Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/EU08.20250217
Published: July 2, 2025

Comparative Evaluation of Innovation Process Models – Guide for Practical Application

Johannes Müller, Ann-Kathrin Müller, Moritz Schöck and Albert Albers
Institute of Product Engineering
Karlsruhe Institute of Technology
Kaiserstr. 12, 76131 Karlsruhe, Germany
johannes.mueller@kit.edu, annkathrin.mueller11@gmail.com, moritz.schoeck@kit.edu, albert.albers@kit.edu

Abstract

As part of this work, a comprehensive analysis of existing Innovation Process Models (IPMs) in literature is carried out. The analysis is based on Albers' and Schumpeter's understanding of innovation and the descriptions and representation of IPMs in literature. Frequently recurring components or noticeable differences in literature are identified and used as criteria for further analysis. The criteria are categorized to show the results in table form to provide a clear and quick overview. Key points highlight similarities and differences of the models, focusing on frequently recurring phases such as idea generation, technical realization (invention) and market launch. In addition, structural contents such as sequential processes, parallel activities, and feedback loops are analyzed. It is identified that these are idealized processes to present basic procedures clearly. Therefore, feedback loops or iterations are neglected. An innovation impulse is often triggered by a customer need or problem, whereby these phases are included as upstream activities. Customer integration and decision points are not explicitly included in most models, but decisions to stop or continue ideas are made regularly. The focus of the models varies, and newer models incorporate agile methods alongside classic sequential processes. The aim is to support users in identifying similarities and differences between own process models and the models in literature. The procedure for analyzing a case study is presented as an example. This clear presentation of differences and similarities enables companies to adapt and further develop their innovation processes to meet specific requirements.

Keywords
Innovation process model, innovation, process assessment, agile process models and analysis.

1. Introduction
Long-term mega trends such as digitalization, globalization, artificial intelligence (AI), software, and agility bring along changes. They have a strong influence on companies, their value creation and competitiveness. By using systems engineering, for example, companies want to save costs and time while increasing quality (Dumitrescu et al., 2021). Companies also see the shortening of innovation cycles as a challenge while quality remains the same. Therefore, innovations and innovation management play a central role (CAMPUS 02 - Fachhochschule der Wirtschaft, 2010). Schumpeter defines an innovation as an invention that has been successfully introduced to the market (Schumpeter, 2003). Albers expands this understanding by emphasizing that there must be a customer need that is met by the technical implementation of an idea. This is the precondition for the resulting invention to be successfully launched on the market (Albers et al., 2016a; Albers et al., 2022). A market advantage, such as new customers and higher market shares, can only be achieved if the product satisfies a customer need (Albert Albers et al., 2018). As it is only possible to judge whether a product has been successful after its market launch, it can only be determined retrospectively whether it is an innovation. According to Albers, innovations failure tends to occur more often, which is not captured by retrospective categorization (Albers et al., 2015). Process models are an important part of innovation management

© IEOM Society International

to show and standardize activities from the definition of customer benefits, derivation of a product profile, technical development of the idea through to market launch, and to clarify processes (Verworn and Herstatt, 2000).

In the literature, there are numerous Innovation Process Models (IPMs). Examples include models according to Thom (1980), Brockhoff (1999), Herstatt (2014),Coopers Stage-Gate Model (Cooper, 1990) and its evolution (Cooper, 2014), Witt (1996), Geschka (1993), Vahs and Brem (2015), Pleschak and Sabisch (1996), Agile Systems Development (ASD) (Albers et al., 2017) and some more. Differences in IPMs and the level of detail of the models and phases depend on the objective, issue, or focus. Many companies have adapted existing process models to their needs or developed them individually to standardize innovation activities (Verworn and Herstatt, 2000).

As mentioned in the beginning, the constantly changing conditions and challenges might result in new needs and requirements. This must be considered in individual IPMs. Due to the lack of references, it is difficult for companies to identify exactly what needs to be changed in the process to react to the changes. Numerous models are represented in the literature, but there is a lack of clear presentation and comparability. This shows the need for a clear comparison of IPMs to provide researchers and companies with a quick and easy overview of the models and characteristics available in the literature. Researchers in the field of IPMs can use the results of this paper to quickly gain an overview of the similarities, differences, and characteristics of the numerous IPMs available in literature.

2. State of the Art

The execution of projects is generally supported by a process, which is typically adapted and reused to serve as a template for subsequent projects. To document these processes, modeling is often employed (Bender and Gericke, 2021). This has led to the development of numerous process models over time, each differing in the requirements they address and their content. These models serve as a foundation for communication in development processes and provide an ontology that researchers and practitioners can use to describe and study these processes (Wynn and Clarkson, 2018). The multitude of existing models can be classified based on several characteristic properties. For instance, there are activity-based and phase-based models, which employ different strategies. Some process models are problem-oriented, while others are solution-oriented, and they also vary in terms of abstraction and level of detail. Many of the original process models date back to times when products were significantly less complex and interdisciplinary. Today, products are characterized by a strong integration of domains such as mechanics, mechatronics, electronics, and software, and are typically developed alongside a service system (Dumitrescu et al., 2021). Even the business model is closely linked to the actual product. Consequently, new approaches have emerged to address these challenges. Agile thinking and practices, and the principles of systems engineering, have become established in the development of cyber-physical systems, introducing new aspects to process models (Müller et al., 2024). For example, the iPeM forms a metamodel that describes the development process based on activities, which can be iteratively traversed using a dynamic phase model based on a reference process (Albers et al., 2016b). Similarly, product development is described in VDI 2221 to accommodate the iterative repetition of activities (VDI2221 Blatt1:2019-11, 2019). The integration between requirements and individual system components and the associated validation is described in the V-Model to address the increased complexity in the development process (Mathur and Malik, 2010). Development processes are continuously evolving, and models must keep pace. Therefore, it is important to systematically examine these models and identify potential areas for further development.

3. Research Questions and Research Design

3.1 Research Questions

The aim of the work is to identify criteria to analyze IPMs, which is necessary to determine characteristics, differences, and similarities between the different models. The results of the analysis shall be clearly presented to ensure a quick overview, and the differences and similarities between the models shall be highlighted and summarized. This serves as a basis for researchers or companies to conduct an analysis of their own IPMs for improvement. The process of application and how the results can be used is explained using a fictitious example. To achieve this goal, the following research questions are to be answered:

1. What criteria are best suited to categorize IPMs in the literature and to quickly overview their contents?
2. How can the various IPMs be presented to be accessible as a reference?
3. What are the recurring characteristics of IPMs and what similarities and differences can be identified between different IPMs?
4. How can the researchers or the companies apply the results of the analysis of the IPMs in practice?

© IEOM Society International

3.2 Research Design

To answer the research questions, a research design based on the Design Research Methodology (DRM) is used (Blessing and Chakrabarti, 2009). First, the purpose of research and the research gap are clarified in the Research Clarification (RC). This is done through an initial literature review followed by a Descriptive Study I (DS-I). During the literature review, prior papers are identified showing an overview of different process models (Verworn and Herstatt, 2000; Blessing and Chakrabarti, 2009). The models that were mentioned several times in the different papers were identified as relevant IPMs for this paper. As part of further research, newer models have been considered as examples for analysis to highlight trends and changes over time. The focus of the research and analysis lies on the description and diagrams of the IPMs and the detailed phases. Mostly, the first publication documents, the original sources, are used for analysis. First, criteria were developed inductively from the analyzed literature. In the next step, the criteria were categorized into categories with similar content and the way of presentation of the results was defined. The material was clustered to identify similarities, differences, and recurring characteristics. To validate the results, the analysis is followed by a DS-II to show how the results can be applied by companies or researchers. Therefore, a fictitious innovation process was analyzed as part of a case study.

4. Results and Discussion

4.1 Criteria for Analysis of Innovation Process Models

Process models consist of various components that subdivide the overall process into phases. These phases are detailed by specific activities. Both the process diagrams, which show the sequence of phases, and the process descriptions, which contain detailed activities, are relevant for the analysis. The understanding of innovation of Schumpeter and Albers is included in the definition of criteria. Criteria are derived from the assessed documents, categorized, and a dedicated type of presentation of the content of the innovation models is derived. The material was clustered to identify similarities and differences, and recurring characteristics. The criteria are based on the analysis of the identified documents. This is based on Albers and Schumpeter's understanding of innovation. During the analysis of the representation of the IPMs and the detailed descriptions of the documents analyzed, the frequently recurring components in the phases or activities of the process models are included as criteria. This could be an indicator of the relevance of the components, while the rarely occurring components could be attributed to differences.

First, the reference data for the models are recorded, including the *inventor*, the *year of publication*, and the *original source*. There are differences in the focus, the questions, or the objectives of the IPMs. Not only in literature are differences, but companies also adapt their process models to their needs (Verworn and Herstatt, 2000). To ensure an overview of the purpose of the different process models, the *characteristic of the process model* is worked out as a criterion. According to Witt, a simultaneous process is essential to avoid additional process loops, communication problems, and delays (Witt, 1996). For this reason, the models are analyzed regarding their structure: *sequential process flow*, *consideration of parallel phases/activities*, *consideration of feedback loops,* and *consideration of iterations* are included as criteria.

According to Albers' understanding of innovation, three necessary components of the innovation process can be identified: *product profile*, *invention (technical realization of the idea)* and *market launch* (Albers et al., 2019). These criteria form the basis for the analysis of the phases and are supplemented on the basis of additional findings during the analysis. Vahs points out that the impetus for the innovation process is an identified problem that needs to be solved (Vahs and Brem, 2015). Based on the understanding of innovation of Albers a customer need must be identified and solved by an invention. These aspects seem to be relevant and keep popping up. Therefore, the criteria *presence of innovation stimulus* is included to analyze the impetus for the innovation process through the identified problem and customer integration in the process. Other frequently repeating phases or components of the models are the following: *search field determination, idea generation, preparation for market launch* and *acceptance control: post activities*. These components were identified during the literature analysis and are also included as criteria. Failures are very common in the context of innovations and not all inventions become innovations, said Albers et al. (2015). Witt or Brockhoff's models point out that decisions to stop or continue should be made to save resources and focus on the most promising ideas (Witt, 1996; Brockhoff, 1999). Even if decisions are made to pursue the idea further, failures can occur in different forms. This emphasizes the statement made by Albers that many inventions fail along the way. Based on this, two other criteria are considered: *Failure of ideas or inventions* including the cancellation of the process and *decision points in the models*.

4.2 Categorization of Criteria for Clear Presentation

To present the results of the analysis and to ensure clarity and readability, the criteria are categorized below. The purpose of the categorization is to clearly present the results for each category and to provide researchers and companies with a quick overview. For this reason, the results cannot be presented in a large table. Therefore, the results are presented in a table for each category. Thematically similar criteria are assigned to the same category, enabling multiple assignments if the content of the criteria matches. As an example, the criteria *presence of idea generation* can be assigned to two categories: category three and category four. The assignment to category four is explained because idea generation is a frequently recurring phase or activity together with the invention and market launch phases. Category three refers to the early phases and activities of an IPM and therefore idea generation must be included for the sake of completeness. Finally, 6 categories were identified shown in Table 1.

Table 1. Criteria categorized to categories for better content overview and visualization.

Nr.	Category	Criteria
1	Basic data and characteristics of innovation process models.	Inventor & original source (Model)
		Year of publication (Year)
		Characteristic of the process model
2	Structural content of the process models.	Sequential process flow
		Consideration of parallel phases/activities
		Consideration of feedback loops
		Consideration of iterations
3	The presence of early phases/ activities to analyze customer needs and the definition of the product profile.	Presence of innovation stimulus
		Presence of search field determination
		Presence of idea generation
		Definition of product profile
4	The presence of frequently occurring phases/ activities in innovation process models.	Presence of idea generation
		Presence of invention (technical realization of idea)
		Presence of market launch
5	The presence of components for a target- and customer-oriented process.	Customer integration in the process
		Presence of decision points in the model
		Consideration of failure of ideas or inventions
6	Consideration of market launch related activities.	Consideration of preparation for market launch
		Presence of market launch
		Consideration of acceptance control as post activities

4.3 Analysis of Innovation Process Models: Characteristics, Similarities and Differences

In the next step, the IPMs are analyzed based on the criteria for each category. The content of the models identified during the analysis is shown in the six different tables for each category. A placeholder called *own process* is already integrated in the table's last row so that the user can enter his analysis results of the company's own IPM directly there. Differences and similarities are extracted as core statements (key points) of the tables and explained.

Key Points for Category 1: Basic Data and Characteristics of the Innovation Process Models

An overview of the models analyzed and their characteristics depending on the focus or questions can be seen in Table 2. The common opinion in the literature that there are different but legitimate process models existent can be confirmed. Due to this, every model has, based on their focus, different phases or activities included. The characteristics and focus of the models are summarized, but it can be said that each model has a different focus. Especially in newer models, the focus is increasingly on considering agile methods. One reason for this could be that the use of agile methods is popular not only in software development, but also in other areas (Weiss et al., 2023).

Table 2. Category 1- Overview of the analyzed innovation process models in the literature and their focus.

Model	Year	Characteristic of the process model
Norbert Thom	1980	There are three main phases, which are further subdivided. This model is considered as the one that has characterized the subsequent phase models the most (Verworn and Herstatt, 2000).
Klaus Brockhoff	1999	Six-stage model in which planned and unplanned innovations (serendipity effect) and failures are considered. No further subdivision of the stages.
Jürgen Witt	1996	Nine-stage model, with two stages running in parallel, to utilize the findings from technical development and sales at an early stage. The stages are subdivided by concrete work steps (Witt, 1996; Verworn and Herstatt, 2000; Bircher, 2005; Vahs et al., 2023).
Franz Pleschak, Helmut Sabisch	1996	Process results are presented as intermediate goals if they are achieved or not achieved. Collaboration with project partners is considered during the RD phase and centralized feedback or feedback loops.
Dietmar Vahs	1996	The phases of the IPM are enclosed by an overall controlling system for planning, steering, coordinating, and monitoring the innovation process. According to Vahs, this is relevant to ensure target orientation. The focus of the model lies on the early phases of the innovation process (Bircher, 2005; CAMPUS 02 - Fachhochschule der Wirtschaft, 2010; Vahs et al., 2023).
Cornelius Herstatt	1999	The focus of the model is on the early phases, which are detailed by activities such as idea generation, evaluation and specification or product planning. These phases of the fuzzy front end are particularly important, as the key decisions for the rest of the process are already made here (Verworn and Herstatt, 2000).
Horst Geschka	1993	The process model distinguishes between the whole process including early phases and the development of the innovation project.
Cooper Stage-Gate	1990	Coopers model divides the innovation process into stages separated by quality gates. At the quality gates the decision is made regularly to continue or stop the project.
Cooper Triple A System	2014	The evaluation of the original Stage-Gate Process in combination with agile methods to continuously gain customers feedback in iterations.
Agile Systems Design (ASD)	2017	Agile Systems Design (ASD): the focus lies on managing uncertainties in mechatronic systems and the context of product generation development. Iterative development process to evaluate the product together with the customer at an early stage (Albers et al., 2019).
Own process		

Key Points for Category 2: Structural Content of the Process Models
The structural content of the IPMs is analyzed Table 3. In contrast to strong differences in terms of focus and characteristics of category 1, the structural content regarding process flow and connection of phases and activities in this category is very similar. It is increasingly emphasized that not every part of real IPMs is considered but selected components to show the principle. Process models generally visualize a highly simplified and idealized process, which is why parallel activities or feedback loops are neglected to reduce complexity. This is also reflected in the structure of the IPMs. In most IPMs, the phases are arranged sequentially in the process visualization. Only in some models are selected parallel activities considered. Examples for parallel activities can take place both in early phases during problem analysis and strategy development, and at later points in time during technical development and development of the marketing concept. Cooper goes one step further and considers parallel activities in all phases of the Stage-Gate and Triple-A System description, as the process can be accelerated by parallel activities.

A process does not normally run in a straight line, which is why feedback loops to earlier phases often occur in real processes. Except for Pleschak and Sabisch, these feedback loops are not considered in most models. This can also be observed, where iterations are not included in most IPMs.

The newer models such as the ASD or Cooper's Triple A system, which combine agile methods with a conventional, sequential process, are particularly noteworthy. There, iterations in phases are considered due to the application of agile methods. In summary, it can be said that only the necessary components based on the previously defined focus are considered in the process models. The aim of IPMs is not to depict real processes, but merely to show basic relationships and essential components.

Table 3. Category 2- Overview of the structural content regarding sequential process flow and the consideration of parallel activities, feedback loops or iterations.

Model	Sequential process flow	Consideration of parallel phases/ activities	Consideration of feedback loops	Consideration of iterations
Thom	Yes	No	No	No
Brockhoff	Yes	Yes: "planned invention" and "unplanned invention".	No	No
Witt	Yes	Yes: "technical development" and "development of the marketing concept".	No	No
Pleschak, Sabisch	No	Yes: "Problem recognition, problem analysis" and "Strategy formation".	Central feedback loops.	No
Vahs	Yes	Yes: "Collection of ideas" and "idea generation", and overall "parallel innovation controlling".	No	No
Herstatt	Yes	No	No	No
Geschka	Yes	No	No	No
Cooper Stage-Gate	Yes	Yes: parallel activities within the stages.	No	No
Cooper Triple A System	Yes, basic structure.	Yes: parallel activities within the stages.	No	Yes: iterations within the stage.
ASD	Yes, basic structure.	No	No	Yes: iterations within development.
Own process				

Key Points for Category 3: The Presence of Early Phases/ Activities to Analyze Customer Needs and the Definition of the Product Profile

The innovation stimulus can be interpreted on the basis of the analyzed documents as a customer need or customer problem that needs to be solved. The presence of a customer need or problem increases the chances of a successful market launch of the technical solution. In some models, the phases or activities for identifying a customer need or problem are seen as upstream activities that are not explicitly part of the activities or phases of the IPM itself. This emerges only from the descriptions, but not from the process model representation because despite this, it sometimes is included in the model presentation. This understanding could be one reason why most models do not fully meet the criterion, although the underlying understanding is important from the customer point of view.

For defining a search field, situation analysis and problem analysis is important. These components are located before the phase idea generation. This understanding seems to be common, that the search field must be clear at first. The dependency can be observed that if the search field is considered in the model, idea generation is also more likely to occur in the model. The product profile should also be the basis for the idea generation. According to Albers' innovation definition, every model should have a defined product profile. Most models consider activities to define the product profile, however, the activities differ greatly from model to model. Activities are exemplary in the description of the project, the definition of a project plan, or a specification prior to technical implementation. It can be said that activities that take place before idea generation have the purpose of defining a product profile. Most models consider the definition of a product profile at least indirectly through detailed activities. The detailed analysis can be found in Table 4.

© IEOM Society International

Table 4. Category 3- Overview of the early phases and activities.

Model	Presence of innovation stimulus	Presence of search field	Definition of product profile	Presence of idea generation
Thom	No	Yes- Main phase 2 with detailed activity.	Yes- Main phase 2 with detailed activity.	Yes
Brockhoff	No, but project results of idea solving a customer need.	No	No	No
Witt	No	Start of process with defining search field.	Several stages detailed with activities: rough design for product concept, rough selection and suitability analysis, fine selection with profitability analysis.	Yes
Pleschak, Sabisch	Customer need (problem) must be solved.	Problem analysis, strategy development as essential upstream activities, but not part of the innovation process.	Phase 2 for project and program planning and profitability calculation.	Yes
Vahs	Yes- analysis/problem identification, idea should solve customer need (problem).	No	Several stages between brainstorming and implementation to get decision for idea.	Yes
Herstatt	No	No, but the idea generation shall be customer oriented, technology/ cost related.	Phase 2 with detailed activities: development of product concept, product planning (costs, quantities, project), specification, architecture.	Yes reviews & industrial design.
Geschka	No	No	Planning and conception of the project in phase 1.	
Cooper Stage-Gate	No	No	In early stages the idea is evaluated, activities for definition of product profile not explicitly included.	No
Cooper Triple A System	No	No	In early stages the idea is evaluated, activities for definition of product profile not explicitly included.	No
ASD	Yes, basic structure.	No	Detailed activities in the beginning: understanding of systems and its environment.	No
Own process				

Key Points for Category 4: The Presence of Frequently Occurring Phases/ Activities in IPMs

Idea generation, technical development of the idea (invention), and market launch are phases or activities that occur frequently (Table 5). These three components appear in almost all process models. Idea generation is part of most IPMs, partly as activity, partly as individual phase depending on the model. New ideas emerge from this phase or activity, which then proceed through the further innovation process. Coopers Stage-Gate and Triple-A System should be emphasized where the process begins with the concrete project or idea and the criteria idea generation is not met.
According to Albers' understanding of innovation, an idea is realized through a technical solution, whereby the result is referred to as an invention. The technical realization of an idea to create the invention can be interpreted as research and development. Development is a part of all the IPMs analyzed. According to Brockhoff, research and development is a combination of different factors to gain new knowledge and comprises different activities. However, these diverse activities are mostly summarized in one phase in the IPMs and are not explicitly detailed. As already observed in the analysis of the criterion characteristics of IPMs in Pleschak and Sabisch's model, a specialty can be identified: the sale of intellectual property licenses or development support from research or cooperation partners. This plays an important role in the real process and can be seen as an alternative to developing the idea by the company itself. For an invention to be called innovation, the market launch must be successful, and the product must be commercially successful. This could be one reason why market launch plays a very important role as a phase or activity and is therefore considered in all process models.

An interesting perspective by Herstatt refers to the so-called fuzzy front end, which describes the phases and activities between the idea generation and the technical development of the idea, where the information available is fuzzy, not always reliable and things are unknown. Herstatt points out that to detail the idea plays a major role in making the right decisions at an early stage. According to Herstatt, early decisions based on detailed information as reliable as possible could have a direct impact, e.g. on resources. This perspective emphasizes the importance of different aspects, their linking, and the impact of each element.

Table 5. Category 4- Overview of the presence of common phases of the innovation process models.

Model	Presence of idea generation	Presence of invention (technical realization of idea)	Presence of market launch
Thom	Main phase 1 with activities of search field determination, ideation and idea proposal.	Main phase 3 with activities for concrete implementation of the new idea.	Main phase 3 with activities for sales of the new idea to addressee and acceptance control.
Brockhoff	Starting with project idea which can be discarded or developed.	Phase research and development, success leads to (planned or unplanned) invention.	Introduction of a new product to the market as last phase.
Witt	Stage brainstorming with the activity developing new ideas inside/ outside the company.	Stage technical development with detailed activities.	Launch as last stage with detailed activities.
Pleschak, Sabisch	Start of process: generating ideas for new problem solutions, although upstream phases are considered.	Research and development with optional collaborations or licensing.	Launch as last phase resulting in market flop or diffusion.
Vahs	Idea generation and collection of ideas as parallel brainstorming phases.	Phase implementation.	Launch as last phase.
Herstatt	Phase I: Idea generation and evaluation as first activities.	Phase III: Development incl. execution of prior defined specifi-cation within interdisciplinary teams, design reviews and industrial design.	Last phase V including production, market launch and penetration.
Geschka	Preliminary phase 0 including all upstream activities before innovation project is starting.	Phase 2 product and process development.	Phase 4 launch as last phase.
Cooper Stage-Gate	Starting with an idea which is detailed in the following stages.	Stage 3 development.	Stage 5 including full production and market launch.
Cooper Triple A System	Starting with an idea which is detailed in the following stages.	Stage 3 development.	Stage 5 including full production and market launch.
ASD	Not included.	Realize idea by implementing tech. solution: iterative phases, concept, specification, realization to increase maturity/ functionality step wise.	Release as last phase.
Own process			

Key Points for Category 5: The Presence of Components for a Target- and Customer- Oriented Process

In the following Table 6 the models are analyzed regarding the criteria customer integration, decision points, and failures of ideas or innovations to ensure a target- and customer-oriented process. Regarding Witt customer integration is very important not to develop solely product oriented (Witt, 1996). Furthermore, it is important to remember the problem and need of the customer during the process, which shows the importance of the customer inclusion. This thinking is part of most of the process models. The customer can be involved in the innovation process through various activities and in all phases. No standardized picture emerges. Within the newer models, where agile methods play a major role, it can be said that the importance of customer integration increases.

Most ideas do not become innovations, so the innovation process is characterized by failures (Albers et al., 2015). Failures may occur due to economic or technological reasons, or if the in the beginning specified results are not reached. Failures are generally not explicitly included in the model presentation. However, there is a widespread understanding that an idea should not be pursued at certain points. Decisions must be made at regular intervals as to whether the idea should be pursued further or stopped, and therefore fail. Decision points are generally not explicitly included as separate phases or gates in the model presentation, but this understanding is explained in most model descriptions. Within the descriptions, it can be identified that decisions are made at certain points in all models. An exception is the Stage-Gate model, where concrete stages are included in the process description.

In summary, it can be said that this understanding of decision points and failures is mostly the same as in the description of the models, although both are not explicitly included in the process diagrams. One reason might be that the process models show an idealized and simplified process.

Table 6. Category 5- Analysis of criteria customer integration, failures and decision points in the process.

Model	**Customer integration in the process**	**Presence of decision points in the model**	**Consideration of failure of ideas or innovations**
Thom	Not mentioned.	Main phase 2 includes a detailed activity to decide on a plan to be realized.	Not mentioned.
Brockhoff	Not mentioned.	Not mentioned, but decisions must be made due to failures.	Technical or economic failures.
Witt	Customer integrated in different stages, to take early into account their requirements/ wishes defined by different activities.	Not mentioned in model. After each phase, decisions are made based on specific criteria for stopping or continuing. Goal to avoid subjectivity and optimize use of resources.	Not explicitly mentioned in the model. Due to decisions made ideas will fail.
Pleschak, Sabisch	Not explicitly mentioned. Customer needs and problems are seen as precondition for the process.	Idea selection in phase 1, multi-stage selection process is recommended. After each phase positive and negative outcomes/ intermediate goals are defined.	After each positive and negative outcomes/ intermediate goals to stop the process are defined.
Vahs	Existing customer problem must be solved. Integration of customer early for collection of idea & assessment of idea.	Systematically capture, screen and assess ideas to prepare a decision. Previous phases to prepare the selection phase.	Not mentioned.
Herstatt	Market analysis in early stages before defining product concept/ specification. Market tests recommended.	Focus lies on early phases to make valid decisions. Evaluation of ideas in phase I, later decision points not included.	Not mentioned.
Geschka	Not mentioned.	Not mentioned	Not mentioned.
Cooper Stage-Gate	Key component is market orientation; therefore, activities are existent to include the customer.	After each stage, a decision is made based on a quality gate.	Not mentioned explicitly, but implicitly included within the quality gates.
Cooper Triple A System	The iterations/ agile methods are included to continuously gain the customer's feedback.	After each stage, a decision is made based on a quality gate.	Not mentioned explicitly, but implicitly included within the quality gates.
ASD	Validate prototypes together with the customer early in iterative development.	Not mentioned.	Not mentioned.
Own process			

Key Points for Category 6: Market Launch Related Activities

As pointed out already within category 4, the phase market launch is included in nearly every model. One reason might be the understanding of innovation, where innovation can only be such if the market introduction of the invention is economically successful. Half of the models do not include activities to prepare the market launch. The other half of the models consider activities or phases related to prepare the market launch as downstream activities. If downstream activities are included, most models take production introduction into account as a common activity. Some models refer to other preparatory activities such as business analysis, planning, or pilot applications. Other examples for the different activities are pilot applications, marketing, or market tests. It can generally be stated that the downstream activities vary greatly from model to model (Table 7).

Activities after the market launch (post-activities) also vary greatly: acceptance control or follow-up reviews are only some examples. Still, half of the models do not include post activities at all. Connections between the availability of criteria and the consideration of different activities and phases within the models cannot be identified.

Table 7. Category 6- Market launch related activities.

Model	Consideration of preparation for market launch	Presence of market launch	Consideration of acceptance control as post activities
Thom	No	Yes	Yes, main phase 3, acceptance control.
Brockhoff	Phase investment, manufacturing and marketing.	Yes	No
Witt	Detailed activities within last phase: plan and prepare for introduction.	Yes	Detailed activities within last phase: carry out a follow-up campaign.
Pleschak, Sabisch	Production introduction and production setup.	Yes	No
Vahs	No	Yes	No
Herstatt	Phase IV - Prototyping and pilot application with detailed activities.	Yes	Phase V with detailed activity product care.
Geschka	No	No	
Cooper Stage-Gate	Pre- compartmentalization Business analysis gate 5 and full production Stage 5.	Yes	Post implementation review as last step.
Cooper Triple A System	Pre- compartmentalization Business analysis gate 5 and full production Stage 5.	Yes	Post implementation review as last step.
ASD	No	Yes	No
Own process			

4.4 Case Study: Application of Results for Analysis of a hypothetical innovation process models

The tables and key points pointed out above offer a quick and easy overview of existing IPMs in the literature. These results serve as a basis for analyzing an existing IPM. The purpose of the comparison is to help the user understand their own process model and to identify similarities and differences from the literature. A basic understanding is necessary to identify missing components and to further develop the own model. The results of chapter 4.3 were used to analyze a fictitious IPM as part of an exemplary case study. The procedure up to the identification of measures is explained below.

First, the own IPM must be analyzed. The user can use the free row called the *own process,* which is included as place holder in the table to take notes during the analysis of the own process model. Based on the criteria, the content of phases and activities can be identified. Within the fictitious example, category four is used to show the principle. To evaluate the criteria of category four, the following questions were asked within the fictitious example: What is the impetus for starting the process model? Is the search field definition included in the user's model? Does the model include the idea generation phase or activities for generating ideas? Is there any activity or phase included to define the product profile? The results of the assessment are added to the corresponding column. The fictitious result of the procedure is illustrated in Table 8.

Table 8. Exemplary analysis of the individual innovation process models for category 4.

Model	Presence of innovation stimulus	Presence of search field	Definition of product profile	Presence of idea generation
Thom	No	Main phase 2 with detailed activity.	Main phase 2 with detailed activity.	Yes
…				
ASD	Yes, basic structure.	No	Detailed activities in the beginning: understanding of systems and its environment	No
Own process	Process already established; mechanisms existent to start, no separate phase.	Not included.	Profile is defined at a later stage for specific idea, after the decision for development is done.	Not included as separate phase. Workshops included as possible activities.

In the next step, the user must identify similarities and differences from the IPMs available in the literature. Differences in understanding in the literature can be identified by analyzing Table 8 by comparing the results with the content and description of the state of the art. The user can define measures to improve and develop his own IPM. The improvements can be inspired by the content of the tables and key points where components that exist in the literature but are missing in the own model can be included. The procedure for comparing and deriving measures was conducted using the fictitious IPM and the exemplary results are shown below.

An upstream phase for *innovation stimulus* and initiation is not explicitly included. The fictitious process is already established in the company and if the established mechanisms are working, no adaption is needed. In contrast, the criteria *presence of search field* is not fulfilled. Activities such as problem analysis or strategy formation are missing in the established model, which is important to understand why and for which topic an idea generation should be conducted. Search field definition goes hand in hand with activities such as problem analysis or strategy formation, which could already contribute to the definition of the product profile. This is essential for a successful market launch that the customer problem is understood, and that one can generate targeted ideas. Within the analysis it can be observed that in the fictitious model the profile is only determined for specific ideas and therefore the phase/ activity is located after the idea generation. This is a contrast to the literature, where idea generation is carried out in a targeted manner based on the previously defined product profile.

Finally, it can be said that further design and adaption of the early phases seem necessary to ensure valid decisions at an early stage and to make them based on sufficient information. Within the fictitious model the early phases are summarized, partly important activities are missing, and the customer need is not yet fully considered. It is recommended to adapt the model by defining the product profile before idea generation is carried out, so that there is a clear customer benefit, and the company can carry out idea generation target oriented.

A second use case is briefly explained below. If the user wants to develop an innovation process model for a company from scratch, the results of this work can also be used. The user can identify which model is best suited to the use case based on the focus, for example, or combine and adapt relevant components from the models in the form of phases or activities as required. In this way, the process model can be optimally adapted to specific needs and further developed.

5. Conclusion and Outlook

The research results are primarily theoretical in nature and aim to classify and analyze IPMs based on a specific set of criteria. This classification and analysis were performed for selected models documented in the scientific literature, and the information from previous research activities collided. This forms a solid basis for further research for companies or researchers. The theoretical analysis can subsequently serve in practice as a guideline for evaluating individual IPMs or as a basis for their redefinition.

As part of this work, initial criteria were defined to help the user in analyzing the important components of the process models. The criteria were categorized in terms of content to simplify the presentation. In summary, it can be said that the presentation in the form of several tables contributes to clarity a lot. It was possible to extract and summarize the key points of common understanding and differences in the process models. Interestingly, Schumpeter's and Albers' understanding of innovation is considered in most models, although the models are older than Albers' expansion of understanding. In addition, the development towards the application of agile methods in the field of innovation is also noticeable in literature. The tables and results of the analysis can be used to clearly present the differences and similarities to analyze the own innovation process or to define the own IPM based on this. This is shown through a case study and the procedure for the user and fictitious results have been described exemplary. However, it might be difficult to understand the content and process models based solely on tables. The description and particularly the presentation of the models are fundamental to fully understanding the special features and structure. For this reason, it is recommended to use both the presentations. a brief description and the tables.

The defined criteria are a first step towards analyzing IPMs. It is recommended that the IPMs of companies are analyzed as part of further studies and, if necessary, derive further criteria and expand the criteria catalog. Company processes can vary greatly, as these models reflect the processes practiced in the company and are tailored to individual needs. In addition, other IPMs from the literature and application examples can be added in further studies.

References

Albers, A., Bursac, N., Heimicke, J., Walter, B., and Reiss, N., ‘20 years of co-creation using case based learning An integrated approach for teaching innovation and research in Product Generation Engineering’, in , 2017.

Albers, A., Bursac, N., and Wintergerst, E., ‘Produktgenerationsentwicklung – Bedeutung und Herausforderungen aus einer entwicklungsmethodischen Perspektive’, in , 2015.

Albers, A., Gladysz, B., Heitger, N., and Wilmsen, M., ‘Categories of Product Innovations – A Prospective Categorization Framework for Innovation Projects in Early Development Phases Based on Empirical Data’, *Procedia CIRP*, Vol. 50, 2016a.

Albers, A., Heimicke, J., Spadinger, M., Reiß, N., Breitschuh, J., Richter, T., Bursac, N., and Marthaler, F., ‘Eine Systematik zur situationsadäquaten Mechatroniksystementwicklung durch ASD-Agile Systems Design’, 2019.

Albers, A., Marthaler, F., Schlegel, M., Thümmel, C., Kuebler, M., and Siebe, A., *Eine Systematik zur zukunftsorientierten Produktentwicklung Generationsübergreifende Ableitung von Produktprofilen zukünftiger Produktgenerationen durch strategische Vorausschau*, 2022.

Albers, A., Reiss, N., Bursac, N., and Richter, T., ‘iPeM – Integrated Product Engineering Model in Context of Product Generation Engineering’, *Procedia CIRP*, Vol. 50, 2016b.

Albert Albers, Jonas Heimicke, Benjamin Walter, Gustav Nils Basedow, Nicolas Reiß, Nicolas Heitger, Sascha Ott, and Nikola Bursac, ‘Product Profiles: Modelling customer benefits as a foundation to bring inventions to innovations’, *Procedia CIRP*, Vol. 70, 2018.

Bender, B., and Gericke, K. (eds.), *Pahl/Beitz Konstruktionslehre. Methoden und Anwendung erfolgreicher Produktentwicklung,* Springer Berlin Heidelberg, 2021.

Bircher, M., *Die Integrale Produktinnovation. ein Ansatz zur Unterstützung von Innovationsprojekten,* Diss. ETH Nr. 16259, 2005. Accessed October 12, 2024.

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

Brockhoff, K., *Forschung und Entwicklung. Planung und Kontrolle,* Oldenbourg; De Gruyter, 1999.

Cooper, R., ‘Stage-Gate Systems: A New Tool for Managing New Products’, *Business Horizons*, Vol. 33, 1990.

Cooper, R. G., ‘What's Next?: After Stage-Gate’, *Research-Technology Management*, Vol. 57, No. 1, 2014.

Dumitrescu, R., Albers, A., Riedel, O., Stark, R., and Gausemeier, J., *Engineering in Deutschland - Status quo in Wirtschaft und Wissenschaft. Ein Beitrag zum Advanced Systems Engineering*, 2021.

Geschka, H., *Wettbewerbsfaktor Zeit. Beschleunigung von Innovationsprozessen,* Verl. Moderne Industrie, 1993.

Herstatt, C., *Management der frühen Innovationsphasen. Grundlagen - Methoden - Neue Ansätze,* Gabler Verlag, 2014.

Innovationsmanagement in der Praxis, Leykam, 2010.

Mathur, S., and Malik, S., ‘Advancements in the V-Model’, *International Journal of Computer Applications*, Vol. 1, No. 12, 2010.

Müller, J., Pendzik, M., Schock, M., Albers, A., and Paetzold-Byhain, K., ‘Development of a Methodology Profile Based on the Current Maturity Level of Agile Development in Mechatronic Product Engineering’, in Design Society (ed.), *Proceedings of NordDesign 2024*, The Design Society, 2024.

Pleschak, F., and Sabisch, H., *Innovationsmanagement,* Schäffer-Poeschel, 1996.

Schumpeter, J., ‘Theorie der wirtschaftlichen Entwicklung’, in J. Backhaus (ed.), *Joseph Alois Schumpeter*, Kluwer Academic Publishers, 2003.

Thom, N., *Grundlagen des betrieblichen Innovationsmanagements*. Teilw. zugl.: Köln, Univ., Diss., 1976, Hanstein, 1980.

Vahs, D., and Brem, A., *Innovationsmanagement. Von der Idee zur erfolgreichen Vermarktung,* Schäffer-Poeschel, 2015.

Vahs, D., Brem, A., and Oswald, C., *Innovationsmanagement. Von der Idee zur erfolgreichen Vermarktung,* Schäffer-Poeschel, 2023.
VDI2221 Blatt1:2019-11, *Entwicklung technischer Produkte und Systeme - Modell der Produktentwicklung,* Beuth Verlag GmbH, 2019.
Verworn, B., and Herstatt, C., *Modelle des Innovationsprozesses*. Working Paper, Hamburg University of Technology (TUHH), Institute for Technology and Innovation Management (TIM), 2000.
Weiss, S., Paetzold-Byhain, K., Michalides, M., Pendzik, M., Scharold, F., and Stoiber, L., *Agile Entwicklung physischer Produkte 2023,* Technische Universität Dresden, 2023.
Witt, J. (ed.), *Produktinnovation. Entwicklung und Vermarktung neuer Produkte,* Vahlen, 1996.
Wynn, D. C., and Clarkson, P. J., 'Process models in design and development', *Research in Engineering Design*, Vol. 29, No. 2, 2018.

Biographies

Univ.-Prof. Dr.-Ing. Dr. h. c. Albert Albers Albert Albers has been full professor for product development and head of IPEK - Institute of Product Engineering at the Karlsruhe Institute of Technology (KIT) since 1996. He received his doctorate in 1987 under Prof. Palandan of the University of Hannover. Before his appointment to Karlsruhe, Prof. Albers worked for LuK GmbH & Co. OHG, most recently as head of development and deputy member of the management board. He is a founding and former board member of the scientific society for product development WiGeP, a member of the German Academy of Science and Engineering (acatech) and a member of the Advisory Board of the Design Society. Since 2008, he has been President of the Allgemeiner Fakultätentag (AFT e. V.). In addition, Prof. Albers engages in the VDI and serves on the advisory boards of several companies. In 2016, he and the IPEK team were awarded the Honorary Award of the Schaeffler FAG Foundation for excellent achievements and competencies in science, research and teaching in the technical-scientific field.

Ann-Kathrin Müller studied Electrical Engineering in her Bachelor and is currently a master student at Karlsruhe Institute of Technology. She studies part-time Mobility Systems Engineering and Management and her research is focusing on innovation process models and application of agile methods in the field of innovation development. Currently she works as a developer at an automotive OEM.

Johannes Müller Johanes Müller graduated with a master's degree from the Karlsruhe Institute of Technology in 2022. He is a doctoral researcher and team leader in the research group Design Methods and Design Management at the IPEK - Institute of Product Engineering of the Karlsruhe Institute of Technology. His research focuses on the application of agile thinking and practices in the development of cyber-physical systems and the measurement of process improvements through these methods. Additionally, he is an expert in innovation workshops and LiveLabs for collaboration between research, teaching, and industry

Moritz Schöck holds a Master's degree in Mechanical Engineering from the Karlsruhe Institute of Technology (KIT) and an MBA in General Management from Collège des Ingénieurs (CDI) in Paris. With a background spanning automotive and semiconductor industries, as well as management consulting, he brings a unique blend of industrial and strategic expertise to his current role as a doctoral researcher and graduate student at IPEK – Institute of Product Engineering at KIT. His scientific work focuses on enhancing organizational innovation capability and strategically integrating agile methods into mechatronic product development, addressing critical challenges in balancing flexibility and structure in complex engineering environments.

© IEOM Society International