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INVESTIGATING USAGE DATA SUPPORT IN DEVELOPMENT PROCESSES - A CASE STUDY

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Abstract

The design of new product development processes which integrate customer perspective promises great potential regarding rising volatility of external influences, shorter product life cycles and exponential technological advancements. However, the collection of data places great demands on organization's resources and is only useful, if the data collection can ensure adequate quality. Product-Service Systems are a promising approach to collect usage data during their operational phase. A case study was conducted to provide insights to serve as the basis for an information management concept that aims to integrate usage data into design. The observed development process was documented and reconstructed, to identify factors influencing the use of data and information as well as questions that arose during the development project that could be answered by providing usage data. The findings imply that accurate usage data should be provided as early in the development process as possible and that the creation and distribution of information from usage data must be controlled. The proposed concept is designed to meet these requirements by establishing a demand driven information market.

Keywords: Case study, Design process, Knowledge management, Product-Service Systems (PSS)

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1 INTRODUCTION

In an environment of rising volatility of external influences, shorter product life cycles, increasing global competition and exponential technological advancements, product development and the underlying process are more important than ever (Edmondson and Nembhard, 2009; Nijssen and Frambach, 2000). The associated challenges and the struggle to compete demand a transformation of traditional product development approaches. In this regard, the design of product development processes that successfully integrate customers in a democratic manner, through shared decisional power, has great potential. By putting the customer at the centre of the process and actively addressing their needs and problems, improved products as well as new product ideas can emerge. Consequently, these products exhibit a higher probability to offer a distinguished customer experience and therefore to succeed on the market (Fuchs and Schreier, 2011; Hoyer et al., 2010).

However, the endeavour to adequately integrate customers in the development process comes with its own challenges. The collection of data through customer surveys, open innovation programs and test trials is costly and can result in subjective insights. Customer surveys for instance, are often conducted in environments abstracted from the natural interaction between customer and product and thus fail to provide accurate information on the customers' real mind-set and behaviour (Greenberg, 2010). Moreover, the collection of sizeable survey samples or active participants, in the case of open innovation programs or test trials, which also represent the entirety of the target market, raises additional problems. Customer usage data can mitigate some of those problems by offering a more objective perspective on product use, as well as the possibility to identify patterns, unrecognized by non-data driven methods. In the realm of software, the collection of vast amounts of customer data is already used widely for product improvements and the creation of new business models. However, for the development of physical products the use of customer data seems to be comparatively more time and resource intensive. To which degree data can be collected depends on the particular product type. The collection of data on the usage of physical products demands the integration of sensors, data repositories and data transmission technologies. This in turn aggravates an adjustment or change of the collected data, since a recall or refit of the respective machine or vehicle would be necessary, whereas for software a comparatively uncomplicated update is sufficient. Therefore, product-service systems can be seen as a way to enable the targeted gathering of usage data in the context of physical products. Product-service systems combine product and service components, where the product component may consist of mechanical, electronic and software components (Schenkl et al., 2013). A manufacturer of fabrication machines, for instance, can offer a maintenance agreement for a delivered machine. Within the scope of the maintenance, the transmission of data on the machine usage and condition can be agreed on. Using this data, the need for maintenances and repairs can be assessed and consequently improve the durability and productivity of the machine. The data can then be further used by the manufacturer, for instance to investigate load cases applied in practice. Based on the data, for example over-specification of components such as engines can be identified and new, cheaper options can be offered to customers. For optimal use, the right quality, right granularity and time of delivery of such data must be ensured (Krcmar, 2015).

To evaluate these theoretical connections, a case study in the scope of a student development project was conducted. Within this case study, the design process of the student team has been reconstructed and analysed. Specifically, occurring questions regarding customer behaviour and the technical design of the product in development have been documented. Accordingly, iterations caused by the lack of data to answer these questions have been recorded and evaluated. Finally, internal and external factors influencing availability and utilization of usage data have been identified at different points during the design process. The case study findings built the foundation for the development of an information management concept that aims to support the integration of customer usage data in processes for the design of new products within the scope of existing offerings.

The remainder of this paper is structured as follows: Section 2 contains a short analysis on the theoretical background of information management systems, usage data and their respective influencing factors. The findings of the case are presented in section 3. In section 4 these findings are discussed and the information management concept is introduced. Finally, the paper is concluded with a short summary and implications for practical applications and future research in section 5.

2 METHODOLOGY

The student development project examined in the case study was performed in a six-month timeframe in 2016. The project was conceived as an agile product development process and focused on the integration of innovations in an automotive vehicle through the creation of intelligent interfaces. Further emphasis was put on the adaption to the intensification of individualisation and digitalisation trends in the automotive industry. The project team was instructed to use and adjust agile methods to create an iterative, highly customer oriented process. The number of students working on the project fluctuated between nine and ten, mostly from an engineering background. The study was organised as a single longitudinal case study, since the case was examined on more than two points in time, with an emphasis on the underlying processes along the time dimension (Yin, 2014). To ensure high data quality, several methods (Table 1) were used to collect data, enabling the inclusion of data at different points in time from multiple sources on different topics. (Runeson and Höst, 2009).

Table 1. Data collection methods

Data collection methods	Source	Time dimension	Topic
Observation	Author	Continuous	Process; Information demand
Photo documentation	Scrum board	Per board update	Process, Activities
Protocolling	Project team	Per team meeting	Process
Individual survey	Individual member	Weekly during first milestone	Process, Information demand; Iterations; Influencing factors
Sprint documentation	Project team	Per sprint after first milestone	Process, Information demand; Influencing factors
Event triggered survey	Individual member	For every iteration	Iterations
Interview	Individual member	Once per milestone	Usage data, Influencing factors
Evaluation of project artefacts	Documents, Photographs and Videos created by project team	Once per milestone	Process; Information demand
Data map	Team member doing research on this topic	Once at the end of the project	Usage data

The collected data was then analysed to reconstruct the development process, identify and examine the occurring *questions*, resulting *iterations*, and *influencing factors* as well as to assess the hypothetically available usage data. On this basis, the potential support of usage data for the development process was evaluated to subsequently develop the information management concept. In total, seventy different influencing factors were examined. In this paper only the factors that effected data integration are presented.

3 THEORETICAL BACKGROUND

3.1 The management of information

Information management systems (IMS) help organisations to evaluate and utilise information. For this purpose, information is defined as analysed data, consisting of structured facts in a meaningful context (Dalkir and Liebowitz, 2011). In IMS, information is treated as a resource to obtain the intended business goals, its central purpose is the creation of an information market and the harmonisation of the information demand and supply (Krcmar, 2015). The context of customer oriented product development processes (CPDPs) brings about serious difficulties for the harmonisation of the market sides. CPDPs include a multitude of activities with strong relations to a high and very dynamic information demand. On the one hand the constantly changing, often heterogenic and complex customer needs must be investigated, (Hauser et al., 2006; Hoyer et al., 2010) whilst on the other hand product development processes are exposed to an environment of ever changing market, competitive and technological influences (Edmondson and Nembhard, 2009). All these factors play an important role in the definition of the information demand. The dynamic nature of the information demand thereby increases the probability that the requested information is allocated too late, inaccurate or obsolete at the time of delivery. These circumstances also influence the availability of information sources, which is strongly dependent on the development status of communication technologies and the ability of customers to express their wishes, preferences and future needs (Hoyer et al., 2010). Consequently, such downfalls can lead to a decreased ability to quickly respond to changes in the CPDP. The setup of a functioning

IMS supports the creation of valuable knowledge for the use in CPDPs in this regard. Information becomes knowledge, when it is useful, applicable and meaningful and therefore evokes an individual or collection learning effect (Dalkir and Liebowitz, 2011). A promising way to satisfy the demand through reliable information and hence support the setup of a functioning IMS is the employment of customer usage data.

3.2 Supporting the information management of customer usage data

Up to this date no universal definition of customer usage data emerged. Most of the time the collection and analysis of data on user behaviour is put in a larger context of customer data, data mining or "Big Data" (Awazu et al., 2009; Fan and Bifet, 2013; Linoff and Berry, 2011). In what follows, customer usage data is defined as data that gives information about how a product is used. One should apply the same characteristics of customer related data to customer usage data, whilst remaining mindful that customer usage data has its own unique characteristics that must be accounted for.

In general, data must be put into context so it becomes meaningful and can be used as information. For example, numbers representing a monetary value are data, however they only become useful when put in the context of a currency. This implies that from the vast amount of customer usage data useful information has to be extracted by established means such as statistical and mathematical methods, machine learning or artificial intelligence. In so doing the dataset is searched for hidden patterns, associations, changes and other significant structures (Krcmar, 2015; Liao et al., 2010; Ngai et al., 2009).

Customer usage data finds increasing application in many areas. The automotive industry for example, places ever more emphasis on customer usage data-driven analyses. Many manufacturers integrated a broad set of sensors in their models that are constantly transmitting data. A study of the General German Automobile Club (ADAC) identified a myriad of data transmitted from the examined vehicles. Collected data included GPS locations, speed, address information from connected smartphones and configurations of sitting positions. All of which can be used to deduce information such as driving behaviour, user profiles or number of different drivers (ADAC, 2016). The car manufacturer Tesla equipped their model S Sedan 2012 with an always-on internet connection. In combination with several sensors, Tesla can collect data on the driving behaviour and traffic conditions that their customers are subjected to, in order to test Tesla's system for autonomous driving (Simonite, 2016).

The main advantage of customer usage data for the integration of customers in the development process and the information market can be seen in its objectivity. The analysis of quantitative data forms the foundation for more accurate predictions and effective decision-making. This is especially valid for divisions of an organisation, which have so far often been dominated by intuition and "gut feeling". Despite the ability of experienced decision makers to identify patterns and connections, there is great potential to improve management practices through the employment of objective information (McAfee and Brynjolfsson, 2012; Pfeffer and Sutton, 2006). For a successful integration of customer usage data in the information management system an appropriate process environment must be in place. The process environment for an optimal use however is determined by a series of influencing factors.

3.3 Influencing factors on the employment of customer usage data

The literature search resulted in the identification of fourteen factors with an assumed influence on the employment of customer usage data in CPDPs. These factors refer to the elemental technological premises, the supporting knowledge base and the influence on the productivity of the customer usage data employment.

The development statuses of internally and externally available technologies (Thamhain, 2003) as well as the product architecture (Langer and Lindemann, 2009) are hereby seen as the elemental technological premises, since sensors, data transmission media, processors and data storages build the foundation for the data collection. Beyond this foundation, the knowledge base of the project team determines the quality of the data collection.

The knowledge base on agile development and the use of corresponding methods affect the effectiveness and efficiency of the customer integration and thereby promote the potential of the data support due to a better evaluation of the needed data. The availability of further training in the relevant research topics can lead to an improved knowledge base (Kalus and Kuhrmann, 2013). A high functional diversity (Edmondson and Nembhard, 2009) is an additional supporting factor in this sense; offering a broader array of perspectives enhances the ability of the project team to understand customers, which helps to define the needed data.

Whether the employment of customer usage data can fundamentally deliver the expected results while showing an adequate productivity, is however less determined by the actual data collection and analysis, but rather by the context of the development project. The degree to which customers can be integrated in the process (Ili et al., 2010) is the most relevant factor in this regard. The potential to use customer data as a primary source for idea generation strongly increases the utility of the employment of customer usage data. If additionally, user related trends (Ili et al., 2010) have some influence on the development process this utility further increases. Also, important for data employment are the influence of the target market's demography (Langer and Lindemann, 2009), social norms (Langer and Lindemann, 2009) and the availability of potential customers willing to cooperate in the development process (Kalus and Kuhrmann, 2013). The higher the influence of the target market's demography, the more useful the data enabled observation of customer lifestyles becomes. Furthermore, social norms can be partially determined by usage data, but conversely restrict usage data employment, for instance through customers' potential fear of surveillance or attitude towards data ownership. A meagre availability of potential customers willing to cooperate in the development process gives the data support even higher importance, because the employment of customer usage data doesn't demand a direct customer interaction.

4 CASE STUDY FINDINGS

4.1 Process

The development project was organised in three phases and included the work on six different product concepts, from which two were pursued until the end of the project. These two concepts were able to fulfil the articulated goals. The corresponding milestone goals for the first phase were the determination of a product idea, the initial development of three to five prototypes as well as the formulation of a use case. The second phase should subsequently be used to generate a user story and generate two to three product concepts, before the actual realisation of the functioning prototypes, thoroughly tested with potential customers, and the development of associated business models was to take place in the third phase. Hereby a user story constituted a narrative and visual depiction of the product use.

During the process, the intended customer orientation appeared as the most serious problem, whilst the customer testing of the formulated assumptions caused severe difficulties. The most problematic issue seemed to be reaching the full potential from customers for customer surveys. On the one hand the project team found it difficult to define a suitable customer group. Whilst on the other hand, the team also found it difficult to specifically address these customers. Moreover, further problems with the use of the chosen methods emerged, so that in some cases methods were used, which were not suitable for the collection of the intended information. At times, the project team was unable to communicate the product concepts to the surveyed potential customers in an understandable fashion. These problems accumulated in such a way that the quality of the collected data couldn't manifest a sufficient quality.

4.2 Information demand

The intended customer orientation is also reflected in the articulated information demand during the process. 61% of the 228 recorded questions can be attributed to development of a user and driving profile, and therefore to the customer orientation efforts. These questions primarily originated in the use of customer integration methods. The main part of the questions occurred in the first phase, whilst about 20% emerged in the second and third phase. In total the information demand referring to the customer orientation not only made up the quantitative majority, but also developed the greatest impact on the on-going process.

The second substantial part (25%) of the overall information demand was related to the realization of the product concepts. The majority of these questions addressed the actual technical implementation and occurred mainly towards the end of the project. Even though the information demand referring to the realisation of the concepts builds the second largest group by quantity, it developed a far lower impact on the process than the very few questions on process organisation and methods.

In a general sense, the project showed that in the early phases primarily universal information is demanded. The more the process progresses however, the information demand becomes more and more specific, since the product concepts are evermore concretised. This also seems valid for the questions regarding the customer integration. In the beginning, the personalities, personal circumstances and real driving behaviour were the main interests. Later on, the project team focused on specific customer needs and problems, for instance if customers prefer haptic buttons or touchscreens as method of control.

4.3 Iterations

The project team performed 31 iterations during the development process, from which most were connected to several raised questions or even triggered by an uncovered information demand. The iterations were rated in the categories iteration object, predictability, controllability, impact and potential for usage data support. The category ratings were then used to analyse, how to avoid unnecessary iterations and support useful ones. 6 of 31 iterations helped to sharpen the focus of the customer orientation. In average, they exhibit mediocre ratings in all categories and can potentially be avoided or supported by usage data integration. Further 11 iterations were performed to improve the employment of methods. These iterations were triggered by the use of unsuitable methods, insufficient method design and the inadequate number of potential customers the used methods could reach. In total, these iterations developed a rather minor impact, but in contrast were highly predictable and controllable. The integration of usage data could have supported 3 iterations and completely avoided a further 7. The remaining 14 iterations addressed the realisation of the product concepts. Hereby, the majority was caused by the technical implementation, whilst a few also tackled conceptual and design adaptions. Overall, these iterations were highly controllable, but showed very mixed ratings for the other categories. Solely design related iterations could have been substantially supported by usage data. Especially the iterations regarding technical implementation, which can be assumed to have a very low usage data support potential. Altogether the insights suggest that iterations with a very high usage data support potential also hold a low impact on the overall process as well as a relatively high predictability and controllability. This limits the utility of the usage data support for iterations, since in this sense the support or avoidance of iterations with a high impact is desirable. That especially holds true if the iterations are barely predictable and controllable. Thereof it can be inferred that usage data is not a universal remedy, but however can be seen as a promising tool to be combined with other information sources. Furthermore, the insights reveal that iterations for method adjustments mainly occurred in the middle part, while realisation centric ones increased strongly towards the end of the project. The iterations regarding the customer orientation occurred, except in the last two weeks, along the whole process. This observation matches the intended procedure, which was planned to approximate the product concepts to the customer needs first and to perform the main part of the realisation towards the end of the project.

4.4 Information market

Despite the indeed given information sources to answer the arisen questions and conduct the iterations, none of the phases showed market equilibrium. In every phase the information demand exceeded the information supply so that an overall surplus demand accrued.

The information demand almost exclusively related to the user profile, the driving behaviour and the realisation. 196 of 228 recorded questions covered one of these topics. The questions regarding customer orientation by far embody the highest impact. However, there are as few as 12 questions on the process that must also be taken into account. Despite their low quantity, they show a high impact and should be answered thoroughly.

The information supply for the project team was given through internal knowledge, explicit information, and knowledge transfers from the team's network and customer surveys. The project team's assessment of influencing factors on the information supply and the proceeding imply that major information gaps existed. The internal knowledge regarding the problem domain, relevant tools and technologies as well as the employment of development methods had a slightly positive influence on their process, but were according to the observed proceeding not sufficient to answer a great number of the questions in a profound manner. This is also reflected in the negative assessment of the knowledge base about potential customers and the lacking functional diversity. The internal knowledge however was improved by the offered trainings. Additionally, the knowledge transfers from the team's network offered useful information. The available explicit information mostly consisted of state of the art research and online content, despite the lack of a design guideline, played a valuable support role in the process. The further supply of information through customer surveys was limited as well, since the survey samples were relatively small and difficulties with the employment of methods prohibited an adequate information quality.

Based on the manifestations of information demand, supply and use, the overall creation of market equilibrium in the observed development process must be seen as merely mediocre. The articulation of concrete, structured and relevant questions resulted in its entirety in a satisfactory and expedient information demand. Nevertheless, the supply of information wasn't enough to match this demand due to the presented reasons. Consequently, the possible utilization of information for the advancement of the process in general and the iterations in particular were only partly given.

5 IMPROVEMENT POTENTIALS THROUGH INFORMATION MANAGEMENT

5.1 Potential for improvement

By reconstructing the observed development process, the lacking functional diversity of the project team, the development and employment of methods and the customer orientation are identified as the main problem areas. A higher functional diversity and more distinct experience for the development and employment of development methods can be attained by assembling the project team more carefully and providing adequate training prior to the project. To utilise the potential for an improved customer orientation however, more in-depth adjustments of the development process are necessary. The insights of the case study show that the vast majority of the information demand referred to the customer orientation. This topic in turn also presented the most severe obstacles and manifested a high dependency on the availability of potential customers, the use of development methods and the experience of the project team. Hereof the results indicate that information about the customers should be in place as early in the process as possible. Thereby the wide-reaching impacts of a variety of iterations on customer integration, triggered by questions in the first and second phase, can be controlled and mitigated if necessary. In this regard, the information demand at the very beginning of the development process seems to be the most influential. This demand is mainly determined by the used methods and can therefore be anticipated very well. For the realisation of these improvement potentials the harmonisation role of the information market through the supply of information must be revised. This must not only include the securing of an information supply, which could be considerably improved by customer usage data, but also care for the supplied information's right quality, granularity and time of delivery. A functioning information management system can enable the timely availability of needed information due to the profound anticipation of the information demand early on, so that the information is useful, applicable and meaningful.

5.2 The information management concept

Accordingly, an automated system for the handling and refinement of information should be created. For this purpose, organisations can utilise their experiences from former development projects and project them on to future ones. In order to do so the system must be adaptive, accurate and efficient. The ability to learn refers to recognition; which questions and iterations are to be expected for the upcoming project? Since iterations are not to be avoided in every case, the accuracy of the provided information must enable the support of useful, focused iterations, whilst negative, resource-wasting iterations should be avoided. Moreover, the information supply must only contain the necessary quantity of information, otherwise the possibilities to create information from the available data are theoretically infinite. The available usage data in the case study could, for instance, be used to determine, which radio channel customers prefer, even though this information is eventually of no importance for the development endeavour.

5.2.1 Determination of the information demand

The first step to reach these objectives is to determine the information demand. The main problem hereby is the discrepancy between implicit and actual articulated demand. Especially in CPDPs, the information demand seems particularly dynamic, so that the project team eventually fails to ask the right questions and demands information that is irrelevant for the product development. The consideration of past projects can counteract this discrepancy and enable a more accurate information demand. In the context of the proposed information management concept the determination of the information demand is performed using a classification scheme to connect past and future projects. The classification scheme's parameters are project orientation, used methods and development object. The project orientation describes whether the focus of the development project lies on customer orientation, technical product

improvements or basic research. The alignment of the project with the same orientation enables the identification of relevant information demand categories and the initial prediction of the upcoming information demand and iterations, especially regarding process related questions. The development methods used in a project enable the further anticipation of presumably occurring information demand. Many development methods generally embody a similar information demand for a different project because of their structured procedure. Therefore, the upcoming information demand can be predicted very accurately, if the used methods are known before the project starts. The development object is the product, process or service, in the centre of the development process. In many cases the different development project of an organisation focuses on similar objects, since they are determined to a high degree by the organisation's core competencies and strategic direction. The information demand of former projects can then be taken up again.
The classification is then used to determine, which classes pose what kind of information demand and iterations to subsequently define a major portion of the information demand before the project even started, without having to define the demand manually for every single project. Beyond that the chronology and the impact of the information demand can be inferred, as shown in the case study. The characterisation of questions and iterations applied in the case study is revisited in the proposed concept to estimate the information demand's impact and consequentially prioritise it (Figure 1).

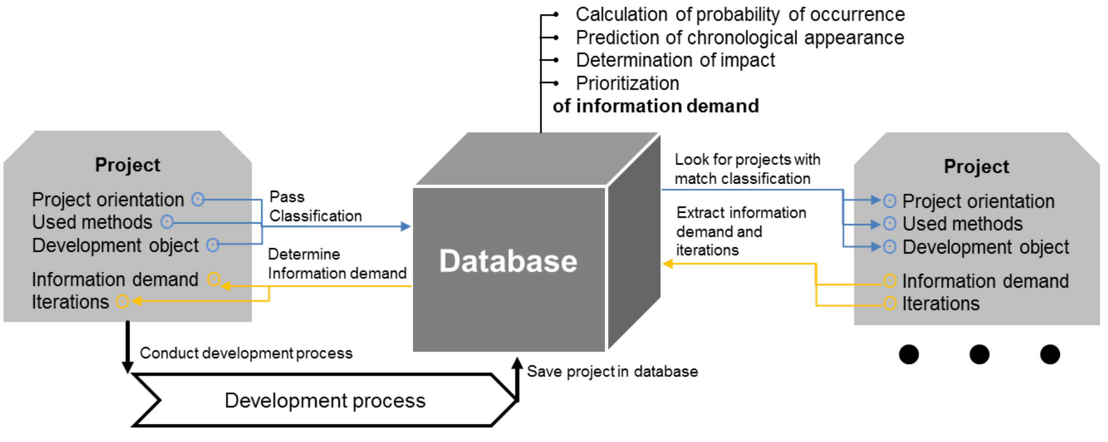

Figure 1. Determination of the information demand

5.2.2 Definition of the suitable information supply

Based on the determined information demand the supply side is defined. In contrast to a resource based approach which includes all available data, the available data is only captured and processed into information to the extent that it is most probably needed to answer the information demand. The reduction of the information supply increases the resource efficiency, performance, and clarity of the database, representing the information market and furthermore enabling the mitigation of the data complexity that is caused by the infinite number of possibly inferable information. The focus on the actually needed information leads to the supply of an optimised amount of data. Besides the right amount of data, the employment of customer usage data substantially improves the data quality. Because of the defined information demand, the customer usage data can be purposefully condensed as well and offer high quality data due their objectivity, currency and quantity. A formulated question regarding customer behaviour is hereby translated into a quantifiable factor, which is in turn divided in further factors representing the underlying connections to be examined (Figure 2). These factors can be measured directly or indirectly by combining different usage data to eventually create a customised set of supplied information. Together with answers to questions which were already articulated and validated in past projects, customer usage data consequentially builds the information supply side of the information management concept (Figure 3). In addition to the provision of the predicted information supply at the project start, information requests need to be possible in later phases, when more specific questions arise, which might not have occurred in similar projects. For this purpose, a standardised form sheet, similar to a simulation inquiry could be used (Schweigert et al., 2015).

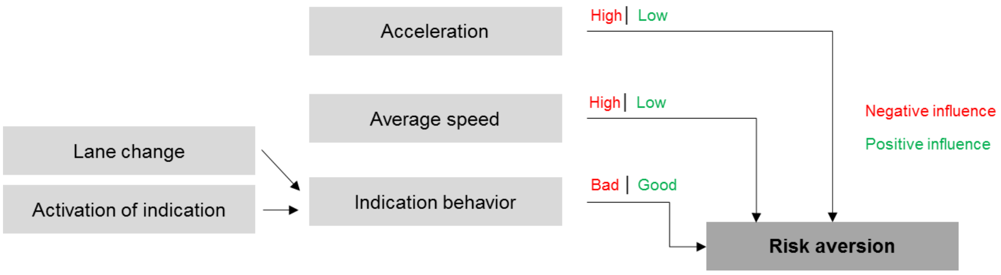

Figure 2. Example for the translation of demanded information for usage data support

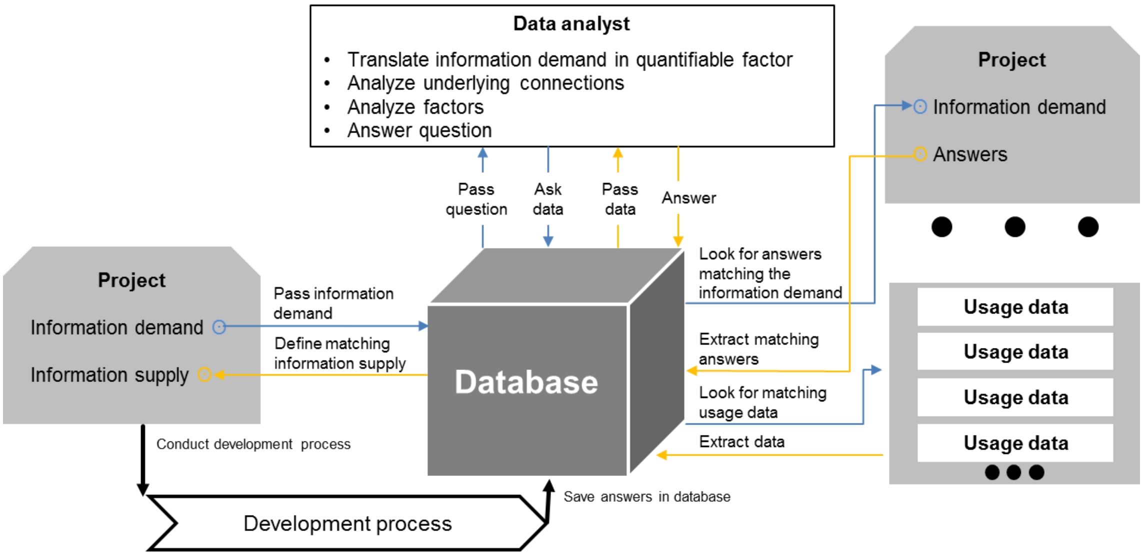

Figure 3. Definition of the suitable information supply

5.3 Creation of the concept's optimal process environment

The management of factors influencing data support primarily addresses internal factors, since external factors are largely detached from the organisation's control. Among the internal factors the product architecture has the highest impact: The architecture limits the degree to which usage data can be collected and must therefore integrate the necessary technology, such as sensors, or at best provide interfaces for later upgrades. In this respect, accurate predictions about the future demand of usage data should be made, since a new development or an upgrade of the respective development object is likely to be a great expense. Further influence comes from employing state of the art technology to use in data collection, requiring adequate investments. Furthermore, the project team's composition must reflect the intended use of customer usage data. Members must know how to handle the necessary technologies, which data is needed and how to analyse and integrate the data into the process. Suitable development methods and a high functional diversity should be used in a supportive role.

6 CONCLUSION

This paper presents an information management concept to tackle the information asymmetry in CPDPs. The concept is based on insights from a case study, which reveal that the collection of data using traditional methods raises serious difficulties regarding data quality and currency. Accurate data on the behaviour of customers is necessary as early as possible, and creation and distribution of information needs to be controlled. In the dawn of the ‘internet of things’ even more data will be available, so that future competitiveness will be dependent on the organisation's ability to effectively and efficiently utilise vast amounts of data. For this purpose, the proposed information management concept can be used as the interface between customer usage data and product development, further growing with every conducted project. However, the proposed concept needs to be tested on its efficacy by applying it in a project with access to actual customer usage data. So far, causalities between data and questions in the case study are based on assumptions by the designers involved.

REFERENCES

ADAC, (2016), www.adac.de. [Online] Available at: https://www.adac.de/infotestrat/technik-und-zubehoer/fahrerassistenzsysteme/daten_im_auto/default.aspx?ComponentId=260789&SourcePageId=8749&quer=daten [Accessed 15 July 2016].

Awazu, Y. et al. (2009), "Information–communication technologies open up innovation", *Research-Technology Management*, 52(1), pp. 51-58.

Dalkir, K. and Liebowitz, J. (2011), *Knowledge management in theory and practice*, s.l.:MIT press.

Edmondson, A. and Nembhard, I. (2009), "Product Development and Learning in Project Teams: The Challenges Are the Benefits", *Journal of Product Innovation Management*, 26(2), p. 123–138.

Fan, W. and Bifet, A. (2013), "Mining big data: current status, and forecast to the future", ACM sIGKDD *Explorations Newsletter*, 14(2), pp. 1-5.

Fuchs, C. and Schreier, M. (2011), "Customer empowerment in new product development", *Journal of Product Innovation Management*, 28(1), pp. 17-32.

Greenberg, P. (2010), "The impact of CRM 2.0 on customer insight", *Journal of Business & Industrial Marketing*, 25(6), pp. 410-419.

Hauser, J., Tellis, G. and Griffin, A. (2006), "Research on Innovation: A Review and Agenda for Marketing Science", *Marketing Science*, 25(6), pp. 686-717.

Hoyer, W. et al. (2010), "Consumer Cocreation in New Product Development", *Journal of Service Research*, 13(3), pp. 283-296.

Ili, S., Albers, A. and Miller, S. (2010), "Open innovation in the automotive industry", *R&D Management*, 40(3), pp. 246-255.

Kalus, G. and Kuhrmann, M. (2013), *Criteria for software process tailoring: A systematic review*, San Francisco, USA, s.n., pp. 171-180.

Krcmar, H. (2015), *Informationsmanagement*. Berlin Heidelberg: Springer.

Langer, S. and Lindemann, U. (2009), *Managing cycles in development processes - Analysis and classification of external factors*, s.l., s.n., p. 539–550.

Liao, S., Chen, Y. and Deng, M. (2010), "Mining customer knowledge for tourism new product development and customer relationship management", *Expert Systems with Applications*, 37(6), pp. 4212-4223.

Linoff, G. and Berry, M. (2011), *Data mining techniques: for marketing, sales, and customer relationship management*, s.l.:John Wiley & Sons.

McAfee, A. and Brynjolfsson, E. (2012), "Big data: The management revolution", *Harvard Business Review*, 90(10), pp. 61-67.

Ngai, E., Xiu, L. and Chau, D. (2009), 'Application of data mining techniques in customer relationship management: A literature review and classification", *Expert Systems with Applications*, Volume 36, p. 2592–2602.

Nijssen, E. and Frambach, R. (2000), "Determinants of the adoption of new product development tools by industrial firms", *Industrial Marketing Management 29*, 121–131 (2000), 29(2), pp. 121-132.

Pfeffer, J. and Sutton, R. (2006), "Evidence-based management", *Harvard business review*, 84(1), pp. 1-13.

Runeson, P. and Höst, M. (2009), "Guidelines for conducting and reporting case study research in software engineering", *Empirical software engineering*, 14(2), pp. 131-164.

Schenkl, S. et al. (2013), "Managing Cycles of Innovation Processes of Product-Service Systems", *IEEE International Conference 2013*, pp. 918-923.

Schweigert, S., d'Albert, H. and Lindemann, U. (2015), An Approach for the Development of Requirements-Oriented Simulation Management, s.l., s.n., pp. 123-126.

Simonite, T. (2016), MIT Technology Review. [Online] Available at: https://www.technologyreview.com/s/601567/tesla-tests-self-driving-functions-with-secret-updates-to-its-customers-cars/ [Accessed 17 11 2016].

Thamhain, H. (2003), "Managing innovative R&D teams", *R&D Management*, 33(3), pp. 297-311.

Yin, R. (2014), *Case study research: Design and methods*, s.l.:Sage publications.

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