Acceptance Modelling in Product Development – Case Study: Connected Systems for Industry 4.0 Solutions

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Acceptance Modelling in Product Development – Case Study: Connected Systems for Industry 4.0 Solutions

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Abstract. Within Industry 4.0 many connected systems are entering production to optimize the processes. The integration of the manual workstations into a Smart Factory, as a fully connected production, is required as well. Therefore, systems with which the production workers interact as users are introduced. However, as a side-effect, the production employees and their working performance are more transparent as well. This often leads to a lack of user acceptance, even though these systems have positive effects on complete production processes. If, for unforeseen reasons, there is a lack of user acceptance, the introduced system will not be as successful as planned, irrespective of how technically valuable the future product is. Therefore, the potential user acceptance towards the System-in-Development should be understood. This contribution introduces an acceptance model that has been developed and validated within a Live-Lab with industrial participation, as a research environment between laboratory and field studies. For this purpose, influencing factors for user acceptance of connected products were identified. Based on various scientific surveys, the factors were weighted and their interactions analysed in order to enable prognosis regarding user acceptance and to derive recommendations concerning actions for the downstream processes.

1. Motivation – Connected Systems for Industry 4.0 Solutions

In the course of Industry 4.0, the digital interlinking of all components transforms production into Smart Factories. [1] All value-adding networks are controlled in real time, where machines make partly or fully automatic decisions. [2] This is done on the basis of data previously generated, processed and stored along the value chain. This database provides increased transparency along the entire value chain and enables, among other things, the identification of potentials for optimization in the production process. [3] By connecting all components and generating data at the relevant workstations, it is possible to create a holistic digital image of the value chain, from order-entry to invoicing. This makes it possible to use production capacity more intelligent or to optimize individual manufacturing steps. [4] Recent studies show, that industry 4.0 solutions will increase the productivity of German machine builders' production facilities by an average of about 7-11%. [5] In addition, data acquisition in a production line also enables condition monitoring of all machines and thus ensures optimized maintenance cycles and therefore fewer breakdowns. [2] The achieved transparency also means that the work of the people, who are involved in the value-added process will also become more transparent. [6] It can be seen that the general attitude towards data collection, data storage and related issues is predominantly sceptical. [7] However, this is not only evident on a professional level, but it also plays a role in private life, in form of social networks such as facebook or google maps. In this respect, a preliminary study (Fig. 1) was carried out within the scope of this publication, in order to confirm the mood regarding data collection, which was identified in literature also in working life.

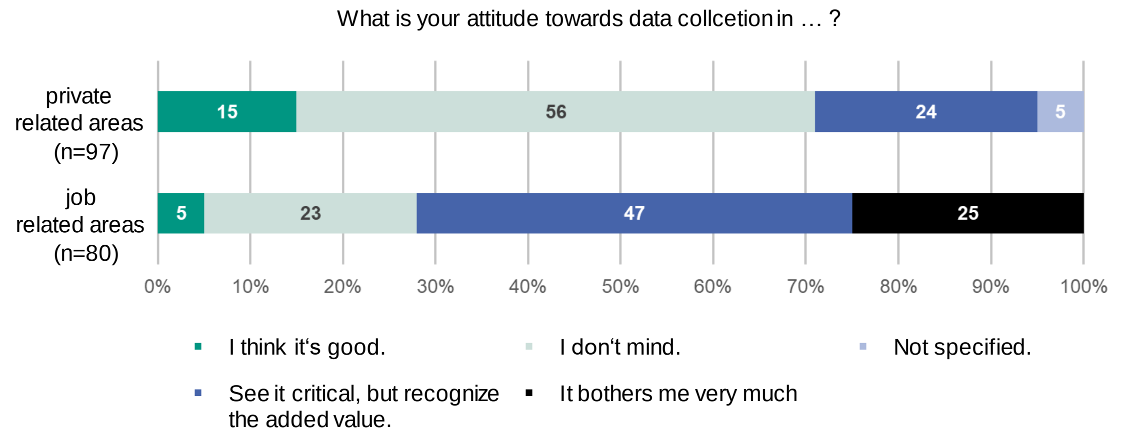

Figure 1. Attitude towards the topic of data collection in the private (at the top) and job-related (below) areas - own preliminary study

The results of the preliminary study show that social networks are widespread in private use, but that the majority of participants remains sceptical about data collection in their working environment. Most respondents state, they use such systems because they believe that their use will result in a personal advantage or there are no comparable alternatives. In the professional environment, scepticism predominates, especially since the personal benefit has not been recognized yet. For companies, which develop production systems, it is a necessary condition for their sustainable economic success that the production workers of their future customers accept and use these systems. This inevitably leads to the fact that the attitude of future users towards the product generation in development represents a decisive influence and success factor in the development process of these companies. Furthermore, globally operating companies cannot allow themselves to violate ethical values towards their employees and, for example, to implement systems that are not accepted by users. However, it is not possible to make a valid statement about the associated acceptance of potential users in the early stage of the development process, especially in the context of connected systems. For this purpose, in this contribution a methodology will be presented, by means of which the developer can model and compare the potential acceptance of different alternative solutions in the early stage of the development process.

2. State of the Art

2.1. Innovation and Diffusion of technical Products in the PGE – Product Generation Engineering

According to SCHUMPETER [8], an innovation differs from an invention by its economic impact. In the innovation process of product development, an idea that leads to a new product is technically implemented into an invention, which in turn has to be taken over by a broad mass on the market and thus penetrates the market (diffusion [9]). In order to achieve this goal, a company must use marketing activities and methods to achieve a suitable market launch of the product. [10] In order to be as successful as possible in this process, a product profile, which is a model-based description of the different benefits from the perspective of customers, users and the provider, forms the restrictive framework for generating ideas and inventions. These profiles describe the demand situation on the market, whilst taking into account the three above-mentioned perspectives and further elements like the competitive situation or the intended core functions of the future product. However, the product profile does not include the technical solution for the identified demand. [10] The profile is also used to continuously validate generated ideas and technical solutions; i.e. the invention, against the identified customer, user and provider benefits, thus increasing the probability of a future diffusion.

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[11] The diffusion of an invention occurs through adoption by individuals, where adoption is the actual take-over. [12] At this point, the real customer, user and provider requirements are relevant. According to ALBERS [13], the development of new products follows the model of the PGE – Product Generation Engineering, which means the development of products in generations [13], is always based on reference products. These can be predecessor products, competitor products, or their subsystems. In addition, new generations are developed through the systematic combination of the activities Carryover Variation (CV), Embodiment Variation (EV) and Principle Variation (PV). [13] In the case of the CV, the embodiment design and solution principle of the subsystem remain unchanged compared with the reference product. This reduces the constructive change effort to a minimal and affect in particular the system boundaries. Within the EV, the existing principle of the reference product is retained, but the embodiment is adapted. In the course of the PV, subsystems are realized by implementing changed solution principles. [14]

The process of product development does not take place sequentially. Activities of product engineering are carried out iteratively and simultaneously over different phases and the engineer is supported by development methods. [15, 16] Within those processes the early and consistent integration of the customer (Co-Creation [17]) is a key factor in the development of products to maximize the customer value. The focus here is set on the integration of all relevant persons into the development process, with regard to a human-centred development, which is of great importance not only to the customer but also to the developer and the user. [10] In addition, ideas, concepts and prototypes are developed iteratively, validated with the customer (e.g. regarding their acceptance of the developed solutions) and further developed throughout the entire process in terms of the scope of functions and degree of maturity. [18] Already in the early stage of PGE a large number of decisions has to be made, which have a massive impact on the downstream development steps and later product properties. [14] In particular, it is important to make decisions based on the predicted adoption of future customers and users in order to strategically align the development of the product. The adoption process can be described as, the adoption by individuals, which in its entirety has already been introduced as diffusion. According to ROGERS, this process consists of five consecutive phases (Knowledge, Persuasion, Decision, Implementation and Confirmation). [8] Various influencing factors determine this mental process. [19] In addition to these factors, the interaction between adoption behaviour and a user's acceptance of the future product is highly relevant.

2.2 Acceptance regarding technical Connected Products

There is no uniform definition of acceptance; the meaning depends on the scientific point of view. Primarily, a distinction is made between the economic and sociological view-points, which leads to differing views on the phenomenon of acceptance. [20, 21] All definitions of the term “acceptance”, irrespective of the scientific field they originate from, contain synonyms such as "Adopt", "Acknowledge", "Affirm", "Agree", but also "Approve". [20–22] In general, however, acceptance does not represent a property, but rather the result of a reciprocal process of the subject-, the object- and the context of acceptance. [21] The subject of acceptance describes the initial point of acceptance (e.g. the user of the relevant product). The object of acceptance situates the acceptance. It describes the object which is accepted. The context of acceptance describes the environment in which the subject of acceptance interacts with the object of acceptance. In literature, so-called dimensions or levels of acceptance are discussed often. Overall, the dimensions of attitude, action and value (Fig. 2) are presented. The dimension of attitude is divided into two different components. [20] The affective component describes the emotional estimation, while the cognitive component contains an estimation based on the mind, which is usually grounded on a cost-benefit comparison. Overall, this dimension describes the decision on which parts are going to be carried over. If it is positive, it is called acceptance. It is important that it can only contain an intention to act, but not concrete action, because it is part of the dimension of action. In scientific jargon, this is also referred to as the conative dimension. It contains the behaviour of the user based on the dimension of attitude and can appear in different forms. Potential forms can be, for example, the purchase or the use of a technical object, but also active resistance or absence of an action. [23] The normative dimension (value dimension) contains the attitude towards the object of acceptance based on existing norms and values, in some cases it is considered as part of the dimension of attitude.

Figure 2. Overview of the different dimensions of acceptance

A distinction must be made between individual and social norms and values. [21] By introducing this dimension, it can be distinguished between the two forms of acceptance, adoption-acceptance and adaptation-acceptance. Both lead to the carry-over of the object, but are based on different circumstances. While in the case of adoption acceptance, all object functions fit into the existing value system and system of objectives and the object is transferred without external pressure, i.e. voluntarily. In the sense of adaptation acceptance, the object does not fit into the value system and system of objectives on which the normative evaluation is based and the object is therefore only transferred by external pressure. [20, 22]

The technical literature distinguishes between four different types of acceptance models. Input-Models are the simplest form of acceptance models. Within these, only the various factors, which influence the process of acceptance, are taken into account and, based on them, the formation of acceptance is presented. [22] Input-Output-Models do not only analyse the influencing factors, but also use them as input variables and additionally differentiate the result of the acceptance process. [22] An-other type are the so-called Feedback-Models, which have a process-related character. [22] They have the special feature that the influencing factors no longer appear as static dimensions, but change through feedback due to the result of the acceptance process. [20] The fourth category consists the Dynamic-Process-Models, which also do have the process-related character but as well are able to change. [22] One of the most common acceptance models is the TAM – Technology Acceptance Model (Fig. 3) by DAVIS [24]. It is designed as an Input-Model and is based on the theory of reasoned action. [22]

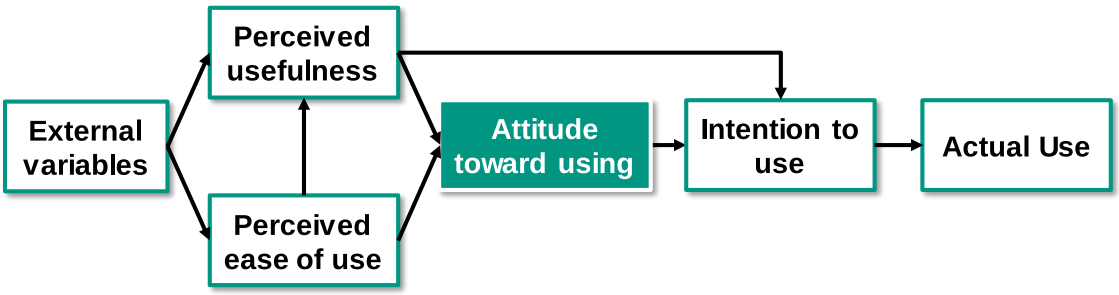

Figure 3. TAM-Technology Acceptance Modell in accordance with DAVIS [24]

The Attitude Toward Using is at the heart of this model. This in turn influences the Intention to Use, which has an influence on the Actual Use. An interesting point regarding the TAM is the separation between the intention to act and the actual action. On the influence side, importance is attached to the two variables Preceived Usefulness and Prceived Ease of Use. These two are in turn influenced by External Variables that are not further specified. Various studies have already demonstrated the usefulness of TAM, but have also shown that the External Variables need to be specified in more detail. [25, 26, 27] Later the TAM was expanded by DAVIS et al. [28] The focus was set on the two cluster of cognitively instrumental- and social variables to describe the input of the model more detailed. [28]

3. Research Approach

As already mentioned, the factor user-acceptance regarding the product to develop within the innovation process is a decisive factor for the sustainable competitive position of companies. If a technical system is not accepted by its users, no adoption will normally occur, irrespective of the other technical design or mode of operation, and success will therefore fail to materialize. In addition, decisions have to be made early in the process, although acceptance is still very vague, for example, whether the product development process should be implemented at all. These decisions in turn have a major influence on the subsequent process. There are already some useful acceptance-models, like TAM, but due to their domain-specific orientation [20], they are only conditionally suitable for use in mechatronic system development. Within the product development process, it is necessary, that the framework of the method is already given and the product developer only decides between various characteristics and receives easy interpretable results. This leads to the following, for this contribution relevant overriding research question: How does an acceptance model have to be designed that makes the construct of acceptance accessible to product developers in the early development stages? In addition, it is intended to identify potential acceptance barriers, but also opportunities with this model, which may accompany the product already in the early stage of PGE and enables the developer to derive recommendations for action with regard to the development strategy.

To answer this overriding question, the following sub-research-questions were derived, which at the same time represent the structure of the chapter of results in this work.

- What is the influence of user acceptance regarding connected products on adoption of products from the perspective of product development?
- Which modules are needed to model acceptance of individuals with regard to connected products?
- How to design an overall acceptance model for potential, future users to make connected products comparable within product engineering processes?
- Which recommendations for action can be derived based on the developed model in the ongoing product engineering process?

The procedure for the research work was therefore as follows:

1. Initially, based on literature research and studies relevant acceptance parameters were identified and then transferred to an initial acceptance model.
2. The overall acceptance model was specified by a networking analysis based on expert surveys and converted into a tool. (AMT - Acceptance Modelling Tool).
3. In a case study within a development process at Trumpf GmbH + Co. KG, the tool and the underlying model were continuously evaluated and refined.

4. Results

4.1. Influence of Acceptance on Adoption from the Product Development Perspective

In literature, there is no consensus whether acceptance is part of the dimension of action or whether it is attributed to the adoption process. [29] From a business management perspective, the acceptance initially only includes the readiness for the carry-over, and therefore is only expressed at the dimesion of attitude. The forms differ between acceptance and resistance. The decision of adoption is based on this and located within the dimension of action. It identifies itself by adoption or rejection. It is important to note that, although the willingness to carry-over, forms a base for the adoption decision, however acceptance does not guarantee adoption. [30] In order to make the concept of acceptance accessible to product developers, an approach based on tried and tested models is required. Within this article, the KANO-Model (Fig. 4) proposed in 1984, is used for this purpose. [31] Acceptance is given, when all basic acceptance-relevant needs are fulfilled from the user’s point of view. User acceptance is strongly restricted, if the product does not meet one of these requirements.

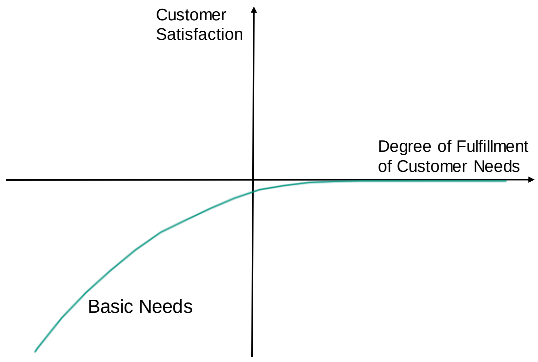

Figure 4. Simplified Model in accordance with KANO [31] – Basic needs represent the influence of Acceptance on Adoption

However, if the acceptance-relevant basic needs are fully met, customer satisfaction will not turn at all into enthusiasm, but only in a neutral attitude [31]. The requirements which are relevant for the respective acceptance, can be divided into the modules of acceptance, which are presented in the following chapter.

4.2. Modules of Acceptance
The construction of acceptance can be based on three modules, the object-, the subject- and the context of acceptance. (see 2.2) Acceptance is always object-related and therefore always focuses on an object as a reference point. Statements concerning acceptance always go hand in hand with the question: Acceptance of what? In principle, the object can be very diverse and may include for example technical products or political opinions. This diversity clearly shows that an acceptance analysis only makes sense with regard to a precisely defined object of acceptance. In the course of this publication, the Object of Acceptance is a connected product to integrate the manual workstation into an industry 4.0 strategy. The subject of acceptance forms the initial point of acceptance. It becomes the focal point by the question: Acceptance of whom? In this context, different characteristics can be distinguished as well. Thus, the subject can include individuals as well as social groups. Within this contribution the relevant subject of acceptance are the user of the connected product. The third module, the context of acceptance, describes the environment in which the subject gets in touch with the object. In principle, it includes all properties that are important for the acceptance process, but cannot be assigned to either the subject or the object. Acceptance is not a synonym for quality, but is rather described and defined by the interaction of the three previously introduced modules. [21] However, these three modules are too coarse-granular to make the construct of acceptance accessible to product developers. Therefore, it is important to describe them with so-called influencing factors. These were developed as part of this research on the basis of literature studies and expert workshops.

4.3. AMT – Acceptance Modelling Tool
The basis of the AMT – Acceptance Modelling Tool (Fig. 5) developed in the context of this contribution, which is strongly oriented towards the TAM - Technology Acceptance Model (See Fig. 3), was derived from the structure of an input-output-model. Heart of the model are the previously identified modules of acceptance and the alternating field they span. All information, necessary for the result of the acceptance process are defined via the input, which is formed by the sum of the influencing factors. The output of the model represents the result of the analysed acceptance process. It comprises the two parameter benefit, which the acceptance subject experiences through the use of the developed product and the change in its external impact within the social group (effect). The ratio of these two indicators reflects the result of the acceptance process.

DAVIS [24] sees the greatest influence on the Attitude Towards Using in the perceived usefulness (benefit). In addition, he attaches enormous importance to the social factors represented by the change in external impact (effect). [28] Due to that, those two quantities describe the output of the AMT.

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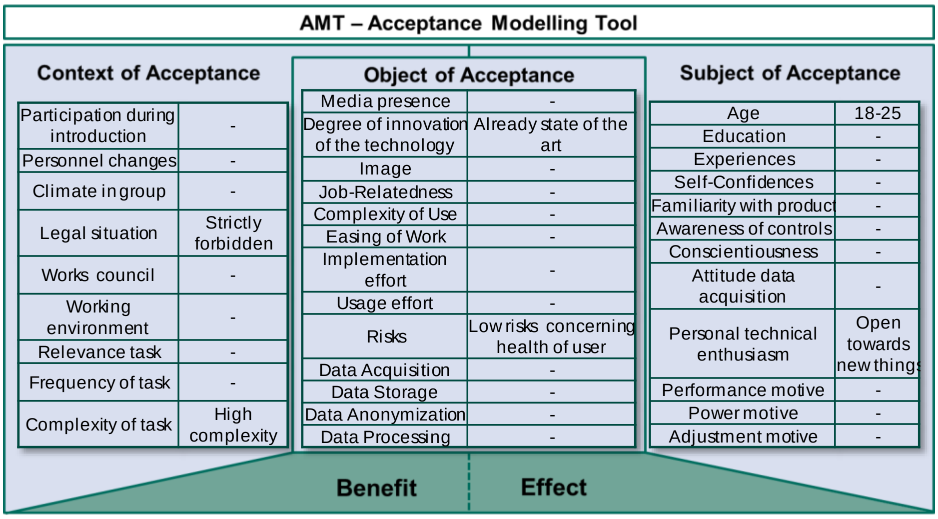

Figure 5. Simplified Overview of AMT, Modules of acceptance and chosen influencing factors, some with exemplary predefined characteristics

For a holistic description of the acceptance modules, various influencing factor were identified on the basis of a literature study [i.a. 25, 26, 27] and an expert workshop. It is important to note, that there are both, generic influencing factors, which are independent of the development context under consideration, and those, which are development context-specific. The tool, which supports the method described in this publication, contains all generic and development situation specific influencing factors and also offers predefined characteristics that the method-user can choose from. To describe the subject of acceptance, three different personae were developed, whose personal characteristics embody extremes (openness, scepticism and indifference) in the form of different user groups to represent potential future users of the developed product in the model. By selecting a persona, the corresponding proficiency level of the various persona-dependent influencing factors is automatically specified. The overall goal of the work behind this publication was to make the complex construct of acceptance quickly and easily accessible to the product developer. Therefore, the output of the model was quantified. The logic described in Section 4.1 has been stored for this purpose. As already mentioned, the user of the tool selects the characteristic of the corresponding influencing factors. Based on this, an assigned value is calculated on the basis of a stored value function. The function is based on the presentation of the basic requirements in the Kano-Model. Since, depending on personal characteristic of the subject of acceptance, different influencing factors also have different influences on the output (benefit and effect) of the model. This is why various persona-specific weightings for influencing factors are stored in the tool. Those weightings are based in an additional survey. Thus, when using the model, quantitative results of the acceptance process are obtained.

The result can be characterized under different aspects with regard to the aforementioned types of acceptance (adoption-acceptance and adaption-acceptance). While adoption-acceptance describes the voluntary adoption of an object, the adoption within the adaption-acceptance only happens because of an external pressure. If the subjectified, i.e. the persona-specific influence of an influencing factor on the output is selected and is compared with the subjectified reference, which is calculated from the persona-specific extremum of the influence-factor, an evaluation in the sense of adoption-acceptance is obtained. In this way, persona-unspecific opportunities and risks can be identified and based on this, object-focused development-priorities can be derived. However, if the subjectified influence is put in relation to the objectified reference, which is calculated from the absolute extreme of the influence over all personae, then it is an evaluation in the sense of the adaption-acceptance. This allows to compare different personae with regard to their acceptance toward the analyzed object, thus subject-specific recommendations for action can be derived.

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4.4. Derivation of Recommendations
Based on the previously evaluated results, recommendations for action have been derived which support the product developer early in the process. In this context, four different fields of action were derived. The first three include the modules described above: object-, subject- and context of acceptance. As a fourth field, general strategies which basically lead to an increase of acceptance have been derived from a survey. In this context it is worth mentioning for example, that an adapted implementation process can promote transparency and thus generate trust. Official quality seals can also build up trust in the object of acceptance, i.e. in the networked system, and in its introduction. Another strategy involves creating additional incentives, for example by implementing a gamification approach. However, if the previously identified development priorities are to be met in a targeted manner, the other three fields of action are relevant. Development context-specific recommendations for action can be derived, if concrete opportunities or risks are identified based on the identified key indicators. For example, if the evaluation of adaptation-acceptance shows, that a persona is unsuitable for the corresponding development context, a change of persona can be forced. This corresponds to a change of the sales market or the place of use. A development potential concerning the context of acceptance is for example the integration of further functions and thus extending the application context. If the object of acceptance - i.e. the actual technical realization - serves as the focal point of consideration, a change in the relevant technology can be aimed at. If, in the course of this consideration, it is analysed that data collection in particular represents the risk, it is recommended that data will be made anonymous or at least be pseudonymised. In the application of the model, further, more concrete measures can be derived based on the opportunities and risks derived from the model, and thus user acceptance can be sustainably increased. It is crucial that the analysis can be carried out at an early stage of PGE. The potential weaknesses and opportunities, which are identified during the process, can thus be addressed as a potential basis for decision-making.

5. Evaluation of AMT in an Innovation Process
The acceptance model was developed as part of the project AIL – Agile Innovation Lab. [18] The focus of the development process, which was held in cooperation with Trumpf GmbH + Co. KG, was set on 'smart manual workstations in sheet metal processing'. Within the innovation process, a system was developed that analyses the work sequence of the operators of manual workstation and thus, among other things, carries out quality control and the necessary documentation. The application in the project enabled the evaluation of the AMT – Acceptance Modelling Tool. The AIL project is structured in time into the phases – Analyze, Identifying Potentials, Conception, Specification, Realization and Release – according to ASD – Agile System Design. [18] The tool was used during the phase of Identifying Potentials for the first time. In this context, the task was to describe the subject- and the context of acceptance initially in a holistic way. In addition, the different product profiles developed during this phase could be evaluated comparably with regard to acceptance by describing the object of acceptance within the AMT. Through the consistent usage of the model in this phase, the profiles and the selection process of these could be optimized with regard to acceptance. The generated insights were used to optimize the model. In the sub-sequent phases, the revised model was further used. In addition, in order to analyse the implemented changes, all previously developed product profiles were evaluated with the new development generation of the acceptance model to validate, whether the changes achieve the desired effect and, in addition the forecasted predictions of acceptance are compliant with the experts' estimates. This iterative approach, which extended over the entire innovation process, enabled the optimisation of the technical solutions regarding acceptance on the one hand and enabled the consequent evaluation of the acceptance model on the other hand.

6. Findings
Within the framework of research on which this publication is based, it was identified, that the result of the interplay between object-, subject- and context of acceptance reflects the result of the acceptance process. In order to model user-acceptance, it is necessary to analyze this interplay

precisely, but as well to quantify the previously gained knowledge regarding the influence of acceptance on adoption in terms of product development. In this context, the approach of the KANO-Model was used. According to this approach user's acceptance of a product is given if all acceptance-relevant basic requirements are met from the point of view of the considered respective user segment. While modelling the acceptance, it was possible to gain insights that the benefit and the effect that the acceptance subject experiences through the use of the acceptance object in a defined acceptance context can be regarded as the acceptance result and thus make the complex construct of acceptance accessible to the product developer. On the basis of various previously identified influencing factors and their characteristics, which are selected according to the development context, key figures could be derived. These support the identification of development priorities. According to this, various recommendations for action were obtained, which can be divided into four different fields. A first area includes common recommendations, which can be applied generally to increase acceptance. The other three areas include recommendations that can be assigned to the three modules of acceptance and eliminate or promote corresponding risks and opportunities. In addition, various alternative solutions can be characterized and compared with regard to the expected user acceptance. Thus, uncertainties that exist in the early stage of the PGE can be resolved and necessary decisions can be made on a sustainable basis.

7. Future Works

To gain a deeper understanding of acceptance, the developed model will be used in further ASD Live-Labs. In the course of this process, further insights, which are necessary for a deeper interpretation of the results, can be acquired with regard to the key indicators. In particular, the acceptance of new technologies is highly dynamic. It will be crucial to continuously analyse, adapt and display the future user and his acceptance. The integration of a monitoring system of acceptance factors and a concept for "intentional forgetting" of assumptions that are no longer current are therefore seen as the next steps during the innovation process.

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