Modelling Advanced Technology Integration for Supply Chains

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Abstract: The fast-paced evolution of supply chains poses increasing challenges as networks have become more complex and dynamic. The intense interaction between information technology and business drives the spread of the physical internet as a supply chain paradigm. While some of the classic supply chain models provide approaches towards the integration of advanced technologies, few publications focus on a comparison or further development of these models. We strived to critically discuss existing supply chain models and to suggest an improved approach for modelling the digital supply chain. We applied the design science research methodology to systematically analyse and critically evaluate four selected supply chain modelling approaches. Based on a literature review and benefit analysis, we present an outlook on the potential future applicability and provide a roadmap for modelling advanced technology integration for supply chains. The comprehensive analysis highlights if and how selected supply chain models can remain relevant regarding the digitalisation of supply chains. Thus, this article informs researchers on future research opportunities and suggests a potential roadmap for practitioners.

1 INTRODUCTION

The fast-paced evolution of global industry and trade poses increasing challenges to both regional and global supply chains as supply networks are an integral part of any business endeavour (Backhaus et al., 2020; Schröder & Wegner, 2019; Storey, Emberson, Godsell, & Harrison, 2006). Companies must compete in challenging and globally integrated environments and often find their supply chains to be insufficiently equipped to face global competition, growing customer expectations, supply chain disruptions and individualised production (Christopher, 2000; Golan, Jernegan, & Linkov, 2020; Zanker, 2018). The supply chain management (SCM) literature provides different approaches towards the integration of advanced technologies, such as data analytics (DA), simulation, or artificial intelligence (AI). For instance, an ecosystem (Averian, 2017), supply chain capability (Naway & Rahmat, 2019) or supply chain structure approach (Bhakoo, Britta Gammelgaard, Singh, & Chia, 2015) are assumed. While the relationship between information and communication technology and SCM processes is well-established (e.g. Kumar, Singh, & Modgil, 2020), few publications focus on a critical comparison or debate regarding existing supply chain models.

The purpose of this paper is to (1) critically discuss existing supply chain models, (2) to determine whether novel technologies could be used to adapt classic SCM models, and (3) to provide a roadmap for modelling advanced technology integration for supply chain to advance theory and practice of logistics and SCM. The design science research methodology (DSRM) for the production and presentation of Design Science Research (DSR) in information systems research (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) is adopted. First, the state-of-the-art section highlights the relevance of selected technological approaches for logistics and SCM. Following the presentation of the methodological approach, the design, development and evaluation of the roadmap are discussed. Finally, the results are discussed and a conclusion including a

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summary of the findings, managerial implications as well as propositions for future research, is provided.

2 STATE-OF-THE-ART OF INNOVATIVE TECHNOLOGICAL APPROACHES IN SUPPLY CHAIN MANAGEMENT

2.1 Emerging Technologies Selection

In selecting advanced technologies for this research project, the authors follow Gartner's five trends for supply chain strategy and maturity model (Hippold, 2020; Mauerer, 2018). The following triad of data-based technologies was selected due to their novelty regarding application for SCM: DA, AI, and simulation. The authors acknowledge the relevance of other emerging technologies such as blockchain, which have also proven significant in the supply chain context (Gammelgaard, Welling, & Nielsen, 2019; Subramanian, Chaudhuri, & Kayıkcı, 2020) and might be included in future studies.

2.2 Application of Data Analytics in Logistics and Supply Chain Management

Runkler (2015) describes DA as "an interdisciplinary field combining aspects of statistics, machine learning, pattern recognition, systems theory and artificial intelligence, defined as the application of computer systems to the analysis of large amounts of data for decision support". Numerous literature reviews on the application of DA in SCM and logistics highlight the relevance of this research field and illustrate how the use of DA methods can significantly increase efficiency (e.g. Mishra, Gunasekaran, Papadopoulos, & Childe, 2018; Tiwari, Wee, & Daryanto, 2018). DA enables the advancement of supply chain 4.0 by improving the end-to-end process transparency of the supply chain (Christopher, 2021). Examples of DA application in logistics and SCM are manifold and include, for example, big data analytics in cold chain logistics (Gupta, Chaudhuri, & Tiwari, 2019), arrival time modelling (van der Spoel, Amrit, & van Hillegersberg, 2017), and the use of process mining for supply chain analysis (Górtowski, 2018).

2.3 Application of Simulation in Logistics and Supply Chain Management

Supply chains form complex systems due to the large number of companies involved and their networking (Kaczmarek, 2002). Gutenschwager and Alicke (2004, p.178) state that "simulation can help to examine such complex systems and make them understandable for the user", because simulation is one of the most powerful technologies for decision support, as complex systems can be realistically represented (Chandra & Grabis, 2007; Oliveira, Lima, & Montevechi, 2016). Often, event-discrete simulation is the only possibility to map complex supply chains with reasonable effort, as it allows a cooperation of all actors in a supply chain (Krischke & Grzesch, 2009; Kuhn & Rabe, 1998). Reasons for the use of simulation in the SCM environment can be the investigation of tactical problems, the evaluation of different production or procurement options, batch size optimisation, or profitability analysis (Fechteler & Gutenschwager, 2014).

2.4 Application of Artificial Intelligence in Logistics and Supply Chain Management

Following several so-called AI springs and winters (Duan, Edwards, & Dwivedi, 2019), the current revitalisation of AI research is fuelled by the advancement of BDA. AI "can be defined as human intelligence exhibited by machines; systems that approximate, mimic, replicate, automate, and eventually improve on human thinking" (Gesing, Peterson, & Michelsen, 2018, p.3) and includes a great variety of techniques such as machine learning algorithms and agent-based modelling. Recent comprehensive literature reviews and special issues (e.g. Fosso Wamba, Queiroz, Guthrie, & Braganza, 2021; Toorajipour, Sohrabpour, Nazarpour, Oghazi, & Fischl, 2021) illustrate that the areas of interest for AI application are widespread. AI is used in contexts such as scheduling and routing (El-Yaakoubi, El-Fallahi, Cherkaoui, & Hamzaoui, 2017), cloud computing for supply chain integration (Manuel Maqueira, Moyano-Fuentes, & Bruque, 2019), and interorganisational integration and coordination (Sergeyev & Lychkina, 2019).

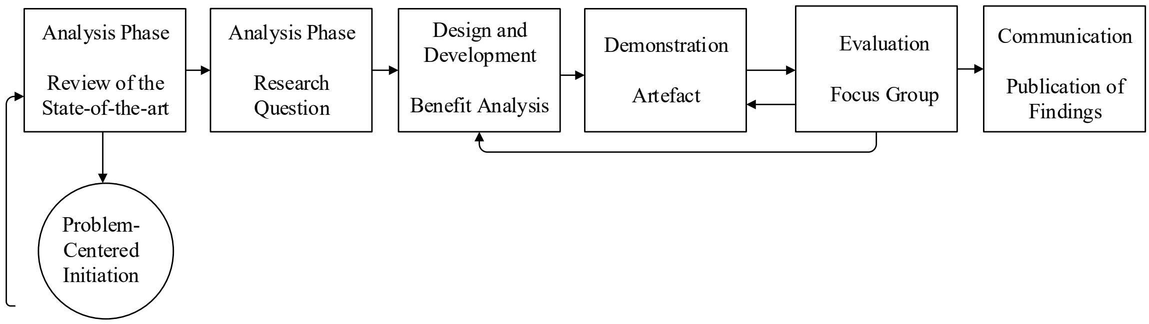

Figure 1: Adapted design science research methodology (DSRM) (based on Peffers et al., 2007, p.54).

2.5 Research Gaps and Focus

The conceptualisation of the problem space and the addressed solution space follow the recommendations of Maedche, Gregor, Morana, and Feine (2019) and comprise the following four dimensions: needs, goals, requirements, stakeholder. As the classic supply chain models designed in the 1990s mostly do not relate to new technologies, supply chain managers and lecturers lack models that actively incorporate advanced technologies. The review of the state-of-the-art shows that the application of technological approaches such as DA, simulation, and AI in logistics and SCM drives the increasingly fast-paced digitalisation of supply chains.

This paper aims to investigate whether the technologies described above can be used to map classic SCM models to exploit the potential of advanced technologies. This paper thus strives to (1) critically discuss existing supply chain models, (2) to determine whether novel technologies could be used to adapt classic SCM models, and (3) to provide a roadmap for modelling advanced technology integration for supply chain to advance theory and practice of logistics and SCM by addressing the following question: Which supply chain modelling approaches are potentially suitable for the integration of advanced technological concepts?

3 METHODOLOGICAL APPROACH

This paper is based on the DSRM for the production and presentation of DSR in information systems research, as proposed and developed by Peffers et al. (2007) (see Figure 1). It intends to evaluate classic supply chain modelling approaches regarding their applicability for the implementation and illustration of innovative technological approaches. The findings are subsequently distilled into a roadmap for future supply chain modelling as a DSR construct (Peffers, Rothenberger, Tuunanen, & Vaezi, 2012).

The research entry point for this paper is thus a problem-centred initiation. The first two activities are conducted as a review of the state-of-the-art, including an assessment of the application of innovative technological approaches in SCM followed by the research question. A benefit analysis in activity three is chosen for the comparison and critical evaluation of the predominant supply chain modelling approaches. This paper adopts the process for the implementation of a benefit analysis as described by Kühnapfel (2014). Subsequently, the artifact demonstration and evaluation in activities four and five is done using focus group research to gather expert opinions (O'Gorman & MacIntosh, 2015). The final activity consists of the communication of the research results to the relevant interest groups.

4 ARTEFACT DESIGN AND DEVELOPMENT

The artefact is developed iteratively following eight steps of benefit analysis:

1) Organisation of the Working Environment

To allow for a systematic and transparent research process, group discussion using a focus group is chosen as the research method for the evaluation step of the benefit analysis. First, the purpose of the focus group is defined, and the focus group conversation guide is developed based on the comparison of the decision alternatives derived from the literature. As suggested by O'Gorman and MacIntosh (2015) the authors choose a purposive non-probability sampling strategy in the second phase. The selected four participants from the authors' research network are experts in the fields relevant for this paper (DA, simulation, AI) and experienced academics with a computer science or informatics background and knowledge of logistic and SCM processes. As. The main section of the focus group is organised relatively loosely in three parts, the first dealing with the participants' impressions on the suitability of the SCM models for the technological concepts, the second with improvements and adjustments for the technological concepts and the third with an individual ranking of the SCM models for the technological concepts.

2) Identification of the Decision Problem
The benefit analysis aims to evaluate the selected supply chain models, hereafter referred to as decision alternatives, concerning their applicability to advanced technological approaches. The focus group participants evaluate the suitability of the decision alternatives and prioritize them in relation to their respective areas of expertise.

3) Selection of Decision Alternatives
Classic supply chain models encompass declarative, simulation, and optimisation models. Due to the need for comparability of the modelling concepts and approaches, this paper focuses on declarative SCM models. The supply chain models to be included in the benefit analysis are defined following a review of the literature:

- the Supply Chain Operations Reference (SCOR) model, (APICS, 2017b)
- the supply chain model based on Metz, (Metz, 1998)
- the supply chain modelling approach by Bowersox (Bowersox & Closs, 1996)
- the model developed by Cooper, Lambert and Pagh (CLP) (Cooper, Lambert, & Pagh, 1997)

These decision alternatives are derived from the literature and represent some of the most used models in the field of logistics and SCM. While there are numerous other models available, the SCOR, Metz, Bowersox and CLP models are chosen due to several reasons. First, all four decision alternatives were developed in the 1990s during the early phases of SCM research. Second, literature searches using the Scopus database and Google Scholar underline their academic and practical relevance. Third, previous research as well as domain knowledge of the authors facilitated the choice.

4) Collection of Decision Criteria
Following the definition of the decision alternatives (i.e. supply chain modelling methods), the decision criteria need to be selected. The criteria should be complete, assessable, relevant and reproducible (Kühnapfel, 2014) and their selection is highly relevant for the benefit analysis as it has a significant impact on the study results (Sonntag, 2015). A review of the literature is used to compose an initial list of potential criteria (see Table 1).

5) Weighting of Decision Criteria
The seven decision criteria are weighted to result in a total of 100 %. Comprehensiveness, abstraction levels, adaptability and usability are estimated to be the most relevant. The authors judge endorsement, development over time and application rate to be the least important criteria in the context of this study. As a next step, those ranked on the same level were given the same weight. Further discussion and iterations yielded the final weight distribution of the selected decision criteria illustrated in Table 2.

6) Evaluation of Decision Criteria
Before the determination and evaluation of the respective criterion values, an appropriate scale needs to be defined. For this paper, a rating scale of 1 to 3 was chosen as the criteria do not differ enormously in importance. Table 2 shows the criteria and the respective meaning of the scale.

Table 1: List of decision criteria.

Criterion	Description
Application rate	Number of publications on the supply chain model within the last 5 years (Google Scholar, Scopus)
Development over time	Growth in publications referring to model (first decade after publication compared to second decade, Google Scholar), Model updates (if applicable)
Endorsement	Which organisations promote or use the model Predominantly used in research or practical application
Usability	Standardisation of elements, Simplicity of the model
Comprehensiveness	Depiction of flows relevant in logistics and SCM
Abstraction levels	Availability of different abstraction levels
Adaptability	Model adaptability to changing market requirements

Table 2: List of decision criteria including respective scales and weighting.

Criterion	Scale and Meaning	Criterion Weight
Application rate	1=low, 2=medium, 3=high	0.1
Development over time	1=decline, 2=stagnation, 3=growth	0.1
Endorsement	1=not applied in practice, 2=somewhat applied in practice, 3= widely applied in practice	0.1
Usability	1=extensive training required and low standardisation, 2=somewhat standardised with some training required to use, 3= standardised and easy to use	0.1
Comprehensiveness	1=some of the relevant flows can be depicted, 2=the majority of relevant flows can be depicted, 3= all relevant flows can be depicted	0.2
Abstraction levels	1=only 1 level, 2=2 levels, 3= more than 2 levels	0.2
Adaptability	1=low, 2=medium, 3= high	0.2

7) Utility Calculation

For this paper, the authors encouraged the focus group participants to discuss the defined decision criteria in relation to the decision alternatives. Subsequently, the focus group transcript was thoroughly analysed to identify the suitable ranking. In addition to the focus group discussion, the rating values are based on findings from the literature. Each rating value is then multiplied by the corresponding criterion weight. Adding up all the resulting criterion values enables the researchers to obtain the specific utility value for each decision alternative.

8) Result Documentation

This section presents a summary of the results of the benefit analysis for each decision alternative based on the seven decision criteria. An overview of the individual rating values and overall utility values is shown in Table 3.

First, the decision criterion ***application rate*** will be analysed. A Google Scholar search for the publication period from 2017 to 2020 on 24th March 2020 using the search phrase “SCOR supply chain model” yielded 5,130 results, compared to 6,060 for “Metz supply chain model”, 2,760 for “Bowersox supply chain model” and 1,370 for “Cooper Lambert Pagh supply chain model”. Additionally, a Scopus search using the same search terms with no time restriction was executed on 2nd April 2020 and resulted in 503 matches for the SCOR model, three for Bowersox and three for CLP.

Second, the researchers considered the ***development over time***. Again, Google Scholar was used to gain an overview of the development in references by comparing the first decade following the first publication of the respective models and the second decade thereafter. The search phrase “SCOR supply chain model” resulted in 11,200 matches for the first decade from 2006 to 2015 and 2,750 for the second period from 1996 to 2005 (02.04.2020). This shows a continuity in research publications while the number of references in the second decade is four times higher than during the first. The focus group participants support this observation and state that the SCOR model development is driven by the industry. This observation is also strengthened by the continuous updates of the model versions since 1996. The Metz supply chain model exhibits a similar development over time as the number of references tripled in the second decade (15,500 results in 2008-2017, 5,400 results in 1998-2007). Although the Google Scholar search results for the Bowersox and CLP model indicate usage in more recent times (7,890 results in 2007-2016 and 2,480 results in 1997-2006 for Bowersox, 3,840 results in 2007-2016 and 987 results in 1997-2006 for CLP), the application appears to decline.

Concerning the model ***endorsement*,** SCOR is generally viewed as the most commonly used approach, as the APICS consortium, which comprises over 45,000 members and approximately 300 channel partners (APICS, 2017a), develops and promotes it. The other three modelling approaches appear to be mainly used in research.

The fourth decision criterion is ***usability***. SCOR is an approach to describe the actual and the target state of the supply chain, consists of standardised levels and comprises a set of tools and KPI to make it user friendly. Metz similarly depicts the targeted process with increasing integration over four integration levels. Furthermore, in the focus group discussion, it was noted that the Bowersox model, similar to the CLP model, is more of a reference framework that appears to be of limited usefulness because there is no operational focus.

For the criterion ***comprehensiveness*,** SCOR is observed to include material, information and financial flows (Corsten & Gössinger, 2008). The participants argued that descriptions for resources, state transitions as well as for events triggering state transitions are not included. As a descriptive modelling approach, SCOR is not intended for the depiction of resources but for the description of connections, like process description languages, and might thus potentially not be useful for simulation. Metz's modelling approach includes different levels of integration for mapping internal material and information flows. The focus group participants further criticised that the model does not correspond to the definition of SCM as it only focuses on one organisation. Also, an additional level depicting individual activities or process steps is missing. On the other hand, the Metz model can map the types of information that cannot be mapped in the SCOR model and it can also show the entities corresponding to the activities. Concerning the Bowersox modelling approach, material, financial and information flows are included. The technology context presents a potential to describe how the supply chain technology works, but it would need to be extended (e.g. centralised or decentralised structure, starting points for technology integration) to be comprehensive. In general, the focus group discussed its shortcomings due to it being a reference framework. From today's perspective it is not complete as it only shows the relevant main components. The CLP comprises value-adding processes along the supply chain and business-wide processes, it also depicts material flow, relationships, and information flow. It is however criticised by the participating experts due to its simplicity. A technological aspect is completely missing, and it consequently cannot be used for the integration of novel technological approaches at the moment.

The next criterion is the level of ***abstraction*.** The SCOR model provides the highest variability of abstraction levels, which was also highlighted in the focus group discussion. The second modelling approach proposed by Metz considers information and material flows in a company as a low integration level and those with other companies as a higher integration level and thus also supports for different abstraction levels. Bowersox and CLP are different as they are reference frameworks offering an abstract four-dimensional perspective and the viewpoint of an individual company within the supply chain, respectively.

Lastly, the ***adaptability*** of the modelling approaches for the integration of novel technologies is considered. The focus group found that the adaptability of the SCOR-Model might be restricted due to missing descriptions, for example of resources. An extension of the model is judged to be possible as it is already quite comprehensive but would perhaps also remain on a descriptive level. The Metz model includes an information processing function, an integrative SCM perspective and ICT development as enablers for complexity handling as well as a specific consideration of ICT developments. The model by Bowersox focuses on internal and external supply chain integration which could possibly be a suitable starting point for technology integration across company borders. Finally, the CLP model has an information flow facility structure as a management component. Table 3 illustrates the resulting total utility values for the decision alternatives. To assess the potential of each modelling approach in terms of its future applicability and suitability, participants were asked to provide an overall judgment. Across all experts, the SCOR model was rated as the most promising option, followed by Metz. Due to its continuous updating and widespread use in practice, the SCOR model is chosen as the basis for the targeted roadmap construct for modelling advanced technology integration for supply chains.

Table 3: Resulting overall utility values for the decision alternatives.

Criterion/ Modelling Approach	SCOR			Metz			Bowersox			Cooper/Lambert/Pagh		
	RV	**W**	**CV**	**RV**	**W**	**CV**	**RV**	**W**	**CV**	**RV**	**W**	**CV**
Application rate	**3**	**0.1**	**0.3**	**2**	**0.1**	**0.2**	**2**	**0.1**	**0.2**	**2**	**0.1**	**0.2**
Development over time	**3**	**0.1**	**0.3**	**3**	**0.1**	**0.3**	**1**	**0.1**	**0.1**	**1**	**0.1**	**0.1**
Endorsement	**3**	**0.1**	**0.3**	**1**	**0.1**	**0.1**	**1**	**0.1**	**0.1**	**1**	**0.1**	**0.1**
Usability	**2**	**0.1**	**0.2**	**2**	**0.1**	**0.2**	**1**	**0.1**	**0.1**	**1**	**0.1**	**0.1**
Comprehensiveness	**3**	**0.2**	**0.6**	**2**	**0.2**	**0.4**	**1**	**0.2**	**0.2**	**1**	**0.2**	**0.2**
Abstraction levels	**3**	**0.2**	**0.6**	**2**	**0.2**	**0.4**	**1**	**0.2**	**0.2**	**1**	**0.2**	**0.2**
Adaptability	**3**	**0.2**	**0.6**	**2**	**0.2**	**0.4**	**2**	**0.2**	**0.4**	**1**	**0.2**	**0.2**
Overall Utility Value	**2.9**			**2.0**			**1.3**			**1.1**		
RV = Rating Value, W = Weight, CV = Criterion Value												

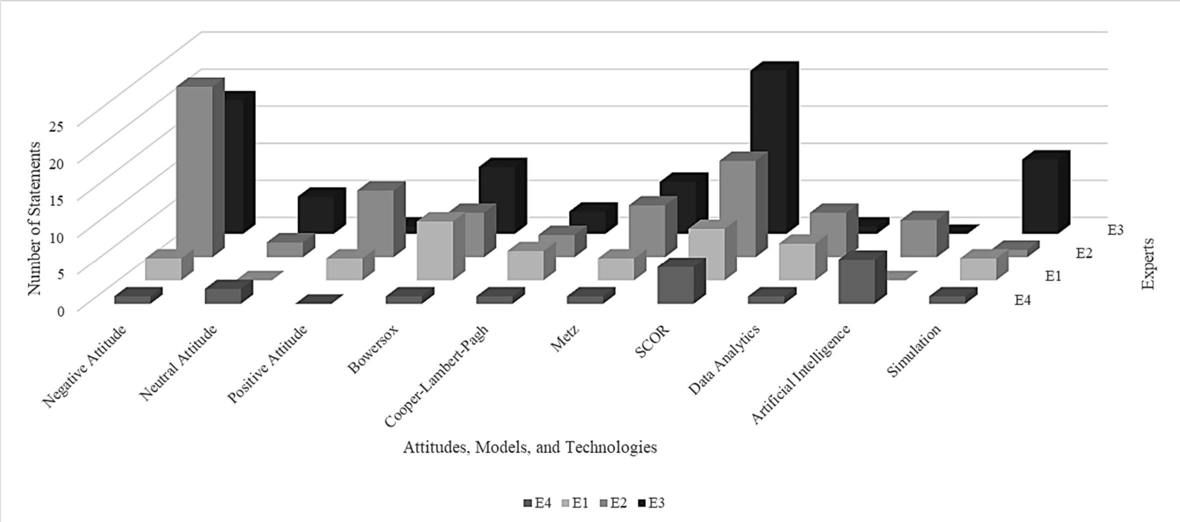

Figure 2: Number of statements per expert regarding attitude, modelling approach and technological approach.

The Bowersox and CLP models, on the other hand, are not considered useful in this context. This is also reflected in the experts' statements, as shown in Figure 2 As shown by Figure 2, the attitudes expressed by the experts vary substantially. Due to their familiarity with the SCOR model, the experts were able to quantitatively make the most statements about this modelling approach (19 statements, thereof 11 negative statements). At level 4, the SCOR model serves only as a purely descriptive model to describe a fact, but does not reveal any reference to the application of the technologies under consideration (E1, E2, E3, E4). The experts also appear to be relatively familiar with the Metz model (nine statements), which is also not fundamentally different from the SCOR model. The experts expressed negative thoughts regarding the high abstraction of the model and the lack of integration into the companies involved in the supply chain (seven statements). Relatively speaking, more positive and neutral statements are made about the SCOR model than about the Metz model, which leads the experts to prefer the SCOR model for any future adaption. The CLP model and the Bowersox-based approach will be considered unsuitable for integrating advanced technology.

5 DEVELOPMENT OF THE ROADMAP FOR MODELLING ADVANCED TECHNOLOGY INTEGRATION

A roadmap construct for modelling advanced technology integration for supply chains is developed as a DSR artefact (see Figure 3) based on iterative reading, deductive analysis, and coding of the experts' statements. Using a non-scaled timeline, the roadmap represents an approach towards the integration of advanced technologies, which can potentially lead to a more flexible design of the supply chain. The individual steps of the roadmap are divided along four main identified streams of DA, SCOR, AI, simulation.

Currently, it is judged to be difficult to adapt or extend models such as SCOR and Metz to integrate novel technological aspects (E4). The experts assess the potential of the individual technological approaches quite differently, but the potential increase in supply chain flexibility through the opportunities enabled by DA and AI are generally acknowledged. Level 4, the most precise description of the SCOR model, goes down to the process element level to which resources can be added in the Information and Communication Lane. For instance, E1 states that “(SCOR) level four would not be sufficient for a data analysis, because I still need to describe somewhere where I get which data at which process step and, therefore, before I could do any further processing” and summarises that “if I suddenly wanted to start simulating or analysing something, then (…) I wouldn’t get any further because I need other methods”. An extension of level four is thus necessary for both DA and AI. The current supply chain process needs to be recorded in more detail and a process description is required. This is supported by the experts who state that “to be able to do that I would have to have a state model of the system, plus a description of the event” (E2) and

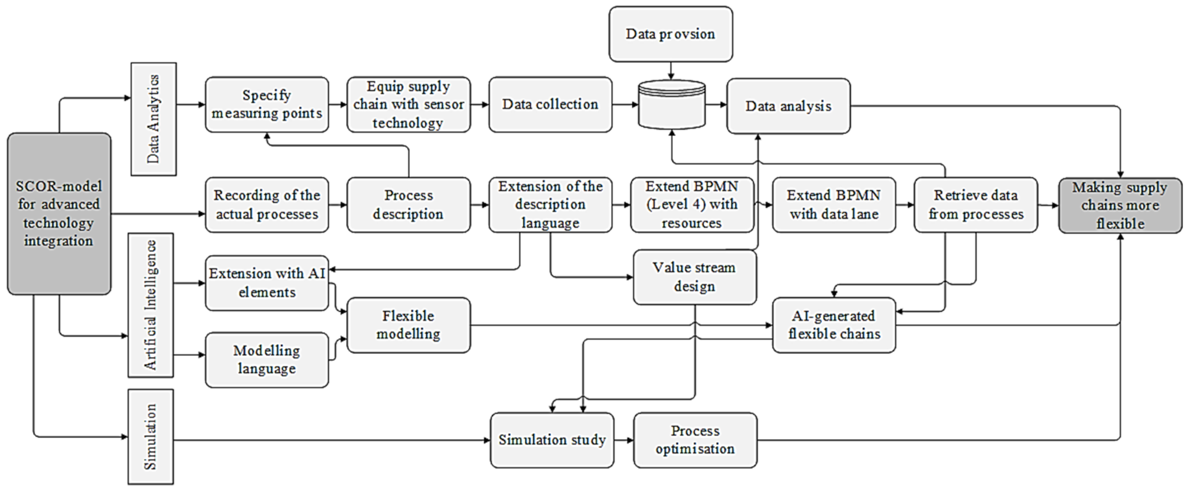

Figure 3: Roadmap construct for modelling advanced technology integration for supply chains.

that "the point is to first describe these interrelationships (…) which is represented in more detail in other description languages" (E3).

As a next step, the description language needs to be extended. For this purpose, the process description on level four in the Business Process Model and Notation could be developed to include resources and elements of data analysis. To do this, detailed data about the process must be available. To achieve this level of detail, specific measuring points must first be defined for data acquisition and these must be equipped with sensors as suggested by the experts. E2 states that "when it comes to data, I have to be able to specify some kind of measuring point. (…) the whole logistic supply chain process must be, so to say, equipped with sensors, among other things, to simply have an overview of the processes", a sentiment which is mirrored by E1 who says that "the actual data generation, or data transfer, or something like that, would have to be included in some way". Retro-lifting the existing models is proposed as a possible approach (E4). In addition to the recorded data, process information is included in the analysis. A need to examine the current model to define to what extent it allows a flexible approach is expressed by E4. Instead of designing a rigid supply chain, AI or machine learning tools can be applied to determine a suitable supply chain for a particular task. E4 argues that "we need the learning ability of the individual components, the ability to communicate between the individual components in the SCOR model. (…) To achieve this, we need data". It is further stated that "when AI complements classic SC modelling, it builds new models that create far more flexibility" (E4).

6 DISCUSSION

The benefit analysis and focus group discussion revealed that the modelling approaches currently available to supply chain managers all have shortcomings. In addition to the decision criteria included in the benefit analysis, the participants also discussed aspects of model validity. So, to evaluate the validity of the supply chain models, but also of the developed artefact in the form of the roadmap construct, use cases, scenarios or a specific purpose need to be applied. The researchers thus decided to evaluate and develop the artefact following a later quantitative empirical survey.

The focus group also yielded interesting ideas concerning the relation between the modelling and the technological approaches as well as regarding the potential for further development. In general, the experts consider the application of the modelling approaches for the integration of advanced technological approaches to be of little use, except perhaps the application of SCOR for simulation, if reasonably possible, as the available supply chain modelling approaches could be applied and subsequently transferred into a simulation model. However, in their current versions, none of the models are judged to be sufficiently advanced for the integration of advanced technological approaches such as DA, simulation or AI. These models primarily describe the current state of affairs and facilitate communication about the supply chain, but they are only conditionally suitable for strategic decisions and likely only useful in technology implementation projects up to a certain stage such as the problem definition. In addition, SCOR and Metz should also be considered separately from Bowersox and CLP as the have a different purpose.

Overall, the modelling and the technological approaches are regarded as separate entities that are orthogonal to one another. On the one hand there are the modelling approaches as descriptive languages that can be used to enable shared understanding and on the other hand there are technology-based methods of analysis. If and to what extent they can be combined could be discussed and should be weighed against the potential cost and usefulness as well the intended purpose.

While the findings suggest that the integration of modelling and technological approaches needs to be carefully examined, the literature suggests that innovative supply chain design, and thus supply chain modelling, can have positive effects. For instance, Arlbjørn, de Haas, and Munksgaard (2011) found that the integration of innovative supply chain designs, innovative supply chain management practices and enabling technology could make initiatives such as the introduction of new products and services more likely to be successful. Similarly, a mediating effect of technology integration on the relationship between supply chain capability and supply chain operational performance was observed by Naway and Rahmat (2019).

7 CONCLUSION AND LIMITATIONS

The proposed roadmap construct for modelling advanced technology integration for supply chains is developed as a DSR artefact during the research process. It describes a possible approach towards the integration of advanced technologies along the four main roadmap streams of DA, SCOR, AI and simulation. Moreover, the evaluation of supply chain modelling tools regarding the integration of advanced technological approaches will be useful for both research and practical application as it provides a basis for scientific discussion and the modernisation of supply chain models.

First, as a practical contribution, the critical discussion of the established supply chain modelling approaches enables supply chain managers and decision makers to choose the appropriate tool more easily and to perhaps also consider a model that was previously unknown. The proposed roadmap construct can serve as a driver for digitalisation within the supply chain and for the integration of novel technological concepts in SCM. The contributions to research include the applied systematic methodological approach based on a benefit analysis and qualitative research tools, incentives for the advancement and development of advanced supply chain modelling as well as a critical discussion about the timeliness and future applicability of established supply chain modelling approaches. The paper consequently proposes various avenues for future research regarding the combination of supply chain modelling approaches and novel technological concepts as well as strategic SCM.

Despite the systematic structure of the methodological approach, several research limitations need to be acknowledged. The choice of the supply chain modelling approaches and the technological concepts is subjectively based on the personal experience of the researchers. Disregarded technologies, such as blockchain, and other supply chain modelling approaches can be included in future research. Concerning the research approach, benefit analysis has been criticised for its relatively time-consuming process as well as the subjectivity regarding the determination and weighting of the criteria and the evaluation and interpretation. The focus group method also has its limitations such as information overload, subjectivity of both the participants' opinions and the researcher's interpretation as well as the influence of group dynamics.

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