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Product Development through Co-Creation Communities - General Measures For A Distributed And Agile Planning Preparation in Cross-Company Production

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Abstract

The crises of recent years revealed the vulnerability of our global and linearly aligned value chains, and new concepts are being sought to meet ecological, economic and social demands. The possibility of producing locally at the place of need in adaptable and highly dynamic manufacturing networks is increasingly coming into focus. However, such structures would have to be built up laboriously, whereas an existing network of small and medium-sized enterprises is available in many industrial nations. Cross-Company Production (CCP) in such local networks could help to address the problems mentioned. Another recent phenomenon is the shift of development processes into the digital sphere and its simultaneous opening up to the public. Open development processes can offer considerable advantages by bundling the wisdom of the crowd across company boundaries, however the digital platforms for collaboration do not have their own product capacities. The interaction of Co-Creation Communities (CCC) and Cross-Company Production (CPP) networks could counter this shortcoming. To ensure cost-efficient production and success on the market, an early exchange of knowledge between development and production is targeted in every company through highly standardised processes in the field of Planning Preparation (PP) a subdivision of Operations Planning and Scheduling (OPS). In the new value creation constellation this exchange is limited, as high fluctuation, various developers and numerous companies involved lead to new challenges. In this approach, a meta synthesis of known innovation and product development processes was performed to gain a better understanding of their structure and to identify measures fulfilling the tasks of Planning Preparation (PP). Aligned with the principles of Cooper's Stage-Gate Process a basis of measures is built up. After that each measure is valued according to relevance and involvement for the introduced entities creating an overview of general measures. Finally, the need for a distributed and agile Planning Preparation (PP) is derived.

Keywords

Co-Creation; Open innovation; Planning Preparation; Producibility; Operation Planning and Scheduling

1. Introduction

Operations Planning and Scheduling (OPS) acts at the interface between product development and production, it takes on, among other things, the role of a knowledge mediator between these two [1]. In order to understand the motivation behind this research, the two entities of product development and production need to be contextualised by currently important influences. First of all, digitalisation in all areas of everyday life has greatly changed the way we collaborate [2,3]. This is also having an increasing impact in the field of innovation and product development. The software tools required are available to a broader mass, not least because there are also increasingly user-friendly open-source solutions [4]. People have the opportunity

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to participate more in this initial step of value creation and to implement their own ideas, either for private use or as a secondary occupation [5]. Platforms (e.g. Github, Instructabels, GrabCad etc.) have become established and enable participants to further develop or publish their own artefact related information and designs [6], whereas a decade ago studies only analysed less than a hundred open-source designs, simply because there were not more available [7]. Today, numerous of artefact related information and designs can be retrieved at various levels of complexity [8]. The ever-increasing emergence of co-creation is leading to the development of new values in the digital sphere [9]. In order to materialise the developed artefacts, appropriate production capabilities are needed. This introduces the second major issue that needs to be understood for this research, the production of goods. While there has been an accelerated change in the way digital product development works, production depends on physical capabilities and skills that cannot be easily modified. The multiple crises of recent years have exposed the vulnerability of today's primarily linear value creation [10,11]. The climate crisis, for example, has become one of the dominant issues in our way of life, politics and economy [12],[13]. Industrial CO_2 emissions [14], transport of goods and short product life cycles are directly connected to our value creation system [15]. Local, smaller and more flexible manufacturing units at the place of need could address these problems, increase sustainability in all three dimensions (social, ecological, economic) and strengthen the overall resilience of the production sector. It is evident that there is an extensive net of small and medium-sized enterprises (SMEs) [16,17], both in densely populated areas and in their periphery. A future professionalised local production of open and collaboratively developed artefacts is a rewarding target [18,19]. While there are already existing research approaches to harnessing co-creation approaches for single (industrial) companies [5] the further investigation focuses on Cross-Company Production (CCP) networks of small and medium-sized enterprises working together with Co-Creation Communities (CCC). The interaction of the two entities is already observable, but existing open source hardware (the result of co-creation communities) still shows major shortcomings in the technical documentation and consideration of manufacturing-relevant basic principles that are to be confronted by this approach.

2. Structure of the Approach

2.1 Research Objective

The interaction of CCP and CCC leads to new challenges in creating value [20]. Quite fundamentally, there is a lack of producibility due to the non-fulfilment of general technical documentation criteria within these openly developed artefacts. As a sub-discipline of OPS, Planning Preparation (PP) includes advising people involved in the development process with regard to producibility. In order to implement this, measures are carried out at various points in the development process, such as an engineering assessment or the creation of a functionality overview. These general measures for implementing the knowledge flow between product development and production require assessment. The following research question arises:

> ***Which general measures are necessary for fulfilling the tasks of planning preparation? Which entity of the value creation system is involved in the measures and what relevance does the measure have for the value creation task of this entity?***

The approach seeks an outcome that can be understood as a overview of general measures to fulfil the tasks of PP (stated in Chapter 3) in a new value creation environment. It is intended to provide a possible basis for the layout and optimisation of digital, collaborative and platform-oriented product development processes in terms of *producibility*. In the following the methodological approach is explained to the reader in more detail. Subsequently, all the theoretically relevant terminology is defined and the current interaction between production and product development in industry is explained, with a particular emphasis on why existing models for the organisation of the product development are inadequate. Finally, the measures found are displayed and an evaluation using the criteria of relevance and necessary involvement are presented (compare Chapter 5).

2.2 Applied Method

The basis for identifying the measures is an existing literature research on innovation and product development processes, which was expanded to include more current models in order to obtain a complete picture [21,22]. Subsequently, a meta synthesis was performed. The qualitative method [23] is an evaluation of existing research. The models aggregated from the literature research were examined for statements on possible operational measures, which were selected and categorised [24]. The aim is to integrate and deepen findings from analyses and studies already conducted in a specific field of research. In this way, new insights are gained. A crucial aspect of meta-synthesis is the extraction of content from the texts of the selected studies without necessarily considering the original contexts of the studies [25,26]. During the content analysis, the process steps and their respective measures have been transferred. Based on the principles of *Cooper's Stage-Gate* Process the steps were transferred into stages. In addition, a further subdivision of the process steps into further phases could be found in some of the models. These were also transferred. The result was numerous phases and measures that could be combined and solidified. The evaluation of the identified measures was carried out through expert workshops, the used criteria are presented later on (Chapter 5).

3. Theoretical Background and Current Concepts

The Product Development Process (PDP) is the systematised sequence of work steps to think through an initial idea and make it available for production. Following these steps within a chosen context makes it become a product development project [27]. The outcome of this process is an unmitigated image of an artefact, the artefact on the other hand is the result of the value creation activities of the stakeholders in the value creation system [28]. The artefact consists of tangible and intangible components [28]. Product development and the subsequent materialisation can be assigned to the product creation process following the Product Life Cycle (PLC) according to DIN ISO 15226 [29]. In a company, many product development processes and product creation processes can run in parallel; at system level, numerous systemic processes also run on top of these individual processes. At the interface between product development and production, one of the tasks of PP as a sub-discipline of OPS is to ensure a sufficient flow of information in the development process. Currently, the PDP is designed according to the principle of integrated product development (compare Concurrent Engineering and Simultaneous Engineering). Information is exchanged between the production department and the development environment at an early stage. At the interface between development and production OPS acts as a knowledge aggregator and mediator between the two sub-disciplines of product development and production.

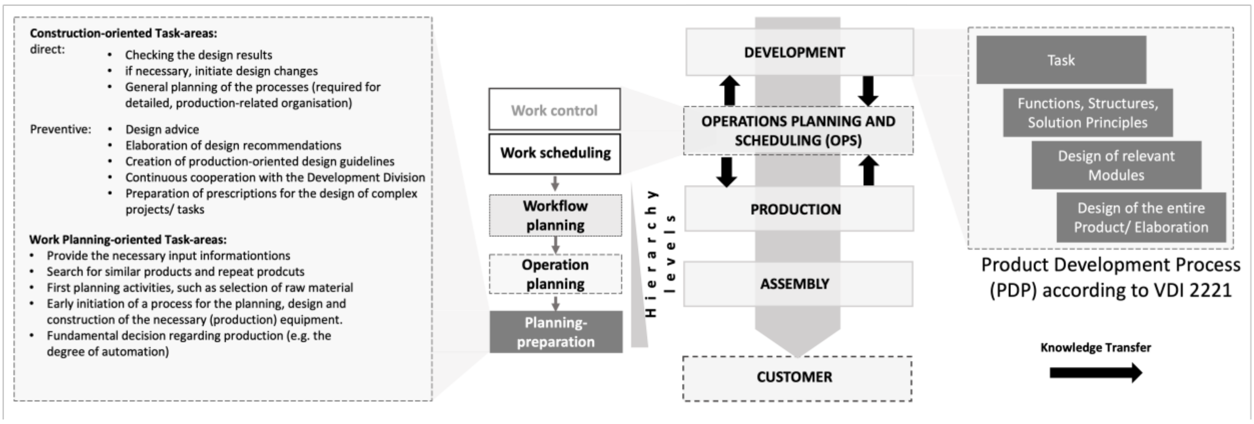

Figure 1: The roles of development, OPS and production in a company [30].

As shown in Figure 1., knowledge transfer occurs in the process. OPS essentially describes all organisational functions that must be fulfilled in order to bring a product design into production and thus ultimately to the customer. PP is a sub-area of OPS that is divided into the two sub-areas of design-oriented tasks and planning-oriented tasks. In classic literature, the consultation of the development department is always placed in the foreground, while the measures that fall under this are not further specified. Other tasks are stated rather vaguely as *"checking the design results"* or (giving) *"design advice"* (compare Figure 1.) [30]. Nevertheless, the improvement of the overall *producibility* of an artefact can be seen as a major goal of PP. In this context, the definition of *producibility* must be mentioned; it includes influencing factors such as materials management, production, assembly and testing, the associated logistics and the control mechanisms and support measures used for this purpose [31].

There are many standards in the field of product development, but these often refer to interaction within companies or company networks dominated by a single company. For example, modern concepts of product development presuppose the interaction of all relevant knowledge and information carriers of a company at the earliest possible point in time; this full integration should enable a holistic product development [32].First mentioned by OLSSON in the late 1960s [33] the term *Integrated Product Development* was introduced by EHRLENSPIEL [34]. These processes can be referred to as *Concurrent Engineering* or *Simultaneous Engineering* as a working methodology [34,35]. In all these concepts parallelisation of activities is the common approach to reduce development times and ensure cost-efficient production at an early stage. A possible strategy for a more detailed separation of the development process was introduced by COOPER [36].The stage-gate process follows a division of the development steps into so-called stages and gates that follow a temporal horizon. Each stage is associated with several measures which help to complete the objective of the gate. This can be an "*internal resolution*", a "*successful test*" or "*the creation of a concrete technical document*". In his latest update COOPER points out that rigid adherence to gates and stages is no longer appropriate for the complex development tasks prevalent today and that there must be iterations and feedback loops [37].

4. Challenges in the interaction of Co-Creation Communities and Cross Company Production

It was already predicted that the introduced concepts only work inadequately. The value co-creation scenario outlined in Chapter 1 assumes numerous companies and a variety of developers to be involved [20]. Furthermore, the development projects in such an environment show different degrees of professionalism and are characterised by phases of varying activity and changing project management. SAUBKE et al. (in press) showed that the interaction of CCP and CCC inevitably leads to new challenges due to the diversity of network members, the systematics of network governance and the network maxims [20]. In addition, it must be assumed that the means of production and the competencies of the employees are diverse. The network members are autonomously operating enterprises with a high degree of specialisation. They are horizontally and vertically disintegrated [38]. Governance follows decentralised structures and requires a higher coordination effort. There is a need for coordination between the individual companies with regard to the overarching value creation task. Productivity and optimisation can be cited as the maxims of the entrepreneurial actors. It becomes clear that the interaction of a multitude of different companies with an unknown mass of digitally collaborating developers, however, leads to further challenges in fulfilling the task of PP. The usual knowledge carriers are distributed and are no longer directly accessible or easy to bring together. But precisely all the details about production capabilities and the functionality of production systems have an high influence on the *producibility* of an artefact [38]. In the value creation constellation of CCC and CCP there will be no department that can take care of the tasks of PP or orchestrate the measures associated with them. For example, the motivation of an entrepreneur to spend resources on consulting tasks for an artefact that she or he may never produce or only produce in small quantities can only be assumed to a limited extent. The requirement is therefore no longer to carry out as many measures as possible to complete the task, and to do so in parallel, but its is rather to examine which tasks are of particular relevance for the participating entities and to clarify who is involved in the execution of a measure and to what extent.

5. Findings of the Analysis

5.1 Collection and Classification of Measures according to the Stage-Gate-Process

Aiming at the alignment of the systematics of general measures for Planning Preparation PP, the Product Life Cycle PLC according to DIN ISO 15226 [29] was used as a basis. The PLC is a well-established concept in marketing and product management that describes the stages a product goes through from its introduction to the market until its eventual decline and discontinuation. It systematises the product related value creation process into ten phases, of which four can be assigned to product development. These four phases are Planning, Knowledge, Development and Production. These four phases build the baseline in the new structure of stages and activities. The basis of the research was a summary of all PDPs and innovation processes that had been subjected to a published literature review by EVELEENS [21]. The literature research has a clear focus on innovation processes, but there is a lack of clarity in many concepts. In general a clear distinction between the innovation process and product development process is only possible to a limited extent. Therefore, recognised process models of product development were added from a published overview in a scientific publication by LENDERS [22]. In total 14 concepts were integrated in the meta synthesis.

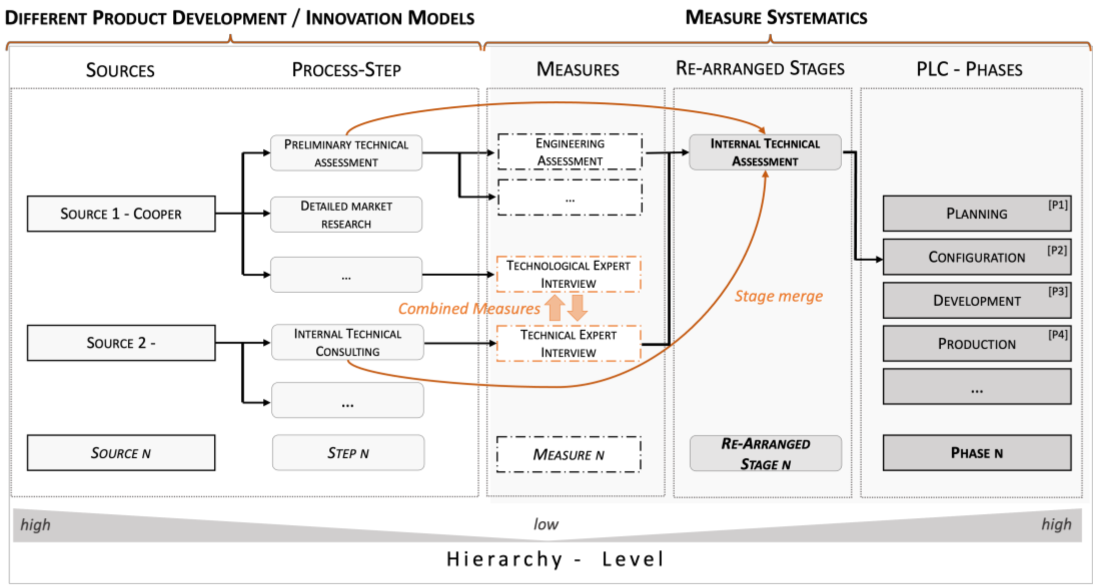

Figure 2: Procedure of identifying measures and stages.

In order to obtain a comprehensive overview of the possible stages and activities within the PLC, the above-mentioned sources were systematically examined for phases, stages or steps of the individual process structure, hereinafter referred to as process-steps. The procedure of the re-arrangement of the identified measures and process-steps is shown in Figure 2. Moreover, possible measures that can be assigned to the process-steps were selected through the analysis. The target was to unify the process-steps and finally transfer them into stages. According to the same principle, the identified measures were combined. The measures represent the lowest hierarchical level and can be associated with operational activities.

The grouping of these measures takes place in stages and several stages can in turn be assigned to the phases of the PLC. In 35 of 55 stages relevant measures could be identified. This led to a total of 103 measures, of which 30 were selected (displayed in Table 2., Chapter 5.2. The complete model can be requested through the corresponding author.

Table 1: List of innovation and product development models

No.	Related Models	Author	Reference
1.	Diffusion Of Innovations	Rogers (1962)	[39]
2.	An Investigation Into The New Product Process Step	Cooper (1986)	[36]
3.	Towards The Fifth-Generation Innovation Process	Rothwell (1994)	[40]
4.	Organizational Innovation - Review Critique And Suggested Research Directions	Wolfe (1994)	[41]
5.	World-Class New Product Development Benchmarking Best Practices Of Agile Manufacturers	Dimancescu (1996)	[42]
6.	Trends And Drivers Of Success In NDP Practices: Results Of The PDMA Best Practices Study	Griffin (1997)	[43]
7.	A Multidimensional Approach To The Adoption Of Innovation	Cooper J. (1998)	[37]
8.	Auditing Best Practice For Effective Product Innovation Management	Cormican (2004)	[44]
9.	Managing Innovation	Tidd & Bessant (2005)	[45]
10.	The Innovation Value Chain	Hansen (2007)	[46]
11.	Concept Development And Design	Ponn (2011)	[47]
12.	Design Theory [Konstruktionslehre]	Pahl/Beitz (2013)	[48]
13.	Integrated Design Engineering An Interdisciplinary Model For Holistic Product Development	Vajna (2014)	[31]
14.	Design Of Technical Products And Systems Configuration Of Individual Product Design Processes	VDI (2019)	[49]

5.2 Introduction of the Relevant Measures and Assessment

In an **initial step** all identified measures were valued with regard to their conformity with the tasks of PP introduced before (compare Chapter 3). Measures such as *"Engineering Assessment"* were assigned to the PP systematics, although they might include logistics or assembly aspects. All measures with a high level of consistency regarding the tasks performed by PP are listed in Table 2. In some models, measures were mentioned which have a technical aspect, but which is not associated with PP's overall target to increase the artefacts *producibility*. Furthermore, in some of the models examined, measures were identified that could not already be assigned to any of the four phases of the PLC considered and also have no technical reference. From today's perspective, these would not be implemented at such an early stage of the process. These measures were excluded. With the emergence of new technologies since the 1990, for various reasons some measures are no longer adequate. The following measures are examples of this: *„Structuring And Planning The Market Launch"* or *"Provide An Effective User Education"*. As already indicated in the beginning, in a **second step** an assessment was made. The resulting list was evaluated:

- Evaluation criteria I. - What is the relevance of this measure to the entity?
  (*The outcome of the measure e.g. knowledge inflow is required)*
- Evaluation criteria II. - To what extent is the entity involved in the Execution?
  (e.g. knowledge carrier).

In the evaluation, a differentiation must be made between the shared value creation activity (successful cooperation of the CCC and CCP) and the domain-specific value creation task (production and development). When assessing relevance, it is therefore important to consider the extent to which the measure affects one's own value creation task and whether the measure also has a particularly positive influence on the PP's tasks (increase in *producibility*). The evaluation follows the scheme **low**, **medium** and **high**, because limiting resources (time, costs) make prioritisation necessary. Nevertheless, it is a basic premise that all stakeholder have an interest in the success of the shared value creation activity. For example, the measure *"(Technical) Review Of Competing Products To Improve Manufacturing Decisions"* was rated with a high relevance for the producer. The argumentation that such a decision could be less important to the producer because otherwise he could simply take on another value creation task (producing of another artefact) loses its validity against this background. The evaluation has shown that a measure can have a high relevance for one entity, but the implementation of the measure depends fundamentally on another entity. Under certain circumstances, this leads to conflicts. In addition, it must be assumed that the effort of the measures is not the same - this could not be considered. For a better understanding, some of the measures mentioned are explained in more detail. The measure *„Knowledge About Innovation In The Considered Field"* is assigned to the stage *"Needs"*. As outlined at the beginning, a focus was placed on PLC steps one to four, i.e. this is an Initial Stage which is a measure to support the developer within the framework of the idea exception. To be well informed about your own field of innovation is highly relevant for the developer, on top of that he is highly involved completing the measure. In contrast, the producer is confronted from the outset with many different artefacts. He cannot use his scarce resources for the agglomeration of knowledge in diverse disciplines, this measure has therefore less relevance for him. The measure no. 2 prescribes the *"Creation Of A Technological Solution System To Overcome A Problem"*. The evaluation of this measure is particularly interesting, the introduction of technical support systems has a high relevance for both entities. However, shaping and introducing the system itself can only be done to a limited extent through the involvement of the two entities. The sponsorship would have to be taken over by another entity.

In summary, the assessment helps to prioritise tasks and assign a corresponding entity, which can be of high importance for a system architecture or the selection of suitable support technologies to achieve the overall objective of increasing the producibility of openly and collaboratively developed artefacts.

Table 2: Selection of the 30 Measures most important for PP and their Evaluation.

medium = ■ **high = ■■** **very high = ■■■**

No.	Identified Measures	Stage	Relevance CCC	Involve. CCC	Relevance CCP	Involve. CCP
1.	*Knowledge About Innovation In The Considered Field*	Needs	■■■	■■	■	■
2.	*Creation Of A Technological Solution System To Overcome A Problem*	Research	■■■	■	■■■	■
3.	*Advice On Hardware Components (Material, Etc.)*	Research	■	■	■	■■■
4.	*Performance Input And Estimation Of The Idea*	Development	■■	■■	■■■	■■
5.	*Transfer Of The Development Results Into Information Required For Production*	Development	■■■	■	■■■	■
6.	*Consideration Of (Product) Logistics*	Development	■	■■■	■■■	■
7.	*(Technical) Support For A Decision-Making Process (If An Idea Should Be Pursued)*	Initial Screening	■	■■■	■■	■■■
8.	*(Technical-) Review Of Competitors Products To Improve Manufacturing Decisions*	Pre. Market Assessment	■■■	■	■■■	■
9.	*Engineering Assessment*	Pre. Tech. Assessment	■■	■■	■■■	■■
10.	*Identify And Define Product Specifications*	Pre. Tech. Assessment	■	■■	■■■	■■■
11.	*Conducting A Capability/Feasibility Analysis*	Pre. Tech. Assessment	■■■	■■■	■	■■■
12.	*Generic Development Of A Product Design-Model*	Pre. Tech. Assessment	■■	■■	■■■	■■
13.	*Costs And Sales Forecast (Technical Perspective)*	Business Analysis	■■■	■■■	■	■
14.	*Pooling Of Technical Expertise*	Product Development	■■■	■	■	■
15.	*Identification Of Missing Knowhow (in the development process)*	Product Development	■■■	■■■	■■■	■■■
16.	*Detailed And Transparent Presentation Of Technical Issues/Problems/Questions*	Product Development	■■	■	■■	■
17.	*Production Trial/ Testing Of The Production Processes*	Trial Production	■■■	■■■	■■■	■■■
18.	*Emphasis On Satisfying User Needs*	Idea Generation	■	■■	■■■	■■■
19.	*Attaining Cross-Project Synergies And Inter-Project Learning*	Research, Design, Dev.	■■■	■■	■■■	■■
20.	*Development Emphasis On Creating User Value*	Research, Design, Dev	■	■	■■■	■■
21.	*Checking The Solution Path (Product Design/Structure)*	Projecting / Specifying	■■■	■■■	■	■
22.	*Determination Of A Manufacturing Strategy*	Conceptualise /Design	■	■	■■■	■■■
23.	*Support For Simulating Production At An Early Stage (Predictive Engineering)*	Construction	■	■	■■■	■■■
24.	*Peer - Review On Decisions*	Configuration	■■■	■■■	■■■	■■■
25.	*Clarification And Itemisation Of The Assignment, Task Or Problem*	Clarification	■■	■■	■	■
26.	*Collecting Available Information On The Product Context*	Clarification	■■	■■	■	■
27.	*The Identification Of Information Gaps*	Clarification	■■	■	■	■
28.	*(Technological) Support For The Search For Innovative Solutions*	Search For Solution	■■■	■	■	■
29.	*Solution Mapping*	Search For Solution	■■	■■	■	■
30.	*(Technological) support for the definition of the overall function*	Search For Solution	■■■	■	■	■

5.3 Conclusions and evaluation of the results

After the evaluation, two conclusions can be drawn. First, the planning preparation environment changes drastically. Since many developers and numerous companies are involved in this new value-creation constellation, one can speak of the distributed character of PP. It must be assumed that there are dislocated knowledge carriers that extend the distribution by the aspects of spatial and temporal separation. Distribution may make it necessary to make knowledge more accessible through storage and generalisation. This distribution makes knowledge aggregation necessary to a higher degree and also has a concrete effect on the necessary technical systems that are referred to in the measures. In order to meet the requirements of this value-creation environment while at the same time keeping development time low and producibility high, PP has to be agile to a high degree. Following the use of the term in software development (achieving executable software as early as possible in the development process), the use of the term 'agility' in the hardware context is intended to meet the overriding goal of creating producible hardware as quickly as possible while at the same time maintaining a transparent source of knowledge. For example, decisions can be positively influenced at an early stage with a *"peer review on decisions"* (c. Table 2, No. 24), but for this to happen, knowledge carriers must be linked to knowledge needs short term. At the same time, there must be a high degree of transparency regarding knowledge creation in order to create credibility, which also must be tracked and made accessible for both entities. The evaluation of the measures in terms of relevance and the degree of involvement in the fulfilment of the tasks is widespread. Some of the measures focus on positively influencing the development process at an early stage in terms of producibility. Other measures provide producers with sufficient assistance. Overall, the participation of both entities is necessary. Furthermore, according to the evaluation scheme, some measures cannot be fulfilled by the two entities. Another party is needed to moderate between the two. An intermediary could function as the needed knowledge aggregator stated before and could provide a suitable digital infrastructure for the process.

6. Critical Analysis and Outlook

The overarching goal of this approach is to increase the *producibility* of artefacts developed in Co-Creation Communities (CCC) for the production in Cross-Company Production (CCP) Networks. Following the classical organisational structure of Operations Planning and Scheduling (OPS), this is a task of the subdivision of Planning Preparation (PP). In contrast to the approaches of integrated product development, where the shortening of the development time and the parallelisation of tasks are in the foreground, it is now more important to examine which tasks are of relevance for the participating entities and to clarify who is involved in the execution of a measure and to what extent. This product development process may require a more sequential orientation again in this value-creation constellation. It was deduced why existing concepts only function insufficiently. In order to take all approaches into account, a fundamental analysis of existing concepts for innovation and product process design was performed and numerous measures were identified to achieve the overarching goal: The increase of *producibility*. Fourteen theoretical and published process models were analysed during the processes to identify possible stages and related measures. These were then ordered in the sense of the stage-gate process. Based on the challenges in the interaction of Cross-Company Production (CCP) and Co-Creation Communities (CCC) described in Chapter 4 the measures identified were evaluated. It shows whether a measure is relevant for an entity and through whose involvement it can be fulfilled. Therefore, the research question of identifying and evaluating suitable measures could be adequately answered. Furthermore, it has been shown that the Planning Preparation (PP) tasks can only be fulfilled through an additional entity. This intermediary must mediate between production and development, take responsibility for fulfilling tasks and monitor them. This is only possible through technological support. In this regard, the temporal and spatial separation must be further observed. Even if the basis for the development measure systematics consisted of fourteen different models, each of which is based on an extensive and contemporary case study, it may have improved the expressiveness to conduct a direct survey in the companies and within the developer community. Another topic for further research is which measures can be supported technologically. On top of that, the technological feasibility needs to be assessed and concrete technologies must be detected. Therefore, the systematics found so far provide initial assistance in optimizing and designing digital platforms for the organisation of value creation systems. In general, the approach to improve the outcome of product development processes in Co-Creation Communities (CCC) by achieving higher *producibility* bears great potential to impact future value creation systems positively.

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