

Dealing with Market Uncertainty in Product Development – A Systematic Literature Review

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Abstract: Product development and the associated processes are always characterized by uncertainties, whereby a distinction can be made between technological and market uncertainties. These uncertainties cannot be avoided, which is why it is necessary to deal with them adequately in the context of product development. To enable this, however, it is first of all necessary to understand the facets, characteristics and causes of market uncertainties in order to be able to select suitable approaches in accordance with the situation and requirements. Therefore, within a Systematic Literature Review, five aspects of market uncertainty and their correlations with potential causes were identified. Furthermore, eight approaches to deal with market uncertainties were identified and analyzed regarding the addressed causes and facets of market uncertainty.

1. Motivation

Major motivation of product engineering is innovation, the development of systems successful at the market [1]. Thus, core challenge is the translation of the right development objectives to the corresponding design. Thereby, formulating these objectives is a non-trivial undertaking. The process of gathering as well as the objectives themselves are affected by uncertainties [2]. Market shares are defined by the purchasing behaviour of the customers [3], who decide for a product based on their explicit and implicit demands. These uncertainties can represent both, an opportunity and a risk for the success of the product development. The relevance and diverse reasons and sources for uncertainties shall be illustrated considering an example of the past – microelectromechanical systems (MEMS), an emerging technology of the 1980-90's [4].

A proposed use case for MEMS was microsurgical instruments as catheter-based surgical equipment. The promising objective of this system was offering an alternative to heart bypass surgery by cleaning out clogged arteries. On the one hand, high spending in healthcare and the aging of the population, offers an attractive development of the market. On the other hand, the healthcare sector was already subject to cutting the spending that resulted in significant market and economic uncertainties. Technological uncertainties arise, because the MEMS technology was one approach competing with the established but more intrusive bypass surgery as well as technologies using laser beams or endoscopic surgery, which were both already established in less sensitive operations. Furthermore, the MEMS would be highly sophisticated instruments to meet the required precision and resilience what contradicts the high pressure of costs of usually single use equipment [4]. Considering today's surgical approaches, the promising MEMS technology couldn't be established on the market as less revolutionary techniques such as balloon catheter and stents are widely used.

2. Product Development and Uncertainties

Product development can be addressed and described by three interacting systems. “Through the system of objectives, the operation system and the system of objects product development can be described as the transformation of a (vague at the beginning) system of objectives into a concrete system of objects by the operation system.”[5] (Fig. 1)

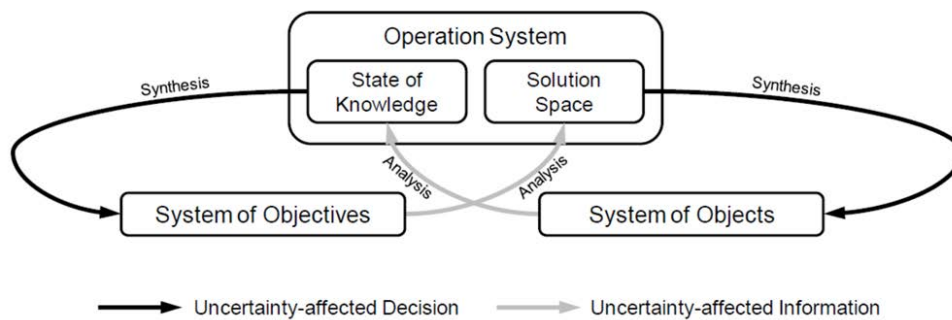


Fig. 1 System triple of product engineering [6]

Hereby, the operation system is socio-technical system that comprises the human and non-human resources, methods and processes required in a product development project. The operation system creates and links the system of objects and objectives. Within the system of objectives, all objectives, requirements and boundary conditions relevant for the product development project as well as their interrelations and reasonings are collected and specified by the operation system. The system of objects contains physical and virtual (immaterial) artefacts and results created by the operation system corresponding to the system of objectives. In the end of the product development project, the system of objects contains intermediate results as well as the final product as solution of the product development project [5]. As already stated, the system of objectives comprises all objectives relevant for the product development project. Thus, the quality of this system is essential for the success of the whole project. Starting point is a vague initial system of objective that has to be evolved throughout the complete project [6]. As already depicted in figure 1, the creation of the system of objectives, is a process driven by uncertainty [6].

Uncertainties describe both the probability that assumptions made will turn out to be wrong and the probability that previously unknown influences will occur that affect the product, its development and its success in the market [2]. These influences can be both negative and positive, meaning that they can represent either a

risk or an opportunity [7]. According to WIEBEL [8], uncertainties cannot be avoided, but always occur. However, due to the impact of uncertainties, adequate handling of them is crucial for developing companies. MCMANUS and HASTINGS [7] distinguish between lack of knowledge and lack of definition with respect to uncertainties. Lack of knowledge means missing knowledge and lacks of definition describe outstanding decisions or specifications.

In the context of product development, a distinction is often made between market and technology uncertainties. Technology uncertainties comprise lack of knowledge or definition regarding technical feasibility and market uncertainties describe lack of knowledge and definition regarding customer needs [9] or the willingness to pay [10].

3. Research Design

Product development can be described as the transformation of an initially vague initial system of objectives into a system of objects through a suitable operation system, whereby the transformation involves an interplay consisting of analysis and synthesis [5]. In this context, uncertainties are always present, which influence the product, its development and thus also the success of the product on the market. These uncertainties cannot be avoided, but due to the effects of these, an adequate handling of these uncertainties is required. Therefore, a deeper understanding of uncertainties, their causes and effects, but also suitable approaches to counteract the existing uncertainties is necessary. For this purpose the following research questions are to be answered:

1. Which characterizations, in terms of causes, definitions and appearances of market uncertainty can be found in literature?
2. Which approaches for managing market uncertainty in product development can be identified in literature?

In order to answer these research questions, a Systematic Literature Review was conducted according the approach by KITCHENHAM [11], whereby the two digital libraries Scopus and Web of Science (WoS) were screened for relevant literature. Therefore the following search-string was used:

„Market Uncertainty“ OR „Demand Uncertainty“ OR Unsicherheit AND (Produktentwicklung OR “Product Development” OR “Product Engineering” OR “R&D”).

For the search, only German and English literature was included and books and book chapter were removed from the list just like duplicates. This resulted in a total of 1546 relevant documents. Subsequently, the titles and abstracts of the documents were analyzed, and only publications that explicitly mentioned market uncertainties in the context of product development were considered further. This resulted in a reduction of the list to 103 documents. Subsequently, the remaining 103 publications were fully analyzed. Thereby, the information regarding the understanding of market uncertainties as well as the approaches to deal with those uncertainties were extracted, compared and finally consolidated if possible.

4. Characterisation of Market Uncertainty

The analysis of the scientific publications with regard to the term "market uncertainty" revealed various aspects of market uncertainty, whereby these can be assigned to the topics of **market configuration**, **customer needs** and the associated **willingness-to-pay**, **product realization** and **product utilization**. In many cases, however, it is not possible to make a clear-cut distinction; rather, there are interactions between the causes and aspects of market uncertainty. Table 1 below provides an overview of the results.

Tab. 2 Aspects of market uncertainty

Market configuration	• Lack of knowledge regarding <i>market characteristics</i> such as market composition	12
	• Lack of knowledge regarding <i>composition of the target market</i> and regarding <i>target customer</i>	13,14,15
	• Lack of definition regarding <i>addressed target customers</i> and <i>definition of the residual market</i>	16
	• Lack of knowledge regarding the <i>competitive situation</i> due to <i>turbulent, changeable and thus unpredictable competition</i> and <i>behavior of the competitors</i>	13,17,18,20
	• Lack of knowledge regarding <i>financial profitability of products</i>	21
	• Lack of knowledge regarding <i>demand</i> (quantity)	22,23,24,25
	• Lack of knowledge regarding <i>sales per customer</i>	16
	Potential causes:	
	• New, previously unaddressed target customers	27
	• Changing target customers	27,28
	• Premature market entry	29
	• Short product life cycles	25
	• Market dynamics	30
	• Changing customer needs	31
• Behavior of competitors (e.g. new competitors)	13,17,20	
• Changing market characteristics (e.g. fluctuating demand)	32,33	
Customer needs	• Lack of knowledge regarding <i>customer needs</i> , especially at an early stage	9,16,21,34
	• Lack of definition which <i>customer needs are to be addressed</i> , especially at an early stage	35,36,37
	Potential causes:	16,38
	• Emergence of new markets	
	• Entry into new markets with existing products	39
	• Market dynamics	36,38,40,41
	• Complexity of markets (large amount of possible states, for example, uncertain evolution of needs)	18,41
	• Changing customer needs (abrupt or continuous change)	17,18,36,37,42,43
• Technological change	44	
Willingness-to-pay	• Lack of knowledge regarding <i>willingness-to-pay</i> , especially at an early stage	9,10,45,46
	• Lack of knowledge regarding the <i>price limit of different target customers</i> especially at an early stage	47
	Potential causes:	48
	• Lack of knowledge on the customers' side with regard to the benefits of the product	
	• Difficulty of objectively evaluating product benefits from the customer's point of view when the maturity level is low	46
	• Lack of knowledge regarding price sensitivity of customers	45,46
• Customers' subjective perception of quality	49	
Product realization	• Lack of knowledge regarding the <i>satisfaction of customer needs</i> through technical realization	9,16,50,51
	Potential causes:	50
	• Discrepancy between customer requirement and technical realization	
	• Discrepancy between required and realized product properties	51
• Lack of customer acceptance for new technologies	4	
Product utilization	• Lack of knowledge regarding relevant <i>use-cases</i> of the product to be developed	4,52
	Potential causes:	4
	• Use of new technologies in the application	
	• Lack of knowledge regarding the actual application in the field	52
	• Lack of knowledge regarding legal regulation	4

It can be seen that all of the aspects of uncertainties found can be described as knowledge and definition gaps. Furthermore, it can be seen that there are some parallels between the different clusters, especially with regard to the potential causes. This is also shown in the following figure. Here, the effects found were visualized, with the aspects of market uncertainty on the left and the causes on the right side. The arrows represent, an effect on the present market uncertainty. It is important to mention that only cause-effect relationships identified in the literature are shown.

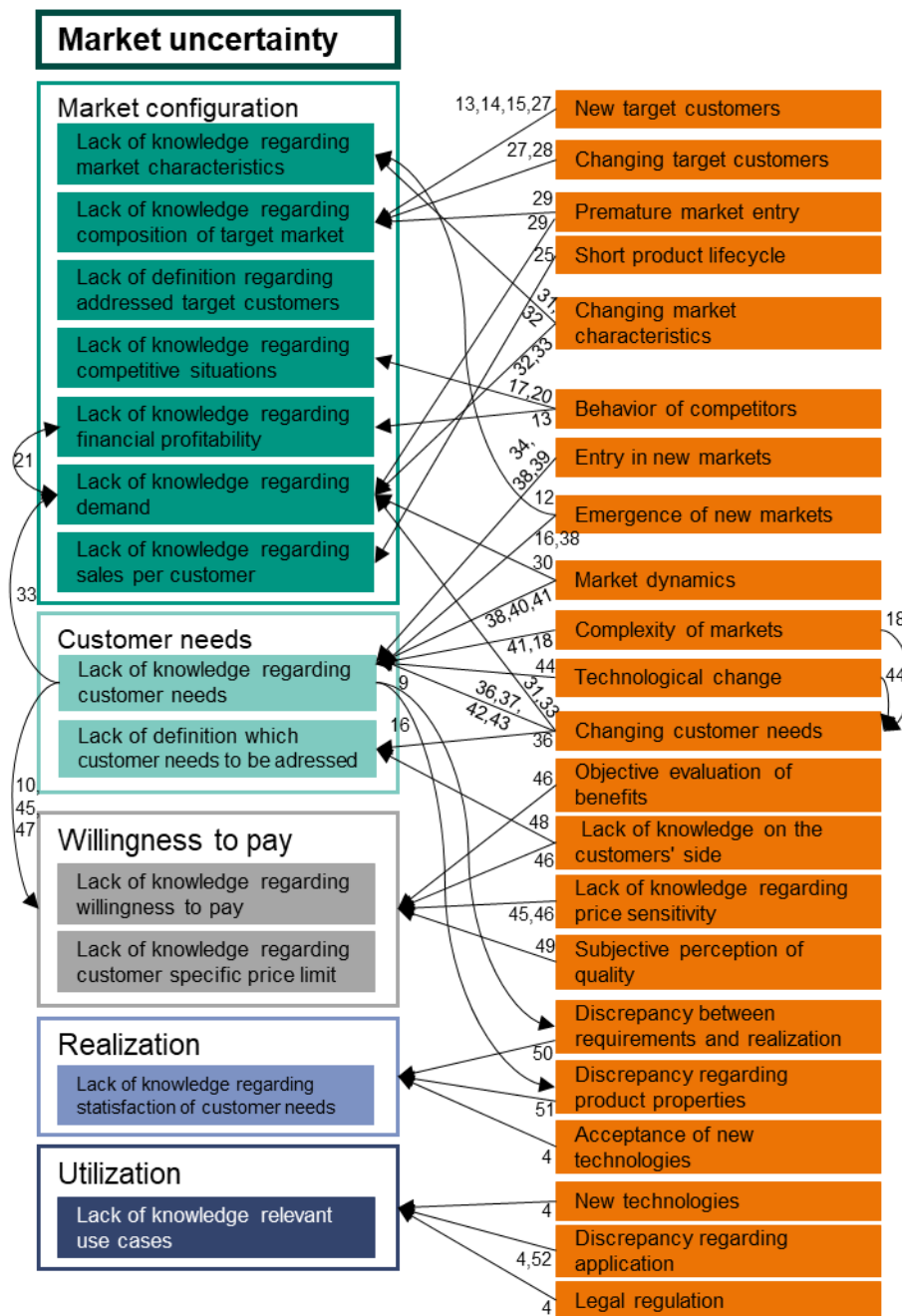


Fig. 2 Illustration of the correlations between market uncertainty and corresponding causes

It is evident that the correlations do not represent a unidirectional relationship, but rather a complex inter-relationship between causes and effects. For example, some aspects of market uncertainty are in turn causes of other aspects of market uncertainty.

Furthermore, it becomes apparent that there are a large number of interactions, especially in the center of the illustration in the case of lack of knowledge with regard to customer needs. Thus, many of the causes have an effect on this type of aspect of market uncertainty and at the same time it represents a source for further other aspects. Taking a deeper look, it can be concluded that there are further interactions between the different forms of market uncertainty that have not been considered in the literature so far.

5. Approaches for Managing Market Uncertainty

In the literature, approaches have been identified to support the management of market uncertainties. Furthermore, it was extracted from literature which of the previously discussed aspects and causes of market uncertainty are addressed by the approaches. Table 2 below provides an overview of the results.

Tab. 2 Approaches for managing market uncertainty

Scenario Planning	In Scenario Planning, for example based on expert knowledge, consistent alternative futures are determined, which are described in form of hypothesis.	
	• Supports to gain <i>knowledge about future customer needs</i>	53
	• Supports to create a vision regarding future sale levels and thus to gain <i>knowledge regarding the demand</i>	10,54
	• Supports approximations about future events, environmental conditions etc. and thus to <i>gain knowledge regarding future market characteristics</i>	55
Modular Design	In Modular Design, a product is created by combining different modules, and the characteristics of the overall product are the result of the modules' functions.	
	• Provides flexibility with regard to the product features and thus the <i>possibility to address different customer needs</i>	53
	• Provides the possibility to change components and functionality and thus <i>helps coping with changes</i> (target customer, market characteristics, market dynamics or customer needs)	56,57
	• Provides the possibility to address different kind of target customers with familiar products and thus supports regarding the <i>lack of knowledge regarding target markets or utilization</i>	39,22
	• Supports product developers to compare different concepts <i>regarding the fulfilment of customer needs</i> by offering a separation of products in different levels of functionality and components. Thus, <i>lack of knowledge regarding the satisfaction of customer needs</i> is reduced.	51,58, 59
Speed of Development	Increasing the Speed of product Development is identified in some descriptive studies as a success factor.	
	• Increasing the speed of development, relative to the industry benchmark, helps in the context of <i>new or dynamic markets regarding the behavior of competitors</i> , especially when companies are able to build up relevant knowledge quickly.	38,60
Cooperation in product development	Some approaches for integrating suppliers or partner companies into the development of products are presented, whereby the type and degree of integration varies according to the characteristics and causes of the present market uncertainty.	
	• In the context of <i>new markets</i> , market uncertainty can be reduced if a common standard is established.	61
	• Partial or total integration of suppliers helps to build knowledge in the course of <i>unknown or undefined customer needs</i> .	62
	• In the event of <i>changes in customer needs</i> caused by the <i>behavior of competitors</i> or <i>technological change</i> , lack of knowledge can be reduced through cooperation with direct competitors.	63
	• Within <i>dynamic markets</i> , fewer development activities should be outsourced.	36,64, 65
	• Within <i>emerging markets</i> , company collaborations in the sense of an open innovation approach help to acquire knowledge.	66
Learning Strategies	Learning Strategies include generating, capturing and making knowledge available. A distinction is made between explorative and exploitative learning strategies.	
	• Support to gain <i>knowledge regarding customer needs</i> especially in <i>dynamic markets</i>	67
	• In the case of <i>short product life cycles</i> , exploitative learning is often applied to <i>generate the necessary knowledge</i>	68
	• In the case of <i>dynamic or emerging markets</i> , explorative learning is applied in order to generate new knowledge to reduce uncertainty regarding <i>market characteristics</i> or <i>customer needs</i>	12
	• Learning orientation helps to deal with <i>lack of knowledge regarding demand and regarding customer needs</i> in the context of dynamic markets	69
Customer Relations	Customer Relations describe the establishment and maintenance of customer relationships and the associated acquisition of knowledge.	
	• Close customer contact (e.g. Marketing or Sales) supports to gain <i>knowledge regarding target market and customer needs</i>	16,34
	• Customer surveys support the generation of <i>knowledge regarding customer needs</i> and the <i>competitive situation</i> in case of rapid changes	42

Integrated Design	Integrated Design involves knowledge sharing and interdisciplinary collaboration between developers and marketers	
	<ul style="list-style-type: none"> • Interdisciplinary communication (e.g. by digital exchange-platforms) supports to gain knowledge regarding customer needs. 	35,50
	<ul style="list-style-type: none"> • Experienced managers support this exchange, which is particularly necessary in dynamic markets. 	70
Uncertainty specific project execution	Decisions are made based on the existing uncertainties. Based on the evaluation of the existing uncertainty the planning of the procedure in the development or the product portfolio is carried out.	
	<ul style="list-style-type: none"> • Product and project planning early in development helps to systematically deal with market uncertainties. Planning reveals missing knowledge, which is then made available within product development 	9,21
	<ul style="list-style-type: none"> • An adequate process model - consideration of iterations - helps to deal with market uncertainties. The early identification of existing market uncertainties through evaluation supports the appropriate selection of a process model. 	40
	<ul style="list-style-type: none"> • Alignment of the product portfolio according to the present market uncertainty helps to deal with market uncertainties by choosing an adequate process model 	26
	<ul style="list-style-type: none"> • Based on defined criteria, lacks of knowledge regarding legal restrictions, acceptance of new technologies, customer needs can be identified. Market analysis or expert interviews can then be conducted to generate knowledge. 	4

It can be seen that the approaches can be roughly divided into two different categories. There are approaches, such as **Learning Strategies** or **Scenario Planning**, which support the product developers in acquiring knowledge and thus reducing the existing lacks of knowledge. And there are also approaches that address the issue of changing conditions. The objective of these is to be able to react to changes by creating flexibility (**Modular Design**) or to circumvent changes by increasing the **Speed of development**.

Based on figure 2, in the following section, the interdependency between the various approaches presented for managing market uncertainties and the addressed characteristics and causes of market uncertainty is presented. It assists users to select approaches for coping market uncertainties that are appropriate to the situation and requirements.

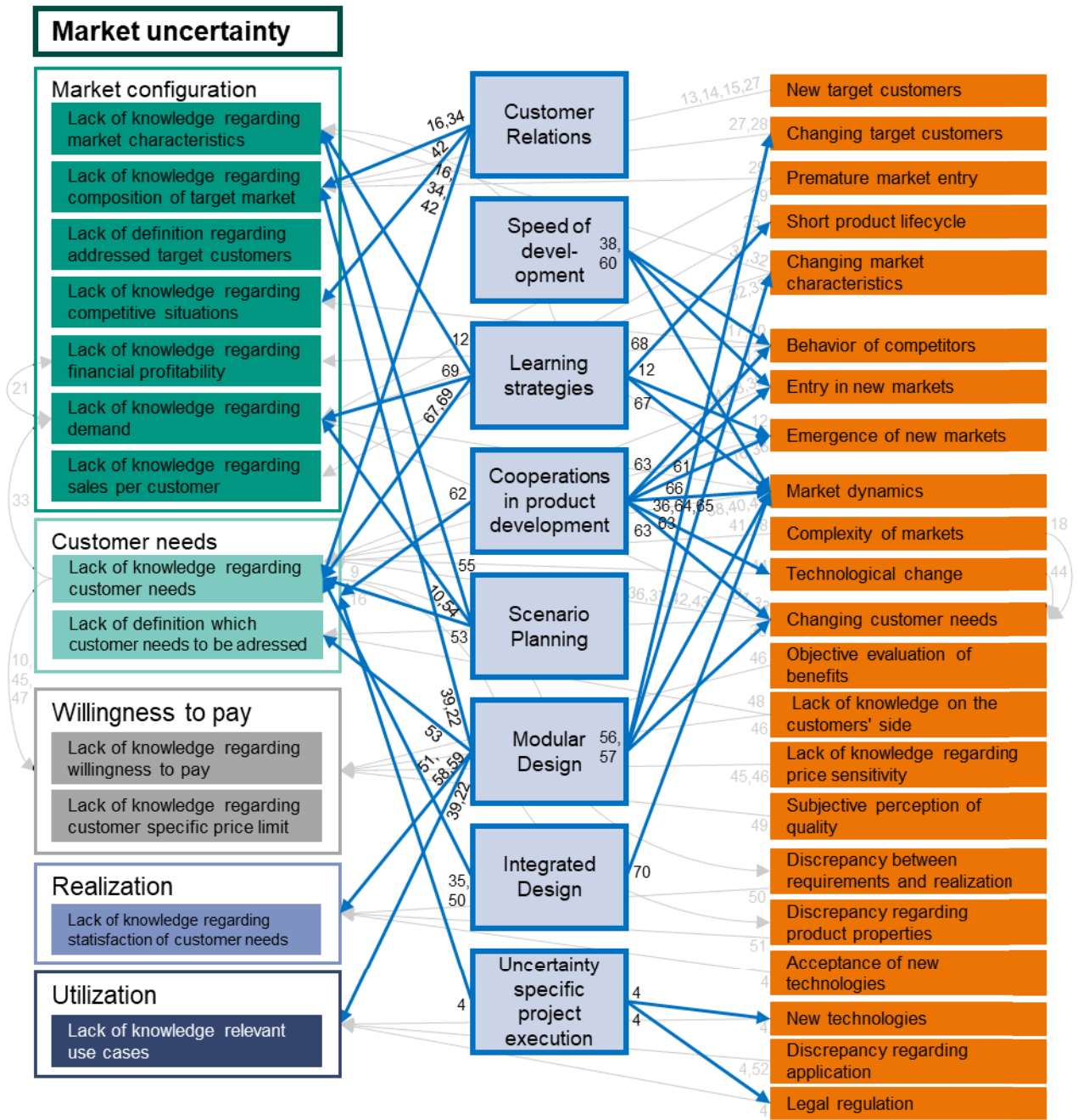


Fig. 3 Illustration of the approaches for managing market uncertainty and the correlations to market uncertainty and corresponding causes

6. Conclusion and Outlook

The term market uncertainty was characterized by means of a systematic literature review. In doing so, various characteristics were identified which could be assigned to the topics **market configuration**, **customer needs** and the associated **willingness-to-pay**, **product realization** and **product utilization**. In addition, the causes of market uncertainty in product development were identified. Furthermore, the interdependencies between the causes and the aspect of market uncertainty were presented. It should be noted that it is not possible to make a clear-cut assignment, but rather that a complex interplay could be found. For instance, aspects of market uncertainty may in turn be a cause of other aspects.

Furthermore, eight clusters of different approaches for dealing with market uncertainties were identified in the literature, which directly address the identified characteristics and causes of market uncertainties. A distinction could be made between two different types of approaches. On the one hand, there are approaches for generating knowledge, and on the other hand, there are approaches for countering market uncertainties resulting from changes in conditions (change of customer needs, behavior of competitors). By linking the approaches to the causes and characteristics of market uncertainty, it is possible to select approaches that are appropriate to the situation and requirements.

In subsequent research, it is important to gain a deeper insight into the interrelationships between the causes and characteristics of market uncertainty. In particular, it is important to empirically analyze relationships that have not yet been described in the literature but are nevertheless probable. Furthermore, it is important to identify additional approaches that support the handling of market uncertainties. In this context, it is especially important to consider validation, which is the central activity for creating knowledge in product development and therefore to reduce market uncertainty [5].

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