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PROCESS MODEL FOR DATA-DRIVEN BUSINESS MODEL GENERATION

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Abstract

Digitalization is advancing fast and at the same time the volume of data is increasing. Examples from industry show that business models using big data can lead to competitive advantages. Currently the number of smart products is rising, which means more data will be available to engineering companies. The challenge is to extract additional profits and value from it. The literature review revealed that existing process models and methods for business model generation do not consider data in a distinct way. This paper synthesises existing work on business model generation and experience gained during a case study in an engineering student project to develop additional support for the generation of data-driven business models. The developed business model canvas helps to better outline the data requirements of business models. The developed process model describes the important phases for generating data-driven business models. The results of the case study indicate that the support helps to make the data perspective more visible and leads to new ideas. Furthermore, the support improves the coordination between product and business model development. The paper closes with a outlook.

Keywords: Business models and considerations, Case study, Design management, Big data

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1 INTRODUCTION

Companies like Netflix and Amazon achieved the lead over their respective competitors by implementing data analytics of large and diverse data sets (Big Data) into their business model (Muhtaroglu et al., 2013). They analyze the usage of their service by means of data analytics and utilize the insights for its improvement. Each customer's usage behavior is tracked and gathered into his user profile. These companies learn to predict the customer's future needs by looking both, at his current needs and at user profiles with similar key preferences. Analyzing customer's data helps to better understand the preferences and needs of customers (Gassmann et al., 2013).

But the evaluation of usage data (data created during the use phase by the product itself or related services) is not limited to media or online retailing companies. For example, vehicle manufacturers collect data, especially sensor data, on the test bench or while performing test drives (Dinter et al., 2015). Tesla uses the collected field data to evaluate the actual usage of their cars and design the reliability of their product accordingly (Geiger and Sarakakis, 2016). This form of data-driven product development helps meeting the requirements in a more efficient way by avoiding over-engineering and reducing development time (Van der Vegte, 2016). The leverage of field data from car fleets can be extended to the monitoring of production cars. State-of-health measurements collect relevant sensor data from time to time to assess the state of the vehicle. The sensor data could be transferred via telematics units to the car manufacturer, who then gains new insights into the usage of his vehicles. This leads to Big Data, because the amount of collected data exceeds one GB per day form a customer fleet of one million vehicles (Johanson et al., 2014).

Smart, connected devices are major reason for the increase of usage data (Porter and Heppelmann, 2014). Such devices merge together physical components and smart components (e.g. sensors) with connection abilities. Smart, connected devices offer the customer a variety of new benefits: Monitoring of the product ensures its availability (e.g., allows for predictive maintenance) (Van der Vegte, 2016); personalization is reached through the adaption of the product's handling to his user's preferences. But on the other hand, conventional manufacturers of goods face new challenges when they want to profit therefrom. They must develop new competences in data handling and analysis to enhance their products with value-added services. Thus, manufacturers need to innovate their business models. The trend is moving away from product sale, shifting to product-as-a-service, where new services are offered together with the product (Porter and Heppelmann, 2014).

To facilitate these data-driven business opportunities that derive a value proposition from usage data, data analytics or Big Data should have a central part in business model development. However, this paper is not about Big Data analysis, but on how to integrate insights from data analytics into a business model in a systematic manner. A data-driven business model can only be carried out, if the data resources are defined and available in the required quantity and quality, because they are the main facilitator for this type of business model. The objective of this paper is to provide methodological support for creating data-driven business models by introducing a process model and a methodical tool for business model generation.

This paper is organized as follows: Chapter 2 of this paper summarizes the state of research regarding business model development and highlights opportunities for Big Data in data-driven business models. The requirements for the process model are derived from the literature and from a students' development project named 'MyMINI' in Chapter 3. The generation or redevelopment of a business model requires not only a process model, but also methodical tools. They are introduced in Chapter 4. In chapter 5 the process model is used during a case study in the MyMINI project. The case study serves as initial evaluation of the process model.

2 STATE OF RESEARCH

This chapter will present existing theory for business model development as well as outline the concept of Big Data. This forms the theoretical background for data-driven business models.

2.1 Business Model Development

A business model structures and defines the key elements of a company. The scope is to describe the core characteristics that are needed to offer an added value. This includes the statement of the company's purpose, its strategic orientation, its infrastructure and its processes (Muhtaroglu et al., 2013).

2.1.1 Elements of a Business Model

The characteristics of a company are clustered into a series of key elements. Together they form the business model, which clarifies who the company's customer is and what he values (Ovans, 2015). Furthermore, it specifies how the company can make a profit.
Zaki et al. (2014) identified in their literature review following business model elements: The 'value proposition' is the offered customer benefit which forms the central purpose of the company. The 'customer segments' are willing to pay for it to satisfy their needs. These payments form the 'revenue stream' of the company. To offer a 'customer benefit' the company has to perform 'key activities' and requires 'key resources'. Both generate expenses which are outlined in the 'cost structure'.

2.1.2 Business Model Canvas

The established method for depicting the elements of a business model is the 'Business Model Canvas' by Osterwalder et al. (2016). This tool is described in the reference book 'Business Model Generation' by Pigneur and Osterwalder (2011). It summarizes a business model in a structured and condensed form. Each element of a business model has its own box on the canvas. Due to that, dependencies between elements of the business model become obvious. In the center of the Business Model Canvas is the company's value proposition. This comprises the offered product and/ or service. On the left side of the canvas the required resources for offering the value proposition are stated: the key activities, the key resources and the key partners that are needed. On the right side of the canvas the customer segments, the type of relationship between company and customer and its channels are specified. The financial aspects of the company are declared in the lower part of the canvas. The canvas helps to analyze and redesign existing business models or to create new ones. It supports the development process of a business model by visualizing the objectives of the business model development. Different drafts of the new model can be documented with the canvas for evaluation.

2.1.3 Process Model for Business Model Generation

The process model for the development of a business model with the Business Model Canvas by Pigneur and Osterwalder (2011) consists of five phases: At the beginning, in the 'Mobilize' Phase, the development project is started with the definitions of its goals, the assembly of the team and other organizational matters. The following phase has the scope of 'Understanding' the potential customers and the environment of the company. Ideas are also gathered in this phase. The next phase is the 'Design' phase of the business model generation. It uses brainstorming for selecting ideas and creating prototypes with help of the business model canvas. These are tested to get feedback. The most promising draft is realized in the following 'Implementation' phase. The working business model will be observed in the 'Manage' phase. It should be evaluated continuously for improvement.

2.2 Understanding the Concept of Big Data

Big Data is basically characterized by the volume of the datasets, their complexity and by the technology which is required to analyze these datasets (Ward and Barker, 2013). The 'original 3V' definition by Laney (2001) uses three dimensions to describe the concept of Big Data: Volume, Variety and Velocity. Recent publications extend this definition to '4V' by adding Value (Dijcks, 2013) or to 5V by adding Value and Veracity (Demchenko et al., 2014). The collection and evaluation of usage data (e.g. machine-generated data from sensors in automobiles) corresponds per definition to Big Data (Dijcks, 2013), as it meets the 3V criteria (Johanson et al., 2014) and in case of a data-driven business model also the Value criteria.
Several companies successfully integrated Big Data into their business model. Well-known examples include Google, Amazon and Netflix. Netflix, for instance, collects usage data to get to know the viewing preferences of its customers. That's how Netflix manages to offer a TV program, which meets its viewers' expectations better than conventional TV stations (Simon, 2014).

Big Data Analysis is also applicable in the mechanical engineering sector, like Taleris proves. Taleris is a Joint Venture between GE and Accenture. They use Big Data analysis of aircraft turbine sensor data for predictive maintenance (Dinter et al., 2015). Further case studies for the application in the technical sector (e.g. ThyssenKrupp and DB Schenker) can be found in the Bitkom compendium by Dinter et al. (2015).

2.3 Data-Driven Business Models

Big Data Analysis is required for realizing a data-driven Business Model, because the insights from the gathered data are the main resource for the value proposition which is derived from data. For example, manufacturers of jet engines evolved their business model from selling their product to selling the usage of its product in a product-as-a-service system (PSS). This has been facilitated by the collection of sensor data. The data allows the company to measure the usage of their PSS, charge correspondently and to improve the maintenance of the product (Van der Vegte, 2016). The customer has the advantage that he only pays for the real usage of the product and not for its possession.
The business model of companies that use Big Data is analyzed in several literature sources, which show how those company offer a data-driven value proposition and profit from Big Data (Muhtaroglu et al., 2013; Zaki et al., 2014). First methodical approaches and methodical tools for discussing a company's data in regard to its business model can be found in literature (Mathis and Köbler, 2015). Nevertheless, literature does not provide any process models that prescribe the methodical approach for developing data-driven business models.

3 REQUIREMENT FOR DATA-DRIVEN BUSINESS MODEL GENERATION

In the last chapter examples were given of the advantageous implementation of Big Data into business models. The business model generation theory with the business model Canvas by Pigneur and Osterwalder (2011) gives general methodological support for (re-)developing a business model. But it does not give any advice on how to profit from data resources and how to develop a data-driven business model. Therefore, a process model is required that guides through the development of a new data-driven business model. A process model describes the sequence of tasks that are needed to reach a desired target state, starting from an actual state. It is developed by analyzing successful procedures and deducing recommendations for action (Lindemann, 2009). A Process Model for data-driven business model generation should suggest the usage of methodological tools to analyze, visualize and understand the data from the environment of the business model. In addition, a methodological tool is needed to document, structure and visualize the results of the business model generation. This methodology shall support the review of existing business models as well as the development of new business models to reach the same benefits from Big Data analysis as in the reported examples. The (re-) developed business model defines the new strategy and shows where a company should change its organizational structures and processes. Furthermore, a data-driven business model shows the potential of implementing collected user data from the companies' products and services as well as the needed data resources for offering a data-driven value proposition.

3.1 Generic procedure for business model innovation

Business model generation by Pigneur and Osterwalder (2011) is perhaps the most renowned business model theory, but not the only one. Daniel Schallmo (2015) identified in his study 12 approaches for business model innovation. Almost all of them are based on case studies and differ in their level of abstraction. A detailed comparison of them led to the conclusion that no approach is particularly suitable for the development of data-driven business models, because none of them specifies how to handle data and derive a value proposition from data. Moreover, the general validity of the prescribed actions to innovate a business model is not consistent, i.e. some are too vague and some are too specific. For example the Activity System by Zott and Amit (2010) focuses on activities to create a value proposition. It only consists of three elements regarding the activities in general, which is too vague.
A generic procedure for business model innovation was synthesized as a reference model from the approaches in the study by Schallmo (2015). The generic procedure contains basic steps for innovating a business model.

- Identification of need for improvement of the existing business model.
- Analysis of the company's environment.

- Design of the business model in terms of Design Thinking.
- Documentation of the business model draft with the Business Model Canvas.
- Estimation of costs and revenues.
- Realization of the new business model.
- Scenario analysis.

The generic procedure for business model innovation is a blueprint to support companies in mastering the transition towards a data-driven business model, but more specific requirements concerning the integration of Big Data are derived in the following paragraph.

3.2 Case Study: MyMINI Project

The MyMINI student project involved agile, innovative product development with the aim of integrating an innovation in an existing car. One of the authors was constantly involved in the project over its course of six months. During the MyMINI project two case studies were conducted. The case studies were performed with the support of the adapted 'Case Study Research' theory by Eisenhardt (1989). They were documented in regard of objectives and executed tasks. The development project was not supported by a Process Model for data-driven business model generation during the first case study, so the lack of methodical support could be discovered. The requirements for the process model were deducted from the documentation of the first case study. It should:

- Offer a guideline for an efficient development process with a highly promising result.
- Specify the tasks and resources required for designing a business model.
- Align the needed tasks in a chronological order.
- Integrate helpful methodical tools into the workflow.
- Emphasize the significance of usage data.
- Be fit for designing business models for both products and services.
- Support the creative development of new business models, which provide a value proposition derived from usage data.
- Visualize the key elements of the business model.
- Guide the redesign of existing business models regarding the integration of usage data.

3.3 Need for Process Model Development

The first case study in the MyMINI project showed, that especially engineers with little experience in business model generation need the support of a process model. In addition, the process model should match corresponding tasks of product development and business model generation for synergy. Its application shouldn't be limited to a student project, but it should also support the redesign of existing business models in the industry or the generation of new business models in start-ups. This requires a process model for data-driven business model generation that reaches both the objectives of the generic procedure as well as the learnings from the student project.

Several benefits are expected from the new process model. It gives an engineer the framework for business model generation. The value proposition realized by the product and enhanced by its usage data are documented and communicated by an improved canvas. The process model's application raises the awareness of the potential of usage data among engineers. It leads the interdisciplinary work of business model generation and product development. It serves as methodical background for the development of a PSS. The aim in long term is to shift development projects from product design to designing a holistic solution.

4 DATA-DRIVEN BUSINESS MODEL GENERATION

The publication *"Taking Advantage of Data Generated by Products"* by Van der Vegte (2016) points out a data *'processing chain'*, that starts with the collection of data and ends with the results of data processing. Those results are used to gain an advantage, like improving maintenance, improving product development, or simply put, to design the product regarding its actual use (Van der Vegte, 2016). The data-driven business model generation focuses on this aspect of the business model. It states which data resources must be collected to offer the improved customer benefit and which insights are gained from data. A data map of the system supports the documentation and is, together with the business model

canvas, one of the methodical tools that are used during the process of data-driven business model generation.
The requirements from the literature review (see Section 3.1) and from the MyMINI case study (see Section 3.2) were the basis for the enhancement and redesign of the business model generation procedure by Pigneur and Osterwalder (2011) in order to create a 'Process Model for data-driven business model generation'.

4.1 Data-Enhanced Business Model Canvas

Pigneur and Osterwalder (2011) center their business model generation theory around the Business Model Canvas (see Section 2.1.2). This is a form for structuring and describing the key elements of a business model. It is used for discussion of an existing business model to find its weaknesses and for the development of a new business model. The Business Model Canvas by Pigneur and Osterwalder (2011) neither includes the consideration of captured data from the product usage and from the customer nor required data resources for running a data-driven business model. Therefore, the Business Model Canvas was edited and the resulting 'Data-Enhanced Business Model Canvas' is shown in Figure 1. The enhanced canvas can now depict business models that offer a data-driven value proposition and profit from data resources, as demanded in Section 2.3.

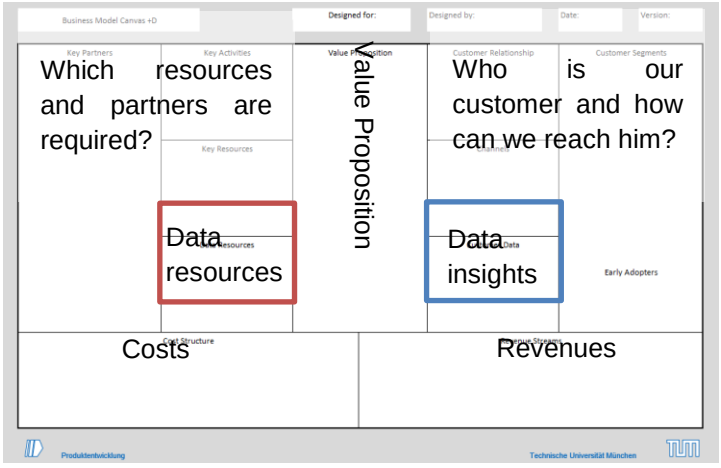

Figure 1. Data-Enhanced Business Model Canvas

Data resources, like user profiles or sensor data for offering a data-driven value proposition, are noted on the left side of the canvas. The value-proposition does not only need data for its operation, but can also contribute to collect usage data. Data about the performance or the usage characteristics of the product can be of interest for the company or for partners who are willing to pay for that data (Pigneur and Osterwalder, 2011). Therefore, collected data is on the right side of the canvas, the 'revenues and customer' side.

4.2 Process Model for Data-Driven Business Model Generation

The Business Model Canvas is a methodical tool and its application needs regardless of the use case a process guideline, which is summarized below. The process model for data-driven business model generation has the same phases as the theory by Pigneur and Osterwalder (2011) shown in Section 2.1.3: Mobilize, Understand, Design, Implement and Manage.

4.2.1 Top-Down vs. Bottom-Up Approach for Business Model Development

A data-driven business model offers a value proposition derived from data. This is the reason for two different approaches within the process model. On the one hand, you can proceed in a Bottom-Up approach. This is similar to a market-pull proceeding (Mowery and Rosenberg, 1979), because you start with a customer study and identify their needs, which you try to fulfil with the support of data. On the other hand, you can proceed in a Top-Down approach, which is similar to a technology-push proceeding (Nagel, 2003). In this case, you start with analyzing the data resources you have and try do derive a customer benefit from it. It must be decided beforehand how you want to proceed when (re-)developing a business model. The Top-Down approach needs more resources, e.g. it can be used for finding new

opportunities with the usage data from existing products of the company. Whereas Bottom-Up is the 'start-up way' to find in an efficient matter a solution for customers' needs, e.g. by offering the customer a personalized service based on his usage data.

4.2.2 Detailed description of the Process Model for Data-Driven Business Model Generation

1. 'Mobilize': The first phase of the business model generation by Pigneur and Osterwalder (2011) starts the project by formulating objectives, assembling the team and planning the further actions.
2. 'Understand': The environment of the company is analyzed in the second phase. This comprises market analysis, customer analysis and trend analysis. The 'data-driven' process model differs in this phase from the theory by Pigneur and Osterwalder (2011). The insights from data analysis must be made accessible and easy to process for the developers of the business model. The available data in the product system should be visualized, so that developers can see benefits derived from data. A possible tool for visualizing the results of the data analysis is a 'Data Map'. It gives an overview of the possible data connections in the system, because it shows source and destinations of data in the system as well as the functions realized by data. The tasks depend on the choice of Bottom-up or Top-down approach, as shown in Figure 2:
   - The Bottom-Up starts with the customer perspective. The customer needs are identified and available usage data from products or product prototypes is used to provide additional value. However, the main objective is to offer a certain use case and this might imply that the product or service needs to be adjusted in order to obtain the required usage data.
   - The Top-Down approach, in contrast, starts with the data analysis. A potential solution is derived from the available data, which can be offered to the customer. It must be validated, if the customer sees a benefit in it. The main objective is to take advantage of available usage data without changing the product or services.
3. 'Design': The data-driven Business Model Canvas is used as the main tool in the third phase. The elements of the Canvas are defined with the findings from the 'Understand' phase. According to Pigneur and Osterwalder (2011), this happens in an iterative process. It starts with brainstorming for solutions. Prototypes of the business model are created, possibly with help of existing frameworks like the 'Data-Driven Business Model Framework' by Zaki et al. (2014) and documented in the Business Model Canvas. These drafts are tested by obtaining feedback from experts. The most promising prototype is selected and taken over to the next phase.
   The tasks slightly differ in Top-Down and Bottom-Up approach:
   - Bottom-Up: During brainstorming in the design phase, the value proposition element is defined with help of the insights from data analysis (which can be visualized in a data map).
   - Top-Down: The potential customer benefit, derived from data, that has been found earlier in the 'Understand' phase must be fully validated with the customer while testing the prototype in the design process.

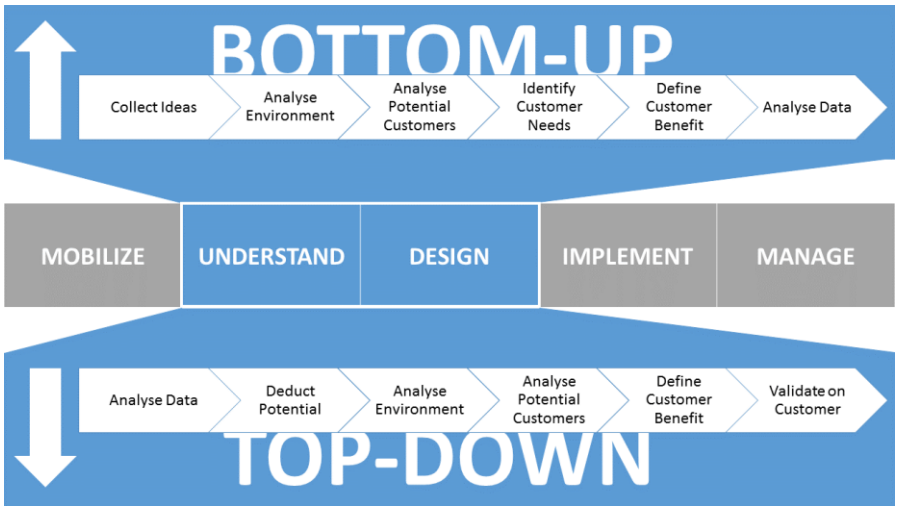

Figure 2. Bottom-Up vs. Top-Down Approach during 'Understand' and 'Design'

4. 'Implement': The selected business model draft is put into practice in the fourth phase. The actual

tasks in this phase vary depending on the key elements of the business model. The tasks to carry out a business model that is centered on a product differ from a business model for a service.

5. 'Manage': The operating business model is constantly revised for need for improvement in the fifth phase of the process model. The required tasks, per Pigneur and Osterwalder (2011) are the environmental analysis and the continuous evaluation through experts and key figures. If required, the business model should be redesigned. The process model then starts again with the 'Mobilize' phase.

4.3 Integrated Process Model for Product Development and Business Model Generation

Both, innovative product development (Böhmer et al., 2015) and business model generation share certain tasks in the concept phase, like idea generation, idea selection, concept development and concept test. Figure 3 shows the merger of product development and business model generation, which has several advantages. Working on tasks together in an interdisciplinary team of product developers, business model experts and data analysts during the innovation process ensures the efficient fulfillment of the objectives. It is guaranteed that the business model for the product profits of its usage data, because product and business model are developed simultaneously. Tools like the data map visualize the available usage data in the product ecosystem. Data analysts can give feedback and request further usage data from the product prototypes. This influences the product development, because the product must deliver the required data. Engineers can therefore add sensors to the product or trace values correspondingly (Van der Vegte, 2016). This means, a product is developed regarding the data-driven value proposition of the business model, resulting in a data-driven development.
Usage data cannot only help to provide customer value but can also support internal tasks in product or service development. For example, customer requirements can be formulated and met more adequately with help of data, even as far as offering a customized service or product to the customer (Li et al., 2015).

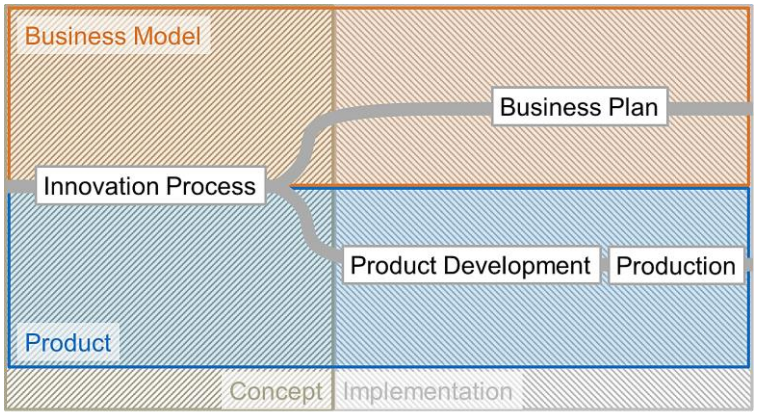

Figure 3. Product development and business model generation

5 APPLICATION OF THE PROCESS MODEL

5.1 Innovation Process in the MyMINI Project

Two case studies were conducted within the MyMINI project. The first one focused on the development of a product and its business model without the support of a process model for business model generation to evaluate where support is needed (see Section 3.2). The second case study, in contrast, employed the process model, presented in Chapter 4, in combination with a product development process (see Section 4.3). Students with a mechanical engineering background were guided through the generation of a business model for the product they developed. Moreover, the business model was not created after the product development, but accompanied the product development with its iteration phases. It was ensured, that all the product features of each prototype phase were implemented into the business model and vice versa. The business model was validated on the customer. That also means that all the product features were validated. The data resource was defined in the business model, as well as the possible insights from usage data to improve the service.

The MyMINI project used a Bottom-Up approach for efficient innovation of a new product with limited resources. Customer needs while driving a car were questioned and an idea developed to meet the needs. The result was the seamless integration of Spotify stations into the car radio for a personalized radio service. Due to the close cooperation of engineers responsible for the product development and for business model development, it was possible to match the product design and the required usage data for the desired business model. It became clear that both perspectives should not be considered separately, but need to go hand in hand during the design phase of the product and business model.

5.2 Initial Evaluation of the Process Model

The initial evaluation of the process model was conducted during the second case study in the MyMINI project to prove the applicability of the process model for data-driven business model generation in a product development project. Its guidance led to the conception of a personalized music streaming service, whose business model considers the required usage data and customer data.
The MyMINI project faced a couple of impediments. The required data resources were not as openly available as expected. This affected the use of the data map as well as the potential of the business model. The student development team should have combined more academic disciplines for the interdisciplinary development of the product and its business model.
The findings of the initial evaluation were that the Bottom-Up approach is suitable for the application in an agile product development project, despite the drawbacks mentioned above. The business model development went hand in hand with the product development thanks to the guidance of the process model. Work packages in the innovation phase, like idea finding or customer analysis were executed together in teams for product and business model development. This is more efficient than integrating a product in an existing business model or developing a business model for the product afterwards. Several drafts of the business model were created and evaluated together with experts from the industry. The business model drafts showed how to implement the music streaming solution in car-sharing, offer it through aftersales channels or distributing it directly through an online shop. The methodical tools ‘Data Map’ and ‘Data-Enhanced Business Model Canvas’ were used and evaluated during the business model development. The generic procedure for business model generation (see Section 3.1) was used as a reference for validating the process model with the result that the process model satisfies the requirements sufficiently.

6 SUMMARY AND OUTLOOK

This paper shows how the business model theory by Pigneur and Osterwalder (2011) was enhanced and redesigned in order to support the generation of data-driven business models. A data-driven business model derives its value proposition from the analysis of customer and usage data. The data is collected through the companies’ products or services. Usage data must be integrated together with the product into the company’s value proposition. The developed process model distinguishes between a Top-Down approach that derives a customer benefit from analysis of available data and a Bottom-Up approach that tries to satisfy an identified customer need with help of usage data. The resulting business model is depicted with the Data Enhanced Business Model Canvas. The Bottom-Up approach was applied in the MyMINI student development project and hence initially validated. The case study has also shown the advantages of integrating the business model generation and the product development. The newly developed product fulfills the value proposition of the business model and collects the required usage data. The promising Top-Down approach still has to be validated. This would be feasible in a development project that starts with an extensive pool of existing usage data and would be carried out in an interdisciplinary team that includes data analysists. The findings of the data analysis could be visualized in a ‘Data Map’ and used to formulate a value proposition.

REFERENCES

Böhmer, A., Beckmann, A. and Lindemann, U. (2015), 'Open Innovation Ecosystem - Makerspaces within an Agile Innovation Process', in *ISPIM Innovation Summit*, Brisbane, Australia, 6-9 December, ISPIM.

Demchenko, Y., de Laat, C. and Membrey, P. (2014), 'Defining Architecture Components of the Big Data Ecosystem', in *Collaboration Technologies and Systems (CTS)*, Minneapolis, USA, 19-23 May, IEEE. https://doi.org/10.1109/cts.2014.6867550

Dijcks, J.-P. (2013), *Oracle: Big Data for the Enterprise - An Oracle White Paper*, Oracle Corporation http://www.oracle.com/us/products/database/big-data-for-enterprise-519135.pdf [accessed 09.04.2017]
Dinter, B., Franz, T., Grapenthin, S., Konrad, R., Nienke, S., Velten, C. and Weber, M. (2015), *Big Data und Geschäftsmodell-Innovationen in der Praxis: 40+ Beispiele*, Berlin: Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e.V.
Eisenhardt, K. M. (1989), 'Building Theories from Case Study Research', *The Academy of Management Review*, 14(4), 532-550. https://doi.org/10.5465/amr.1989.4308385
Gassmann, O., Frankenberger, K. and Csik, M. (2013), *Geschäftsmodelle entwickeln - 55 innovative Konzepte mit dem St. Galler Business Model Navigator*, München: Carl Hanser.
Geiger, C. and Sarakakis, G. (2016), 'Data Driven Design for Reliability', in *Annual Reliability and Maintainability Symposium (RAMS)*, Tucson, USA, 25-28 Jan., IEEE. https://doi.org/10.1109/rams.2016.7448023
Johanson, M., Belenki, S., Jalminger, J. and Fant, M. (2014), 'Big Automotive Data - Leveraging large volumes of data for knowledge-driven product development', in *IEEE International Conference on Big Data*, Washington DC, IEEE. https://doi.org/10.1109/bigdata.2014.7004298
Laney, D. (2001), '3D Data Management: Controlling Data Volume, Velocity and Variety', *Application Delivery Strategies*.
Li, J., Tao, F., Cheng, Y. and Zhao, L. (2015), 'Big Data in product lifecycle management', *The International Journal of Advanced Manufacturing Technology*. https://doi.org/10.1007/s00170-015-7151-x
Lindemann, U. (2009), *Methodische Entwicklung technischer Produkte - Methoden flexibel und situationsgerecht anwenden*, 3., korr. Aufl. ed., Berlin: Springer.
Mathis, K. and Köbler, F. (2015), 'Data Canvas und Data-Need Fit: Daten für neue Geschäftsmodelle nutzen' in Fischer, H., Endmann, A. and Krökel, M., eds., *Mensch und Computer 2015 - Usability Professionals*, Berlin: De Gruyter, 42-50.
Mowery, D. and Rosenberg, N. (1979), 'The influence of market demand upon innovation: A critical review of some recent empirical studies', *Research Policy*, 8, 102-153. https://doi.org/10.1016/0048-7333(79)90019-2
Muhtaroglu, C. P., Demir, S., Obali, M. and Girgin, C. (2013), 'Business Model Canvas Perspective on Big Data Applications', in *2013 IEEE International Conference on Big Data*, Santa Clara, CA, USA, 6-9 October, IEEE. https://doi.org/10.1109/bigdata.2013.6691684
Nagel, A. (2003), 'Beyond Knut Holt's Fusion model, balancing market pull and technology push', *International Journal of Technology Management*, 25(6/7). https://doi.org/10.1504/ijtm.2003.003126
Osterwalder, A., Smith, A., Philip, T., Hopkins, C. and Galindo, F. (2016) *The Business Model Canvas* [online], available: https://strategyzer.com/canvas [accessed 10.10.2016].
Ovans, A. (2015), 'What Is a Business Model?', *Harvard Business Review*, (01/2015).
Pigneur, Y. and Osterwalder, A. (2011), *Business Model Generation Ein Handbuch für Visionäre, Spielveränderer und Herausforderer*, 1. Aufl. ed., Frankfurt am Main: Campus.
Porter, M. and Heppelmann, J. (2014), 'How Smart, Connected Products Are Transforming Competition', *Harvard Business Review*, (November 2014).
Schallmo, D. (2015), *Bestehende Ansätze zu Business Model Innovationen Analyse und Vergleich der Geschäftsmodelle*, Wiesbaden: Springer Fachmedien. http://dx.doi.org/10.1007/978-3-658-09901-5
Simon, P. (2014), *Big Data Lessons From Netflix* [online], Partner Content, available: https://www.wired.com/insights/2014/03/big-data-lessons-netflix/ [accessed 31.10.2016].
Van der Vegte, W. F. (2016), 'Taking Advantage Of Data Generated By Products: Trends, Opportunities And Challenges', in *ASME IDETC/CIE 2016*, Charlotte, North Carlolina, August 21-24. https://doi.org/10.1115/detc2016-59177
Ward, J. S. and Barker, A. (2013), *Undefined By Data: A Survey of Big Data Definitions*, St. Andrews: University of St. Andrews, http://arxiv.org/abs/1309.5821v1 [accessed 16.11.2016].
Zaki, M., Hartmann, P., Feldmann Niels and Neely, A. (2014), *Big Data for Big Business? A Taxonomy of Data-driven Business Models used by Start-up Firms*, Cambridge: Cambridge Service Alliance [Working Paper] available: http://cambridgeservicealliance.eng.cam.ac.uk/resources/Downloads/Monthly%20Papers/2014_March_DataDrivenBusinessModels.pdf [accessed 12.01.2017].
Zott, C. and Amit, R. (2010), 'Business Model Design: An Activity System Perspective', *Long Range Planning*, 43, 216-226. http://doi.org/10.1016/j.lrp.2009.07.004

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