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An approach for continuous monitoring of product properties between strategic foresight and the product engineering process

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ABSTRACT: Rapid pace of change and increasing complexity in today's world demand innovative approaches to product development. Foresight methods enable the anticipation of future scenarios and the derivation of product properties. However, current approaches lack mechanisms to continuously align product development with evolving environment and customer requirements, often resulting in late changes and high costs. Early detection of deviations is needed. This paper presents an approach for continuous monitoring, bridging strategic foresight and the product engineering process (PEP). By analyzing prior work and literature, a process model was developed to identify tipping points where product adaptations are necessary using indications and indicators. Initial evaluation through a case study using coffee machines showed the approach's usability but improvement potential was also identified.

KEYWORDS: design process, foresight, product development, requirements, robust design

1. Introduction

In a world characterized by rapid changes and increasing complexity, the demands on the development of future products continue to rise. To address these challenges, it is essential to strategically anticipate the environment, its constraints, and the needs of customers. Foresight methods offer the potential to develop and describe alternative future scenarios. By employing established methodological approaches that link strategic foresight with product development, it becomes possible to derive future product properties.

However, existing approaches do not have the capability to continuously connect emerging environmental deviations with the corresponding adjustments required in product properties throughout the entire product engineering process. Since product planning is inherently based on assumptions, it is critical to detect at an early stage whether the actual future diverges from the anticipated one. Such deviations result in a misalignment of the planned product with its evolving environment, failing to meet customer expectations and requirements. Deviations are often detected late leading to late-stage changes, resulting in significant costs.

To deal with this issue, continuous monitoring, and alignment between product plannings and future developments are necessary. An integrated approach to monitoring could enable the early detection and consideration of relevant deviations in expected conditions and requirements. This paper focuses on developing an approach for continuous monitoring that bridges strategic foresight and the product engineering process. Existing contributions of prior work are being analyzed, combined, and refined to create a process model.

2. State of research

2.1. Understanding of innovation and product engineering process

The product engineering process (PEP) is part of the product life cycle and can be described with three activities: strategic planning, product development and production system development (Albers & Gausemeier, 2012). Foresighted and system-oriented development is the basis for future innovation. Innovation is defined as successful realization of a technical invention as product in the market (Schumpeter, 1939). With the product profile this understanding was extended by Albers, Heimicke et al. (2018), which is a model to describe the need situation and the benefits for supplier, customer and user. This is in line with Patnaik and Becker (1999), who emphasize the importance of initially focusing on needs rather than specific solutions to keep all possible solutions open. The early phase of product engineering is essential because the influence on later development is very high, and success depends largely on the decisions made here (Cooper & Kleinschmidt, 1993; Verganti, 1997). Product development can be understood as a continuous interaction of system of objectives, operating system and system of objects (Ropohl, 1975). Based on this system triplet, Albers et al. (2016) have developed the iPeM - integrated Product engineering Model, with which the PEP can be described in several phases based on basic and core activities. Several generations, the associated production system, the strategy and the validation system are mapped in levels (Albers et al., 2016).

2.2. Developing future products using strategic foresight in the PEP

The growing uncertainty in today's society, caused by rapid technological advances and political changes, has increased the need to be able to better assess future developments (Schwarz, 2023). The main reasons for the use of strategic foresight are the long development times caused by iterations and the desire to develop innovative products (Gausemeier, 2019). It was often regarded as a separate process but is more and more being incorporated into the PEP (Müller, 2008). The term strategic foresight corresponds with the future management. With future management, companies want to react adaptively and quickly to changes in the future (Westkämper, 2006). With increasing time horizon, a distinction is made between three levels: the operational, tactical, and strategic level. Depending on the time horizon addressed, different foresight instruments can be assigned to these levels: prognoses (short-term), trends (medium-term) and scenarios (long-term). (Siebe, 2018) Scenarios are used to show possible developments in the future. They are distinguished from trends by thinking in an open and networked way. Scenarios for different purposes can be created focusing on environment, customer or technologies. (Fink & Siebe, 2011) The scenario technique according to Gausemeier et al. (1998) consists of five steps. Based on an analysis of the previously defined scenario field, factors that describe the current situation are identified. From these, a manageable number of key factors are selected for the further process through evaluation. For each key factor, alternative projections of how the factor may develop in the future are drawn up based on two dimensions to be defined. Scenarios are created through the plausible combination of one projection of each key factor. These are transferred to a map of the future space and described. Measures can then be derived in the scenario transfer. (Gausemeier, 2019; Gausemeier et al., 1998; Siebe, 2018) In addition to the use of scenarios for the strategic orientation of companies, there are approaches for deriving product characteristics for implementation in the PEP. The integration of elements of trend and future research aims to anticipate future market requirements and customer needs (Weissenberger-Eibl & Almeida, 2019). Meyer-Schwickerath (2014) examined the link between the scenario technique and strategic foresight with the PEP in the context of the activities in iPeM and achieved an integration of the foresight into the PEP via the system of objectives. Ehls et al. (2022) describe four fields, e.g. foresight in new product development, that have potential for linking foresight with innovation management. Gordon et al. (2019) propose to insert the understanding of foresight into the design thinking process. Albers, Dumitrescu et al. (2018) describe the need to build a methodical bridge between future visions and technical subsystems. Albers, Marthaler et al. (2022) have developed an approach for deriving product profiles and properties of future product generations using strategic foresight. The properties are evaluated for their future relevance using the Kano model. If the properties contribute to customer satisfaction when different scenarios occur, they are considered as future-robust. Another approach was introduced by Kuebler et al. (2023) to plan upgrades by determine if product properties which were derived from scenarios are static or dynamic. Static properties are those which are robust against several scenarios, whereas dynamic properties should be designed upgradeable. The different properties can be combined to product scenarios, showing different possibilities for products similar to environment scenarios. In both approaches a roadmap can be created to plan for development prioritization.

2.3. Monitoring in strategic foresight and the product engineering process

Monitoring is the "targeted, continuous observation of specific sections and objects of a system to record information about activities and changes" (Sieg, 2007). Monitoring is a recognized and fundamental activity in companies. In the PEP, for example, monitoring can be used to check the status of research, development or production. (Gruber et al., 2003; Gruber & Venter, 2006) In strategic foresight, monitoring is an essential part of the process. Due to the high rate of change in environment, it is necessary to observe changes. Monitoring is part of scenario controlling and trend management in strategic foresight and therefore has a direct influence on the change in the characteristics of the key factors. Within scenario controlling, the relevant areas of the future space of the scenarios are examined and unforeseen changes in the development of the environment are identified earlier. The first step is to check whether and in what form this has an impact on the probability of occurrence regarding the scenarios assessed at the beginning. Trend management deals with developments in the future. Relevant, known trends are observed, but new, unexpected trends are also considered and analyzed. These changes are reported and, if necessary, incorporated into the scenarios like a projection. (Fink & Siebe, 2016) In an analysis of various methods for scenario creation, influencing and key factors were identified as central elements and therefore possible starting points for monitoring. A subsequent investigation of various methods for monitoring shows the need for methodological support, as no suitable approaches were identified which integrate monitoring of the future environment development continuously into the PEP. (Thümmel et al., 2023) In order to create an understanding, Albers et al. (2024) have introduced a definition of monitoring in the context of the PEP. This classifies monitoring as part of validation activities by systematically searching for information on previously identified relevant indicators for the future environment. Systematic observation during development is intended to support the cross-generational recognition of changes and the introduction of suitable actions. In order to evaluate the product orientation and identify deviations, product profiles were localized in the future space using equivalent scenarios (Thümmel, Kiss et al., 2024). An initial overall approach for the continuous integration of foresight into the PEP was developed using a five-step process model (Thümmel, Heller et al., 2024). The five steps include planning of the monitoring, continuous valuation of the product properties and environmental development, indicator-based deviation identification, action recommendation and the adjustment of the development planning.
This gives an initial overview of the necessary steps, but the activities within the process have not yet been defined in more detail. To describe the continuous connection between strategic foresight and the PEP, a descriptive model was developed by Thümmel, Urbina Puch et al. (2024). It describes how information can be condensate from news leading to indications and indicators. By using qualitative and quantitative indicators, the increasing level of detail within the plannings in the PEP can also be considered with progress over time. To achieve this, the system of objectives was structured over time to represent the concretization during product development.

3. Aim of research and methodology

3.1. Research need and research goal

In product engineering, anticipating, and adapting to evolving customer needs is critical for ensuring product relevance and competitiveness in the future environment. Strategic foresight methods, such as scenario planning, provide valuable tools for predicting future demands and integrating them into the PEP. However, these methods are typically only applied at the start of the process, resulting in a static alignment of product attributes with customer requirements for an uncertain future environment.
As the PEP proceeds over time, the risk increases that the actual future will deviate from the initial estimates and therefore the plans no longer match the environment and subsequently the customer requirements and expectations. Changes are detected but often late which leads to high costs for change or changes cannot be implemented at all. To deal with this risk a continuous monitoring and validation

between the strategic foresight and the product properties planned in the PEP is necessary. So far, there is no suitable method known which leads to the need for a systematic approach. Hence, the goal of this paper is to develop a systematic approach for integrating strategic foresight for continuous monitoring and validation of product properties into the PEP with focus on anticipating and addressing future customer requirements. The aim is to enable early detection of shifts in customer needs, requirements, and expectations as well as boundary conditions and competitive context, allowing early adjustments in the plannings of the affected product properties in the PEP.

3.2. Research design

Based on the research need and research goal, the following research questions were derived. With the questions, this work can be structured. The results will also be analysed and evaluated according to the research questions.

1. Which goals and requirements are relevant for an approach for continuous monitoring between foresight and the PEP and are therefore basis for developing an approach?
2. How could an approach look like for continuous monitoring between foresight and the PEP?
3. What improvement potentials can be identified through the preliminary validation to test the application of the developed approach in a case study?

To answer the research questions, the approach will follow the Design Research Methodology (DRM) of Blessing and Chakrabarti (2009). In a first descriptive study, the understanding of existing approaches is enhanced by analyzing them and requirements for monitoring are identified. This is achieved through a systematic literature review and insights gathered from an expert workshop. Building on the findings from the first descriptive study, in the subsequent prescriptive study an initial model consisting of a description model and a process model is developed. Expert feedback is incorporated to iteratively refine the proposed approach. The concluding second descriptive study focuses on an initial validation of the approach by using expert evaluations and a case study.

4. Definition of the requirements on an approach for monitoring

To address the first research question, this section outlines the systematic process for defining the goals and requirements towards the intended approach. These are derived by conducting interview studies, literature reviews, and expert workshops, providing a base for the development of the approach.

4.1. Collection and categorization of goals and requirements

The initial phase of the study involves analyzing interview data from in total 29 interviews conducted in three previous studies within this context in the past two years alongside additional findings from the literature. The interview experts each have knowledge and experience in at least one of the areas strategy and foresight, innovation management, product development and system integration, and marketing and sales. The interviews themselves are not part of this publication as they were conducted beforehand in different projects, mostly with automotive context but not limited to that. Nevertheless, the results in the form of qualitative statements and possible requirements towards a methodology are input for this study. In this process, the 155 possible key elements from the interviews were identified, merged and edited and divided into four categories: 32 influencing factors, 17 goals, 16 requirements, and 10 premises. Influencing factors describe contextual elements that shape the environment in which the approach operates. While they do not describe specific goals, they highlight the need for adaptability. For instance, evolving customer demands provide critical context for shaping the monitoring framework. Derived from these influencing factors, goals represent the overarching objectives of the methodology, such as maintaining alignment between product properties and customer requirements, ensuring adaptability within the PEP. Requirements translate these goals into actionable criteria, defining what the methodology must achieve to be effective. These include among others the seamless integration of monitoring into existing workflows, the efficiency of the processes, and ease of implementation. Premises, in contrast, are assumptions that support the success of the approach but are beyond its direct control and might be ensured to enable the usage of the approach. Examples include the availability of reliable foresight data or sustained organizational support, which are critical for implementing the monitoring system effectively. The most relevant key elements for the development are the requirements, followed by the goals. Premises are taken to be ensured, whilst influencing factors are not considered within the development of the approach.

4.2. Refinement and validation through expert workshop

The defined goals, requirements, premises, and influencing factors are refined in an expert workshop with 9 experts in product development and at least basic knowledge in foresight. The 75 key elements are divided into 6 smaller clusters to enable operability in the workshop: methodological and process aspects, strategic orientation, company culture, risk management, business environment and products, knowledge transfer. Each cluster was processed by two or three experts to refine the wording and also the initial categorization of the key elements into goal, requirement, premise or influencing factor. During the workshop, the experts affirmed and emphasized the importance of precise terminology to avoid ambiguity and ensure practical applicability. They highlighted the necessity of aligning the approach with existing workflows in the PEP while maintaining adaptability. Additionally, the role of clear communication channels within organizations is underscored as critical for the methodology's successful implementation.

4.3. Interim summary

The systematic definition and validation of requirements towards the approach addresses the first research question by identifying the key elements of influencing factors, goals, requirements and premises as necessary criteria to integrate continuous monitoring between foresight and the PEP. The identified requirements and goals towards the approach to be developed are: support making relevant and unknown aspects observable; support focusing on known aspects; assist in the delta analysis between plans and environment development; metric for measuring risks and uncertainties; integration of foresight methods and consideration of long-term aspects with a structured process for collecting, interpreting, and utilizing insights from customer, technology, and competitive foresight activities; iterative character; practical methodology; clear and consistent description as well as visualization of all process steps. This sets the basis for developing an approach in this contribution, able to maintain product relevance in dynamic environments.

5. Development of an approach for monitoring

The approach for continuous monitoring within the PEP was developed through an iterative process, addressing the second research question. By combining strategic foresight with monitoring, the approach enables that product properties can be continuously aligned with changing market requirements and technological developments during the development process. While the descriptive model of Thümmel, Urbina Puch et al. (2024), which was developed in parallel, aims to decribe the identification of indications and indicators, this approach emphasizes the iterative refinement of the initial process model of Thümmel, Heller et al. (2024).

5.1. Iterative delvelopment process

Discussions with experts of foresight and product development highlighted several limitations in the initial approach, which was primarily structured "bottom-up" and relied mostly on environment scanning. This led to the implementation of a "both-sides-to-the-middle" strategy that combines "top-down" foresight analysis with "bottom-up" environment scanning to ensure a comprehensive perspective. This revised strategy allows a more robust identification process, capturing both indications and indicators to define tipping points. Indications provide early warning signals from external environment, while indicators quantify possible changes based on foresight data generated initially at the beginning of the PEP. Indicators are used to signal when a certain key metric or value is reached or passed. They are defined based on information from foresight and the PEP and are therefore linked to product properties. Iterative feedback loops with experts during the development of the process model ensured that potential improvements were identified and implemented.

5.2. Process model of the continuous monitoring approach

The process model is of iterative nature, emphasizing the interconnectedness of its phases with feedback loops that allow dynamic adjustments. The process model is illustrated in figure 1. The integration of indications and indicators, resulting in the definition of tipping points, ensures a proactive and responsive approach to continuous monitoring between foresight and the PEP.

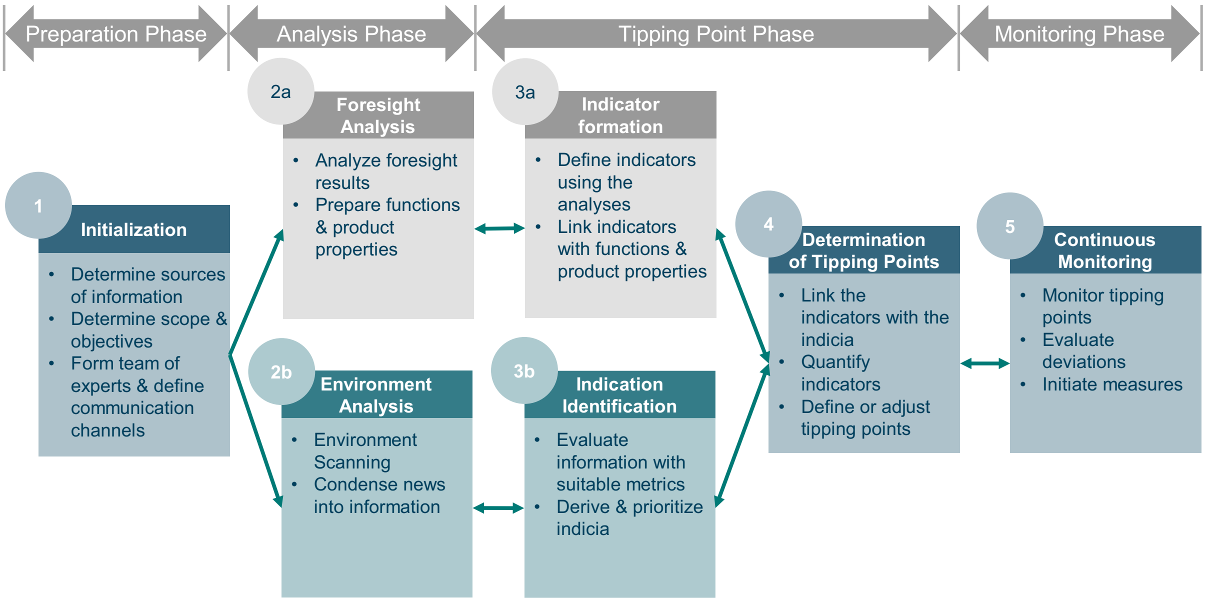

Figure 1. Process model for continuous monitoring between strategic foresight and the product engineering process

The process model is structured into four phases, each of which contain specific steps with sub-activities that form a dynamic and adaptive monitoring framework. The Preparation Phase focuses on establishing the foundation for effective monitoring. The activities in this initialization include defining the scope and objectives of the monitoring process, defining information sources, and forming a cross-disciplinary team of experts. These ensure that the subsequent phases are based on clear and aligned goals, minimizing inefficiencies and ensuring a targeted approach. The Analysis Phase involves conducting foresight and environmental analysis as parallel steps. The foresight analysis examines scenarios, trends, and prognoses, as well as the product properties and features derived from them. In parallel, the environment analysis focuses on identifying weak signals of change in the environment, e.g. changes in technology, demand or boundary conditions. This dual “both-side-to-the-middle” approach ensures that both long-term and immediate environment developments are taken into account. In the Tipping Point Phase indications and indicators are defined based on the previous analyses in parallel steps. Afterwards they are assigned to each other by determining the correlation, followed by defining tipping points as thresholds for critical changes towards the product properties. The tipping points provide actionable triggers that signal the need for adjustments in the PEP. The Monitoring Phase aims for the continuous observation of indications towards the indicators and tipping points. Deviations from the expected thresholds initiate actions. They could either be change requests in the PEP or enter feedback loops, meaning revisit earlier phases when necessary. This ensures that adaptions of the indicators and tipping points can be made if the thresholds seem not adequate anymore with proceeding PEP.

5.3. Interim summary

The developed process model provides a structured, iterative framework for continuous monitoring within the PEP. It should enable proactive and early adjustments to product properties in response to evolving market and technologies. By combining indications and indicators, the approach aims for comprehensive monitoring and informed decision-making based on foresight and environment analysis. Feedback from initial validation through expert discussions was implemented to enhance the robustness of the model. However, there is certainly still room for improvement. The model answers the second research question by providing a possible approach for continuous monitoring between foresight and the PEP. In the following, the process model and especially its main steps will be described in more detail while conducting a case study.

6. Case study using the approach for monitoring

The developed methodology for continuous monitoring was applied to a case study using coffee machines. Using data from earlier investigations, environment and market scenarios, a list of product properties as well as product scenarios were available. The data covers the general possibilities of coffee machines like different sizes and types for private use, but also properties like connection to the internet, existence and techniques for integrated grinding etc. The case study focuses on the applicability of the approach in the analysis and the tipping point phase, which contain the core activities of the approach described in the chapter above. The investigation based on the case study adresses the third research question.

6.1. Analysis phase

In the analysis phase, foresight analysis and environmental scanning are conducted in parallel to gain a comprehensive understanding of market dynamics. This process ensures the identification of both long-term strategic indicators and short-term market indications in a next step, which collectively form the basis for subsequent monitoring.

6.1.1. Foresight analysis

The foresight analysis was divided into four main activities in order to gain long-term strategic insights. First, a scenario analysis was conducted to identify the key drivers, constraints and issues in the defined environment, market and product scenarios. This resulted in factors that are critical to future product success, e.g. regulatory trends towards sustainable materials. Each key topic was assessed regarding its strength and probability on a scale of 1 to 5. E.g. the increasing regulatory density towards sustainability is assessed high and therefore identified as a potential indicator. This was followed by a trend analysis in which potential developments relevant for the coffee machines were identified and evaluated. Nine trends were analyzed using a commercial database of trends and focused research, including micro (local, short term), macro and mega (global, long term) trends. These trends were assessed for relevance and urgency, and the values were multiplied to determine the strength of each trend in the development process. Particular emphasis was placed on sustainability and environmental awareness, which are driving demand for environmentally friendly products and forcing companies to integrate sustainable materials and production processes, opening up new market opportunities.
As part of the forecast analysis, specific market forecasts for coffee machines were used to gain valuable insights into future market trends and enable well-founded assumptions for strategic product development. The market forecasts were summarized in a table that included key metrics such as market growth and sales forecasts, and these trends were evaluated in terms of their impact on the development project. The trends of smart coffee machines and the demand for technologically advanced products in Germany were particularly strong. Finally, the derived product properties, which also include functions and features, were analyzed in terms of their long-term relevance and the amount of change required. Exemplary properties, based on the results of the strategic foresight and product planning, were evaluated on two criteria: probability of change and effort for change. Properties such as “sustainable energy use”, “solar powering”, “health monitoring” and “fully recyclable materials” were classified as critical, as they refer to relevant social and technological trends that are highly dynamic.

6.1.2. Environment analysis

The identification of information by environment scanning was simulated with ChatGPT-4o from OpenAI due to the high effort required for a complete scanning and is not described further. A total of 50 weak signals were generated, covering all six PESTEL categories (political, economic, social, technological, environmental and legal).

6.2. Tipping point phase

In the tipping point phase of the approach, two parallel activities were carried out: indicator formation and indication identification. These activities aim to identify tipping points that indicate the transition to a new market situation and to early signs of possible changes in the market environment.

6.2.1. Indicator formation

The indicator formation serves to derive quantifiable indicators from the results of the preceding foresight analysis. These indicators cover different time perspectives: L-indicators refer to long-term, structural changes that are monitored by external studies and macroeconomic analyses from the scenario analysis. M-indicators focus on medium-term trends, which are identified through the use of trend databases and market analyses. S-indicators record short-term market developments based on quantitative data such as sales figures and market shares from the forecast analysis. A suitable measurement method and a reliable data source were defined for each indicator. The final indicators serve as key performance indicators for the early recognition of changes in the environment and are crucial for monitoring during product development. These indicators are linked to the relevant product properties by rating the assumed influence of each indicator on a product property on a scale of 0 to 3. A high value indicates strong influence, which means the respective indicator must be monitored closely.

6.2.2. Indication identification

The identification of indications is achieved by structurization of information derived from environment scanning. Each information is rated on a scale of 1 (low probability of occurrence) to 5 (high probability). Furthermore, the relevance of each signal is determined by assessing and multiplying the urgency and impact. The indications with high relevance and probability are given priority for further analysis, as they have the greatest potential to signal significant changes in the development process.

6.2.3. Determination of tipping points

The tipping points are identified using a structured linkage analysis between key indicators and relevant indications. The strength of the links between them is rated on a scale of 0 to 3 (strong link). On this basis, the most critical indicators that have both high relevance and strong links to the relevant indications can be identified. These indicators have the highest potential to predict significant changes in the system or in customer needs.

Once the relevant indicators have been identified, the tipping points are determined by setting upper and lower thresholds to signal when a significant change in the system is expected. These thresholds are defined using statistical methods that use historical data to calculate the moving average (μ) and standard deviation (σ) of each indicator. The tipping points are then calculated using the following formulas:

$$upper\ tipping\ point = \mu + k_u \times \sigma$$
$$lower\ tipping\ point = \mu + k_l \times \sigma$$

Here, k_u and k_l are sensitivity factors that reflect the expected trends indicated by the qualitative indication. If indications point to growth, the upper tipping point's sensitivity factor (k_u) is increased to capture potential upward shifts. In contrast, a more sensitive lower tipping point (k_l) is used to detect possible negative trends. For example, using market data from Statista, the moving average for the "average selling price per smart coffee machine" in 2024 was €149.28, with a standard deviation of €13.41. Strong links were identified between this indicator and trends such as "economic recovery post-pandemic" and "advances in IoT integration in household appliances," suggesting continued price increases. Therefore, a higher sensitivity factor k_u =1.5 was applied for the upper tipping point, while k_l =0.75 was chosen for the lower tipping point, anticipating a more sensitive reaction to any downard shift. The resulting tipping points for 2025 are:

$$upper\ tipping\ point = 149.28 + (1.5 \times 13.41) = 169,39€$$
$$lower\ tipping\ point = 149.28 + (0.75 \times 13,41) = 139.22€$$

These tipping points serve as critical thresholds, enabling early detection of significant market shifts and guiding strategic adjustments.

6.3. Discussion

The application of the developed monitoring approach to the case study demonstrated that the approach is in principle usable and provides valuable insights. The results of this first evaluation based on revised scenarios from foresight are positive. The methodology permitted a systematic assessment of product properties based on assumptions. Through the utilisation of research and assessments, preliminary insights into market potential were obtained. However, the approach still has to be improved. The following improvement potential was identified, which answers the third research question:

The approach was applicated by using a simplified case study with predefined, existing data with assumptions which limits the representativity of the investigation. Furthermore, the assessments carried out were subjective, as they were based on evaluations and research without incorporating further expert knowledge. Therefore, a more robust validation could be achieved by incorporating experts and utilizing more comprehensive data sources as well as advanced analytical tools, as this would significantly enhance objectivity, accuracy, and predictive power. Integration of more experts into the further development of the approach could also improve it by gaining more insights of several contexts. Especially, the assessment criteria need to be evaluated and also the sensitivity factors need to be specified. Another advantage could be gained by linking the evaluations across the phases using adequate criteria. This would increase both the efficiency by reducing the effort of assessment as well as the effectiveness by improving the consistency of the results.

7. Summary, conclusion and outlook

The goal of this publication was to develop an approach for continuous monitoring of product properties in the PEP. Based on an analysis of relevant previous works and a literature review, requirements for an approach were identified and further specified in an expert workshop (research question 1). The developed approach consists of a process model with five main steps in four phases for practical implementation and a description model representing the underlying logic. By combining the results of strategic foresight with the current environment development, the approach enables to identify tipping points that signal the need to adapt product properties (research question 2). In an initial application evaluation by conducting a case study, the applicability was shown but also several potentials for improvement were identified (research question 3).

The developed approach is an important step to improve the fit between planned products and future customer needs. Since defined product features and customer needs often change during the PEP, it is crucial for long-term market success to establish a support that detects such changes at an early stage and enables an appropriate response. Future studies should evaluate – and refine – the approach in more complex case studies to further increase its practical relevance. The creation of a database of indicators and the further development of the evaluation metric for the analysis of scenarios and trends also offer potential. Furthermore, an expansion of the monitoring phase and closer integration of the approach with established models and processes could help to optimize the practical application and benefits in industrial processes. Eventually, a guideline with proposals for action when reaching certain levels of deviation from tipping points could be created as a reference.

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