Industry 4.0: Business Process Management Maturity Model for the digitalized interorganizational value chain

Claus Nottbrock [1]

[1] *University of Antwerp, Antwerp 2000, Belgium*

Abstract

This research aims to develop a Business Process Management Maturity Model (BPM MM) and assessment tool (AT) that improves the performance of interorganizational value chains. The actual research lacks on methodical approach to build BPM MMs towards the inter-organizational business processes and digital Industry 4.0 innovations. Current BPM MMs in the domain of I4.0 primary focus on technological perspective and single organization. Future research is mandatory to consider the required capability for highly integrative and interorganizational value chains. The research design follows the Design Science Research methodology to develop a novel artefact through a transparent, rigorous procedure. The research initiates three sub-projects for the design and evaluation of the BPM MM and AT. It supports firms and business partners to determine gaps that limits the maturity of their interorganizational value chain and implement actions to bridge those gaps.

Keywords

design science research, maturity model, business process management, interorganizational, value chain, digital innovation, Industry 4.0

1. Introduction

Firms are forced to reach highest level of performance out of their business processes (BP) by engaging in novel digital Industry 4.0 (I4.0) innovations [1, 2]. “Industry 4.0 can be described as the increasing digitalization and automation of the manufacturing environment as well as the creation of a digital value chain to enable the communication between products and their environment and business partners” [3]. Digital innovation (DI) is defined as “a product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT”[4]. However, majority of firms are still facing difficulties to understand the concept from their organizational perspective [5] and mainly focus on single organizations [6, 7]. It is about the way how value chain processes are managed with a wide variety of innovative I4.0 technologies [8]. Therefore, firms lack knowledge concerning the interorganizational capability areas [9] and its horizontal integration of digital I4.0 innovations [10, 11], that can be assessed and improved by a BPM MM, in order to reach highest level of performance out of the cross-organizational value chain [8, 12]. In order to overcome these difficulties and support firms to determine the “as-it-is”- and “should-be”-states for a successful realization of these digitalized innovations aligned within interorganizational value chain new tools are needed [13]. Researchers conclude that MM should be the tools to develop mandatory organizational capabilities and aligned goals, under consideration that BPs have a lifecycle that is defined, manage, measure and controlled [14, 15] and effective [15]. To determine the BPM MM of all involved firms within the interorganizational chains is “major prerequisite” to reach the highest performance out of BPs [16]. BPM MM is defined as “a model to assess and / or to guide best practice improvements in organizational maturity and process capability, expressed in lifecycle levels, by taking into account an evolutionary road map regarding (1) process modelling, (2) process deployment, (3) process optimization, (4) process management, (5) the organizational culture and / or

Proceedings of the Demonstration & Resources Track, Best BPM Dissertation Award, and Doctoral Consortium at BPM 2021 co-located with the 19th International Conference on Business Process Management, BPM 2021, Rome, Italy, September 6-10, 2021
EMAIL: Claus.Nottbrock2@student.uantwerpen.be
ORCID: 0000-0002-1038-5835 (A. 1)

(6) the organizational structure" [17]. The actual literature covers a number of existing I4.0 MMs, [12] identified three publication streams of MMs related to (1) manufacturing scope, (2) supply chain management scope, (3) digital integration technology scope, or a combination of different scopes. However, only some of the MMs (e.g. SIMMI4.0 [18]) partially cover relevant aspects, but lack to consider the required capabilities of a highly integrative and interorganizational BP application in the field of DI. Furthermore, most of the I4.0 MMs lack a self-assessment tool to support firms in assessing the maturity value chains, which also include an AT that support firms as roadmap on their path toward investing into DI [12, 19]. Out of this, the researcher could not identify an existing MM that has an explicit focus on the requirements for firms of digital Industry 4.0 innovations in combination with the interorganizational BPM-view. Therefore, the researcher concludes to the following problem statement: "Firms are not capable to select and improve their BPs along the interorganizational value chain to the full extend out of digitalized I4.0 innovations". Out of this overall research question was determined: *How should a prescriptive Business Process Management Maturity Model be designed to improve the interorganizational value chain performance of firms out of digitalized I4.0 innovations?*

2. Research methodology and techniques

The purpose of this Design Science Research (DSR) aims to determine a BPM MM and AT that is improving the performance of interorganizational value chains out of DI. It embeds the theoretical background to the DI and BPM research by proposing a framework for technological-, organizational- and institutional-perspectives and designs a methodological research scheme that develop and evaluate a novel artefact. The research will follow the DSR methodology process of [20] defining six steps as shown in Fig. 1 [21]. The central element is the design and development of the MM and its Assessment Tool (AT) out of an iterative procedure [22]. This will determine existing knowledge in the research domains, and it follows the research strategy in the method framework. This offers a solution-oriented framework to solve problems that are difficult to solve based on incomplete knowledge [23]. The research will achieve rigor by the "appropriate applying existing foundations and methodologies" [24] and applying methods to both designing and evaluating the artefact and its process. This design science research will be conducted socio-technical systems on firm level. Hence, the inter-organizational chain will be the unit of analysis [25-27]. The artefact design follows the method framework for DSR and design guidelines of [28]. The overall dissertation of the researcher applies the methodological steps of the applied framework for DSR and split it into three sub-projects (Figure 1). The individual results will be published in single publications: (1) determines state-of-the-art under-standing and problem explication; (2) determines solution objectives and requirements, design / develop the artefact, demonstrate artefact by pilot study; and (3) evaluates the artefact and communicate results.

3. Proposed Solution

[29] conclude that most of the existing I4.0 MMs lack a solid theoretical foundation and are derived based on an arbitrary design method. Furthermore, they lack transparency regarding the methodological steps, documentation, description of dimensions, and their empirical validation [22, 29]. In order to improve the rigor and relevance of this overall DSR the researcher will publish the results of the SLRs (Sub-Project 1) as contribution to the existing body of knowledge by understanding the state-of-the-art problem with potential solutions, identifying gaps in BPM research, and comparing existing MM capabilities. The second publication is summarizing the results of the Sub-Project 2 with the relevant three DSR phases objectives of solutions, design and development of the artefact, demonstration and process evaluation. The final paper will communicate the final results of the Sub-Project 3 and the final product evaluation with the validated AT, and the relevant BPM MM documentation.

3.1. Sub-project 1: Problem identification and motivation

A good method is crucial for a comprehensive and accurate Systematic Literature Review (SLR) for IS studies [30]. SLRs will be carried out in this sub-project to identify the specific state-of-

the-art research problem and justify the relevance of a solution. In order to increase the trustworthiness of the SLRs the researcher will follow the SLR guidelines by [31], with three phases, (1) formulating the research questions and the search strategy; (2) screen, filter and extract information based on criteria, organize and prepare information for analysis, code and analyze date; and (3) synthesizing the results. The researcher appliers the Qualitative Data Analysis (QDA) and a SLR end-to-end process flow [30] and report the method outlined in the Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) statement [32]. Two SLRs will be planned thorough and in-depth exploration, analysis on addressing the research questions. The reason to carry out two systematic literature reviews is to facilitate through, and in-depth exploration and analysis focused on each research questions in order to contribute input to the first two stages of the DSR Methodology. The purpose of the first SLR (DSR step 1: problem identification and motivation) with the research questions would be categorized as descriptive review and the scoping review methodology in order to identify the conceptual boundaries and potential research gaps [33]. This SLR aims to define current literature on the combined topic of digital innovation and business process management, beyond maturity models, to ensure that the research questions are comprehensively addressed. The second SLR (part of DSR step 2: Objective of solutions) aims to define current MM capabilities and levels in IS-related BPM literature in order to open up for an informed discussion of future research potential.
To address the research questions, these have to be distilled as represented in the research purposes. Thus, this first iteration will be a conceptual-to-empirical and derived criteria and requirements of existing academic MMs from literature. An inductive approach will be used to categorize knowledge from the literature, iteratively, analyzed and revising by constant MM comparison and the information collected. One of the most important results of this first sub-project will be the understanding of the state-of-the-art problem and gaps in research. This output will provide a basis for the MM and its assessment-tool design strategy.

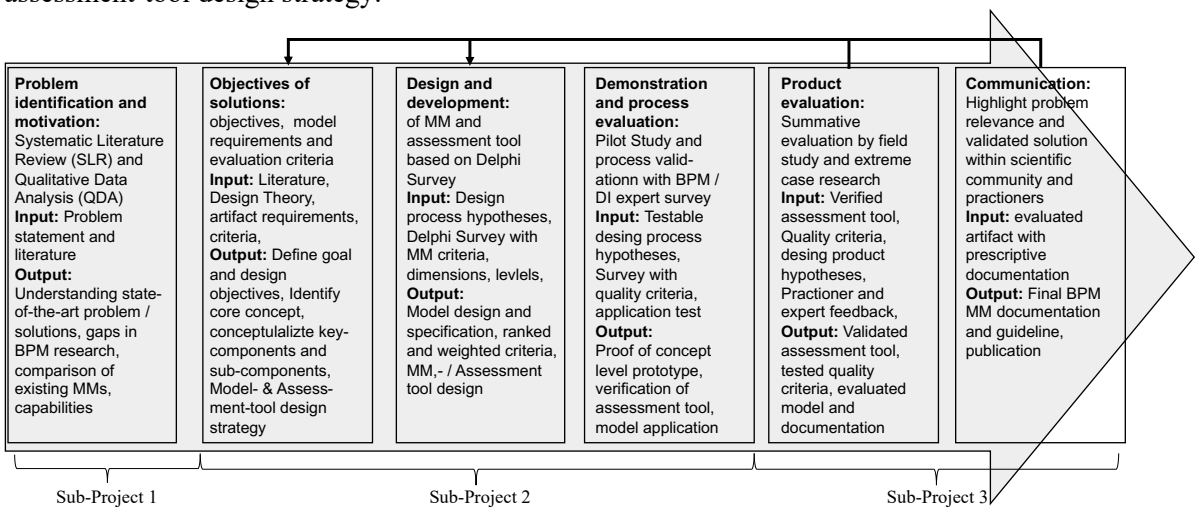

Figure 1: The DSR Methodology of Peffers et al. (2007) applied for this research

3.2. Sub-project 2: Artefact objectives, design, and demonstration

In this first section the iterative procedure aims to define the MM solution objectives and determine the set of requirements to be fulfilled to access DIs in interorganizational BPM MM in a systematic manner. Based on the conclusion of the two SLRs, design recommendations and as well as the core concept of the MM- and its AT-design, as novel artefact, will be identified. The second section describes the artefact design and development. It follows the method framework for design science research and design guidelines of [24], the IS artifact types of [34], the IS design theory components of [35] in order to increase the research validity and reliability of this DSR. To address this task, the Delphi technique has been adopted during the development of a novel MM for BPM [36]. This iterative procedure deals with the artefact design and the design process hypotheses [12]. Thus, iterative development comprised the procedures used to define an architecture and structure (e.g., capabilities, dimensions) for this MM and its AT. These iterations will empirical-to-conceptual, applying the MM

elements proposed from the first iteration to empirical methods with academics and professionals to collect relevant insightful and practical information. The Delphi survey is a group facilitation technique, which is an iterative multistage process, designed to transform opinion into group consensus [37]. This academic and practitioners' experts that will be pre-selected and invited to this survey to collect and define the assessment method criteria and improvement method criteria by a quantitative survey. The third section demonstrates the BPM MM with its process and its AT. The application test will be based on a single case study in a pilot study. The novel artefact will be tested for validity and reliability [38]. To proof the concept of the instrument items an expert survey with academic experts and practitioners. The results of this evaluation activity might determine further iterations through the DSR process described in Fig. 1. Subsequent iterations may refer to the same or an updated 2nd stage related to objectives and requirements or to the 3rd stage related to the design and development.

3.3. Sub-project 3: Artefact evaluation and communications of results

The novel BPM MM with its content and its AT will be evaluated in terms of quality, utility and efficacy based on field studies in purposely selected firms. These will observe and measure how well the BPM MM and its AT supports a solution to the problem. It will show that the artefact is applicable and useful in practice [39, 40]. To strengthen this evaluation the researcher will define formative (process) and summative (product) evaluation specifications, combined with a naturalistic strategy out of a field study in order to gain qualitative interpretative feedback and qualitative feedback about the evaluation criteria [41]. The extreme case research will be selected for further case study investigation [42]. The firms of the field study with the highest and the lowest maturity will be further analyzed to gather further information on unusual cases that might explain why some firms achieve higher score compared to other firms. It aims an evaluated artefact and its prescriptive documentation. Finally, the problem and its importance of the artifacts to solve problems in an effective way will be communicated, when appropriate. This prescriptive documentation will contribute to the academic- and practitioner knowledge.

4. Relation to Business Process Management (BPM)

This research agenda supports the transition towards the domains of DI and BPM with it interorganizational business processes. It embeds the theoretical background of four research domains BPM, digital innovation, value-chain, and collaboration. Digitalization by itself involves new technologies, systems and relationships that assist firms to reach highest level of performance out of their business processes. These socio-technical structures require firms to re-evaluate and re-organize [43] interorganizational relations that enables firms to work together along their value chain process through these novel digital innovations [6]. BPM, under consideration of the dynamic capability view, is able out of reconfiguration and integration of firm's business processes to cope with these environmental changes [44]. The contribution of this research will propose a research design and its methods for a sound BPM MM development that will have a wide practical application and acceptance in firms to support these to improve their business process performance as dependent variable.

5. Achieved results and open issues

This research and its DSR design started already with the first sub-project and its SLR in order to understand the state-of-the-art problem and potential solutions, the existing gaps in the BPM research domain, and the comparison of existing MM capabilities. However, the DSR methodology with artefact evaluation is a central element of this research and needs to be planned in an early stage. It refers to a formative evaluation and aim to observe and measure how well the MM and AT support firms for "successful actions in improving the (…) performance of the evaluand."[41]. According to the literature it was identified the lack of transparency regarding empirical validation and a proper evaluation [22, 29]. However, there are only a limited articles available to specify validation and evaluations for maturity models [45].

References

1. Sambamurthy, V., A. Bharadwaj, and V. Grover, *Shaping Agility through Digital Options: Reconceptualizing the Role of Information Technology in Contemporary Firms.* MIS Quarterly, 2003. **27**(2): p. 237-263.
2. Looy, A.V., M.D. Backer, and G. Poels, *A conceptual framework and classification of capability areas for business process maturity.* Enterprise Information Systems, 2014. **8**(2): p. 188-224.
3. Oesterreich, T.D. and F. Teuteberg, *Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry.* Computers in Industry, 2016. **83**: p. 121-139.
4. Fichman, R.G., B.L. Dos Santos, and Z. Zheng, *Digital innovation as a fundamental and powerful concept in the information systems curriculum.* MIS quarterly, 2014. **38**(2): p. 329-A15.
5. Wagire, A.A., et al., *Development of maturity model for assessing the implementation of Industry 4.0: learning from theory and practice.* Production Planning & Control, 2020: p. 1-20.
6. Plomp, M.G. and R.S. Batenburg, *Measuring chain digitisation maturity: An assessment of Dutch retail branches.* Supply Chain Management: An International Journal, 2010.
7. Issa, A., et al., *Industrie 4.0 roadmap: Framework for digital transformation based on the concepts of capability maturity and alignment.* Procedia CIRP, 2018. **72**: p. 973-978.
8. Büyüközkan, G. and F. Göçer, *Digital Supply Chain: Literature review and a proposed framework for future research.* Computers in Industry, 2018. **97**: p. 157-177.
9. Jolanta, Ž. and V. Mantas, *Structured literature review on business process performance analysis and evaluation*. 2018, HAL.
10. Liao, Y., et al., *Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal.* International Journal of Production Research, 2017. **55**(12): p. 3609-3629.
11. Frederico, G.F., et al., *Supply Chain 4.0: concepts, maturity and research agenda.* Supply Chain Management, 2020. **25**(2): p. 262.
12. Caiado, R.G.G., et al., *A fuzzy rule-based industry 4.0 maturity model for operations and supply chain management.* International Journal of Production Economics, 2021. **231**.
13. Schumacher, A., S. Erol, and W. Sihn, *A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises.* Procedia Cirp, 2016. **52**(1): p. 161-166.
14. Lockamy, A. and K. McCormack, *The development of a supply chain management process maturity model using the concepts of business process orientation.* Supply Chain Management: An International Journal, 2004.
15. Mettler, T., *Maturity assessment models: a design science research approach.* International Journal of Society Systems Science, 2011. **3**(1-2): p. 81-98.
16. McCormack, K.P., *Business process maturity: theory and application*. 2007: Verlag nicht ermittelbar.
17. Van Looy, A., M. De Backer, and G. Poels, *Defining business process maturity. A journey towards excellence.* Total Quality Management & Business Excellence, 2011. **22**(11): p. 1119-1137.
18. Leyh, C., et al., *Assessing the IT and Software Landscapes of Industry 4.0-Enterprises: The Maturity Model SIMMI 4.0.* Information Technology for Management: New Ideas and Real Solutions, 2017. **277**: p. 103-119.
19. Mittal, S., et al., *A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs).* Journal of manufacturing systems, 2018. **49**: p. 194-214.
20. Peffers, K., et al., *A design science research methodology for information systems research.* Journal of management information systems, 2007. **24**(3): p. 45-77.
21. Peffers, K., et al. *Design science research evaluation*. in *International Conference on Design Science Research in Information Systems*. 2012. Springer.

22. Becker, J., R. Knackstedt, and J. Pöppelbuß, *Developing maturity models for IT management.* Business & Information Systems Engineering, 2009. **1**(3): p. 213-222.
23. Van Aken, J.E., *Management research as a design science: Articulating the research products of mode 2 knowledge production in management.* British journal of management, 2005. **16**(1): p. 19-36.
24. Hevner, A., R. , et al., *Design Science in Information Systems Research.* MIS Quarterly, 2004. **28**(1): p. 75.
25. Dyer, J.H. and H. Singh, *The relational view: Cooperative strategy and sources of interorganizational competitive advantage.* Academy of management review, 1998. **23**(4): p. 660-679.
26. Cropper, S., et al., *The Oxford handbook of inter-organizational relations*. 2008: Oxford Handbooks.
27. Sydow, J., E. Schüßler, and G. Müller-Seitz, *Managing inter-organizational relations: Debates and cases*. 2015: Macmillan International Higher Education.
28. Hevner, A. and S. Chatterjee, *Design science research in information systems*, in *Design research in information systems*. 2010, Springer. p. 9-22.
29. Marx, F., F. Wortmann, and J.H. Mayer, *A Maturity Model for Management Control Systems.* Business & Information Systems Engineering, 2012. **4**(4): p. 193-207.
30. Bandara, W., et al., *Achieving rigor in literature reviews: Insights from qualitative data analysis and tool-support.* Communications of the Association for Information Systems, 2015. **37**(1): p. 8.
31. Kitchenham, B. and S. Charters, *Guidelines for performing systematic literature reviews in software engineering.* 2007.
32. Moher, D., et al., *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* PLoS medicine, 2009. **6**(7): p. e1000097.
33. Xiao, Y. and M. Watson, *Guidance on conducting a systematic literature review.* Journal of Planning Education and Research, 2019. **39**(1): p. 93-112.
34. March, S.T. and G.F. Smith, *Design and natural science research on information technology.* Decision support systems, 1995. **15**(4): p. 251-266.
35. Walls, J.G., G.R. Widermeyer, and O.A. El Sawy, *Assessing information system design theory in perspective: how useful was our 1992 initial rendition?* Journal of Information Technology Theory and Application (JITTA), 2004. **6**(2): p. 6.
36. de Bruin, T. and M. Rosemann, *Using the Delphi technique to identify BPM capability areas.* 2007.
37. Hasson, F., S. Keeney, and H. McKenna, *Research guidelines for the Delphi survey technique.* Journal of advanced nursing, 2000. **32**(4): p. 1008-1015.
38. De Bruin, T., et al. *Understanding the main phases of developing a maturity assessment model*. in *Australasian Conference on Information Systems (ACIS):*. 2005. Australasian Chapter of the Association for Information Systems.
39. Sonnenberg, C. and J. Vom Brocke. *Evaluation patterns for design science research artefacts*. in *European Design Science Symposium*. 2011. Springer.
40. Prat, N., I. Comyn-Wattiau, and J. Akoka, *Artifact Evaluation in Information Systems Design-Science Research-a Holistic View.* PACIS, 2014. **23**: p. 1-16.
41. Venable, J., J. Pries-Heje, and R. Baskerville, *FEDS: a framework for evaluation in design science research.* European journal of information systems, 2016. **25**(1): p. 77-89.
42. De Haes, S. and W. Van Grembergen, *An exploratory study into IT governance implementations and its impact on business/IT alignment.* Information Systems Management, 2009. **26**(2): p. 123-137.
43. Yoo, Y., et al., *The next wave of digital innovation: Opportunities and challenges: A report on the research workshop'Digital Challenges in Innovation Research'.* 2010.
44. Niehaves, B., et al., *BPM capability development–a matter of contingencies.* Business Process Management Journal, 2014.
45. Wendler, R., *The maturity of maturity model research: A systematic mapping study.* Information and software technology, 2012. **54**(12): p. 1317-1339.