POTENTIALS AND GOALS OF MODELS IN STRATEGIC PRODUCT PLANNING AND INNOVATION MANAGEMENT

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ABSTRACT

New trends and technologies in product creation increase complexity, but at the same time create new potentials such as efficiency rise in task processing by Artificial Intelligence. Established models in the early phase of product creation such as the W-model or the Aachener Innovation Management model, do not fully exploit these new potentials in the field of strategic product planning and innovation management (SPPIM). For this reason, existing models are analysed in SPPIM in order to derive a requirements profile consisting of potentials and goals for a new model. A new model in SPPIM lays the foundation to support companies in enabling a more efficient task fulfilment by taking advantage of new technologies and trends. To guide the development of advanced SPPIM models, the derived potentials and goals are applied to the guideline VDI 2220:1980.

Keywords: Innovation, Early design phases, Product-Service Systems (PSS), New product development

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1 INTRODUCTION

Complexity in product creation continuously increases while available product creation time becomes shorter and shorter (Gräßler et al., 2022). Challenges such as an increasing amount of knowledge and cross-linking of multiple disciplines occur in the field of product creation. New technologies such as digital twin and artificial intelligence offer high potentials in facing these challenges (Luft, 2022). An exemplary potential is the increasing efficiency. By forcing a virtual product creation and the use of computer-aided systems throughout the whole product creation process, lead time and costs can be saved. This reduction leads to an increasing efficiency (Stark, 2011; Anderl 2020). Moreover, a focus on planning and developing not only mechanical products but also product service systems (PSS) offer the chance to provide customized products. Further, the connection to the customer can be improved (Hepperle, 2013). These potentials have already been used in the field of product engineering for example, within the new V-Model of VDI/VDE 2206:2021 (VDI/VDE 2206:2021). Aspects such as a broader product understanding were integrated into the new V-Model by focusing on cyber-physical systems in addition to original mechatronic systems (VDI 2206:2004). In the early phase of product creation established models (in this context understood as a visualization of activities and their interdependencies) do not fully exploit the potentials created by new trends and developments. Especially the VDI 2220:1980 "Product Planning; flow, terms and organization", representing a broadly used guideline companies use for defining business processes, has shortcomings in relation to today's state-of-the-art in technology and product creation processes. Examples of these shortcomings are the traditional material understanding of the product and the waterfall-like structure which does not enable an agile workflow (VDI 2220:1980). The early phase of product creation is classified in the areas of strategic product planning and innovation management (SPPIM) in this paper. The tasks and delimitation of SPPIM are oriented to the overarching goal of the engineering order or business plan for transfer to product engineering (Gausemeier et al., 2016; Gräßler, 2015; Scheed et al., 2021).

To fully harness the identified potential for improvement (shortcomings), the potential must be opened up in future models of strategic product planning and innovation management. To do so, an overview about potentials in product creation followed by a corresponding requirements profile for new SPPIM models is necessary. The following two research questions sum this up:

RQ1: Which current and future developments in product creation (e.g. technologies or business models) exist in the field of SPPIM?

RQ2: How do models in SPPIM need to be revised based on these developments?

This paper is structured into five sections. The introduction (see section 1) is followed by the research design chosen to answer the research questions (see section 2). Subsequently, the state of the art and the results of the systematic literature review of SPPIM is presented (see section 3). Then, the analysis and potentials in SPPIM are described and discussed through a case example (see section 4). Finally, a summary of the results and an outlook on further research perspectives is given (see section 5).

2 RESEARCH DESIGN

The applied research design comprises three steps (Figure 1). First (see section 3.1), a systematic literature study is performed according to the PRISMA 2020 statement (Page et al. 2021). Three different search strings are used for searching in data bases "Web of Science" and "Science direct (cf. Table 1). The search strings include the subject area SPPIM, which was already narrowed in the introduction and focuses the area of engineering in product creation. Selection of relevant articles is performed within two stages. First, title, keywords and abstracts are analysed to single out papers which are within product planning, strategic product planning or innovation management. Second, full papers are analysed regarding core models, processes, frameworks and methods, general characteristics and process steps of SPPIM. As a result of the literature analysis, 22 papers remain for further analysis. Out of the 22 papers, 4 papers are allocated to of strategic product planning, 8 papers to product planning and 11 papers to innovation management. The literature study in Web of Science and Science Direct has shown that especially trends and developments of the last years are found in publications of these databases from which framework conditions for models can be derived. Core models, however, are mainly found in further known key literature, e.g. Cooper 2010. For this reason, literature study is extended to additional literature in product creation with further books, papers and articles by focusing on the early phases and subject areas of SPPIM in key literature: In total 16 further

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relevant sources are found. For literature search, no restriction of the time period was chosen in order to be able to include older, frequently cited key literature.

Table 1. Search results of literature study

Search term	**Data base**	**Results**	**Relevant results**
"Strategic Product Planning" AND ("Model" OR "Process" OR "approach" OR "procedure model" OR "method" OR "concept")	Science direct	70	1
"Strategic Product Planning" AND ("Model" OR "Process" OR "approach" OR "procedure model" OR "method" OR "concept")	Web of Science	18	3
"Product Planning" AND ("Model" OR "Process" OR "approach" OR "procedure model" OR "method" OR "concept")	Web of Science	132	7
"Innovation management" AND ("Model" OR "Process" OR "approach" OR "procedure model" OR "method" OR "concept")	Web of Science	42	1
"Innovation management model" OR "model of Innovation management" OR "model for Innovation Management"	Science direct	81	10
Additional literature			16
Sum		343	38

In the second step (see 3.2), major models, frameworks and methods, general characteristics and process steps of SPPIM are classified, based on similarity, in "Analysis", "Detailing", "Monitoring and Interface Management", "Further Product Creation and Lifecycle" and "Strategy". Based on the classification, main steps and elements within the field of SPPIM are identified. Moreover, in order to find further potential within product creation (which has not been addressed within SPPIM), current trends and methods in other fields of product creation e.g. product engineering are analysed with the help of literature. For this purpose, an additional search is carried out using search terms such as "new technologies", "trends" or "need for revision" in the area of product creation. For this second literature research on new technologies, the time period was limited to 5 years. Based on these results, a requirements profile for a future SPPIM models is created within the third step (see 4.1). This requirements profile is represented by eight potentials. To include the potentials into future SPPIM models, associated goals are formulated. The need for revision is concretised and discussed on the guideline VDI 2220:1980 as a core reference for users in the scientific as well as in the companys' environment (4.2). As a result, the study provides guidance for the creation of new SPPIM models.

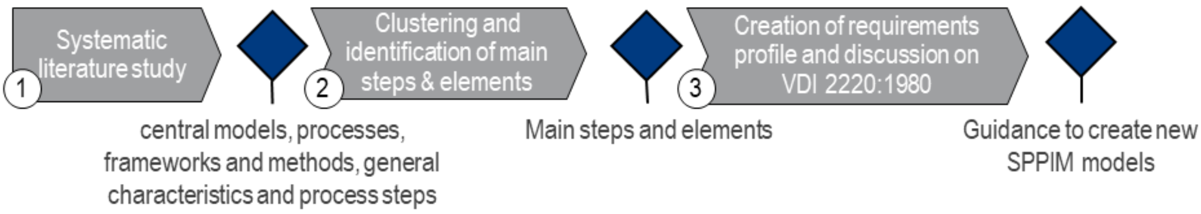

Figure 1. Research design

3 STATE OF THE ART AND LITERATURE ANALYSIS

The recognition of market potential, finding and planning new product ideas with respect to company's goals and strategy are essential, as they guarantee long-time existence of a company (VDI 2220:1980). These tasks are fulfilled by several business units such as SPPIM, which all include similar activities (VDI 2220:1980; Bender et al., 2021; Scheed and Scherer 2021). Therefore, with respect to RQ1 (see section 1), literature regarding all three task fields are included into literature study for identifying potentials in SPPIM. In addition, other models in product creation (e.g. VDI/VDE 2206:2021 as a subsequent model that uses the transfer artefact of SPPIM "engineering order") are considered as well

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as overarching topics and interfaces, like agility and interdisciplinarity. These further models in product creation include models from different tasks fields along the product creation process e.g. engineering or production. Based on the results, literature is analysed regarding core elements, developments in product creation (e.g. new technologies, integration of basic principles) and process steps.

3.1 State of the art

As an analysis of the current situation, different definitions and descriptions of the field of SPPIM are identified in literature. Following, these descriptions are explained as a basis for the derivation of potentials. Interfaces to core models in product creation are explained with reference to representative examples like the V-model and the generic Product Lifecycle Model (gPLC). By considering these interfaces and partial overlaps, it is ensured that the analysis in the paper at hand covers all relevant fields while keeping its clear and narrow focus on SPPIM.

Innovation Management: According to DIN EN ISO 56000:2021, innovation management is the coordinated activity with regard to new value-creating entities. Thereby, innovation is an invention which creates or redistributes value. Management is defined as aligned activities for leading and steering an organization. As a result, innovation management includes tasks such as the decision about an innovation vision, innovation strategy, innovation goals and innovation processes (DIN EN ISO 56000:2021-10). Kadar et al. state that "innovation management is focused on the systematic processes that organizations use to develop new and improved products, services and business processes. It involves development of creative ideas within the organization and the networked environment" (Kadar et al., 2014). Triggered by market pull and technology push, the innovation management together with strategic planning is the starting point of product creation process. (Gräßler, 2015).

Product Planning: The goal of product planning is finding the right product ideas with respect to the business model of a company. Within this process, the product ideas need to be sufficiently attractive on the target market and realizable. Also, the developing and detailing process of the product should be planned to create a product in an efficient way. As a result of the product planning, the order for starting product engineering is handed over to the engineering department (Bender et al., 2021). Several models, concepts and processes of product planning exist for example VDI 2220:1980. In the guideline, planning of new, future-oriented products is described as one of the most important activities to ensure the future success of a company. Product planning is divided into the activities of "product finding", "product planning tracking" and "product monitoring" (VDI 2220:1980).

Strategic Product Planning: Gausemeier et al. present product innovation process as four cycles: strategic product planning, product engineering, process engineering and production system design. Within the cycle of strategic product planning, three tasks are named: identification of potentials and recommendations of action for the future, finding process of products and the positioning in one's own product portfolio, business planning which summarises the decisions about the business and product strategy and the business plan. The goal is the transfer to product design, for example, through an engineering order. (Gausemeier et al., 2016; Scheed et al., 2021)

Core models in product creation: Product idea passes through further steps described in the gPLC. The gPLC has emerged from analysis of existing lifecycle models and addresses all steps in process of product creation, from Strategic Planning to Operation and Service Delivery, but also Decommissioning. Key aspects of the model are circularity of materials and information and the associated agility to use information and materials in all steps of product lifecycle. (Gräßler and Pottebaum, 2021)

In order to obtain a marketable product, identified product ideas have to be handed over to engineering (engineering order). Representative for engineering is the V-Model of the guideline VDI 2206:2021. The V-Model describes mechatronic and cyber-physical systems as well as hybrid service bundles. The guideline addresses problems of interdisciplinarity, complexity and interconnectivity.

3.2 Identification of core elements and task fields in SPPIM

Within literature study, fifteen models and process descriptions within the field of SPPIM are identified out of the 38 relevant sources. The identified literature in the field of strategic product planning and product planning is predominantly published by German authors, while literature about innovation management is mostly published by international authors. This can be a hint to the fact that in international context, innovation management is the most dominantly used term when talking about the tasks of recognition of potential, finding and planning new product ideas with respect to the companys' goals and strategy. In contrast, (strategic) product planning is a term, dominantly used in German-

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speaking scientific communities. For further analysis, based on the identified models and processes, included process steps are analysed and classified which is shown in Figure 2 (key of sources in Table 2). For classification, similar process steps of the models are identified and summarised into five classes. In addition to the naming in the model, descriptions in the text were used to recognise a comparison between different namings and delimitations. The criterion of temporal dimension was also considered.

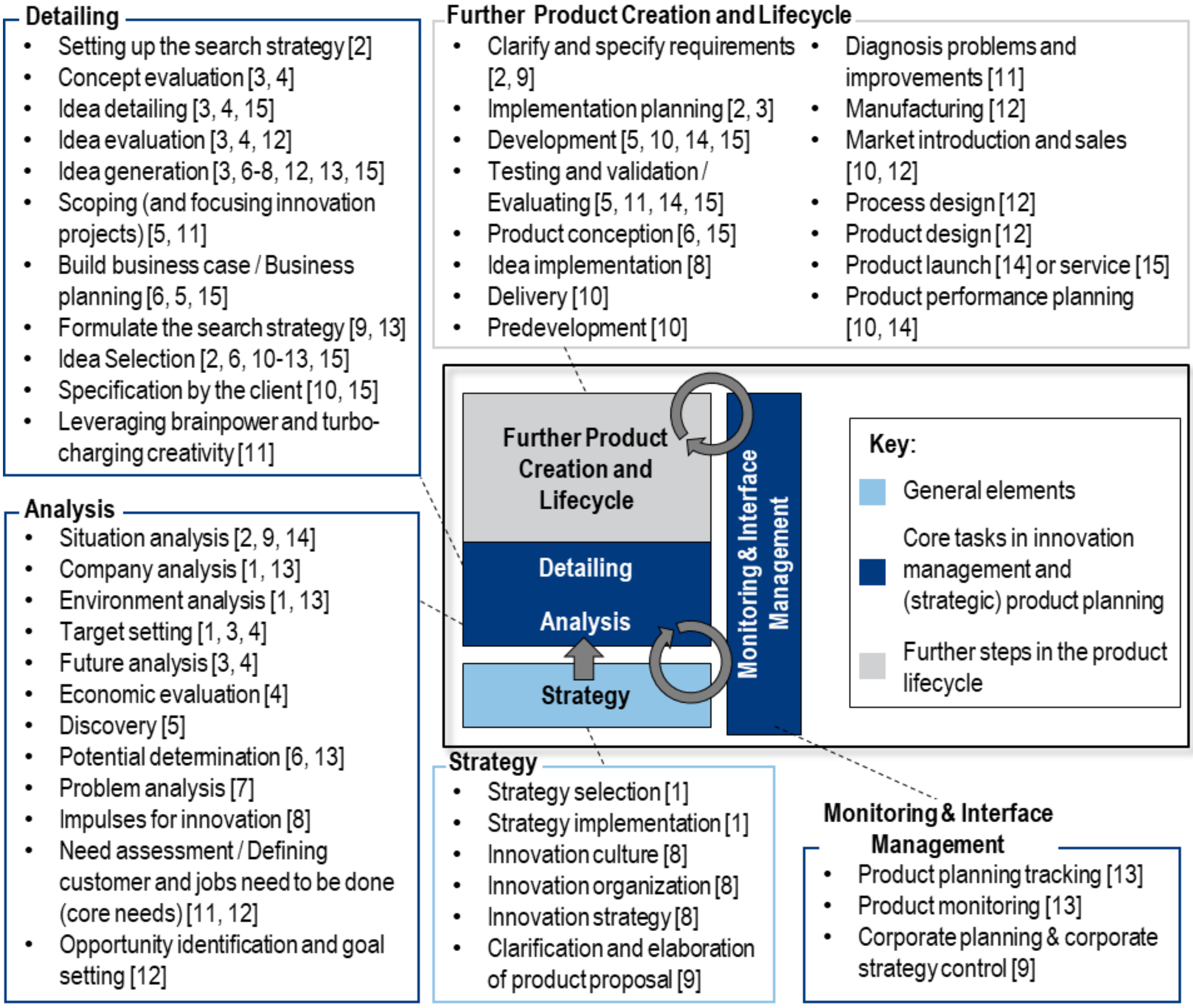

Figure 2. Visualization of the classified tasks fields in SPPIM

The classes are "Analysis", "Detailing", "Monitoring and Interface Management", "Further Product Creation and Lifecycle" and "Strategy": The class "Analysis" includes activities, which focus on identifying current and future potential of the company and customer needs. Process steps such as situation, environment and company analysis are identified within models of SPPIM (VDI 4520:2017; Bender et al., 2021; Brandenburg, 2002; Bea et al., 2019). The class "Detailing" focuses on the process of finding, selecting and detailing product ideas based on the results of the class "Analysis". As a result, the idea generation and selection are included in SPPIM (Brandenburg, 2002; Salerno et al., 2015; Niewöhner et al., 2021; Şimşit et al., 2014; Bender et al., 2021). Within the class "Monitoring and Interface Management", tracking and monitoring activities are included. Within the VDI 2220:1980 the product planning includes tracking and product monitoring in accordance to product realization and product support (VDI 2220:1980). Activities such as engineering, manufacturing and launching of products are summarized in the class "Further Product Creation and Lifecycle". Salerno et al. e.g. suggest either to continue with the product engineering or to sell products / take product orders (Salerno et al., 2015). Strategically focused activities are assigned to the class "Strategy". Niewöhner et al. highlight the requirements to include an innovation strategy, organization and culture among others into the company to guarantee an ambidextrous innovation management (Niewöhner et al., 2021).

To sum up, task fields such as analysis, detailing, monitoring, interface management and further product creation can be identified as classes of task fields in SPPIM. Additionally, strategic aspects (e.g.

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innovation and company strategy) are an important element in SPPIM. The box with black border in Figure 2 highlights a visualization of the classified task fields in SPPIM. The base in SPPIM is given by the overall strategy (light blue) of the company. These principles have an impact on the task fields such as analysis, detailing, monitoring and interface management (shown in dark blue). The task field of monitoring and interface management as part of the product planning shows a control function synchronizing strategy and guiding principles as well as results from the analysis and detailing phases throughout the whole product lifecycle (shown in light grey) including decommissioning of the product. Between the different tasks, iterations and repetitions are included presented by the grey circled arrows.

Table 2. Key of sources

index	source	index	source
[1]	Bea et al., 2019	[9]	Reik et al., 2013
[2]	Bender et al., 2021	[10]	Salerno et al., 2015
[3]	Brandenburg, 2002	[11]	Şimşit et al., 2014
[4]	Bleicher, 1999	[12]	Tuominen et al., 1999
[5]	Cooper, 2010	[13]	VDI 2220:1980
[6]	Gausemeier et al., 2016	[14]	VDI 4520:2017
[7]	Hepperle, 2013	[15]	Verloop, 2004
[8]	Niewöhner et al., 2021		

4 ANALYSIS AND POTENTIALS OF MODELS IN SPPIM

Based on the results of the literature analysis of the models in SPPIM, potentials for the revision of further SPPIM models are derived by compiling the inputs and potentials for SPPIM found through the literature research and transferable aspects from other models in product creation. 23 relevant sources do not include a model for SPPIM, so they cannot be assigned to the classes, but still provide relevant starting points for the revision of SPPIM. Oriented on the classified task fields in SPPIM, gaps are identified and drafted into potentials for a new SPPIM model. Based on the potentials, goals for the revision of SPPIM models are derived. Goals represent a requirements profile.

4.1 Potentials and derived goals

Potential 1 – Target Product: As stated by Gräßler et al. classical products consisting of mechanical and software-parts are not the main engineering artefacts anymore (Gräßler et al., 2016). In fact, cyber-physical systems (CPS) as well as product service systems (PSS) moved into the focus of engineering. By including target products such as CPS and PSS, processes become more complex. Reasons are more involved disciplines, innovations as product service systems with resulting new business models and more data to be processed (Gräßler et al., 2016; Kernschmidt et al., 2012; Hepperle, 2013). Therefore, CPS and PSS has to be included into the understanding of the target product in SPPIM. Based on this inclusion, the processes in SPPIM, especially "Detailing", need to be adapted to digital business models.
→ Goal 1: Expansion of understanding of the target product regarding to PSS
Potential 2 – Target User: Gräßler et al. argue that in accordance to the target product, also the circle of target users of a model has to be enlarged (Gräßler et al., 2016). Developers are faced greater challenges than described in current models. It is now necessary not only to regard material products, but also to integrate and think about associated services in form of PSS. Experts in disciplines of CPS and PSS need to be addressed by models for SPPIM and thus interdisciplinarity has to be represented for example in the area of "Strategy" and innovation culture. (Gräßler et al., 2016; Niewöhner et al., 2021)
→ Goal 2: Wider range of target group and enable interdisciplinary work
Potential 3 – Agility: The engineering cycles of products are becoming faster and more volatile in market. This is accompanied by additional changes in customer needs and requirements. Therefore, agility in processes is a main factor guaranteeing adaptability to changes and fulfilling the customer needs in product planning (Gräßler et al., 2016). Therefore, agility as a basic principle needs to be added to a current model in SPPIM as it is not presented in the current task fields of SPPIM in Figure 2.
→ Goal 3: Enabling an agile workflow
Potential 4 – Tailoring: Braun et al. state that SMEs are usually not able to select the right methods in innovation management due to a lack of experience or personal resources (Braun et al. 2004). Salerno

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et al. state that traditional models in innovation management require a time-consuming planning and many resources (Salerno et al., 2015). Therefore, they are not appropriate for companies with high insecurity and complexity. Additionally, they describe that innovation processes differ between companies: Some companies include a break within the engineering, others start into the product creation process by having ideas or specifications of products by the client himself called as "development to order (closed)" (Salerno et al., 2015; Pich et al., 2002; Rice et al., 2008). According to Orawski et al. no generic model in the early phase of product creation exists which provides the necessary flexibility for a product planner to adapt the model to their requirements (Orawski et al., 2011): The shown task field of SPPIM must be expanded.
→ Goal 4: Giving opportunity for tailoring to companies and SPPIM situations
Potential 5 – Model-based product planning: In their research, Löwer and Heller state that "strategic, technological and market boundaries have not been modelled yet" (Loewer and Heller, 2014) to make data about customer feedback for example usable in product planning. Therefore, they suggest a data model in accordance with a "process model for innovation and idea management" (Loewer and Heller, 2014). Additionally, in the engineering phase, model-based approaches are used to support interdisciplinary work and transparency of information. Since the interdisciplinary work also increases in product planning due to the engineering of CPS and hybrid service bundles (see Potential 1), an enlargement of the model-based approaches to product planning is necessary. This need is also stated by Vogel-Heuser et al. suggesting an enriched Business Process Model and Notation (BPMN+I) to support "collaboration between interdisciplinary teams" (Vogel-Heuser et al., 2020). This point influences and supports superordinately all shown task fields of SPPIM.
→ Goal 5: Enabling modelling for better information transfer and improved traceability in SPPIM
Potential 6 – Circularity: Nowadays, circularity is an important topic having an impact on all fields of product life. Gräßler and Pottebaum present a generic Product Lifecycle including circularity of information and material (Gräßler and Pottebaum, 2021). Circularity of information and material for products is not yet represented in models of SPPIM and should be added to a current model of product planning. In contrast to Potential 5, this potential focuses on the product and not the processes of SPPIM.
→ Goal 6: Focusing product circularity in information and material in all areas of SPPIM
Potential 7 – Interface Management: As explained within Potential 5 (Model-based product planning), interdisciplinarity in product planning increases. Therefore, interfaces such as technology management, product portfolio management, road mapping and releases of products become more important. (Reik et al., 2013; Fotrousi and Fricker, 2016; Guideline VDI 4520:2017) On the one hand, interfaces are indispensable, as the integration of CPS and PSS (Potentials 1 and 2) requires the involvement of heterogenous disciplines. On the other hand, interfaces between the steps in the product creation process have to be observed in order to ensure the accuracy of fit to other steps, for example the accuracy of fitting to the VDI 2206:2021. Thus, at the "Strategy", not only the innovation culture, for example, and the "Monitoring and Interface Management" must be considered, but also other involved interfaces.
→ Goal 7: Focusing on interface management in SPPIM
Potential 8 – New technologies and business models: Since 1980, many new technologies were invented. The Gartner Hype Cycle provides an important indication of relevant in future technologies. Starting from the Internet of things and services to Artificial Intelligence and Big Data. (Niewöhner et al., 2021). According to Gartner, technologies like the Metaverse, Cloud Sustainability and Digital Humans have great potential in becoming an emerging technology within the next 5 to 10 years (Davis, 2022). In addition, Fotrousi et al. explain in their research that Software as a Service (SaaS) cloud computing can be used in analyzing the users behaviour for product planning and management (Fotrousi et al., 2013) but also the virtual product creation as a new technology can reduce time and costs in SPPIM (Stark, 2011, Anderl, 2020). The technologies and business models presented reflect only a part of what needs to be considered in a current model of SPPIM. Depending on the scope and use of the model, further technologies and business models may also added. For this reason, the possibility must also be created to continuously integrate other new technologies and business models in an agile manner in order to also keep the task field continuously up-to-date.
→ Goal 8: Continuous inclusion of new technologies in SPPIM

These eight potentials can be classified into the following categories: methods, technologies, tools, users and guiding principles (Figure 3). The classes identified within 3.2 and 4.1 are used as the core

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elements of the visualization. Based on the strategy, guiding principles are derived such as agility, adaptability, circularity and virtual product creation. These principles impact the methods, technologies and tools (light blue) applied by users (light blue) in the product planning task fields such as analysis, detailing, monitoring and interface management (dark blue). Between the different tasks, iterations and repetitions are included presented by the grey circled arrows to represent agility and circularity within product planning. Due to the task fields (and not explicit by detailed tasks) the model is adaptable to every part of company or product planning project.

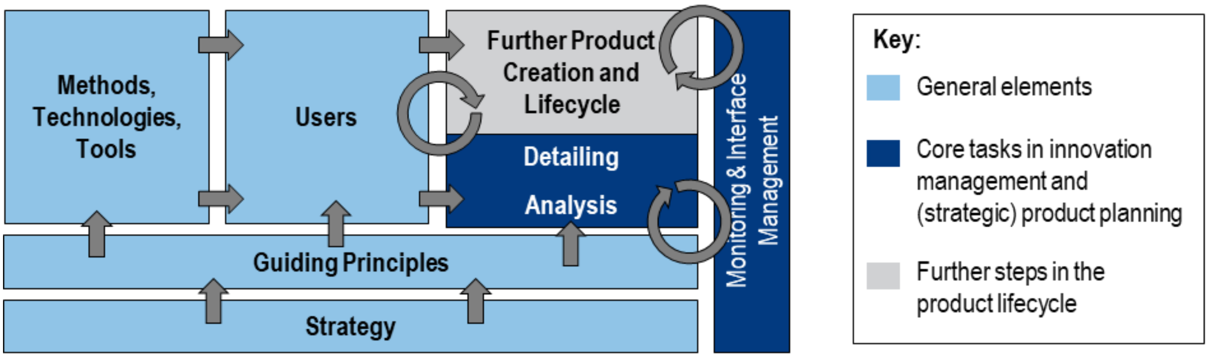

Figure 3. Visualization of potentials in SPPIM

4.2 Case example of VDI 2220:1980

Within the following section, the Potentials identified in Section 4.1, are discussed regarding the VDI 2220:1980. One potential for improvement is to enlarge the focus on mechatronic products towards CPS and product service systems (Potential 1). Based on the enlargement of the target product, also the target group within the VDI 2220:1980 should be expanded to experts of CPS and PSS (Potential 2). The VDI 2220:1980 shows a waterfall-like process model including a strict alignment of activities with only a few backslopes (e.g. from product monitoring to product finding). This structure does neither offer the possibility for agile procedure (Potential 3), adaptability of the model to a company's situation and resulting needs (Potential 4), nor does it include a circularity of information or material (Potential 6). Since in 1980 products were not as complex as today, interface management is not an important element of the VDI 2220:1980 (Potential 7). Additionally, new technologies and trends such as the Internet of things and services as well as Big Data are not yet considered in the VDI 2220:1980 (Potential 8). However, the integration of new technologies should be integrated as independently as possible from the respective technology in order to quickly replace obsolete technologies by new ones in the future without having to fundamentally revise a model. An integration of these points into the model is important to meet current requirements. This integration can be realized by focusing a model-based product planning (Potential 5) which is not yet included in the VDI 2220:1980.

5 CONCLUSION

In this paper, a requirements profile for future SPPIM models is identified, which is derived from current trends and developments in SPPIM. These trends and developments are identified based on a systematic literature review on SPPIM and adjacent topics. Based on this literature review eight potentials for a new model in SPPIM are identified and transformed into a requirement profile. To exploit the full potential in SPPIM, future models must now be developed according to the findings obtained. How to use the requirement profile and revise an established SPPIM model is shown by the case example VDI 2220:1980. From this, the need for a revision of the guideline becomes clear in order to increase the applicability for changed needs of the extended target groups (Potential 2) and to update the guideline by including new technologies (Potential 8). Moreover, a better interface management (Potential 7) and a tailoring concept (Potential 4) lead to an improved efficiency in SPPIM. Further aspects that should be considered in this context are methods of SPPIM, which provide support for standardisation and automation. One example is the integration of Scenario-Technique with connected databases and automation using algorithms and Artificial Intelligence (Gräßler et al., 2022). Further advantage offered by Scenario-Technique and other foresight methods is the continuous view into future developments especially in process of finding new sustainable products or services (Gräßler et al., 2017). In addition to the identification and evaluation of ideas with

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the help of the Scenario-Technique, linking and complementing the potentials of the modelling and the method in order to continuously create transparency and increase the efficiency of both potentials. Navrade shows one possibility of such a modelling of methods in SPPIM, which can be extended and integrated into a new model of SPPIM (Navrade, 2008). Overarching desire to innovate and responsibility of environment and people are important topics to discuss in SPPIM as a deepening of the Potential 6 and to focus sustainability.

REFERENCES

Anderl, R. (2020), “Virtuelle Produktentstehung”, In: Bender, B. and Göhlich, D. (Eds.), *Dubbel Taschenbuch für den Maschinenbau 2: Anwendungen*, Springer Berlin, Heidelberg, pp. 117-141. https://doi.org/10.1007/978-3-662-59713-2_6

Bea, F.X. and Haas, J. (2019), *Strategisches Management, Unternehmensführung*, UVK Verlag, Munich. https://doi.org/10.36198/9783838587073

Bender, B. and Gericke, K. (2021), *Pahl/Beitz Konstruktionslehre: Methoden und Anwendung erfolgreicher Produktentwicklung*, Springer Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-57303-7

Bleicher, K. (1999), *Das Konzept integriertes Management*. Campus, 5th edition, Frankfurt. https://doi.org/10.1007/978-3-322-88977-5

Brandenburg, F. (2002), *Methodik zur Planung technologischer Produktinnovationen*, Doctoral dissertation, Fraunhofer-Institut für Produktionstechnologie IPT.

Braun, T., Gausemeier, J., Lindemann, U., Orlik, L. and Vienenkotter, A. (2004), “Design support by improving method transfer - A procedural model and guidelines for strategic product planning in small and medium-sized enterprises”, *Proceedings of the Design 2004 - 8th international Design Conference*, Dubrovnik, 18.05.-21.05., Design Society, Glasgow, pp.143-148.

Cooper, R.G. (2010), “The Stage-Gate Idea to Launch System”, In: Sheth, J. and Malhotra, N. (Eds.), *Wiley International Encyclopedia of Marketing*, John Wiley & Sons, Chichester. https://doi.org/10.1002/9781444316568.wiem05014

Davis, M. (2022), "What's New in the 2022 Gartner Hype Cycle for Emerging Technologies", Available at: https://www.gartner.com/en/articles/what-s-new-in-the-2022-gartner-hype-cycle-for-emerging technologies (accessed 2 November 2022).

Fotrousi, F. and Fricker, S.A. (2016), “Software Analytics for Planning Product Evolution”, *Software Business*, 7th International Conference, Ljubljana., Springer Cham, Switzerland, pp.16-31. https://doi.org/10.1007/978-3-319-40515-5

Fotrousi, F., Izadyan, K. and Fricker, S.A. (2013), “Analytics for Product Planning: In-depth Interview Study with SaaS Product Managers”, 2013 *IEEE Sixth International Conference on Cloud Computing*, Santa Clara., IEEE Computer Society, Massachusetts, pp. 871-879. https://doi.org/10.1109/CLOUD.2013.33

Gausemeier, J., Echterfeld, J., Amshoff, B. (2016) "Strategische Produkt- und Prozessplanung". In:

Lindemann, U. (Eds.): *Handbuch Produktentwicklung*, Hanser, Munich. https://doi.org/10.3139/9783446445819.fm

Gräßler, I. and Oleff, C. (2022) *Systems Engineering - Verstehen und industriell umsetzen*, Springer Vieweg Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-64517-8

Gräßler, I. and Pottebaum, J. (2021), “Generic Product Lifecycle Model: A Holistic and Adaptable Approach for Multi-Disciplinary Product-Service Systems”, *APPLIED SCIENCES-BASEL*, Vol. 11 No. 10, p. 4516. https://doi.org/10.3390/app11104516

Gräßler, I., Hentze, J. and Yang, X. (2016), “Eleven Potentials for Mechatronic V-Model”, *6th International Conference Production Engineering and Management*, Lemgo, pp. 257-268.

Gräßler, I., Pottebaum, J. and Scholle, P. (2017), “Integrated Process and Data Model for Agile Strategic Planning”, *11th International Workshop on Integrated Design Engineering*, Magdeburg.

Gräßler, I., Tusek, A.M., Thiele, H., Preuß, D., Grewe, B. and Hieb, M. (2022), “Literature study on the potential of Artificial Intelligence in Scenario-Technique”, *XXXIII ISPIM Innovation Conference Proceedings*, Copenhagen, 05.06.-08.06., LUT Scientific and Expertise Publications, Copenhagen.

Gräßler, I. (2015), “Generic Product Creation System”. In: *13th Industrial Simulation Conference* 2015, Valencia, Spain, June 1-3, S. 173-177. https://doi.org/10.3390/app11104516

Hepperle, C. (2013), *Planung lebenszyklusgerechter Leistungsbündel*, Doctoral dissertation, Technische Universität München.

Hilt, M.J., Wagner, D., Osterlehner, V. and Kampker, A. (2016), “Agile Predevelopment of Production Technologies for Electric Energy Storage Systems - A Case Study in the Automotive Industry”, *Procedia CIRP*, Stockholm, Elsevier Procedia, Amsterdam pp. 88-93. https://doi.org/10.1016/j.procir.2016.04.189

Kernschmidt, K., Hepperle, C., Mörtl, M. and Vogel-Heuser, B. (2012), “Lifecycle Oriented Planning of Mechatronic Products and Corresponding Services“, In: Rivest, L., Bouras, A. and Louhichi, B. (Eds.)

https://doi.org/10.1017/pds.2023.292 Published online by Cambridge University Press

Product Lifecycle Management. Towards Knowledge-Rich Enterprises, Springer, Berlin, Heidelberg, pp.349-358. https://doi.org/10.1007/978-3-642-35758-9_31

Loewer, M. and Heller, J.E. (2014), "PLM Reference Model for Integrated Idea and Innovation Management", In: *Product Lifecycle Management for a Global Marke*t, Springer, Berlin, Heidelberg, pp. 257-266. https://doi.org/10.1007/978-3-662-45937-9_26

Luft, Thomas (2022), "Komplexitätsmanagement in der Produktentwicklung: Holistische Modellierung, Analyse, Visualisierung und Bewertung komplexer Systeme.", FAU University Press, Erlangen. https://doi.org/10.25593/978-3-96147-541-4

Navrade, Frank (2008), *Strategische Planung mit Data-Warehouse-Systemen*. Wiesbaden: Gabler. https://doi.org/10.1007/978-3-8349-9762-3.

Niewöhner, N., Lang, N., Asmar, L., Röltgen, D., Kühn, A. and Dumitrescu, R. (2021), "Towards an ambidextrous innovation management maturity model", *Procedia CIRP*, Enschede, Elsevier Procedia, Amsterdam, pp. 289-294. https://doi.org/10.1016/j.procir.2021.05.068

Orawski, R., Krollmann, J., Moertl, M. and Lindemann, U. (2011), "Generic Model of the Early Phase of an Innovation Process regarding Different Degrees of Product Novelty", *Proceedings of the 18th International Conference on Engineering Design (ICED11)*, Copenhagen, Design Society, Glasgow, pp. 57-68.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P. and Moher, D. (2021), "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews", *BMJ*, Vol. 10 No. 1, p. 89-100. https://doi.org/10.1136/bmj.n71

Pich, M.T., Loch, C.H. and Meyer, A. de (2002), "On Uncertainty, Ambiguity, and Complexity in Project Management", *Management Science*, Vol. 48 No. 8, pp. 1008-1023. https://doi.org/10.1287/mnsc.48.8.1008.163

Reik, A.U., King, M. and Lindemann, U. (2013), "Investigation of the Information Generated by Technology Management Tools and Links to Strategic Product Planning Stages", *IEEE International Conference on Industrial Engineering and Engineering Management*, Bangkok, pp. 330-334. https://doi.org/10.1109/IEEM.2013.6962428

Rice, M.P., O'Connor, G.C. and Pierantozzi, R. (2008), "Implementing a Learning Plan to Counter Project Uncertainty", *IEEE Engineering Management Review*, Vol. 36 No. 2, pp. 92-102. https://doi.org/10.1109/EMR.2008.4534821

Salerno, M.S., Gomes, L.A., Silva, D.O., Bagno, R.B. and Freitas, S.D. (2015), "Innovation processes: Which process for which project?", *Technovation*, Vol. 35, pp. 59-70. https://doi.org/10.1016/j.technovation.2014.07.012

Scheed, B. and Scherer, P. (2021), "PORTFOLIO - Strategische Produktanalyse und -planung und strategisches Preismanagement", In: Scheed, B. and Scherer, P. (Eds.), *Strategisches Vertriebsmanagement: Methoden für den systematischen B2B-Vertrieb im digitalen Zeitalter*, Springer Gabler, Heidelberg, pp. 133-186.

Şimşit, Z.T., Vayvay, Ö. and Öztürk, Ö. (2014), "An Outline of Innovation Management Process: Building a Framework for Managers to Implement Innovation", *Procedia-Social and Behavioral Sciences*, Vol. 150, pp. 690-699. https://doi.org/10.1016/j.sbspro.2014.09.021

Stark, R., Hayka, H., Israel, J.H., Kim, M., Müller, P. and Völlinger, U. (2011), "Virtuelle Produktentstehung in der Automobilindustrie", *Informatik-Spektrum*, Vol. 34 No. 1, pp. 20-28. https://doi.org/10.1007/s00287-010-0501-z

Tuominen, M., Piippo, P., Ichimura, T. and Matsumoto, Y. (1999), "An analysis of innovation management systems' characteristics", *International Journal of Production Economics*, Vol. 60-61, pp. 135-143. https://doi.org/10.1016/S0925-5273(98)00183-2

VDI (1980), "VDI 2220 Produktplanung: Ablauf, Begriffe und Organisation No. VDI 2220:1980", Verein Deutscher Ingenieure, Düsseldorf.

VDI (2004), "Design methodology for mechatronic systems No. 2206:2004", 2004-06, Beuth Verlag GmbH, Düsseldorf.

VDI (2017), "VDI 4520 Blatt 1-Produktmanagement: Einführung und Grundlagen No. VDI 4520:2017", Verein Deutscher Ingenieure, Düsseldorf.

VDI (2021), "VDI 2206 Development of mechatronic and cyber-physical systems (CPMS) No. VDI 2206:2021", Verein Deutscher Ingenieure, Düsseldorf.

Verloop, J. (2004), "Insight in Innovation: Managing Innovation by Understanding the Laws ", Elsevier, Amsterdam.

Vogel-Heuser, B., Brodbeck, F., Kugler, K., Passoth, J., Maasen, S. and Reif, J. (2020), "BPMN+I to support decision making in innovation management for automated production systems including technological, multi team and organizational aspects", IFAC-PapersOnLine, Vol. 53 No. 2, pp. 10891-10898. https://doi.org/10.1016/j.ifacol.2020.12.2825

https://doi.org/10.1017/pds.2023.292 Published online by Cambridge University Press