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Simulation-Based Business Model Innovation Process for Business-to-Business Contexts

Christoph Ksouri-Gerwien[1,*] and Jens Poeppelbuss[2]

Abstract:

Innovating service-oriented business models in industrial business-to-business (B2B) contexts presents a complex and risky endeavor. Recently, System Dynamics (SD) modelling and simulation has been suggested as a tool for prototyping and experimentation in business model innovation (BMI). However, knowledge of how to best utilise SD in BMI is scarce. Therefore, our research objective was to develop a new simulation-based approach for BMI, particularly for B2B contexts. We conducted a two-and-a-half-year action design research study with two industrial firms, Alpha (start-up) and Beta (incumbent firm). We developed and simulated new service-oriented business models as part of the two BMI teams. Our study resulted in the simulation-based BMI process containing phases, tools/techniques, and goals. Our findings demonstrate that SD, as a dynamic and visual modelling language, facilitates collaborative and cognitive activities during BMI, such as communication, design, evaluation, and decision-making.

Introduction

The business model (BM) of a firm describes the rationale of how it creates, delivers and captures value (Massa and Tucci, 2013; Osterwalder and Pigneur, 2010). The process of business model innovation (BMI), i.e., developing and implementing a new BM or modifying an existing one (Foss and Saebi, 2017), represents a challenging task for practitioners as it incorporates a certain level of complexity, uncertainty and risk (Taran *et al.*, 2019). The industrial

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[1-2] Chair for Industrial Sales and Service Engineering, Ruhr-Universität Bochum, Germany
*Corresponding author: christoph.ksouri-gerwien@isse.ruhr-uni-bochum.de

business-to-business (B2B) context, confronted by servitization as an industry-defining trend, constitutes a particularly challenging environment for BMI endeavours for various reasons. First, servitization leads companies to transform their value propositions from products to customer solutions, i.e., integrated and customised bundles of products, services and software (Kohtamäki *et al.*, 2019). Integrating these different components into bundles raises the complexity of value propositions and corresponding value creation structures. Second, firms need to partner with other firms in ecosystems to purposefully integrate their competencies and capabilities into such solutions (Kohtamäki *et al.*, 2019; Zott and Amit, 2010). Such partnerships involve inter-organisational coordinative efforts and risks. Third, customer relationships are less focussed on one-time investments and transfers of ownership but increasingly availability-, benefit-, or outcome-oriented, e.g., considering pay-per-use or subscription BMs, aiming at promoting long-term participation and revenue sharing (Bock *et al.*, 2023). This raises the complexity of economically sustainable value capture in the long term.

The academic literature provides several frameworks and tools to guide and support the BMI process (Athanasopoulou and Reuver, 2020; Wirtz and Daiser, 2018). Following Wirtz and Daiser (2018), the BMI process contains the following main phases: (1.) analysis, (2.) ideation, (3.) feasibility, (4.) prototyping, (5.) decision-making, (6.) implementation and (7.) sustainability. The phases of prototyping and decision-making are of utmost importance for firms in particular, as the subsequent implementation of a new BM usually requires significant investments (Frankenberger *et al.*, 2013). However, knowledge about BM prototyping and decision-making is still scarce (Wirtz and Daiser, 2018), and scholars call for new tools and methods to facilitate these activities (Athanasopoulou and Reuver, 2020; Fruhwirth *et al.*, 2020).

McGrath (2010) suggests approaching BMI experimentally by prototyping and evaluating new BMs before the decision for a significant investment, i.e., the BM implementation, is made. For this purpose, the literature provides several BMI tools. Early-phase BM prototypes aim to conceptualise and communicate the BM's core logic and elements (Szopinski *et al.*, 2022). They primarily rely on static modelling languages, such as canvases (Athanasopoulou and Reuver, 2020; Szopinski *et al.*, 2022), and qualitative evaluation methods, e.g., expert judgment, multi-criteria or scenario analysis (Gilsing *et al.*, 2022). While these tools are generally valuable for designing new BMs, they are often inadequate for comparing and deciding between different BM alternatives (Athanasopoulou and Reuver, 2020). As the BMI process proceeds toward implementation, BM evaluation methods tend to become rather quantitatively oriented to enhance decision-making, with spreadsheet-based business cases and cost-benefit calculations being common (Gilsing *et al.*, 2022).

Beyond such standard calculations, Gilsing *et al.* (2022) also see the potential for dynamic systems analysis and simulation analysis to support BM decision-making. In this regard, System Dynamics (SD) is gaining growing attention in BM and BMI research. SD is a computational modelling and simulation approach to analyse complex systems and enhance decision-making (Sterman, 2000). Since BMs can be considered as systems (Zott and Amit, 2010), SD has already been used in recent years to model the inherent structures of BMs and simulate the outcomes in various future scenarios (e.g., Abdelkafi and Täuscher, 2016; Cosenz *et al.*, 2020; Moellers *et al.*, 2019 to name a few). In these studies, SD has been illustrated as a suitable tool to quantitatively evaluate BMs in different practical cases, e.g., Patagonia (Cosenz *et al.*, 2020), though without appreciably relating it to the BMI context. Moellers *et al.* (2019) specifically analyse the impact of SD on a manager's cognition in different BMI phases. However, as they focus on the car manufacturer BMW with the firm-specific BMI process, the applicability to other practical contexts remains limited (Moellers *et al.*, 2019). Moreover, none of the previous studies is dedicated to the B2B context with its particularities. Against this background, our research objective is to develop a new simulation-based BMI process for B2B contexts that systematically integrates SD modelling and simulation.

To develop the simulation-based BMI process, we followed the action design research (ADR) method

(Sein *et al.*, 2011). We conducted this study with two German firms, anonymised as *Alpha* and *Beta*, who faced the challenge of BMI in the B2B context. Alpha is a start-up (founded in 2017) offering a solution comprised of hardware, software, and service components to analyse manual work processes, mainly in the logistics sector. Beta is a corporate power plant manufacturer seeking to innovate its strategic spare parts business. Both firms intended to transform their prior transactional and product-centric BMs towards service-centric and relationship-based BMs, which we refer to as service-oriented BMs in the following. Concerning the market implementation of such a new service-oriented BM, both firms anticipated significant investments and business risks, which they wanted to mitigate. In both cases, new BMs were successfully developed and evaluated using SD modelling and simulation before implementation. We aggregated the learnings from both cases into the *simulation-based BMI process*.

Methodological approach

With this research, we pursued the dual mission of solving real-world problems – developing new service-oriented BMs for Alpha and Beta and evaluating them before market implementation – and simultaneously contributing to the academic knowledge base by integrating SD simulation as a quantitative BM evaluation approach into the BMI process. Therefore, we conducted a two-and-a-half-year ADR project with Alpha and Beta from Q1 2020 until Q3 2022. ADR has already proven useful in achieving similar objectives in BMI research, e.g., developing a process framework for circular BMs (Santa-Maria *et al.*, 2022) or business model development tools (Ebel *et al.*, 2016).

To guide the effective development of the simulation-based BMI process, we first analysed the practical and theoretical problems and aggregated them into the underlying "class of problems" (Sein *et al.*, 2011, p. 40), i.e., utilising SD to support quantitative evaluation and decision-making in B2B BMI. Thereafter, we built a "theory-ingrained" (Sein *et al.*, 2011, p. 40) initial design of the simulation-based BMI process. For this purpose, we integrated processual knowledge from BMI (Frankenberger *et al.*, 2013; Gassmann *et al.*, 2020; Osterwalder and Pigneur, 2010; Wirtz and Daiser, 2018), Design Thinking (IDEO, 2012; Lewrick *et al.*, 2018) and SD modelling (Martinez-Moyano and Richardson, 2013; Sterman, 2000). The *generic BMI process* of Wirtz and Daiser (2018) provided the basic process structure, which we modified and adapted with method elements from Design Thinking and SD modelling (Henderson-Sellers *et al.*, 2014). Design Thinking helped to infuse a user-centred and experimental approach into the process, and SD modelling provided the primary approach for quantitative modelling and simulation. Primarily, we augmented the generic BMI process with two new phases to accommodate quantitative evaluation through SD simulation before implementation, i.e., the *definition* phase and the *quantitative simulation* phase (plus a preparatory team-alignment phase).

We used the simulation-based BMI process in the two firms, first in Alpha and then in Beta, to further develop the initial design and evaluate it. In each case, we participated in the firm's BMI team, developed a new service-oriented BM, and prototyped it with SD software (we used *Silico*). In the SD software, we conducted simulation experiments to evaluate the new BM and support decision-making regarding the subsequent implementation (Table 1). We continuously journaled and reflected on the research process to capture findings and evidence relevant to further developing and evaluating the simulation-based BMI process (Sein *et al.*, 2011). Due to the COVID-19 pandemic, most research activities, e.g., interviews, workshops, and modelling, were conducted remotely using Zoom and MS Teams for communication and Miro for collaboration.

Lastly, we evaluated the effectiveness and utility of the simulation-based BMI process by conducting surveys and interviews with both firms' BMI teams (Sein *et al.*, 2011). The evaluations took place after executing the new BMI phases that we included in the simulation-based BMI process. We evaluated the definition phase with the BMI team of Alpha and the quantitative simulation phase with the BMI team of Beta.

Table 1.

BMI phases and activities	Operationalisation at Alpha	Operationalisation at Beta
Phase 1: Preparation		
Align BMI team with adequate competencies, knowledge and authority	BMI team: Two researchers with BMI and SD competencies. Three founders with business knowledge and authority. Two additional employees with specific knowledge in sales and marketing.	BMI core-team: Two researchers with BMI and SD competencies. Two functional experts with technical and business knowledge. BMI extended team: One decision-maker, one marketing, and one probabilistic expert.
Equip team with adequate resources	Cooperation agreement with external funding defining action plan and responsibilities.	Cooperation agreement with firm-internal funding defining action plan and responsibilities.
Phase 2: Analysis		
Analyse current business model & business ecosystem	Numerous interviews with the founders, among others in the project initiation stage.	Numerous interviews with BMI team, among others in the project initiation stage.
Analyse customer problems, needs and causes	Four internal interviews with sales people and project managers of Alpha to prepare inquiry with customers. Six laddering interviews with customers of different customer segments focussing on customer jobs, pains and gains.	Eight internal interviews with Beta's employees, e.g., from engineering, sales and finance, to elaborate customer jobs, pains and gains.

Table 1: BMI phases and activities operationalised in the cases of Alpha and Beta

Table 1.		
BMI phases and activities	**Operationalisation at Alpha**	**Operationalisation at Beta**
Phase 3: Definition		
Define and prioritise customer segments, define goals for BMI	Two half-day workshops* with BMI team to consolidate the data in customer segments, decide for one focal customer segment and define user stories.	Discussions with BMI team to define customer segments, to decide for one focal segment and to define two pilot use-cases for the new service-oriented BM.
Formulate dynamic hypothesis of the problem	One half-day Workshop* with BMI team following the group-model-building approach to define and map problem-variables and their root causes.	One half-day Workshop* with BMI team formulating the dynamic hypothesis and map the business ecosystem with the E3-value modelling notation.
Map business ecosystem	One half-day Workshop* with BMI team to map the business ecosystem with the E3-value modelling notation.	
Phase 4: Ideation		
Generate new BM ideas	One half-day Workshop* with BMI team to generate new ideas to enhance the value proposition following the 635 method (Lewrick et al., 2018). One half-day Workshop* with BMI team to generate ideas for a new revenue model based on BM patterns (Gassmann et al., 2020).	The idea of the new service-oriented BM already existed in the mental models of Beta's BMI team members. Through discussions, we conceptualised the idea, improving problem-solution-fit.
Conceptualise ideas roughly, focussing on customer needs and value proposition fit	One half-day Workshop* with BMI team to consolidate and prioritise the generated ideas.	

Table 1: BMI phases and activities operationalised in the cases of Alpha and Beta (*Continued*)

Table 1.		
BMI phases and activities	**Operationalisation at Alpha**	**Operationalisation at Beta**
Phase 5: Qualitative conceptualisation		
Develop conceptual prototypes, test prototypes and gather qualitative data	Event** with approximately 20 customers where poster prototypes were presented stating the ideas and corresponding questions. Three interviews with customers to test the ideas and get feedback.	Five interviews with customers to test the new BM idea and get feedback.
Develop comprehensive BM concepts, decide whether to pursue or drop BM concepts	One half-day Workshop* with BMI team to consolidate gathered data and prioritise ideas to pursue to simulation stage.	Discussions of the BMI team to consolidate gathered data and decide to pursue to simulation stage.
Phase 6: Quantitative simulation		
Develop SD simulation models, test model structure and behaviour	Numerous modelling sessions*** over a three-month period with the founders to model Alpha's and the key customers' value creation and capture structures.	Numerous modelling sessions*** over a two-month period with the BMI team to model Beta's and the key customers' value creation and capture structures.
Gather quantitative data	Five interviews with founders and employees from marketing and sales to discuss model structure and parameters. Three interviews with customers to gather quantitative value creation and capture parameters with regard to Alpha's value proposition.	Three interviews with Beta's employees, e.g., from marketing and probabilistics, to gather additional data. One half-day Workshop** with BMI team to discuss model structure and parameters.

Table 1: BMI phases and activities operationalised in the cases of Alpha and Beta (*Continued*)

Table 1.		
BMI phases and activities	**Operationalisation at Alpha**	**Operationalisation at Beta**
Conduct simulation experiments, concretise BM concept and make final decision	Two 2h-workshops* with BMI team where simulation results are presented, discussed and further experiments are conducted. The founders made the decision to proceed the final BM to the implementation stage.	One 3h-workshop* with BMI team where simulation results are presented, discussed and further experiments are conducted. The decision-maker made the decision to proceed the final BM to the implementation stage.
* Workshop was executed digitally via Miro (collaboration) and MS Teams or Zoom (communication), comprehensive pre- and post-processing included. ** Workshop is executed physically. *** Modelling sessions were executed via Zoom (communication) using Silico (SD-modelling).		

Table 1: BMI phases and activities operationalised in the cases of Alpha and Beta (*Continued*)

Key Insights

The main result of this research is a new BMI approach emphasising BM design and evaluation using SD modelling and simulation before market implementation: The simulation-based BMI process. The simulation-based BMI process extends the established BMI process derived from literature by three additional phases, i.e., *preparation*, *definition*, and *quantitative simulation*, including corresponding activities, tools/techniques, and goals (Figure 1). In the following, we describe the new phases and illustrate empirical findings from their execution in the two case companies, Alpha and Beta.

3.1 Phase 1: Preparation

The goal of the preparation phase is to align a team with adequate attributes to execute the simulation-based BMI process, i.e., BMI and SD competencies, business knowledge, and the authority to make BM-related decisions. The BMI teams in both cases of Alpha and Beta consisted of the firms' internal practitioners responsible for business knowledge and authority and external academics responsible for BMI and SD competencies. The competencies for qualitative modelling of the current BM's problems and quantitative modelling and simulation of the new BM in SD software were indispensable for the subsequent BMI phases.

3.2 Phase 3: Definition

The definition phase aims at merging the gathered data from the prior analysis phase, e.g., by conducting laddering interviews with customers (Reynolds and Gutman, 2001), into a common understanding of the problem, context, and goal (IDEO, 2012). Therefore, the BMI team jointly develops different qualitative models. First, customer segments are defined by focusing on their needs, e.g., by elaborating on jobs to be done or pains and gains (Osterwalder *et al.*, 2014). Second, the BMI team formulates the so-called "dynamic hypothesis", a graphical representation of the current BM's problems and its root causes (Martinez-Moyano and Richardson, 2013; Sterman, 2000). The dynamic hypothesis is developed in

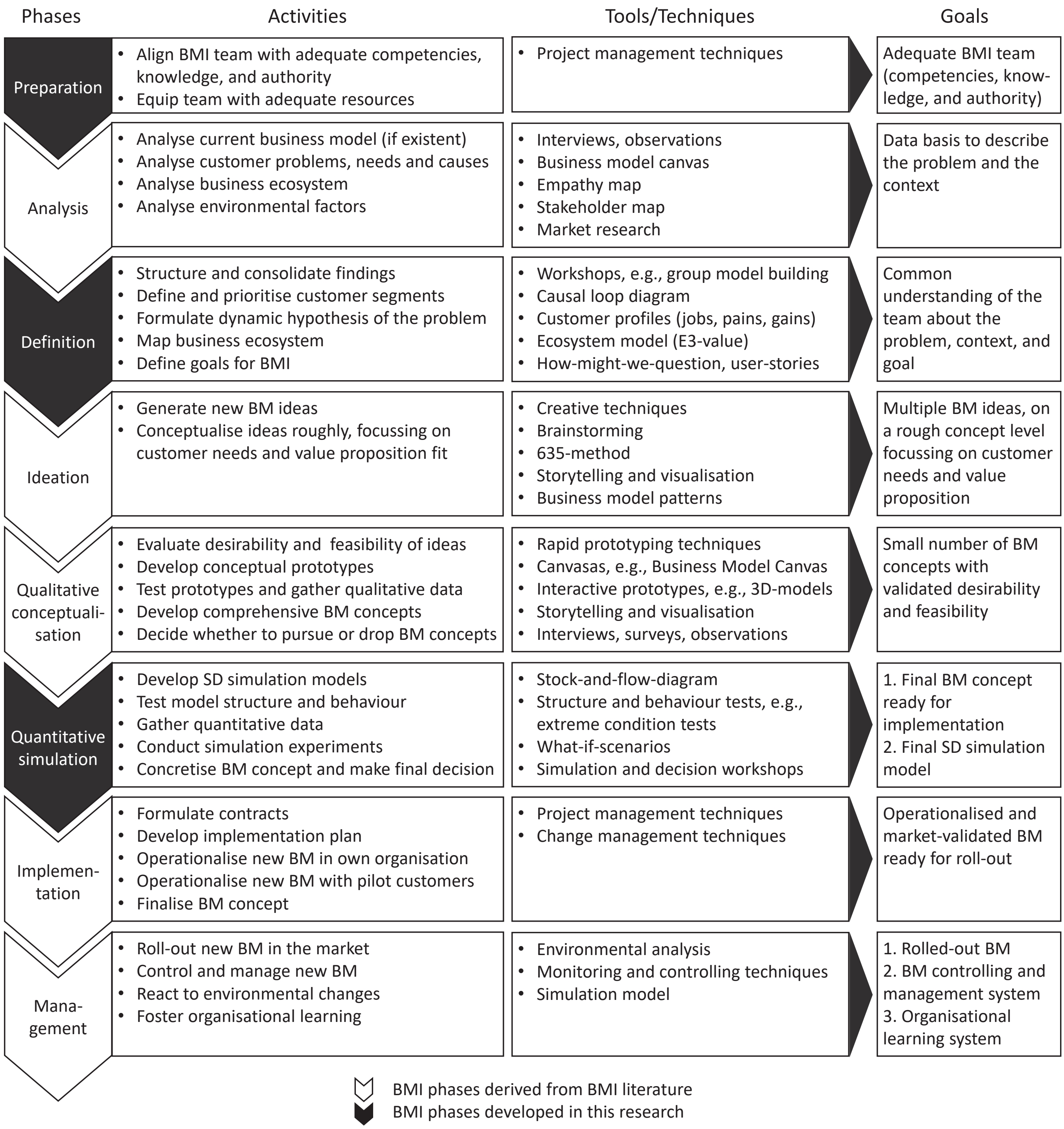

Figure 1: The simulation-based business model innovation process

group workshops where the team members discuss their mental models and successively formulate a shared understanding (Wilkerson *et al.*, 2020). Third, the business ecosystem is described by utilising the e3-value modelling notation, i.e., the BMI team elaborates on the actors, the activities they execute, and the value objects they exchange (Gordijn and Akkermans, 2001). Lastly, the goals for the BMI are defined concerning the key customer segment(s), e.g., via user stories (Lewrick *et al.*, 2018).

To evaluate the definition phase, Alpha's team members assessed and described their understanding of customer segments and needs, as well as the problems and root causes with the current BM before and after the definition phase.[1] Moreover, they rated the transition of their interpersonal team understanding, i.e., the coherence of the individual understandings within the BMI team, throughout the definition phase.[2]

Alpha's BMI team members stated their understanding of customer segments and needs has developed from a moderate (3) to an in-depth level (5). One of Alpha's employees said his *"knowledge significantly deepened,"* and one founder explained that *"[the joint activities in the definition phase] actually revealed a significant gap in our understanding of the daily customer life."* Moreover, after the definition phase, the participants developed a predominantly common (4) interpersonal team understanding of the customer segments and needs – whereas they had assessed it as partly common (3) before. Regarding the current BM's problems and root causes, the BMI team members developed their previous moderate (3) individual understanding towards an advanced level (4). One of Alpha's founders explained, *"I became aware of our buying centre issues in a completely different manner,"* while another stated that *"we identified new problem areas and broadened our perspectives."* In terms of interpersonal team understanding, the participants indicated that they developed a predominantly common (4) team understanding regarding the current BM's problems and root causes. In contrast, they had previously assessed it as little common (2).

3.3 Phase 6: Quantitative simulation

After phase five, i.e., the *qualitative conceptualisation*, which aims at conceptualising the new BM and evaluating its desirability and technical feasibility, the following *quantitative simulation* phase aims at further developing the new BM towards a ready-to-implement status and evaluating its financial viability (Gassmann *et al.*, 2020; Lewrick *et al.*, 2018). Therefore, the conceptual thoughts from the previous phase regarding value creation and value capture still need to be quantified (Gilsing *et al.*, 2022, p. 38). Finally, the decision has to be made whether to proceed with the new BM to the implementation phase, which entails significant investment (Frankenberger *et al.*, 2013).

The new BM is modelled and simulated with SD software, building on the SD modelling approach (Martinez-Moyano and Richardson, 2013; Sterman, 2000). To organise the variables and build a comprehensive model structure, we used the *actor-based modelling framework* of Ksouri-Gerwien and Vorbohle (2023). The initial model formulation is based on the dynamic hypothesis and the ecosystem model from the definition phase, followed by an iterative data inquiry, modelling, and validation process. To gather the quantitative data necessary for modelling the value creation and capture structures, interviews with relevant stakeholders holding the respective knowledge, e.g., decision-makers, employees, and customers have to be conducted (Table 1). In the case of Beta, the two primary informants attended joint modelling sessions every week for about two months. Data inquiry and modelling steps alternated until the model produced meaningful results. During this process, the model structure and behaviour are validated with various tests, e.g., extreme-condition test, and by applying real-world data. The resulting simulation model in the case of Alpha consisted of 246 model elements (Figure 2) and 135 in the case of Beta.

Following the model building, the BMI team conducts simulation experiments to evaluate the new BM. Therefore, questions and hypotheses are formulated regarding the new BM, which are to be answered with the simulation model. In both cases of Alpha and Beta, questions were mainly related to profit and customer count, e.g., *"How many customers do we need to be profitable?"* (Alpha) or *"How long is the amortisation period?"* (Beta). To answer these questions, we reduced the complexity of the overall model to a cognitively manageable number of variables. Therefore, we defined three types of variables relevant for BM evaluation: (1) *Performance variables* (outputs) represent the model answers to the posed questions, e.g., accumulated profit over time. (2.) *Scenario variables* (external inputs) affect the

[1] Levels of individual understanding: 1 = non-existent, 2 = little, 3 = moderate, 4 = advanced, 5 = in-depth

[2] Levels of interpersonal coherence: 1 = not at all, 2 = little, 3 = partially, 4 = predominant, 5 = complete

performance variables externally and cannot be influenced by the own BM, e.g., customer usage intensity. What-if scenarios, e.g., worst-, moderate- and best-case scenarios, were defined for these scenario variables to test the new BM under different conditions. (3.) *Control variables* (internal inputs) affect the performance variables internally through the BM design, e.g., price. The simulation experiments were conducted in workshop settings, where the BMI team manipulated control variables dynamically, e.g., via sliders, applied different scenarios, and observed the BM performance. Figure 2 illustrates the interface for simulation experiments in the *Silico* software and Alpha's overall model structure. Lastly,

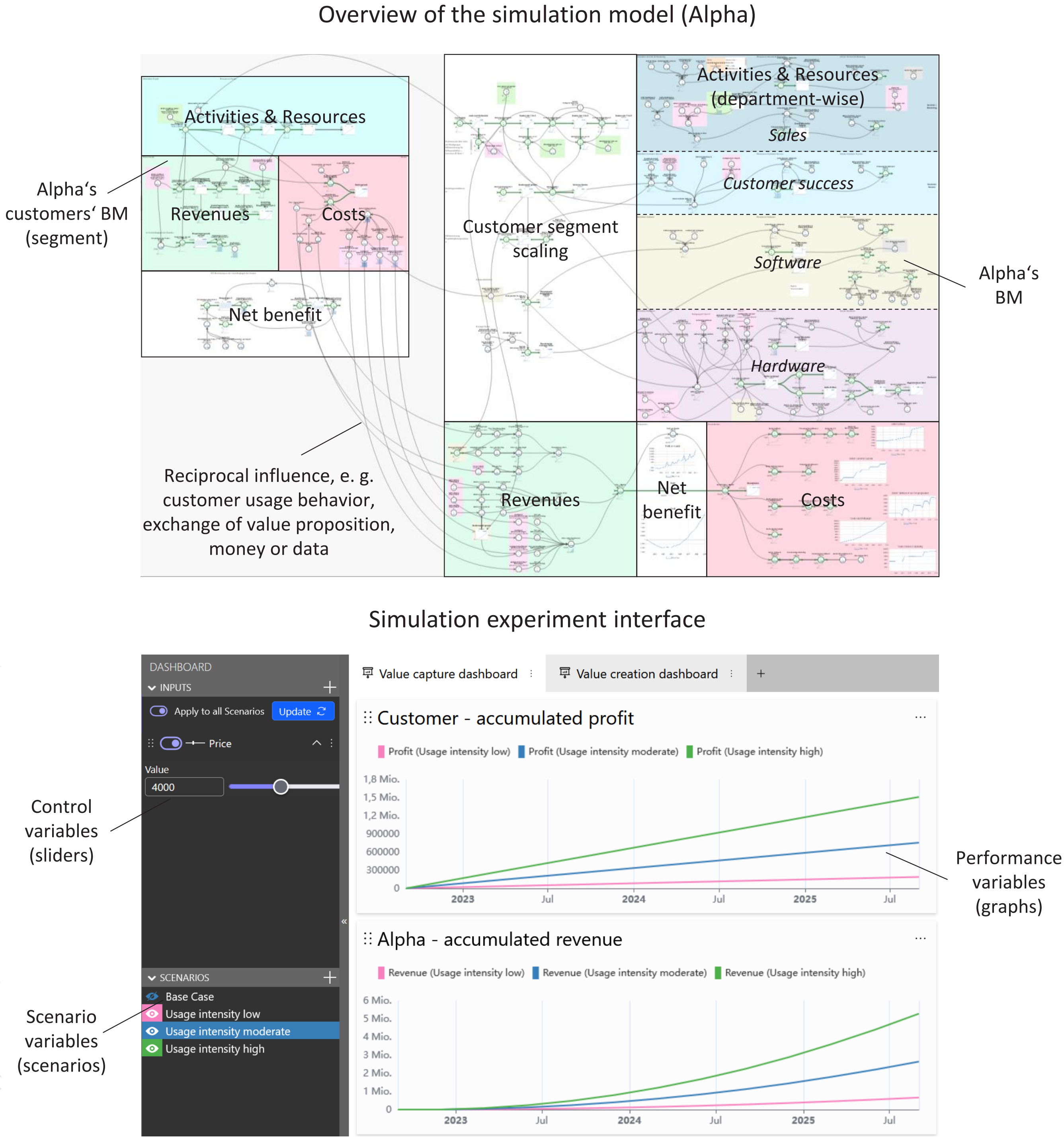

Figure 2. Overview of the simulation model and simulation experiment interface in the case of Alpha (software silico)

the decision-makers of Alpha and Beta made the final decision to proceed with the new BM to the implementation stage.

To evaluate the quantitative simulation phase, we interviewed Beta's BMI team members regarding (1.) the further development of the new BM towards a ready-to-implement status, (2.) the evaluation of the new BM, and (3.) the decision-making support provided by the simulation. The BMI team members were asked to describe the maturity of the new BM before and after the quantitative simulation phase and rate it on a scale from 1 (initial rare idea) to 10 (ready-to-implement BM). On average, the participants stated that the new BM had developed from level 3, i.e., *"a rough idea"* (functional expert 1, Beta) and *"an idea without a business model"* (decision-maker, Beta), towards level 7, i.e., a fully conceptualised and quantified business model. To reach the BM's implementation readiness and approach the market, mainly contractual issues still needed to be resolved:

> *"I think the commercialisation still has to be made, the contractual issues have to be clarified, and the acceptance in the market also has to be tested."* (decision-maker, Beta)

Beta's BMI team members indicated that SD modelling and simulation were more sophisticated to evaluate a new BM than their common approach, i.e., spreadsheet calculations with MS Excel. They agreed that evaluating a BM with spreadsheets is possible since one was an *"Excel crack"* (functional expert 2, Beta) or an *"Excel super programmer"* (decision-maker, Beta). However, the decision-maker explained why he thought that SD is the better option to evaluate a BM compared to MS Excel:

> *"The risks and the business benefits are not easy to calculate because we are not operating in linear conditions. Since many, many variables have an influence on the business model [...] and are partly dependent on each other, this just could not be calculated via common simple Excel solutions, or such calculation methods [invest and cost calculations] just would not do justice to the complexity of the problem."* (decision-maker, Beta)

The decision-maker, moreover, emphasised the usefulness of rapid experimentations with scenario and control variables to explore the system's thresholds, e.g., regarding the profitability of the new BM. Beta's probabilistic expert highlighted the advantages of being able to experiment with highly uncertain parameters or parameters with insufficient data basis to assess the *"sensitivity of the commercial model."* As a consequence of the simulation experiments, the decision-maker developed a *"good feeling"* for the new BM, which grounded his decision-making to proceed with the BM's innovation process:

> *"Because of the model's flexibility, you can simulate what happens relatively quickly and approach different scenarios to see when the whole thing tips over, when it no longer pays off, and when we might be in danger of no longer being able to serve our customers. And that is what is meant by developing a good feeling for it [the new BM]."* (decision-maker, Beta)

Beta's BMI team appreciated the communicability of the simulation model and the simulation results. The probabilistic expert explained: *"To demonstrate, to show people, and to create acceptance, this [simulation model visually formulated in the Silico software] is very good."* The graphical user interface (Figure 2) facilitates joint discussions and further model development within the BMI team – including persons without prior SD experience. The utility of the new approach, i.e., modelling and simulating the new BM with SD, outweighs its costs, as functional expert 1 stated: *"price-performance ratio is top, great."* Lastly, the decision-maker saw further potential for the new approach at Beta. Among other use cases, he emphasised that the simulation model could be used as an instrument for managing the new BM in the long term:

> *"For this [the new service-oriented BM], we need constant risk management. And in my opinion, we create this risk management by constantly adapting this simulation model dynamically. [...] Otherwise, we'll end up managing it in Excel spreadsheets again, with all the disadvantages."* (decision-maker, Beta)

Discussion and Conclusions

In this research, we developed the simulation-based BMI process that integrates quantitative BM design and evaluation using SD modelling and simulation into BMI before the market implementation of a new BM. We applied the process at two firms in the industrial B2B context, Alpha and Beta, where we successfully developed and evaluated new service-oriented BMs. We contribute to the BMI knowledge base by shedding light on how SD modelling and simulation can provide a methodical advancement for BM design and, in particular, for the rarely investigated BMI phases of prototyping and decision-making (Wirtz and Daiser, 2018). We see the potential to generalise the findings from our ADR study as follows (Sein *et al.*, 2011).

The effective execution of the simulation-based BMI process requires a combination of BMI expertise, sound business knowledge, authority, and SD competencies among the BMI team members. The SD competencies manifest in the effective, collaborative formulation of qualitative and quantitative models, which provide the basis for the two new BMI phases definition and quantitative simulation. Consistent with Ebel *et al.* (2016), we also added a preparation phase to form an adequate team constellation in the first place.

The definition phase enabled Alpha's BMI team members to develop a more profound and predominantly coherent problem understanding, e.g., regarding customer needs and the current BM. The evaluation results indicate that the definition phase accomplishes its goal of developing the BMI team members' mental models and merging them into a common team understanding. This common team understanding is critical for an effective subsequent BM design process (Ebel *et al.*, 2016). In particular, the dynamic hypothesis synthesises the firm's and the customers' perceived problems with the current BM into a systemic picture and reveals the root causes. In both practical cases, this led to ideas addressing the causes of problems, not just symptoms. Moreover, from the perspective of the SD modeller, the qualitative models, in particular the dynamic hypothesis and the e3-value ecosystem model, provide fundamental input for the subsequent quantitative simulation phase.

The BM design sub-process of the simulation-based BMI process spans from ideation through qualitative conceptualisation and quantitative simulation to implementation. Along the design process, the dominant course of action can be described as iterative prototyping, experimentation, and learning (Gassmann *et al.*, 2020; McGrath, 2010). BM designs, prototypes, and experiments evolve from a rather qualitative and abstract to a more quantitative and realistic matter (Gassmann *et al.*, 2020; Gilsing *et al.*, 2022). The quantitative simulation phase – the heart of the simulation-based BMI process – augments the BM design process by incorporating quantitative SD modelling for BM prototyping and SD simulation for BM experimentation. It fits seamlessly into the BM design's dominant course of action and bridges qualitative BM conceptualisations, such as canvases, and real-world implementations. As the quantitative simulation phase takes place before market implementation, extensive experimentation and learning with new BMs is achieved while simultaneously containing costs, as emphasised by McGrath (2010). This challenges Frankenberger *et al.* (2013), who argue that a new BM must be fully implemented before it can be tested to some degree.

The quantitative simulation phase encompasses iterative modelling and simulation activities. In both practical cases, we observed that the quantitative modelling process of a new BM already provided significant insights that helped sharpen vague BM characteristics and unnoticed contradictions from the conceptual phase, even before the model was simulation-ready, which is consistent with Sterman (2000). SD modelling, i.e., the collaborative activity of building a formalised simulation model utilising SD software, explicates the mental models and implicit ideas of the BMI team members during the development of the new BM. Modelling transforms the new BM from a cognitive and linguistic scheme into a formal, conceptual representation (Massa *et al.*, 2017), with SD providing the modelling language (Szopinski *et al.*, 2022). The resulting SD model (Figure 2) visually represents the new BM during its development and serves as a communication device for the BMI team (Szopinski *et al*., 2022). Due to its formalised and visual nature, the simulation model reduces a BM's *"sheer complexity"* (Foss and Saebi, 2017, p. 213), lowers the cognitive barriers for the BMI team members and supports them in accomplishing cognitive design-related tasks, e.g., designing and evaluating the BM elements and interdependencies (Massa *et al*., 2017; Massa and Hacklin, 2020). As a result, both BMI teams were able to clarify *"how value is concretely created and captured by the stakeholders"* (Gilsing *et al*., 2022, p. 38) and developed their BM ideas into thoroughly conceptualised and quantified BMs. This progress was primarily achieved through extensive discussions between the BMI team members about the BM design, which were facilitated by the simulation models. Thus, we support the proposition of Moellers *et al*. (2019, p. 397) that *"System Dynamics facilitates shared understanding [...] by providing a neutral and consistent frame for discussion."*

The simulation experiments at Alpha and Beta were performed in customised simulation interfaces via the *Silico* software (Figure 2). These simulation interfaces provide twofold value for quantitative BM evaluation before market implementation. First, they reduce the complexity of the simulation model (> 100 parameters) to a cognitively manageable number of parameters, i.e., performance variables (outputs), scenario variables (external inputs), and control variables (internal inputs). Therefore, it is possible to convert the complex model structure into a suitable narrative for presenting the new BM to people not directly involved in the BM design process, such as the decision-maker in the case of Beta. This is in line with Moellers *et al*. (2019, p. 399) who emphasised that *"the communication of insights from the System Dynamics model to managers not involved in the modelling can be improved through the integration of established metrics and terms and complexity reduction in visual interfaces."* In this regard, the simulation model and the simulation interfaces serve as boundary objects, allowing for sophisticated communication and demonstration of the new BM to a variety of audiences during BM design (Doganova and Eyquem-Renault, 2009). Second, the simulation model, particularly the simulation interface, enables the BMI team to flexibly experiment with parameters that are highly uncertain or based on insufficient data. This allows the evaluation of a new BM's sensitivity and robustness against external uncertainties, thus building more resilient BMs (Montemari and Gatti, 2022). In both practical cases, simulation experiments considering worst-, moderate- and best-case scenarios (Figure 2) and the simulation-based comparative evaluation with the actual BM had become the keystone of the decision-making process on whether to proceed to the implementation phase with a new BM. Since SD modelling and simulation facilitate comprehensive BM evaluation and support decision-making, it addresses the call by Fruhwirth *et al*. (2020) for tool support on convergent thinking activities in BMI and can be considered as *"future business model tooling"* (Athanasopoulou and Reuver, 2020, p. 505).

Quantitative SD modelling and simulation are particularly valuable for BM design compared to spreadsheets, e.g., MS Excel, which was the quasi-standard to quantitatively evaluate almost everything at Alpha and Beta as well as in the industry in general (Gilsing *et al*., 2022; Grossman *et al*., 2007). Compared to spreadsheets, SD is a dynamic and visual modelling language, providing semantics and syntax, i.e., interacting stocks, flows, and variables, to represent a BM visually (Szopinski *et al*., 2022). Therefore, SD can reduce the inherent complexity of a BM and facilitate cognitive tasks during BM design, such as designing, evaluating, and decision-making (as previously elaborated). Furthermore, SD simulation models and interfaces provide an effective means of demonstrating, communicating, and developing BMs, thus emphasising the team character of BMI. Therefore, we consider SD a more appropriate approach to BM design than spreadsheets.

Lastly, we integrated relevant aspects of the customers' BM, i.e., their value creation and capture structures, in the simulation model by following an actor-based modelling approach (Ksouri-Gerwien and Vorbohle, 2023). This led to increased transparency of the customers' perspectives on the newly developed BM and enabled the incorporation of customer orientation early in the BM design and decision-making process. In doing so, Alpha approached value-based pricing by considering the customers' costs and revenues and modified their

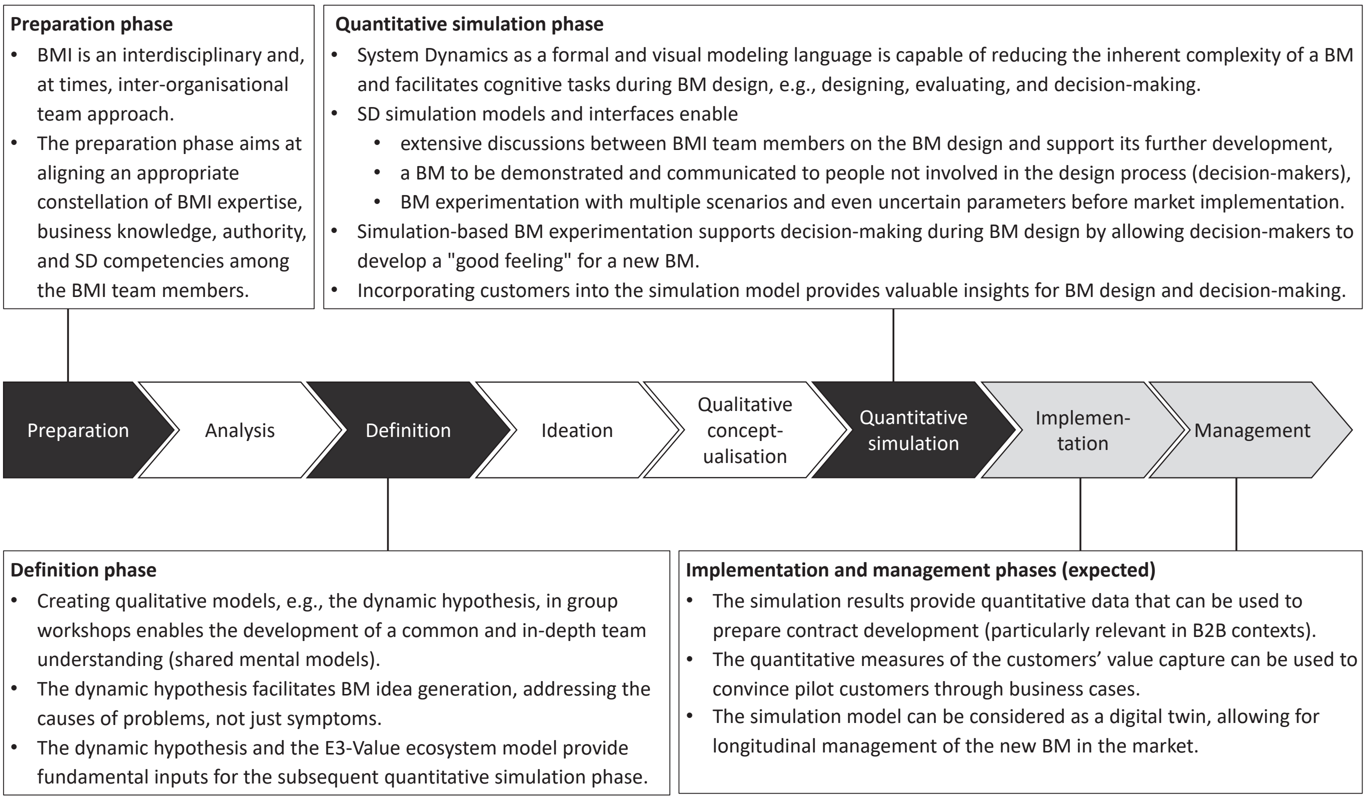

Figure 3. Summary of findings where the simulation-based BMI process contributes to BMI

sales strategy by communicating the customers' expected value. Considering that solutions are *"sold to the top managers through business cases"* (Huikkola *et al.*, 2022, p. 10), we expect this change to be beneficial for convincing pilot customers in the implementation phase. Moreover, since the B2B context requires contracts with clear terms and conditions, the quantitative measures resulting from the quantitative simulation phase prepare the subsequent contract formulation – which we included as the first activity of the implementation phase into the simulation-based BMI process (Figure 1). Figure 3 summarises the findings of where the simulation-based BMI process contributes to BMI.

This research does not come without limitations. We, as researchers, accompanied the BMI processes at Alpha and Beta until the implementation phase. Hence, our study ended after the quantitative simulation phase when the final decision to proceed further with the new BM to the implementation phase was made by both companies. Hence, we were not able to empirically investigate the last two BMI phases, i.e., *implementation* and *management*, in this study, as these will require a lot of additional time. However, Beta's decision-maker already indicated that the simulation model can be used as a digital twin and, thus, as a management tool for the new BM in the long term. Future research should investigate the impact of SD modelling and simulation on these future phases. Moreover, we carried out both BMI iterations of our ADR study with firms with existing BMs as their benchmark. In both cases, customers and data existed to support SD model development and to feed it with input data. Hence, whether the presented simulation-based BMI process is also an effective approach for developing a BM totally from scratch remains unanswered. Still, we expect that even assumption-based modelling can provide insights relevant to BM design (Sterman, 2000) and prepare BMI teams for real-world data inquiry. Lastly, the evaluation results concern specific cases of Alpha and Beta and cannot be generalised.

Finally, we see potential for future research that departs from our findings. Alpha and Beta focussed on customer orientation and financial metrics as their BMI objectives. Adopting our simulation-based BMI process to consider the sustainability and eco-friendliness of BMs could provide an additional meaningful way of using SD modelling and simulation for BMI (Gilsing *et al.*, 2022; Santa-Maria *et al.*, 2022). Since sustainability parameters such as CO_2 emissions are measurable and can be allocated to value-creation activities and required resources, such an approach would enable the consideration of sustainability aspects in BM design and decision-making similar to the customer and financial focus in this study. It might also be worthwhile to extend SD modelling with further simulation approaches, such as agent-based modelling, to increase simulation performance.

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Table 1: BMI phases and activities operationalised in the cases of Alpha and Beta (*Continued*)

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About the Authors

Dr. Christoph Ksouri-Gerwien is a postdoctoral researcher at the Chair for Industrial Sales and Service Engineering at Ruhr-Universität Bochum, Germany. His application-oriented research focusses on the innovation of service-oriented business models using design thinking and systems thinking, particularly the simulation of business models with System Dynamics.

Dr. Jens Poeppelbuss is Full Professor of Industrial Sales and Service Engineering in the Faculty of Mechanical Engineering at Ruhr-Universität Bochum, Germany. His research focusses on service and business model innovation in manufacturing and capital goods industries. He has published in international journals and presented his works at conferences in the Information Systems and Services Marketing disciplines. He is the spokesman of the service management section (WK DLM) in the German Academic Association of Business Research (VHB).