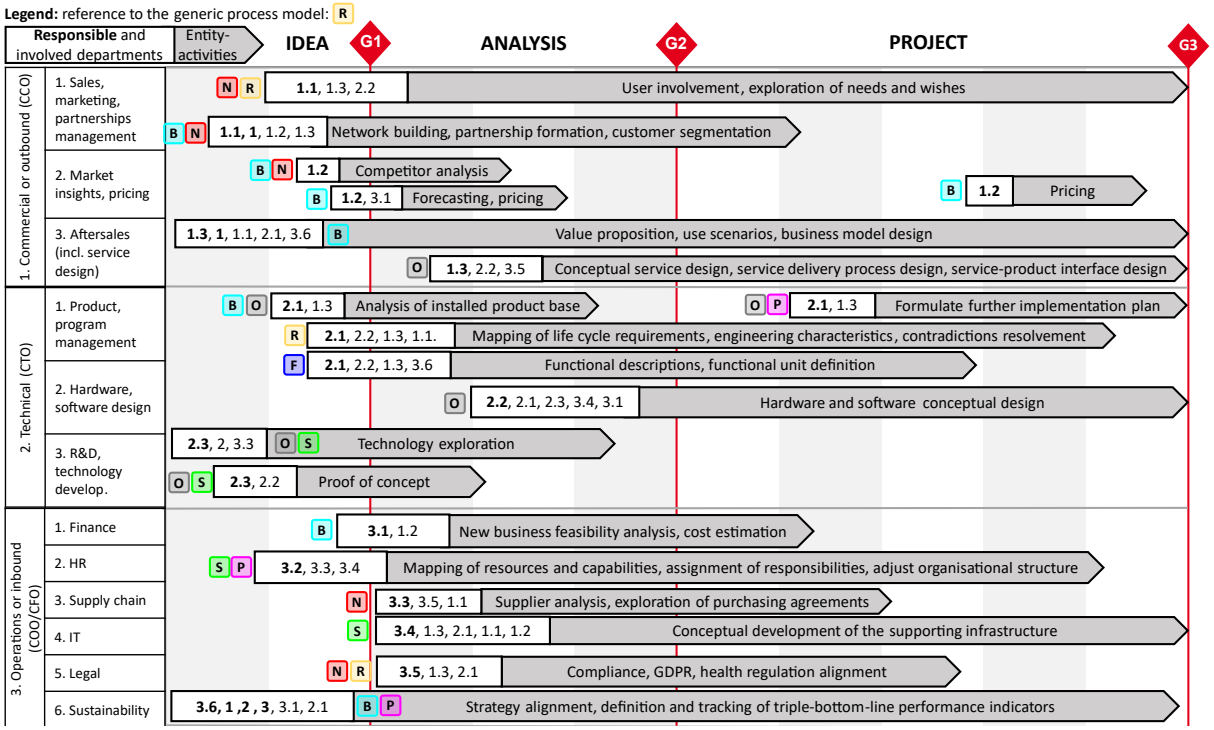

Figure 3. An instantiation of the generic process model adapted to case company 1

4.2 Case company 2

The instantiated process model in case company 2 can be seen in Figure 4. In the instantiation for the second case company, the three main stages were likewise retained, albeit renaming them to fit their existing practices. The content dimension (vertical axis) has been split into eight tracks according to the departmental organisation at the case company. Due to the larger size of the company, the CXO has not been explicitly included in the process. The entities and activities related to them have then been assigned to responsible departments (tracks), accountable departments (dark blue), supporting departments (light blue), and the departments that need to be informed of the decisions (grey). A more granular distinction in the second case company, compared to the first one, was deemed necessary due to the even higher complexity of cross-functional coordination due to the larger number of employees and teams to be involved in the early-stage PSS design. As in the first case company, the activities and

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the IDEF0 notation have not been kept at the same level as in the generic process model. The gates were retained as per the existing process model in the company.

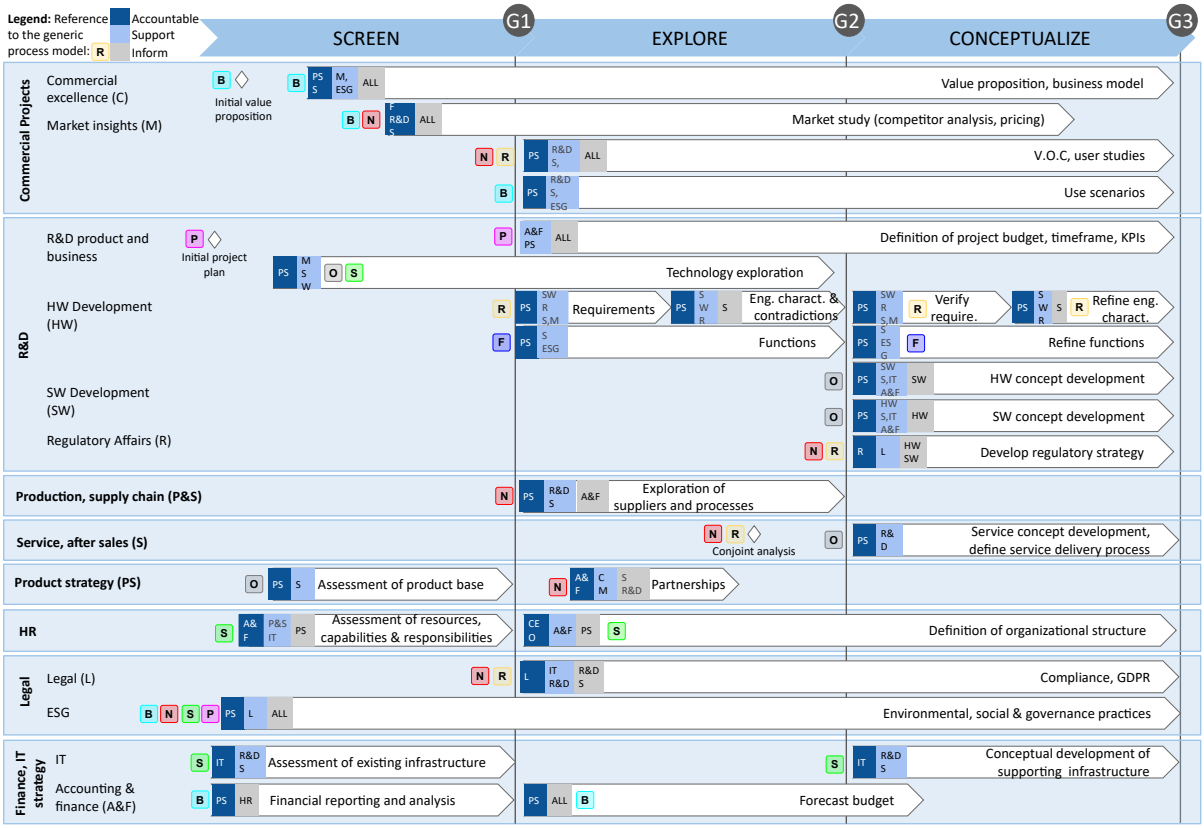

Figure 4. An instantiation of the generic process model adapted to case company 2.

5 DISCUSSION

5.1 The observed process of instantiation

After having instantiated the generic process model in two cases, common patterns have been observed:

- Three stages were seen as an appropriate level of granularity given the existing models.
- It was considered that the instantiated process model would be more easily adopted if the process model for PSS design retains as much of the existing structure, activities and terminology.
- There was a need to explicitly assign the tasks of design of different entities to particular departments that should be responsible for the activity, but also to state the other departments that should be involved or informed of particular activities.
- As PSS design activities are often iterative and cyclical in the generic process model, linear stage-gate process models are lacking in precisely defining when an activity should start and end in reference to other activities. Since PSS design requires engagement from many functional areas of the organisation and the design process requires iterations, it would be of tremendous value to map the information flows together with their contents and timestamps.
- For the sake of industrial applicability and simplicity, the five activities (identification, analysis, definition, evaluation, selection, and refinement) and the IDEF0 notation were omitted from the instantiated models to match the granularity level of the existing models in the companies.
- Due to the industry sectors (food processing and medical device), a much stronger focus on the process model is required on the regulatory issues.
- A detailed prior analysis of the relationships between the departments in the companies would be considered beneficial, as well as the involvement of company representatives in the instantiation processes, supported by the top management.
- The implementation of the instantiated generic process model in a practical setting might require a colossal change in the company culture, which might cause internal resistance.

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5.2 Reflection and plans for evaluation of the generic process model

In order to pave the way for a full descriptive evaluation of the generic process model for early-stage PSS design, an initial reflection was done with respect to a set of eight predefined criteria (utility, consistency, completeness, scope, broadness, precision, simplicity, and clarity) by the authors. These are the criteria planned to be used in future research to evaluate the generic process model by including several manufacturing companies. The initial reflection presented in Table 1 is a result of the authors' attempt to instantiate the process model and is not to be understood as an actual final evaluation.

Table 1. A descriptive evaluation of the generic process model based on the instantiation processes in two cases in relation to the eight criteria.

#	Criteria explained	Descriptive evaluation
1.	Utility - usefulness in supporting the creation of instantiated process models	The generic process model was considered very helpful due to its comprehensive overview of matters to consider and the order of activities to be conducted.
2.	Consistency - level of consistency between the entities proposed by the generic process model	A good level of consistency was observed. Due to a high level of interconnectedness of different cluster entities, additional clarification was occasionally needed with respect to the affiliation of individual entities in the structure versus the network clusters, which cover internal and external actors, respectively.
3.	Completeness - does the model miss any entities or activities?	Despite its comprehensiveness, it has been observed that the generic process model partially lacks considerations of regulatory and compliance entities, which are particularly important for the food processing and medical industries. Furthermore, little attention has been given to the exploration of different technologies for product, service and infrastructure realisation prior to their conceptualisation. Finally, a question was raised in relation to the extent to which the production and operations activities should be considered already in the early stage of PSS design.
4.	Scope - does the model cover the whole early-stage design?	The three stages seem to be an appropriate level of granularity of the early-stage PSS design.
5.	Broadness - is the generic process model applicable to different sectors?	Based on the two sectors, the generic process model showed reasonable adaptability. Although insufficient attention has been identified in relation to the regulatory entities, the generic process model was flexible enough to include such considerations, mainly under the actor-network cluster and the legal departments in the instantiated process models.
6.	Precision - are the contents of the process model defined precisely enough?	The cluster entities defined in the paper are considered to be defined precisely enough, apart from the entities mentioned in the completeness criteria (regulatory, technology, production).
7.	Simplicity - could the model be represented more simply?	It is considered that early-stage PSS design in all its complexity could not be so succinctly depicted more simply. However, the instantiation process models might resort to simpler representations, as seen in the results section.
8.	Clarity - how difficult is the model to understand?	The model can be readily understood at a superficial level, however, it becomes quite challenging to understand all its intricacies, and therefore, extensive accompanying explanations are required.

6 CONCLUSION

This paper has focused on the instantiation of a generic process model for early-stage PSS design in the cases of two capital goods manufacturing companies. The study aimed to prepare the basis for a later evaluation of both the instantiation processes and the generic process model itself, according to eight predefined criteria. This reflection and preparation for a full evaluation were carried out in order to be able to: (i) improve the future versions of the generic process model with the learnings obtained

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through the instantiation processes; and ultimately (ii) support manufacturing companies in structuring their PSS design processes, which have up to now mostly been intuition-based and ad-hoc in nature, therefore often resulting in lengthy development times and unsuccessful offerings in the TBL.
The study has found the instantiation process challenging due to the comprehensiveness of the generic process model which covers numerous aspects and entities. Therefore, support will be needed for companies to alleviate the complexity of the instantiation process, and to increase the accessibility and the adoption rate of structured PSS design processes in manufacturing companies. This could in turn speed up the journey towards CE and ensure a greater success rate of new PSS offerings in the market.
The generic process model, nevertheless, proved as a very helpful starting point for the instantiation of company-specific process models, despite its minor shortcomings in sector-specific matters.
Limitations of this study primarily manifest in the low number of case studies which prohibits generalisable conclusions concerning the sector-, rather than company-specific processes. Furthermore, the inclusion of other company representatives in the instantiation section might have brought further useful insights.
Further research is proposed to evaluate and refine both generic and instantiated process models by means of deep testing and evaluation inside the current and future case companies utilising AR as an approach. Such evaluation should be carried out to ensure the wide applicability of the generic process model. Future case studies should be conducted both in companies that do not have a defined PSS design process model like this research but also compare the generic process model to the process models in the companies that have established PSS design practices. Further case studies and instantiations should also include evaluations from company representatives on a larger scale to avoid bias.

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