Reference Model for Data-Driven Supply Chain Collaboration

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Abstract. This paper presents a strategic reference model for data-driven supply chain collaboration (SCC) designed based on the principles of design science research and the process model for empirically grounded reference modelling. Increasingly competitive and global supply networks require the wider application of collaborative supply chain management. Thus, the different aspects of SCC, including inter-organizational exchange of data and knowledge as well as the integration of novel technologies such as artificial intelligence are essential factors for organizational growth. This paper attempts to fill the gap of a missing overview of this field by providing the results of the development of a comprehensive framework of data-driven SCC. Due to the interdisciplinary focus and approach combining information systems, design science and management research, the paper contributes to the academic debate by providing a macro level perspective on the topic of SCC and a conceptualization and categorization of data-driven SCC. Furthermore, this paper presents a valuable contribution to practice and supply chain processes in organizations across sectors by delivering an adaptable strategic reference framework for application in collaborative processes.

Keywords: Empirically grounded reference modelling · Supply Chain Collaboration · Artificial intelligence · Information systems · Design science research

1 Introduction

The wider application of collaborative supply chain management (SCM) is a requirement of increasingly competitive and global supply networks. Trends such as global integration, population growth and urbanization, digitalization, and automation, as well as social and environmental concerns put supply chain networks under increasing pressure [1–3]. While these challenges drive the development of collaborative supply chain networks [4], cross-industry logistics cooperation for digitalization [5] and supply chain transparency [6–8], organizations and managers also turn towards technological solutions. In the logistics sector, where, according to a German study, approximately half of companies consider themselves to be trendsetters or innovators [5], inter-organizational exchange

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of data and knowledge as well as the integration of novel technologies such as artificial intelligence (AI) are essential factors for organizational growth and competitiveness [9–11].

Despite the comprehensive challenges facing supply chain collaboration (SCC), the disruptive influence of technology on physical and information flows, and the relevance of SCC [3, 4, 12–14], a uniform orientation framework for data-driven SCC is currently not available [4] as research often focuses on specific aspects of data-driven SCC such as flexibility [e.g. 15] or computational experiments [e.g. 16]. This paper thus fills the gap of a missing overview of this field by proposing a comprehensive strategic framework of data-driven SCC. Due to the interdisciplinary focus and approach combining information systems (IS), DSR and management research, the paper contributes to the academic debate by suggesting a macro level perspective on the topic of SCC and a conceptualization and categorization of data-driven SCC. Furthermore, this paper presents a contribution to practice and supply chain processes in organizations across sectors by delivering a strategic reference framework for application in collaborative process management and development. The remainder of the paper presents key concepts, the research approach and methods, as well as the modelling results and discussion.

2 Key Concepts

SCC is a relevant research area within the field of SCM research that has become increasingly heterogenous and comprehensive over the last years [4]. SCC is defined as "seven interweaving components of information sharing, goal congruence, decision synchronization, incentive alignment, resources sharing, collaborative communication, and joint knowledge creation" [14, p. 55] while collaboration is characterized as "a mutually shared process where two or more firms display mutual understanding and a shared vision, and the firms in question voluntarily agree to integrate human, financial, or technical resources with the aim of achieving collective goals" [17, p. 35]. Barratt [18] similarly states that trust, mutuality, information exchange, openness, and communication are the basic components of a collaborative culture.

A development from technology-enabled to technology-centric SCM can be observed as information management plays a central role [19]. As digital transformation profoundly impacts organizational strategy and change [20], also regarding collaborative SCM processes, "today and looking at the near future […] the supply chain is as good as the digital technology behind it" [21, p. 9]. AI is widely considered to be of growing importance and high potential for supply networks as well as the underlying IS [e.g. 22–24]. AI aggregates the "philosophies of machines to think, behave and perform either same or similar to humans" [25, p. 869] and can be defined as "the branch of computer science that is concerned with the automation of intelligent behavior" [26, p. 1]. Data-driven collaboration refers to collaborative processes that are prescribed by relevant data structures [27]. As data-driven collaboration is "happening or done according to information that has been collected" [28], it is determined by, or dependent on, the collection or analysis of data.

3 Research Approach and Methods

DSR has been an established part of research for the last 30 years [29] and is useful for bringing together different disciplines as well as related non-academic organizations. It is suitable to create and evaluate information technology solutions for SCC due to its construction-oriented and problem-solving approach [30, 31]. This paper intends to contribute a DSR artefact in the form of a strategic model, the *Reference Model for Data-Driven Supply Chain Collaboration*. The model characteristics are illustrated in Table 1 [based on 32]. Reference modelling addresses all levels and business fields of enterprises, including strategic and organizational aspects, the design of IS, the description of organizations, business process (re-)engineering, and knowledge management [33, 34].

Table 1. Typology of reference models (appropriate categories underlined) [based on 32, p. 98].

Characteristic		Description			
Model-related	Aspect	Aspect-specific		Multi-aspect	
	Formality	Not formal	Semi-formal		Formal
	Subject	Technical concept	Data processing concept		Implementation
	Objective	Organizational system model		Application System Model	
	Sector	Industry	Trade	SCC	Other sectors
	Task	Support	Purpose		Steering
Method-related	Fulfilment of requirements	Reference model-unspecific		Reference model-specific	
Technology-related	Representation	Print		Computer-aided	
Organization-related	Availability	Unpublished		Published	

A prevalence of analytical and theoretical concepts over empirically developed reference models is acknowledged within DSR [35], which is also described as a worrying "wide gap between theoretical and empirical research in a real science" [35, p. 338]. The approach chosen for this paper bridges the gap between theoretical and empirical construction methods and enables a human-centered perspective on data-driven SCC.

The construction of the *Reference Model for Data-Driven Supply Chain Collaboration* within the DSR artefact development is based on the process model for empirically grounded reference modelling [36] as a deductive approach [37]. The process model has been applied in various contexts [e.g. 38] and consists of five phases, namely planning, model construction, validation, practical testing, and documentation (see Fig. 1).

Phase I of the reference modelling approach covers model-related planning, including the problem identification and definition as well as method-related, organizational, technological and project planning. The steps within this phase are based on the four

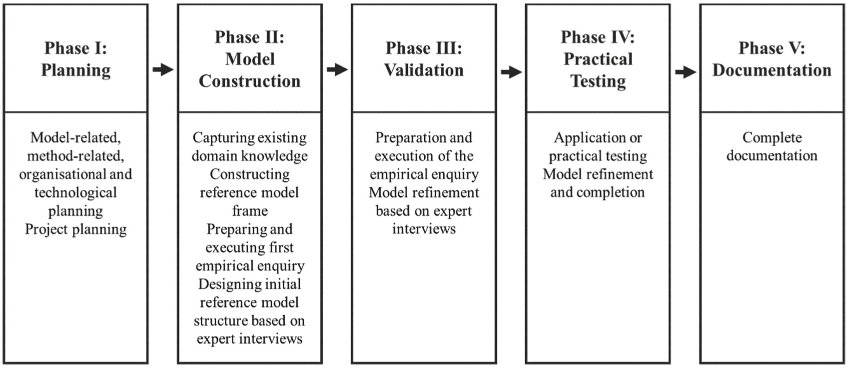

Fig. 1. Reference modelling approach [based on 36].

design areas for reference modelling [39]: organization, model, method, and technology. The model-related planning is concerned with the definition of the reference model domain (i.e. data-driven SCC), which is referred to as the problem definition [40]. Method-related planning is tasked with the selection of appropriate problem-solving and model representation techniques. In addition to the process model for empirically grounded reference modelling [36], natural language is chosen as the representation technique. Organizational planning covers the definition and documentation of a research design, the identification of the experts to be involved in the modelling process as well as coordination of these activities. Technological planning is concerned with the selection of appropriate technologies to support the modelling process, including the model construction, the documentation of the reference model and the recording and analysis of the expert interviews. A top-down approach for complex tasks has long time been established as suitable to achieve different levels of abstraction [40] and is chosen for the project planning.

The second phase is the model construction phase which comprises capturing existing domain knowledge, constructing the reference model frame, preparing and executing the first empirical enquiry, and designing the initial reference model structure. The construction of the reference model frame is useful for structuring the expert interviews and for constructing and documenting the reference model. First, general domain knowledge of logistics process and collaboration modelling is used, including the distinction of different focus levels [e.g. 41] and the Supply Chain Operations Reference Model (SCOR) [42]. The model is intended to include business to customer (B2C) as well as business to business (B2B) collaboration [e.g. 43]. Based on the reference model frame, the first empirical enquiry is prepared and executed to enable the first construction cycle of the reference model based on the experts' domain knowledge. The preparation comprises the identification, examination, and selection of interview participants (IPs), and the creation of an interview guide. To acquire experts for the interviews, we use homogenous purposeful sampling [44]. To incorporate both academic and business-oriented viewpoints and experiences, the qualitative sample comprises four scholarly experts and three experts with a practical SCC background from different industries in Germany and the UK (see Table 2). Thus, the empirical inquiry is based on a total of 14 in-depth semi-structured interviews (seven per round of interviews) in February/March 2021 (first empirical enquiry, 98 pages of transcript) and May/June 2021 (second empirical enquiry, 123 pages of transcript). The interview guide for the first empirical inquiry is structured according to the ARIS concept [45, 46] and the St. Gallen approach to business engineering [47–50]. The transcripts of the interviews are analyzed during iterative sessions of reading and coding using template analysis based on a priori as well as a posteriori coding [44, 51, 52] and the qualitative analysis software Nvivo. Following the first empirical enquiry, the initial reference model structure is designed.

Table 2. Overview of expert interview participants.

IP No	Background	Organization size
IP1	Academic, DE	Public service
IP2	Academic, DE	Public service
IP3	Academic, UK	Public service
IP4	Academic, UK	Public service
IP5	Logistics services, DE	SME
IP6	Retail/e-commerce, UK	Corporate
IP7	Industry conglomerate, DE	Corporate

Phase III is the validation phase which consists of the preparation and execution of the second empirical enquiry and the model refinement. The lists of correction proposals gathered during each expert interview form the basis for the further model refinement. The interview guide for the second empirical inquiry is based on the interview findings from the first round.

Phase IV is tasked with the application or practical testing and the subsequent model refinement and completion. Thus, the *Reference Model for Data-Driven Supply Chain Collaboration* is conceptually applied to a last mile supply chain and logistics network context.

A complete documentation is carried out in the fifth and last phase to ensure increased comprehension and validity.

4 Modelling Results and Discussion

The first empirical enquiry focuses on the following aspects: functions and processes; organization, strategy, and control; data, information systems, and AI/ML. Based on the IPs' suggestions regarding the framework's potential structure and content, the initial model draft is developed. At the beginning, the IPs are asked to define SCC to establish the different perspectives on the topic. The definitions provided by the IPs highlight the focus on togetherness within supply networks as well as the change from competition between organizations to competition between value chains. Overall, there can be different directions, activities as well as degrees of collaborative behavior due to the high complexity of this topic. According to the experts, a re-appearing core aspect of collaboration is the exchange of data and information. Additionally, some experts stressed the harmonizing and superordinate function of SCM and logistics within and across organizations. The objectives of collaboration are described as similar to the general aims of SCM, and include overall success and competitiveness of the value chain, coordinated behavior, customer satisfaction and high service levels, harmonization, smooth flow and efficiency, cost and time savings, high quality and performance, overall optimization, transparency, and risk and disruption avoidance. Following the first empirical enquiry, the IPs' statements are used to design the initial reference model structure.

The second empirical enquiry focuses on the discussion of the initial model draft, the application context of collaborative last mile networks and the influence of AI, as well as the expert evaluation of the strategic *Reference Model for Data-Driven Supply Chain Collaboration.* Based on the IPs' feedback and the subsequent discussion among the research team, the initial model draft is revised and finalized (see Fig. 2). The final *Reference Model for Data-Driven Supply Chain Collaboration* is visualized as a three-dimensional cube. The model distinguishes between the dimensions of collaboration agents, collaboration orientation, and collaboration type. The collaboration agents describe the different actors involved in the collaboration process. These actors can be actual people but also organizations or other entities such as machines and algorithms. The collaboration orientation is the second dimensions and refers to the focus level, i.e. operational, tactical, or strategic collaboration. Some collaborations can take place on an operational level, for example sharing infrastructure or order information. Strategic collaboration could include setting sustainability goals or location strategy planning. The third dimension distinguishes the collaboration types of minor, repeat, and partnership. Depending on the intensity of the collaboration, the type minor could describe a non-standardized exchange of information or one-off interactions, while the type partnership could include the coordination of research and development activities or long-term financial commitments.

The smaller sub-cubes contained within the three-dimensional cube are connected via the communication level (shaded in grey) which can vary in its intensity, depending on the collaboration process characteristics. For instance, a partnership collaboration between several agents might require relatively intense communication. Similarly, the communication is based on both system 1 and system 2 thinking [53]. As the experts consistently highlighted the exchange of data and information as a core aspect of collaboration, the communication level can be regarded as the key enabler of collaborative processes.

Across the communication level, smaller circles depict the actual collaboration process which can connect two or more sub-cubes and thus incorporate an operational, tactical and/or strategic orientation among one or more agents in a minor, repeat, or partnership collaboration type.

The collaboration process circles can be further detailed by zooming in (Fig. 2 on the right). Collaboration is based on general prerequisites such as laws and regulations. The collaboration process comprises three categories (people, process, system) which can be further divided into sub-categories. The people category contains interaction-focused elements (e.g. knowledge sharing, coordination), human-focused elements (e.g.

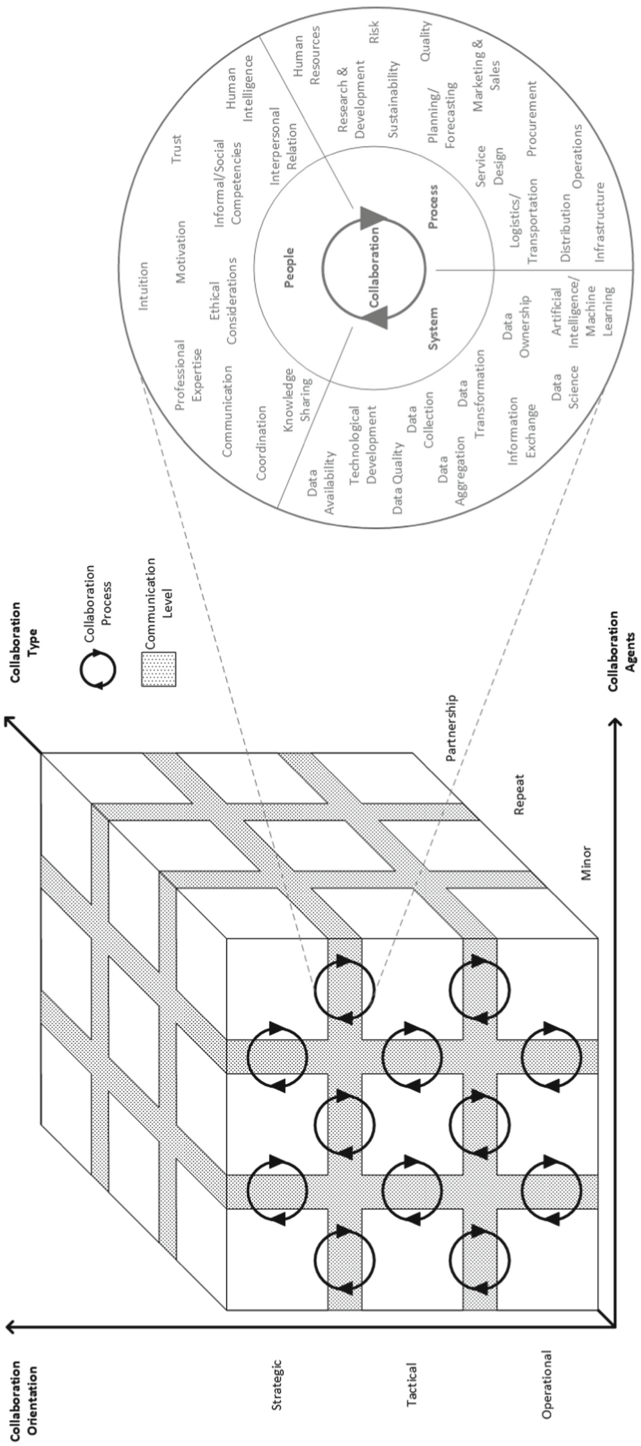

Fig. 2. Reference model for data-driven supply chain collaboration

intuition, professional expertise), and intelligence-focused elements (e.g. interpersonal relation, informal/social competencies). This category can also be applied to organizational entities. The process category contains operational (e.g. distribution) and management processes (e.g. sustainability management). Lastly, the system category comprises relevant elements that enable data-driven collaboration, including data collection and information exchange. The sub-category AI and machine learning can further be broken down according to the different available tools such as supervised learning, agent-based models, and artificial neural networks.

While the model itself proposes a conceptualization and framing of data-driven SCC on a strategic level, instantiations could focus more on a practical process level. Researchers and managers using this model could use the three-dimensional cube to first determine the collaboration characteristics along the three dimensions before further zooming into the collaboration process categories to define relevant areas for management and further development of collaborative processes.

To further highlight the potential model application, an exemplary last mile use case description is provided (see Fig. 3). The example refers to a collaboration between two delivery service providers who share urban depots to provide more environmentally friendly last mile services. The collaboration agents can thus be specified as delivery agent X and delivery agent Y. This collaboration could be classified as a strategic partnership as the aim of both collaborators is to increase last mile sustainability, including social, environmental, and economic aspects. Within the collaboration process, the delivery service providers, i.e. the involved collaboration agents, could use the zoom-in depiction of the collaboration process to discuss their partnership regarding their processes, the people involved in the collaboration, and the underlying systems such as information technology systems. As their shared goal is to enhance the sustainability management and information exchange, they could discuss which categories and components within the collaboration process are relevant for their collaboration. For instance, they could agree to define collaboration sustainability goals according to the UN sustainable development goals 11 (sustainable cities and communities) and 13 (climate action) [54]. In addition, they could decide to implement sharing of additional delivery order information based on data collection enabled through sensors.

The application of this strategic model in specific use cases could thus enable the collaborators to define the type and focus of their collaboration more clearly. In addition, the collaboration process circle to extend and improve the individual components of their collaborative process with a balanced approach to all three collaboration categories (people, process, and system).

This research project applies a formative-summative design-evaluate-construct-evaluate pattern [55]. The expert evaluation of the initial model draft and the estimated revised model (see Table 2) are based on the principles of proper reference modelling, the recommendations for DSR evaluation [56] and the framework for evaluation in design sciences [57]. As the interviewees are both from a business and academic background, practical and scholarly evaluation perspective are included.

The main critical points mentioned by the experts are the ease of use and the level of detail/completeness. According to the IPs, the required detail and thus completeness of the model depends on the user and the use context. Accordingly, the model is not

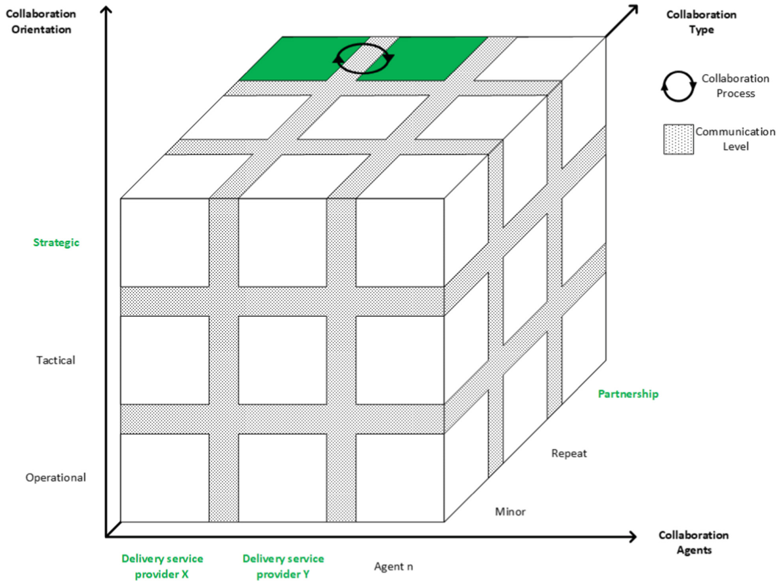

Fig. 3. Last mile collaboration use case example.

Table 3. Expert evaluation feedback averages (evaluation scale 1 = low to 5 = high).

Feedback criteria	Initial model	Revised model
General adequacy	4.17	4,58
Accuracy/correctness	4.14	4.43
Clarity/unambiguity/consistency/systematic structure	4.07	4.75
Level of detail/completeness	3.79	4.00
Internal validity	4.33	4.42
Ease of use	3.71	3.93
Relevance/usefulness/appropriateness	3.93	4.57
Adaptability/generalizability/comparability	4.14	4.50

applicable to every situation and serves as a strategic blueprint for instantiations in different sectors. The ease of use similarly depends on previous knowledge of the user regarding scientific models and can thus be problematic. We intend to further develop the model as an interactive web application including detailed instructions and explanations to enable a more accessible and intuitive model use.

While the research presented in this paper adheres to the seven design-research guidelines [30], the chosen modeling and evaluation approach suffer from several limitations. First, the process model for empirically grounded reference modelling is limited regarding its focus on qualitative methods for data generation. Second, the results of the empirical enquiry and thus the model itself are restricted due to the selection of experts and their respective background. While experts from both a business and academic background are included in the modeling process, opinions and suggestions remain subjective. Third, the artefact evaluation approach is limited as no evaluation method can assess all potential evaluation criteria.

5 Conclusion

This paper presents the results of the systematic empirically based development of a strategic *Reference Model for Data-Driven Supply Chain Collaboration.* The wider application of collaborative SCM is a requirement of increasingly competitive and global supply networks as inter-organizational exchange of data and knowledge as well as the integration of novel technologies such as AI are essential factors for organizational growth and competitiveness. This paper thus fills the gap of a missing overview of the field by proposing a framework of data-driven SCC.

The results contribute to the academic debate on data-driven SCC by providing a comprehensive interdisciplinary conceptualization and categorization combining IS, DSR and management research approaches. Future research avenues include the further analysis of the collaboration dimensions and process categories. Furthermore, this paper presents a valuable contribution to supply chain processes in organizations of different sectors by providing a macro level perspective on the topic of SCC. In addition, the paper suggests an adaptable reference framework for managers focusing on strategic collaboration development and information management. The further development of the model as an interactive web application is intended to enable a more accessible and intuitive model use.

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