Embedded Toolkits for User Co-Design:
A Technology Acceptance Study of Product Adaptability in the Usage Stage

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Abstract
Recent reviews show large failure rates in the commercialization of new product designs. Often, the reason of failure has been not a lack of technological capability of the firm, but a wrong understanding of customer preferences. Extending the concept of adaptable smart products, our concept of "embedded toolkits for user co-design" proposes to design products with build-in flexibility by embedding knowledge and rules about possible product differentiations into the product. This approach can be seen as a scalable attempt towards "open hardware", extending the open innovation paradigm beyond software towards tangible products. Users are enabled to modify a product directly according to their individual needs. We present a technology acceptance study (TAM) of such an embedded toolkit in an automobile. Surveying 163 users demonstrates the general feasibility and value drivers of embedded toolkits. Our paper contributes to the literature by discussing the contingency factors and the tactical and strategic implications of embedded open toolkits for user innovation.

1. Introduction

Product definition has been shown to be critical to new product success [27]. The critical question in this phase is how to define the product amidst customer and technology uncertainty. User satisfaction (and, thus, adoption) with a new product regularly increases with the degree of fit between a user's needs and the characteristics of a product [44]. Conventionally, the manufacturer tries to understand this causal network with detailed information either acquired via market research or assumed via professional knowledge. Previous research has shown that many companies fail to gather this required input in an efficient and effective way [41]. Despite ever increasing methodological knowledge in market research, new product development (NPD) flop rates continue to rise [25].

Von Hippel [47] has explained the problem of firms to understand what customers really want by the stickiness of need information. Sticky information is context specific and difficult to formalize and transfer. Stickiness of customer (need) information is a function of multiple factors, including characteristics inherent in the information itself, such as the way information is encoded. Customers often use a different language to describe their demands and think in different design parameters than the manufacturer. Thomke [39] found that firms regularly have to change design parameters as the requirements (representing information about the customers' needs) are not stable during NPD. Even in highly specialized industrial markets, customers face an inherent difficulty in accurately specifying their needs at the outset of a NPD project, resulting in a co-evolution of the technological solution with the revision of customers' articulated needs [27]. Research further has shown that familiarity with existing product attributes can interfere with an individual's ability to express needs for novel products [39]. Needs become more refined as users come in direct contact with (a prototype of) a new product.

In this paper, we propose a new approach to accomplish this objective by applying a typical process of user innovation as a form of open innovation: embedded toolkits for user co-design. Embedded toolkits combine user co-creation with the idea of postponing certain design decisions in order to reduce the risk of a product flop. The paper will introduce the concept of embedded toolkits by extending the concept of "smart" products [36]. The focus of our analysis and discussion will be to survey potential users (customers) of the perceived usefulness of the idea of an embedded toolkit. We hence are looking for a "proof of concept" from the user perspective. We present a technology acceptance model that analyses the feedback of 163 consumers on different scenarios of embedded toolkits in the automotive industry.

Our paper contributes to the recent literature threefold. First, we develop the idea of embedded open toolkits, utilizing new opportunities of ICT to increase the adaptability and "smartness" of tangible products. Second, we build a conceptual model of the factors driving the acceptance and value contribution of embedded toolkits form the user perspective. Third, we
test this model empirically with a large consumer sample to get a first indication of the feasibility and the acceptance of the basic concept.

2. Postponement in NPD

A firm's flexibility to adjust the values of the design parameters close to a product's final launch is positively associated with higher perceived quality and firm performance [27, 40]. One way to increase the design flexibility is postponement in NPD. The basic idea of a postponement strategy is “… to intentionally delay activities rather than starting them with incomplete information input” [50, p. 468]. Firms should realize benefits from having better information about customers needs before committing semi-finished product concepts to specific design derivatives. This view contrasts traditional views of NPD project managers to focus early and “freeze” a product concept in order to reduce the complexity and time of development. But this decision can prevent the flexibility to react on changing customer requirements. In such cases, postponement in NPD should allow a firm to respond better to changing technologies or not-yet defined market requirements.

But while conventional postponement strategies have been described as a major approach to design products that better fit to customer requirements, a fundamental problem remains: Conventional postponement strategies do not eliminate the task of a firm to identify and fully understand the user preferences. There is, however, surprisingly little research in the postponement literature on how to access this information – although the capability of postponement to reduce uncertainty in product planning crucially relies on forecasting skills and measures to predict the (potential) customers’ needs. Research only recently has studied the connection between measures to acquire need information and postponement efficiency. But this research remains on the conceptual level [7]. As we have argued above, however, the stickiness of need information often prevents firms to access need information correctly. This observation asks for new methods to access the need information and for empirical research testing the contribution of these methods beyond their conceptual description.

3. Product Smartness by Embedded Open Toolkits for User Co-Design

Our idea to fill this gap is as follows: We want to develop a method which enables customers directly to transfer their needs into an artifact that highly corresponds with their needs. This shall be done not before the product is manufactured, but after the product has reached the domain of the customer.

3.1. Definition

Our concept of embedded open toolkits for user Innovation and co-design builds on shifting some specifications of the product into the domain of the user. This strategy isolates the source of uncertainty, i.e. sticky information about user needs, and wants to place it entirely outside the boundary of the manufacturer. A product with a respective toolkit should hence contain (1) a flexible architecture where the values for each design parameter are not fixed, but adaptable, (2) a set of rules about possible combinations of selection of values for each design parameter, and (3) an interface for individual users could differentiate the product according to their preferences by manipulating the values. Note that our idea is not to configure a product with an internet-based toolkit before it is being manufactured, as typical for a mass customization or build-to-order strategy. These configuration toolkits have already been subject of a rather intensive discussion [23, 35, 48]; and there are many examples of this strategy in practice (e.g., NikeID, Dell, BMW).

In our concept, users shall be enabled to modify the product after it has been manufactured and has reached the user domain. The employment of an embedded toolkit in a product can be regarded as an example of product smartness as defined by Rijsdijk and Hultink [36].Smart products are products that contain ICT in form of, for example, microchips, software, and sensors and that are therefore able to collect, process, and produce information. As a result, smart products show some distinctive capabilities (coined "product smartness" [36]) like autonomy, adaptability, reactivity, multi-functionality, ability to cooperate, humanlike interaction, and personality. Smart products possess one or more of these dimensions to a lesser or higher degree. Embedded toolkits are a further development of adaptability and humanlike interaction. They further can be seen as another attempt towards "open hardware", extending the open innovation paradigm towards tangible products.

The key requirement of this concept is the user interface that allows users themselves to adapt a product according to their own requirements, hence addressing a core characteristic of open innovation with users [21, 22, 47, 48]. It shall equip users with the possible solution capabilities to substitute the lack of professional training and experience. As mentioned above, toolkits previously have been suggested in the literature as an element of mass customization strategies [35]. Here, a manufacturer presents its customers possible options to choose for some
elements of the product specification and enables them to adjust a product to their individual preferences via an interactive interface [48]. These toolkits allow users to design a novel product by arranging and combining design parameters and setting values for them before the product is manufactured [23]. However, once specified, the product could not be adjusted any longer to a changing preference set in the usage stage.

In our concept, the toolkit is being embedded in the product architecture, allowing its real-time modification during the usage stage. Consider the example of a dashboard of an automobile (To illustrate this example, we have placed a video with a mock-up prototype of this potential application at http://youtube.com/watch?v=eZU391qlIA). A conventional interface allows the user just to interact with the car and to control specific predefined functionality (as demonstrated in the first segments of the video). In our approach, the user interaction could go much further. She could design the layout of the dashboard, the functions accessible by it, and also parts of the performance controlled by the customized dashboard (as demonstrated in Min. 3:05 and later in the video). Still, all functionality would stay within the safety requirements of the system and would allow full interface functionality with the rest of the car. Obviously, such a solution has much larger opportunities for users to find an exact product fitting to their needs, but demands much larger requirements in designing the solution space of such a flexible system. As demonstrated further in the video (last segment), the modifications of a user could be transferred to the manufacturer during a service check, providing input for the development of future product generations.

3.2. Existing examples

An example of present products with embedded toolkits is the "Adidas 1", a running shoe. To embed flexibility, the shoe is equipped with a sensor, a system to adjust the cushioning, and a microprocessor to control the process. When the shoe's heel strikes the ground, the magnetic sensor measures the amount of compression in its midsole and the microprocessor calculates whether the shoe is too soft or too firm. Then, during the seconds the shoe is airborne, a tiny motor shortens or lengthens a cable attached to a plastic cushioning element, making it more rigid or pliable. Each shoe also has a small user interface that allows for manual adjustments of the product, allowing users to trim the computer's decision to personal taste.

Another example of a product that is adaptable during its usage stage to its user's preferences is Bug Labs's open hardware development system made of sensing and input modules that snap into a low-cost central Linux-based core, allowing a user to mash up her own gadget. The toolkit here comes in form of a rather complex development platform on the base of Eclipse. While probably not a product for the general public now, it strongly demonstrates the trend (buglabs.net).

A last, more advanced example of an embedded toolkit provides Lutron Electronics, a leading manufacturer of residential and commercial lighting controls and systems [35]. During a strong phase of growth in the 1980s, the company faced strong challenges of an exploding product variety, increasing the NPD. At one point, a rather simple dimmer product was offered with 40 base model numbers and over 300 variants in retail to accommodate different wattages, voltages, lamp types, and colors. This proliferation caused the company to radically redesign its product architecture and to postpone the differentiation in the user domain. Its GRAFIK Eye product incorporates in one product the solution space of the 300 variants of its predecessor. The micro-processor controlled product comes with a simple interface that allows simple and quick modification of the user according to the individual needs. It also substitutes variants which before were the result of a custom engineering process. A core element of Lutron's approach is an easy-to-program interface of its products. Both the initial specification for a particular environment and the continuous adjustment can be easily performed by the user, based on an interface that supports the trial-and-error problem solving approach. To define the range and possibilities of built-in adaptability, Lutron evaluates custom specifications developed for individual customers in a conventional engineer-to-order system. These products, however, are the result of an expensive iterative specification process between customers formulating requests and corporate developers interpreting and transferring these requests in a custom design [47]. While such a process sometimes is required for complex commercial lighting solutions, Lutron learned that over time it could include most of these differentiations into an adaptable product, equipped with an embedded toolkit that allows users to make these modifications during the usage stage.

4. A User Acceptance Model of Embedded Toolkits

Apart from the technical realization and the degree of innovativeness that this method could deliver, it is essential that users are willing to accept an embedded toolkit. Do users regard the concept as useful at all? Would they be willing to purchase a product with such
a toolkit? Which drivers would foster the adoption of this concept?

4.1. Model development

In order to investigate the level of acceptance among potential users, we conducted a survey in the domain of the automotive industry. The survey's objective was to explore the acceptance of car owners towards an embedded toolkit with build-in flexibility to enable drivers to differentiate their vehicle according to their personal preferences. Our starting point is the Technology Acceptance Model (TAM) originally developed in the information systems literature [15, 16]. Recently, this approach also has been applied in the marketing literature to investigate the acceptance of certain self service technologies [13]. In its basic version, the TAM consists of two conceptually independent determinants of a person's attitude towards using a new technology: perceived usefulness (PU) and perceived ease of use (in our model coded as a reverse construct perceived complexity of use (PCOU)). PU refers to the degree that using a system will improve users' performance in fulfilling a certain task. These perceptions influence consumers' attitude towards the system and their intention to use it. TAM posits that PU is only partially mediated by attitude and also has a direct link to a usage intention [16]. PCOU is expected to influence attitude as well, because the more complex a technology is to use, the more likely it is that the customer has a negative attitude towards that technology. Previous literature has modified the basic TAM by the process related construct of perceived enjoyment (PE) [8, 17] to capture the benefit of using the technology, independent from any outcome related benefit. Subsequently the following hypotheses will be put forward.

**H1**: Customers’ intention to purchase a new product with an embedded toolkit is (a) positively influenced by perceived usefulness, (b) negatively influenced by perceived complexity (both directly and indirectly through perceived usefulness), and (c) positively influenced by perceived enjoyment.

We further want to investigate the antecedents of perceived usefulness. As stated before, in our case PU refers to the degree that using an embedded toolkit will improve a car’s fit to the preferences of its user. It can be assumed that the perception of usefulness depends largely on the degree of satisfaction with the current product. The better the current vehicle meets the needs and expectations of the user, the less likely it is that the user will deem an embedded toolkit useful. Hence:

**H2**: Satisfaction with the current product has (a) a negative effect on customers’ intention to purchase a new product with an embedded toolkit and (b) a negative effect on perceived usefulness of an embedded toolkit.

The degree of product satisfaction results from several underlying factors. In the context of preference fit, it is conceivable that the product capability, meaning the entity of all functions and features embedded in the car, has an influence on the level of satisfaction. Feelings of satisfaction arise when consumers compare their perceptions of a product’s performance to their expectations [30]. Therefore it can be assumed that a lack of certain features or functions will lead to a lower level of overall product satisfaction.
for the users. On the other hand, as technology advances, more and more features become available and users might load their products with a large number of features, each of which individually might be perceived as useful. The sum of all features, however, can make a product too overwhelming and too difficult to use for the user. Consumers may give more weight to capability and less weight to usability before product purchase and may tend to choose overly complex products. Such an overload might lead to so called “feature fatigue” and a reduced level of satisfaction [42]. A third antecedent for product satisfaction could be the degree of customization that a user has invested into a product before purchase. Similar to the idea of Guilabert that a product may be deemed useful as it is perceived as highly customizable, it will be assumed for this study that users will be the more satisfied with their current vehicles the more effort they put into customization before the purchase [24]. Subsequently the following hypotheses will be put forward.

**H3:** The effect of perceived product customization is (a) positively related to satisfaction with the current product and (b) positively related to perceived usefulness of an embedded toolkit.

**H4:** The effect of perceived product capability is (a) positively related to satisfaction with the current product and (b) positively related to perceived usefulness of an embedded toolkit.

**H5:** The effect of perceived feature fatigue is (a) negatively related to satisfaction with the current product and (b) positively related to perceived usefulness of an embedded toolkit.

### 4.2. Measure development

Figure 1 summarizes the previous discussion and shows the conceptual model of our paper. To test this model, a measurement instrument was developed. Purchase intention was measured by two items on five point scales, i.e. "How likely is it that you will buy a car with an "embedded configurator" from your favorite manufacturer/ from another than your favorite manufacturer?" anchored very unlikely-very likely [32]. Items to measure the perceived complexity of use and the perceived enjoyment of the embedded toolkit were adapted from existing TAM measures of perceived complexity [43] and perceived enjoyment respectively [8]. The TAM literature recommends to develop domain specific measures for perceived usefulness [14]. Hence we conducted qualitative interviews with ten experts from automotive industry. We asked them to list all potential adaptability options an embedded toolkit could provide in their opinion. Adaptability options that were more or less identical or referred to the same subsystem were grouped [16, 19]. We ended up with eight items asking for the usefulness of adapting the following car subsystems: cockpit, seats, ambience-system, electronic control units, communication and infotainment services, chassis, engine and body. Contrary to the predominant “Churchill paradigm” of reflective construct development [10], we hypothesize our measure of perceived usefulness to be formative meaning that the items describe and define the construct rather than vice versa. The discussion of the decision rules put forward by Jarvis et al. with experts clearly pointed to a formative specification of the construct perceived usefulness [28]. It is comprised of the usefulness of the adaptability options, which have been to be different and independent in the experts’ opinion. Dropping one adaptability option was felt to change the usefulness of the embedded toolkit. Due to the different nature of the adaptability options, their inter-correlations in terms of perceived usefulness were expected to be rather low.

For the items concerning the level of satisfaction with the current vehicle and its feature load measures were adapted from existing literature as well. Overall satisfaction was measured by one item on four different seven point scales, i.e. "How do you feel all in all with the features and vehicle characteristics of your current car?" anchored very satisfied - very dissatisfied, very pleased - very displeased, contented – frustrated and terrible – delighted [31]. The three items used to measure the product capabilities as well as the four items used to measure the feature fatigue phenomenon were adapted from Thompson et al [42]. The measures concerning the perceived product customization were developed following the items put forward by Guilabert; six items were formulated for this purpose [24]. Due to space restrictions, the full list of scales is available in an online appendix to this paper (http://tinyurl.com/lmhukt), consisting of a copy of the original survey instrument used for this study.

### 4.3. Data collection and sample composition

We collected survey data with an online questionnaire targeted to owners of passenger vehicles. Respondents were recruited using various mailing lists of associations and by posting a report about the study and a link to the online survey to various online forums and discussion groups. While such an approach is not representative, it is adequate given the exploratory nature of our study [3, 9]. As an incentive for participation the respondents could enter a prize
drawing for an Apple iPod. This yielded a response of 163 usable questionnaires. 22.8% of the sample was female. The average age was 33.6 years. 42.6% of the sample has had a technical education and 35.8% actually work in a technical profession. 21.6% of the sample has already made modifications to its respective vehicles. Non-response bias was assessed by verifying that early and late responses were not significantly different [3]. This test was applied to the demographic characteristics and all principal constructs. t-Test comparisons between early and late respondents showed only insignificant differences (p>0.1).

The survey instrument consisted of three parts. In the first part, respondents were introduced to the concept of embedded toolkits in the automotive environment. Given the early stage of our research, the embedded toolkits were presented in form of eight scenarios, consisting out of text and visual renderings, as typical for this type of concept testing with users [14, 24, 34]. Each scenario described a range of adaptability options that an embedded toolkit could provide in an automobile. Respondents should assess characteristics of the scenario such as the overall usefulness of the toolkit, the expected complexity of use, and the expected enjoyment of using such a system. For a full description of all scenarios, refer to the online appendix to this paper at http://tinyurl.com/1mhukt. In Part 2 of the questionnaire, respondents were asked to indicate their perceived level of satisfaction with their current vehicle, expressed by the perceived product customization, the capabilities, the feature fatigue, and the overall satisfaction with their current car. In the last part, personal traits of the respondents were surveyed, i.e. technical expertise, purchasing habits and socio-demographic background.

5. Analysis

We first tested the specification hypotheses for our proposed usefulness measure. We applied the vanishing tetrad test to statistically determine the appropriateness of formative vs. reflective measurement models for perceived usefulness [6]. This test is supplementary to the necessary substantial reasoning we conducted in the measure development stage. As formative measurement models do not imply any vanishing tetrads, each test was based on the indicator co-variances implied by a reflective measurement model. A significant test statistic suggests that the model implied vanishing tetrads are not zero and should raise concern about the model’s validity. The results of the tetrad test support our hypotheses of perceived usefulness as a formative construct.

Exploratory factor analysis for the seven reflective constructs confirmed the factor structure; extracted factor variances ranged from 72-91%. All item-to-total correlations were above 0.5, reliability analysis revealed Cronbach’s alphas ranging from 0.79 to 0.92. Confirmatory factor analysis (CFA) results were obtained using PLS together with estimating the structural model. All factor loadings exceeded 0.6 and were highly significant. The resulting factor reliabilities ranged from 0.87 to 0.97 and the average extracted variances ranged from 0.62 to 0.91, thus being above the required thresholds of 0.6 and 0.5 respectively. To confirm discriminant validity among the constructs, the square root of average variance extracted was compared with the intercorrelations. The former was found to be greater than the latter for each construct, thus confirming discriminant validity.

In assessing formative constructs, aspects other than internal consistency or reliability are critical; i.e. (1) content validity, (2) item cross loadings, and (3) indicator multi-collinearity [18, 33]. (1) In the section developing the measures, we specified the content and indicators of perceived usefulness based on experts' categorizations. (2) While Rossiter argues that construct and discriminant validity can only be established by these conceptual methods [38], other researchers have argued that even formative constructs should converge in the presence of other constructs [1]. Hence, we followed the approach by Agarwal and Karahanna and checked whether the formative indicators of perceived usefulness loaded higher on their own construct than on other constructs, i.e. whether own loadings are higher than the cross loadings [1]. We found this to be the case for all formative indicators. (3) In terms of reliability of a formative construct, it is warranted to check for indicator collinearity. The highest Variance Inflation Factor for perceived usefulness was 1.73, thus beyond the threshold of 10. Table 1 shows the respective loadings for the perceived usefulness indicators as well as their t-values and significance.

In order to test our hypotheses, we need to estimate the structural model consisting of the regular TAM constructs and the added constructs related to customers’ perceptions of their current product. With perceived usefulness being specified as a formative construct, a decision arises about the appropriate estimation technique for the structural equation model (SEM). We choose variance-based SEM and partial least squares (PLS) estimation over covariance-based SEM and maximum likelihood (ML) estimation. Our main argument for this choice is based on the identification of formative measurement models in variance-based SEM.
Table 1: Formative indicator weights for perceived usefulness

<table>
<thead>
<tr>
<th>Perceived Usefulness indicator referring to …</th>
<th>Estimate</th>
<th>t-value a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>… cockpit</td>
<td>0.348</td>
<td>3.551***</td>
</tr>
<tr>
<td>… seats</td>
<td>0.127</td>
<td>1.463 as</td>
</tr>
<tr>
<td>… ambience-system</td>
<td>0.057</td>
<td>0.650 ns</td>
</tr>
<tr>
<td>… electronic control units</td>
<td>0.276</td>
<td>2.639***</td>
</tr>
<tr>
<td>… communication and infotainment services</td>
<td>0.168</td>
<td>1.832*</td>
</tr>
<tr>
<td>… engine</td>
<td>0.168</td>
<td>1.819*</td>
</tr>
<tr>
<td>… chassis</td>
<td>0.390</td>
<td>4.615***</td>
</tr>
<tr>
<td>… body</td>
<td>-0.067</td>
<td>0.788 as</td>
</tr>
</tbody>
</table>

Notes:
***: p<.01; **: p<.05; *: p<.1; (ns): not significant; two-sided test
a) obtained from bootstrapping re-sampling with 500 samples and sample size 120

A necessary identification condition in covariance-based SEM is that the formative construct perceived usefulness must emit at least two paths in order for its residual error to be identified [29]. These paths can lead to either (a) two theoretically appropriate reflective indicators (MIMIC specification, (b) one reflective indicator and one latent construct with reflective indicators, or (c) two latent constructs with reflective indicators. Unfortunately, in our model perceived usefulness only emits one path to purchase intention and we do not have reflective usefulness indicators in our data set. Other advantages of PLS over ML estimation refer to distributional assumptions and required sample sizes. First, PLS does not rely on the assumption of normal distributions for the measurement items [20]. This assumption is not met in our data as indicated by Kolmogorov-Smirnov tests. Second, PLS is applicable even under conditions of small sample sizes [9]. Finally, our research has an exploratory nature especially with respect to the antecedents of the usefulness of embedded toolkits, because perceptional and attitudinal theories have not yet been extensively developed and applied in the context of smart and adaptable products [36]. It has been argued that variance based SEM is particularly well suited for theory development, because of its focus on predictive power of a model [9, 49]. All in all, this led us to estimate the model using variance-based SEM and PLS estimation, as offered by the statistics software package SmartPLS 2.0 [37]. Figure 2 shows the results for the structural model.

The results clearly confirm the structural model and all hypotheses; all the hypothesized paths are significant. Perceived usefulness is the strongest predictor of purchase intention with a total effect of 0.363 followed by perceived enjoyment with an effect of 0.350 and customized product attachment with a total effect of 0.217. As hypothesized, perceived complexity of use and the overall product satisfaction both have a negative impact on the purchase intention; complexity has a direct effect of -0.124, whereas satisfaction has a direct effect of -0.130. However, both constructs have a rather strong indirect effect on purchase intention through the perceived usefulness construct (-0.396, -0.314).

The feature fatigue construct shows the
expected results as well: It has a negative influence on product satisfaction with an effect of -0.187 and a positive effect of 0.145 on the perceived usefulness. Concerning the product capability and the perceived product customization very interesting observations can be made: Both constructs have a positive effect on product satisfaction (0.258, 0.243), as well as on the perceived usefulness (0.244, 0.199), even though product satisfaction has a negative impact on the usefulness. This result supposedly shows that there are two different mindsets concerning the influence of the level of satisfaction with the current product on the perceived usefulness of purchasing a new product with an embedded toolkit: On the one hand there are customers that have highly customized products with many features. The product meets their needs and the level of satisfaction is high as well and therefore they do not deem an embedded toolkit useful, as they already have reached a high level of satisfaction. On the other hand there are customers that already showed an interest in customizing products, because they have a highly customized product with lots of features. These customers still consider an embedded toolkit to be useful, because such a system would enable them to customize their product even more and better manage the variety of features their product offers.

6. Discussion

Our research demonstrated the general acceptance of embedded toolkit for user co-design among customers. Embedded toolkits hence may complement the existing array of information technologies supporting open innovation. We also could outline the antecedents of a possible purchase intention of a product with an embedded open toolkit among customers. The strong influence of the enjoyment construct and the positive effect of perceived product customization on the perceived usefulness show that the experience of customizing the product with the help of an embedded toolkit itself might be a reason for purchase intention. Customers obviously perceive the process of using the embedded toolkit as entertaining or amusing and would be willing to purchase the toolkit based on hedonic reasons.

Another main driver of purchase intention seems to be dissatisfaction with the current product. Customers are often not contempt with their current product (car) and its feature load. This dissatisfaction might be due to an overload of features and the resulting feature fatigue, but it also could be the result from a lack of preference fit. In both cases, an embedded toolkit seems to be a viable solution for the respondents. Those customers that are overstrained by the feature load could use the embedded toolkit to reduce the number of features, whereas the other users could use the toolkit to create a feature configuration that better suits their preferences and needs.

An astonishing high number of 22% of the respondents reported that they already have made modifications to their current car without the opportunities that an embedded toolkit could offer. Assuming that more people would be willing to make modifications to their vehicles with an embedded toolkit at hand and considering those people that would like to use the toolkit to reduce the feature overload that they experience, it can be stated that a relatively large percentage of the drivers would be willing to use an embedded toolkit. However, the strong negative influence of perceived complexity on the perceived usefulness and the purchase intention shows that the interest in an embedded toolkit can only be assumed for a toolkit that is not too complex to use for the customers.

The result of this study should also be regarded as a customer request for more open systems in the domain of tangible products. Even though there seem to be different motivations, users are obviously interested in products that offer the possibility of differentiating a product during the usage stage. Hence, industry needs to catch up to these demands and develop respective open hardware architectures and supporting systems to allow for their modification also for non-expert users. This paper offers manufacturers interesting results as a starting point for such an endeavour, especially for the automotive industry. Using a formative perceived usefulness construct, we actually could point out those subsystems where customers expect the largest value from an embedded toolkit (refer again to Table 1). Adaptability of the chassis, the cockpit, or the electronic control units seem to be especially interesting for the users. The perceived usefulness for an embedded toolkit with influence on the engine or the communication and infotainment services was still significant, but not as strongly pronounced as the former sub-systems. The result showed no significance for the seat subsystem and especially for the car body and the ambiance system. These findings can be a starting point for further evaluations in the automotive industry.

7. Limitations and Further Research

Certainly, our study has several limitations. First of all, further research has to strive for generalizations. The proposed results need to be cross-validated in other product domains beyond the automotive industry. Also, the PLS method is not without criticism. Its ability to fully account for measurement error depends on the "consistency at large" condition for reflective
constructs and is not given for formative constructs. Future research would clearly benefit in terms of rigour if the facets of utilitarian customization value were operationalized by multi items measures and covariance-based SEM would be used to estimate the structural paths. The advantage of consistently accounting for measurement error has to be outweighed by the greater burden placed on respondents in answering the multi item scales. Another limitation is that our study has been scenario based. Further research conducted by the authors such strives in realizing a real set of working prototypes with toolkit features embedded. This would allow a real test-in-use and piloting of the concept.

But despite these limitations, we believe that our paper contributes to the recent literature. To our best knowledge, it was the first attempt to develop and test a comprehensive structural model of the concept of embedded toolkits as part of smart products. Our study was focused solely on the customer or user perspective. Further research has to take the perspective of the manufacturer into account. Assuming from our data that customers generally accept an embedded toolkit, further research needs to show that the realization of embedded open toolkits could be a valuable source of customer need information for the manufacturer. Beyond technical questions like how to build an embedded toolkit and implement it as an open subsystem into a product, further research needs to prove that customer need information retrieved by the application of embedded toolkits is different or more valuable than the insights from established market research methods. Realizing the concept of embedded toolkits will most likely cause additional cost and effort for a manufacturer and this effort needs to be balanced out with an increase in customer need information. Future studies in the domain should investigate whether the embedded toolkit concept can deliver that increase in information in order to pay back for the additional effort that its realization causes.

References


