Proceedings of the First Australian International Conference on Industrial Engineering and Operations Management, Sydney, Australia, December 20-21, 2022

Foresight in Product Development - A Review on Existing Understandings and Approaches

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Abstract

Early consideration of the future market environment of a new product favors its success. Therefore, the future environment and requirements derived from this must be considered in the development of a product. Foresight provides several instruments for identifying different potential future developments, according to the time horizon referenced in the development of the product. Especially for a medium to long-term time horizon, trends and scenarios are suitable. With scenarios, alternative environments of the future can be described and distinguished. In strategic product planning, future requirements are derived with the help of scenarios to enable a more efficient and often less expensive definition for a product. Due to a volatile market environment, the product must be adapted in many cases or fails to meet the future needs of customers, users or suppliers. There are several approaches to manage this uncertainty. However, there is a lack of an overview of common understandings. In this paper, 29 relevant publications were identified with a systematic literature review considering 382 publications. Six existing understandings were identified but they are not used consistently. Based on the commonalities, two key orientations were found: future-robustness and future-orientation. With future-robustness, developments can be understood which results in products positioned robustly against several alternative futures. The products can be adapted to different future developments with minor adjustments. In contrast, with future-orientation the development is focused on a specific alternative future and thus the product design is made for one chosen solution concept. Therefore, product changes are effortful.

Keywords
Future robustness, future orientation, foresight, scenarios and product development.

1. Introduction
The development of products is subject to prevailing market and technology-related uncertainties (Henderson and Clark 1990). Early consideration of the future market environment therefore favors the development of a successful product (Cooper and Kleinschmidt 1993). Methods of foresight such as the scenario technique represent a tool in the discussion of a potential future picture. Thereby scenarios can be created for the anticipation of the future environment or upcoming technologies on the product to be developed. Further on, it is possible to derive future requirements via scenarios (Meyer-Schwickerath 2014). However, there is no guarantee that an expected future will occur. Depending on the future space considered in each case, several futures can be described as probable. Accordingly, several different potential futures must be expected. It is therefore attempted to align the development of the products with

several future developments, which is accompanied by losses in the optimization of the product for a single use case (Gausemeier 2009). The costs of adjustments in later phases of the product development increase according to the "rule of ten" and thus over the course of the product development (Reinhart and Lindemann 1996). In the worst case, the adjustment to several futures can lead to the fact that the specific needs of the customers, users and providers are no longer considered adequately and thus the use of the product is missed (Albers et al. 2018).

To address the described problem, various methods of foresight have been developed, which reveal differences in the understanding of future orientation. Furthermore, in the development of modern products, different domains are involved which access the information from methods of foresight. For a uniform communication, a general overview of the different approaches and orientations for the integration of future knowledge into the product development is given in the context of this paper.

2. Literature Review

2.1 Essential terms of the subject area of foresight

In the literature, a distinction can be made between distinct types of foresight. Here, three terms are essential, which differ in the time horizon: Prognoses, trends and scenarios (see Fig. 1). In the following, these terms will be examined in more detail.

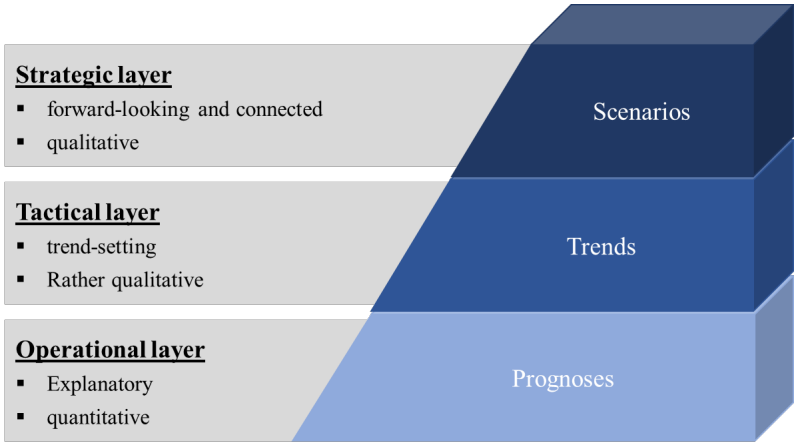

Figure 1. Three levels of foresight according to Fink and Siebe (2011)

According to Fink and Siebe (2011), prognoses are linear extrapolations of quantitative values from the past and the present. They are used to make statements about concrete facts with a short time horizon (Fink and Siebe 2016). Accordingly, they make a prediction about a future state or the future development of a system based on the present state and knowledge of the past development of a system (Vogel-Heuser et al. 2014). The validity of the method is therefore limited to a short observation horizon (Gausemeier 2013).

Trends, in turn, are possible directed future developments that can be considered relevant for future business activity due to a high probability (Gausemeier 2015). It is important to note the one-dimensionality of the observation by trends, as no interaction analysis with other developments takes place (Fink et al. 2002). According to Horx and Eggers (1996), three differentiated categories of trends exist: megatrends, consumer trends, and industry trends. The maturity of these trends exceeds the consideration period of prognoses and is referred to as medium-term in the German-speaking world (Fink and Siebe 2016).

Scenarios used as an instrument for long-term foresight differ from trends in two key respects: networked thinking and future-open thinking, which is referred to as Multiple Future (Gausemeier et al. 2016; Gausemeier 2015). Due to the increasing complexity and dynamics of developments, it is no longer sufficient to describe the object of investigation through influencing factors that are independent of each other; instead, networked thinking is required (Gausemeier et al. 1998). Future-open thinking is necessary because future developments can be predicted less accurately as the time horizon increases. It is not possible to predict the one certain future that will occur. Instead, alternative development possibilities of influencing factors are considered and multiple futures are shaped (Fink and

Siebe 2016). Consequently, a scenario is the description of several possible, consistent situations in the future, which is formed from a complex system of influencing factors (Gausemeier et al. 1998). Several alternative scenarios span the conceivable future space. (Fink & Siebe 2016)

2.2 Important models

The use of foresight results can take place in different contexts. This is illustrated by the four-quadrant model of scenario-based innovation management according to Fink and Siebe (2016), in which four different ways of looking at scenarios and their interactions are described. The aim here is to identify and evaluate future business areas and strategy potentials based on market and performance potentials (Fig. 2). Market potentials are defined as future relevant customer needs (Fink & Siebe 2016). Performance potentials are the internal company possibilities to realize these market performances. The authors integrate foresight as a means of identifying relevant future needs and technologies at an early stage, for example in the form of customer and technology scenarios. In this model, external environmental variables are linked with internal design elements to identify potential. Technology scenarios offer initial starting points for using the results of foresight in product development.

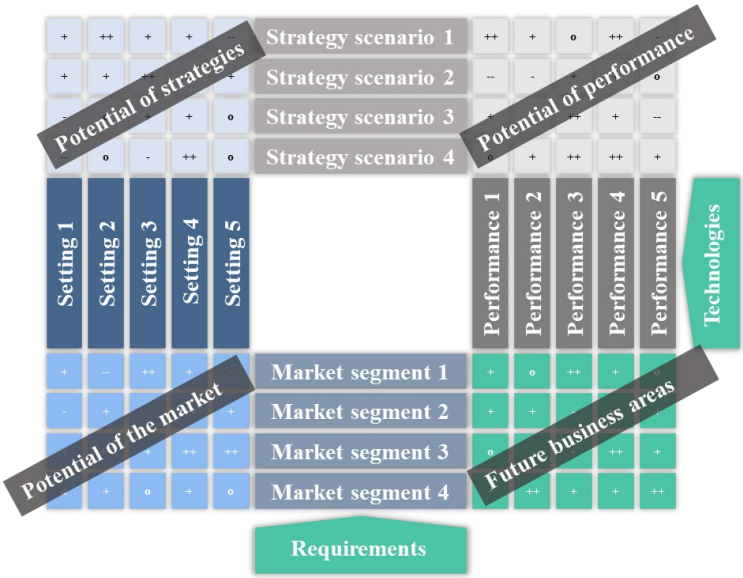

Figure 2. 4-quadrant model of scenario-based innovation management (Fink and Siebe 2016)

Meyer-Schwickerath et al. (2012) analyzed the use of foresight in product engineering and located foresight based on specific activities in the product engineering process. The analysis is based on the activities of product engineering in the integrated Product engineering Model (Albers et al. 2016). Meyer-Schwickerath et al. (2012) recognize that foresight can be used in a supportive manner, especially in the activities Detect Profiles and Detect Ideas. Likewise, the use of foresight is very suitable for the activities Verify and Validate according to the analysis.
According to Lindemann (2005), the use of foresight in product development enables future-robust products to be generated. Marthaler (2021) supports the process of future-oriented profiling. Greve et al. (2019) consider future-robust product program planning.

The systematic approach according to Marthaler (2021) has the goal "to support the identification of search fields with high innovation potential on the basis of methods of foresight and thus to enable the intergenerational planning of development scopes" (Marthaler 2021). Three distinct outcomes are achieved by conducting the approach. First, a portfolio for the classification of product characteristics regarding invention potential and future robustness; second, a roadmap for the cross-generational planning of development scopes; and third, product profiles as concrete search orders or development scopes.

The core of the methodology according to Greve et al. (2018) is an analysis of the current external product diversity, a forecast of the future external product diversity in the form of customer group scenarios to which product scenarios are assigned, and a comparison of the current and future external diversity in the so-called "Program Comparison

Model" (PCM). The PCM can be used to compare existing product families and the product scenarios based on similarity. This allows recommendations for action to be made regarding the product program. Very similar product families can be combined into one family and existing product families can cover future needs (product scenarios). Product families that no longer meet customer needs in the future can be phased out and new ones can be developed for identified market gaps (Krause et al. 2020).

2.3 Interim summary

Gausemeier et al. (2009) mention the terms future-robustness and future-orientation in his work on future-oriented corporate strategy development. Other works, especially in product engineering, such as Marthaler (2021) take up the terms and use them in the context of product development. However, they do not list a precise direction to what extent this is to be interpreted. Especially in product generation engineering the transfer is difficult, according to Albers et al. (2016) later generations are already considered in the development of the current generation. Here, the time horizon is crucial (Marthaler 2021). While scenarios can be considered in the long-term time horizon, only forecasts are important in the short-term.

3. Methods

3.1 Need for Action

As already presented in the theoretical framework, works in product engineering take up the concepts of future-robustness and future-orientation according to Gausemeier (2009), which are, however, located in the context of corporate strategy. Within product development, the transfer of the context of the corporate strategy is challenging, since other boundary conditions must be taken into account and, for example, time specifics must be defined by considering several time horizons (long, medium and short term). Especially in the field of partial future robustness according to Gausemeier, there are definition and knowledge gaps regarding trends and prognoses. To close these gaps, approaches, methods or processes using these terms in the field of product development and product generation engineering must first be identified. This will help to develop a basis for a common understanding of how these terms can be understood. For this reason, the following overall question was defined for this thesis:

What understandings and conceptions exist for the consideration options in foresighted requirements and development management?

To answer this overall question, the following three questions must be answered:

1. What approaches exist that address the consideration options described?
2. Which consideration option and associated terms are referred to?
3. What connection between different uses can be derived from the approaches considered?

3.2 Research Design

The procedure to answer the questions introduced in the previous chapter is based on the Design Research Methodology (DRM) according to Blessing and Chakrabarti (2009) . In this elaboration, the first phase of the DRM, the Research Classification (RC), is conducted by analyzing the state of the research with respect to the research question. The procedure is divided into five phases, as shown in Figure 3 below.

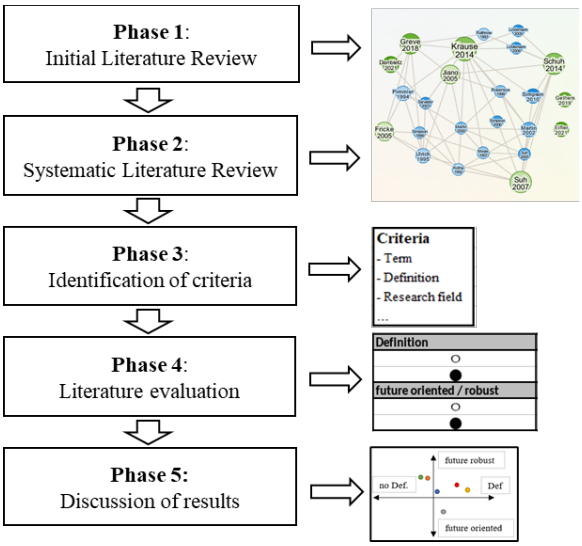

Figure 3. Phase diagram and associated partial results of the literature research conducted

In the first phase, the literature is initially reviewed to obtain an overview of approaches already used to delimit the addressed futures. Used terms and their temporal relations are considered for a first understanding. The focus is on the methods used for foresight and the terms used including definitions. The result of the initial literature research is a theoretical delimitation of the research question as well as the identification of relevant terms and their handling regarding the time horizon. A search string and the framework for phase two emerge from the first phase.

In the second phase, the systematic literature search is carried out in accordance with the Systematic Review in Software Engineering according to Biolchini (2005) with the framework determined in phase 1 in three common search engines. The literature found is sorted out step by step by title, abstract and content for suitability to the research question. The number of literatures needed is determined and then analyzed and sorted.

From the findings of phase two, criteria for evaluation and interfaces regarding foresight and time horizon are derived in the third phase. The criteria must be clearly assignable and provide the ability to classify and evaluate the literature according to the research question. The evaluation of the literature against the criteria takes place in the fourth phase. The result of the literature evaluation is presented graphically using a matrix and circular ideograms, Harvey Balls. This allows the criteria to be easily contrasted and easily surveyed.

In the last phase, the results are discussed. The different understandings and conceptions from the literature as well as their handling are compared and evaluated regarding the research question.

3.3 Preparation of the Systematic Literature Review

The initial literature review is conducted for the general understanding of the research question and review of relevant topics and terms in other studies to further characterize the criteria to the search query (Greve und Krause 2018). In order to obtain the largest set of relevant studies, additional terms such as synonyms and containment by logical expressions must be combined into a search string to the identified keywords (Biolchini et al. 2005). The most important terms that can be derived from the research objective are *future-robust* and *future-oriented*. Synonyms for the two keywords are combined into a first search string in German and English and a first literature search is performed. ResearchGate, Scopus and ScienceDirect are the specified search engines. Through the literature search, the terms used in the search string are sorted out according to their efficiency and further augmented. Since the search turned out to be very broadly based, the study is thematically narrowed down in the next step to the area of requirements/requirements management and the search string is adapted accordingly.

3.4 Conducting the Systematic Literature Review

The initial literature analysis results in 398 search results, which are systematically selected. After the search, the identified publications are first checked for duplicates and sorted out accordingly, e.g., if titles are listed in several

search engines, are available in several languages, or if a newer edition also exists. This leaves 382 publications. Subsequently, the content selection is made according to the title, with 83 papers remaining, and according to the abstract, with 29 papers remaining. The selection process is also shown in Figure 4.

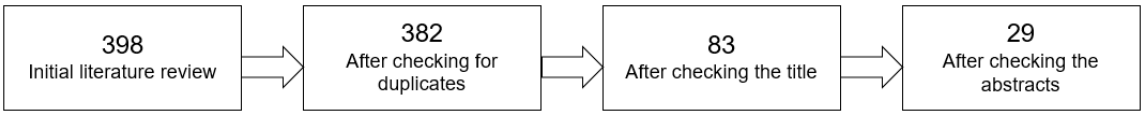

Figure 4. Condensation to essential papers in four stages

Based on the systematic literature search, 29 relevant publications were identified. These were examined in their entirety in terms of content regarding mentions and definitions of conceptions of future orientation.
In the present identified publications, the terms future-robust, future-oriented, robust, future-proof, multiple-generation and forward-looking can be found. However, the terms future-oriented and future-robust are predominantly used in the publications. Therefore, these terms are considered particularly relevant, and the papers are examined separately in this respect.

3.5 Result of the Systematic Literature Review

To identify existing conceptions and understandings of future orientation, all identified publications are reviewed and classified according to the definitions they contain. These definitions do not have to be all-encompassing but must have a defining character for their subarea. The classification is shown in Figure 5 using Harvey Balls.

Furthermore, the extent to which the terms future-oriented and future-robust are used in the publications is examined, as these are included in a large number of the publications. Figure 5 therefore shows whether one of the two terms is used in the publication in question.

ID	Source	Term	Definition	Future oriented	(Future) robust
1	Schuh et al. 2014	future robust	○	○	●
2	Dambietz et al. 2021	future robust	●	○	●
3	Chumnumpan et al. 2019	-	○	○	○
4	Boesl et al. 2017	future oriented	○	●	○
5	Forkel et al. 2019	future oriented	○	●	○
6	Jiang and Allada 2005	robust	○	○	○
7	Andersen 2004	-	○	○	○
8	Gebhardt 2021	future oriented, future proof	○	●	●
9	Greve et al. 2018	future robust	●	○	●
10	Greve et al. 2018	future robust, long term robust	○	○	●
11	Martin and Ishii 2002	robust	○	○	●
12	Suh et al. 2007	-	○	○	○
13	Hennes 2003	future oriented	○	●	○
14	Lin et al. 2011	(forward looking) multiple-generation	●	○	○
15	Lin and Okudan 2013	(forward looking) multiple-generation	○	○	○
16	Lin 2014	(forward looking) multiple-generation	○	○	○
17	Marthaler et al. 2019a	future robustness	○	○	●
18	Marthaler et al. 2019b	future-oriented	○	●	○
19	Marthaler et al. 2020a	-	○	○	○
20	Marthaler et al. 2020b	future robustness	●	○	●
21	Orbach und Fruchter 2011	-	○	○	○
22	Salovaara und Mannonen 2005	future-oriented	○	●	○
23	Samet 2011	-	○	○	○
24	Schneider et al. 2017	-	○	○	○
25	Sodhi et al. 2013	robust forward-looking	○	○	●
26	Stanko and Bonner 2013	-	○	○	○
27	Vettorello et al. 2022	futures-oriented	○	●	○
28	Weidmann et al. 2018	future-oriented	○	●	○
29	Zhang and He 2020	future-oriented	○	●	○

Definition	
○	No definition included
●	Definition included

Future oriented / robust	
○	Term is not used
●	Term is used

Figure 5. Overview of the evaluated papers of the literature search

In a total of four publications, terms of a defining nature are used, with these referring to the terms future-robust and multiple-generation. The two terms future-robust and future-oriented appear in nine publications each. Although the term future-oriented is used very often, it is not defined in any of the publications. However, the terms future-robust

and future-oriented suggest a fundamental differentiation into different development directions, similar to the way this is described strategically by Gausemeier by the terms future-robust and future-focused.

4. Discussion

In reviewing the identified publications, it is noticeable that many approaches simply name the addressing but do not elaborate on how they understand it in their context. This increases the need for a consistent definition in product development, but also the impact on the approaches that use these understandings.

In addition, the analysis of the conceptions of future-orientation and future-robustness reveals the following two problems. Future-robustness design suggests that several alternative futures are addressed. However, multiple futures cannot occur simultaneously. In product development, this can be a hindrance in early decision making. A concrete addressing is given with the future orientation by assumed probability of occurrence, however in this case the actually occurring future can be missed by the evaluation. In case of a missed assumption, later adjustments must be made during the Product Development Process. Decisions at a later stage lead to cost-intensive adjustments compared to the initial implementation at an early stage (Ehrlenspiel und Meerkamm 2017).

Not every product development has to be designed to be future-robust. In the case of a future with a high assumed probability of occurrence, a future-oriented product that is developed specifically for this one future can achieve a higher performance than a product that is designed for various futures. The approach according to (Krause et al. 2020) aims to design a product in such a way that it can endure in as many futures as possible. Hence, this represents a future-robust product development. An approach that reflects future-oriented product development is, for example, the systematology according to Marthaler (2021), in which future-oriented characteristics are adopted from the expected future as the basis for the product development process in the context of profile detection. A consistent use of these terms in the context of the product development could not be determined, however. From the data of the publications, it can be deduced that the term future-oriented in contrast to future-robust has only been used for a shorter time and not uniformly.

It is therefore crucial to classify future-robustness and -orientation in product development and planning and to operationalize them. The two terms future-robust and future-oriented represent two possible directions of future addressing. However, it can be assumed that gradations of robustness and orientation can also be set and defined in the context of product development and planning. Based on this assumption, it may be possible to classify the existing approaches in their future addressing with respect to robustness and orientation as well as the defined gradations.

5. Conclusion and Outlook

The literature analysis within the scope of the present work shows different conceptions in the processing and consideration of information from methods of foresight in product development. For a clear and efficient development, a consistent understanding of these conceptions is needed.

Approaches in 29 publications were identified via a Systematic Literature Review after extensive filtering in 398 papers (Figure 5). The publications were examined regarding the use of terms for handling information from methods of foresight. Beyond a use of terms, a defining character could be identified in only four publications. It could be worked out that the considered terms can be divided in their use into two ways of consideration for the product development, following the understanding of Gausemeier (2009) for the strategy development. Based on the understanding within the framework of the current state of research and the publications considered, the approaches used can be divided into "future-oriented" and "future-robust".

Further work will deal with whether these two approaches are applicable in the field of product development or whether an adapted definition must be proposed for dealing with information from methods of foresight. Further it is to be examined whether a gradation is possible between the two approaches and which consequences for the development of products go along with a certain approach.

References

Albers, A., Meyer-Schwickerath, B. and Siebe, A., Vorausschau im Kontext des Produktentstehungsprozesses mittelständischer Unternehmen - Ein Ansatz auf Basis des integrierten Produktentstehungsmodells (iPeM),

Vorausschau und Technologieplanung: 9. Symposium für Vorausschau und Technologieplanung, Berlin, Heinz Nixdorf Institute Universität Paderborn, Paderborn, 5-6 December, 2013.

Albers, A., Heimicke, J., Walter, B., Basedow, G., Reiß, N., Heitger, N., Ott, S. and Bursac, N., Product Profiles: Modelling customer benefits as a foundation to bring inventions to innovations, *Procedia CIRP*, Vol. 70, pp. 253–258, 2018.

Albers, A., Reiss, N., Bursac, N. and Richter, T., iPeM – Integrated Product Engineering Model in Context of Product Generation Engineering, *Procedia CIRP*, pp. 100–105, Stockholm, Sweden, 15-17 June, 2016.

Andersen, P., Jørgensen, B., Lading, L. and Rasmussen, B., *Sensor foresight—technology and market*, Vol. 24, 2004.

Biolchini, J., Mian, P., Natlai, A. and Travassos, G., Systematic Review in Software Engineering*,* Technical Report ES 679/05, 2005.

Blessing, L. and Chakrabarti, A., *DRM, a Design Research Methodology*, Springer London, London, 2009.

Boesl, D., Bode, M., Liepert, B. and Greisel, S., Structured Megatrends Research as Foundation for Future-Oriented Research-Planning and R&D Roadmapping in Robotics, *2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC)*, pp. 24–30, Mysore, India, IEEE, 8-9 September, 2017.

Chumnumpan, P. and Shi, X., Understanding New Products' Market Performance Using Google Trends, Vol. 27, No. 2, pp. 91–103, 2019.

Cooper, R. and Kleinschmidt, E., Screening new products for potential winners, *Long Range Planning*, Vol. 26, pp. 74–81, Pergamon Press Ltd, 1993.

Dambietz, F., Greve, E. and Krause, D., Simulation-based Performance Analysis for Future Robust Modular Product Architectures, *Proceedings of the Design Society*, Vol. 1, pp. 2671–2680, 2021.

Ehrlenspiel, K. and Meerkamm, H., *Integrierte Produktentwicklung, Denkabläufe, Methodeneinsatz, Zusammenarbeit, Hanser eLibrary,* 6. überarbeitete und erweiterte Auflage, Hanser, München, 2017.

Fink, A., Schlake, O. and Siebe, A., *Erfolg durch Szenario-Management, Prinzip und Werkzeuge der strategischen Vorausschau,* 2nd Edition, Campus Verlag, Frankfurt/Main, 2002.

Fink, A. and Siebe, A., *Handbuch Zukunftsmanagement, Werkzeuge der strategischen Planung und Früherkennung,* 2nd Edition, Campus Verlag, Frankfurt am Main, 2011.

Fink, A. and Siebe, A., *Szenario-Management, Von strategischem Vorausdenken zu zukunftsrobusten Entscheidungen*, Campus Verlag, Frankfurt, New York, 2016.

Forkel, E., Clauss, A. and Schumann, C., Challenges and Opportunities of Interoperable and Future-Oriented Technologies for Production Logistics and Supply Chain Management, *BAM2019 Conference Proceedings*, 2019.

Gausemeier, J., Fink, A. and Schlake, O., Scenario Management: An Approach to Develop Future Potentials, *Technological Forecasting and Social Change*, Vol. 59, No. 2, pp. 111–130, 1998.

Gausemeier, J., Ovtcharova, J., Amshoff, B., Eckelt, D., Elstermann, M., Placzek, M. and Wiederkehr, O., *Strategische Produktplanung, Adaptierbare Methoden, Prozesse und IT-Werkzeuge für die Planung der Marktleistungen von morgen*, Heinz Nixdorf Institut, Universität Paderborn, Paderborn, 2016.

Gausemeier, J., Zukunftsorientierte Unternehmensgestaltung, *Zeitschrift für wirtschaftlichen Fabrikbetrieb*, Vol. 104, 7-8, pp. 623–626, 2009.

Gausemeier, J. (Ed.), *Vorausschau und Technologieplanung, 9. Symposium für Vorausschau und Technologieplanung, HNI-Verlagsschriftenreihe*, Band 318, Heinz Nixdorf Institute Universität Paderborn, Paderborn, 2013.

Gebhardt, M., Spieske, A. and Birkel, H., The future of the circular economy and its effect on supply chain dependencies: Empirical evidence from a Delphi study, *Transportation Research Part E: Logistics and Transportation Review*, Vol. 157, p. 102570, 2021.

Greve, E. and Krause, D., An Assessment of Methods to Support the Design of Future Robust Modular Product Architectures, *Proceedings of the DESIGN 2018 15th International Design Conference*, pp. 335–346, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia; The Design Society, Glasgow, UK, May, 21-24, 2018, 2018.

Greve, E., Rennpferdt, C., Hartwich, T. and Krause, D., Determination of Future Robust Product Features for Modular Product Family Design, *Volume 14: Design, Systems, and Complexity,* Salt Lake City, Utah, USA, American Society of Mechanical Engineers, 11.11.2019 - 14.11.2019, 2019.

Greve, E., Rennpferdt, C. and Krause, D., Strategic Product Program Planning considering variety-induced complexity, *Vorausschau und Technologieplanung: 14. Symposium für Vorausschau und Technologieplanung,* Berlin, Heinz-Nixdorf-Institut, Universität Paderborn, Paderborn, 8-9 November, 2018.

Henderson, R. and Clark, K., Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms, *Administrative Science Quarterly*, Vol. 35, No. 1, p. 9, 1990.

Hennes, N., Machine tools for future orineted production, *WIT Transactions on Engineering Sciences*, 2003.

Horx, M. and Eggers, B., *Trendbuch, Megatrends für die späten neunziger Jahre,* 2. Aufl., Econ, Düsseldorf, 1996.

Jiang, L. and Allada, V., Robust modular product family design using a modified Taguchi method, *Journal of Engineering Design*, Vol. 16, No. 5, pp. 443–458, 2005.

Krause, D., Hartwich, T.S. and Rennpferdt, C. (Eds.), *Produktentwicklung und Konstruktionstechnik, Produktentwicklung und Konstruktionstechnik*, Springer Berlin Heidelberg, Berlin, Heidelberg, 2020.

Lin, C., Kilicay-Ergin, N. and Okudan, G., Agent-based Modeling of Dynamic Pricing Scenarios to Optimize Multiple-generation Product Lines with Cannibalization, *Procedia Computer Science*, Vol. 6, pp. 311–316, 2011.

Lin, C. and Okudan, G., Planning for multiple-generation product lines using dynamic variable state models with data input from similar products, *Expert Systems with Applications*, Vol. 40, No. 6, pp. 2013–2022, 2013.

Lindemann, U., *Methodische Entwicklung technischer Produkte*, Springer-Verlag, Berlin/Heidelberg, 2005.

Marthaler, F., Zukunftsorientierte Produktentwicklung – Eine Systematik zur Ableitung von generationsübergreifenden Zielsystemen zukünftiger Produktgenerationen durch strategische Vorausschau, *Forschungsberichte des IPEK - Institut für Produktentwicklung: Systeme - Methoden - Prozesse*, Vol. 137, Albers, Albert, Matthiesen, Sven, Karlsruhe, 2021.

Marthaler, F., Gesk, J., Siebe, A. and Albers, A., An explorative approach to deriving future scenarios: A first comparison of the consistency matrix-based and the catalog-based approach to generating future scenarios, *Procedia CIRP*, Vol. 91, pp. 883–892, 2020.

Marthaler, F., Heimicke, J., Ou, J., Reiss, N., Bursac, N. and Albers, A., InnoBandit 2.0: A Systematic Approach to Scenario-Based Product Profile Generation in PGE – Product Generation Engineering, *Procedia CIRP*, Vol. 84, pp. 790–797, 2019.

Marthaler, F., Stahl, S., Siebe, A., Bursac, N., Spadinger, M. and Albers, A., Future-oriented PGE-product Generation Engineering: An Attempt to Increase the Future User Acceptance through Foresight in Product Engineering Using the Example of the iPhone User Interface, *Proceedings of the Design Society: International Conference on Engineering Design*, Vol. 1, No. 1, pp. 3641–3650, 2019.

Marthaler, F., Stehle, Stehle, S., Siebe, A. and Albers, A., Future-oriented product engineering through environment scenarios by using the example of future forms of mobility in urban living spaces, *Balancing Innovation and operation*, The Design Society, 12th - 14th August 2020, 2020.

Martin, M. and Ishii, K., Design for variety: developing standardized and modularized product platform architectures, *Research in Engineering Design*, Vol. 13, No. 4, pp. 213–235, 2002.

Meyer-Schwickerath, B., Siebe, A. and Albers, A. (Eds.), *Integrated use of scenario planning and strategic early warning systems to support product engineering processes, 9th Nord Design Conference, NordDesign 2012; Aalborg University, Aalborg; Denmark; 22 August 2012 through 24 August 2012*, 2012.

Meyer-Schwickerath, B., *Foresight for Product Engineering Processes - Using the Integrated Product Engineering Model (iPeM) to align foresight - the example of scenario technique and strategic early warning*, Karlsruhe, 2014.

Orbach, Y. and Fruchter, G., Forecasting sales and product evolution: The case of the hybrid/electric car, *Technological Forecasting and Social Change*, Vol. 78, No. 7, pp. 1210–1226, 2011.

Reinhart, G. and Lindemann, U., *Qualitätsmanagement, Ein Kurs für Studium und Praxis*, Springer Berlin Heidelberg, 1996.

Rennpferdt, C., Greve, E., Kuhl, J., Küchenhof, J., Seiler, F. and Krause, D., Modularisierung in der industriellen Anwendung, *Produktentwicklung und Konstruktionstechnik*, *Produktentwicklung und Konstruktionstechnik*, Vol. 19, pp. 229–254, Springer Berlin Heidelberg, Krause, Dieter, Hartwich, Tobias S., Rennpferdt, Christoph, Berlin, Heidelberg, 2020.

Salovaara, A. and Mannonen, P., Use of Future-Oriented Information in User-Centered Product Concept Ideation, *Human-Computer Interaction - INTERACT 2005*, *Lecture Notes in Computer Science*, Vol. 3585, pp. 727–740, Springer Berlin Heidelberg, Costabile, Maria Francesca, Paternò, Fabio, Berlin, Heidelberg, 2005.

Samet, R., Exploring the future with complexity science: The emerging models, *Futures*, Vol. 43, No. 8, pp. 831–839, 2011.

Schneider, T., Fritz, M., Herberg, A. and Kreimeyer, M., Market-oriented variant planning as the basis for product development, pp. 247–256, 2017.

Schuh, G., Schultze, W., Schiffer, M., Rieger, A., Rudolf, S. and Lehbrink, H., Scenario-based determination of product feature uncertainties for robust product architectures, *Production Engineering*, Vol. 8, No. 3, pp. 383–395, 2014.

Sodhi, M., Sharma, J., Singh, S. and Walia, A., A robust and forward-Looking industrial production indicator, Vol. 48, pp. 126–130, 2013.

Stanko, M. and Bonner, J., Projective customer competence: Projecting future customer needs that drive innovation performance, *Industrial Marketing Management*, Vol. 42, No. 8, pp. 1255–1265, 2013.

Suh, E., de Weck, O. and Chang, D., Flexible product platforms: framework and case study, *Research in Engineering Design*, Vol. 18, No. 2, pp. 67–89, 2007.

Vettorello, M., Eisenbart, B. and Ranscombe, C., The Innovation System Roadmap: A novel approach to instil futures-oriented reasoning in strategic decision making, *Creativity and Innovation Management*, Vol. 31, No. 1, pp. 5–18, 2022.

Vogel-Heuser, B., Lindemann, U. and Reinhart, G., *Innovationsprozesse zyklenorientiert managen*, Springer Berlin Heidelberg, Berlin, Heidelberg, 2014.

Weidmann, D., Seibel, F., Becerril, L., Kattner, N., Lehr, J., Mortl, M. and Lindemann, U., *2018 IEEE International Conference on Industrial Engineering & Engineering Management*, IEEM 2018, Bangkok, Thailand, IEEE, Piscataway, NJ, USA, 16-19 December, 2018.

Zhang, W. and He, Y., Optimal advance selling discount strategy with future-oriented consumers, *Managerial and Decision Economics*, Vol. 41, No. 3, pp. 308–320, 2020.

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