Towards Inter-organizational Decision Support in Supply Chains through Cloud-based Discrete Event Simulation – A Conceptual Business Model and Elements of a Research Agenda

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ABSTRACT

In general, cloud services enable new *inter-organizational* business improvements such as better coordination and collaboration tools as well as information and knowledge sharing. In contrast, discrete event simulation is a matured and highly helpful simulation technique on operational level that is currently used especially for optimizing supply chains *within an organization.* Therefore, this paper proposes a cloud-based discrete event simulation. Herein, the paper uses a mixed method approach and derives a new business potential in the intersection of both research fields. Thereby, we provide a wider understanding of cloud computing that goes beyond the technical functioning. Furthermore, the paper indentifies the major future research directions for creating an economic and effective environment for applying cloud-based discrete event simulations.

KEYWORDS

Information Management, Cloud Computing, Discrete Event Simulation, Business Model, Supply Chain Management, Research Agenda, Design Science Research

1 INTRODUCTION

Whereas in the 1990s logistics research primarily studied the interaction of people, organization structures, and technologies *within* one enterprise, during the last 20 years, the major object of interest has shifted towards the *whole* supply chain (SC), which ranges from up-stream suppliers to down-stream distributors and final customers (e.g., Oliver and Webber, 1992; Handfield and Nicols, 1999; Swafford, et al. 2006; Hazen and Byrd, 2012; Sweeney et al., 2015; Wieland et al., 2021). Furthermore, for many years already, SCs have been dealing with IT-based optimization initiatives. It is self-evident that organizations manage today's market challenges better when investigating the construction and the IT processes of their SCs in more detail as well as aligning business processes and IT processes (Carter and Rogers, 2008; Pereira, 2009; Meer et al., 2012; Pashaei and Olhager, 2015; Tönnissen and Teuteberg, 2020).

For understanding the complex interactions of distributed SCs, stochastic influences, such as demand fluctuation, production site failure, or transportation delay, play an important role. The consideration of such effects is needed to assess the robustness and resilience of simulated SCs (Pereira, 2009; Pashaei and Olhager, 2015; Golrizgashti et al, 2023) and to estimate the costs for various SC designs, resulting from operative activities. In this connection, simulation models offer significant advantages because of the possibility of (i) testing their SCs in repeatable and controllable environments on a detailed modeling level and (ii) tuning the performance bottlenecks before deploying on real world (Gutenschwager and Alicke, 2004). This requires that the simulation results are robust, accurate and suitable.

Although the pressure for optimizing the entire network increases, most companies still tend to analyze their processes mainly isolated from SC partners (Tako and Robinson, 2012; Longo, 2023), which may not necessarily lead to the global optimum. And even if there are inter-company SC optimization efforts, these are often dominated and/or controlled by one company (e.g., the company that may have the higher market power), and possibly an economic buyer-supplier conflict may come up (Stern and Hesket, 1969; Willis and Jones, 2008; Rezapour et al., 2015), which may put one party at a disadvantage.

Discrete event simulation (DES) is an established analysis method for production and logistic systems and a widely used modeling tool which underpins decision support systems (e.g. Ridall et al., 2000; Huang et al., 2003; Agalianos et al., 2020; Greasley et al., 2021). DES is frequently used when important decisions have to be taken, where the far-reaching risks and consequences are not directly assessable. Besides, DES is applied when there are no suitable analytical solutions available (Willis and Jones, 2008; Zee, 2011). In general, simulations are applied to problems with stochastic influences within the analyzed processes (Siebers and Aickelin, 2011; Owen, 2013). Herein, a DES allows a high level of detail (Tako and Robinson, 2012; Kleijnen, 2005) when modeling SCs, calibrating SCs (e.g., transportation routes and frequencies, lot sizes, or safety stocks), and analyzing SC designs (e.g., production and warehousing locations with a given customer structure, insourcing vs. outsourcing or product allocation to central and regional hubs). In literature, there is a broad range of simulation studies analyzing SCs that cover various SC levels within one company (e.g. Lidberg et al., 2020; Melman et al., 2021; Lang et al., 2021). However, there are only few works that consider intercompany effects of specific elements of SC networks (Min and Zhou, 2002; Zee and Vorst, 2005; Greasely et al., 2021)

Simulations, and especially SC simulations, require a high level of expert knowledge of the simulation tools, the modeling, and the interpretation of results. Casual users, thus companies who only carry out such studies rarely, rather rely on external simulation services and abstain from the acquisition of the necessary simulation software as this would be uneconomical. Additionally, smaller companies within the SC do not have the capabilities to handle such simulation systems.

Therefore, this paper proposes a cloud-based DES concept, where a cloud service network offers the DES software to the SC network. This concept offers two major advantages. First, it enables to optimize enterprise-specific as well as global SC approaches that are not decoupled from external SC partners. Especially the global optimization possibilities may encourage organizations to increase their interactions such as coordination, collaboration, or information sharing in order to improve the overall SC network power and resilience. Second, the concept uses general advantages of cloud computing, namely pooling resources and cost efficiency. Even nowadays, the use of adequate simulation tools requires high investments for hardware and especially for software (e.g. Mansouri et al., 2020; Lang et al., 2021; Pan et al., 2022; El Kathib et al., 2022;). In general, the concept aims to meet the requirements of Demirkan and Delen (2013), who postulate already ten years ago the unchanged need for “affordable analytics for masses”.

The aim of the paper is to give cloud service providers and DES users as well as the scientific community a conceptual business model by means of a framework that is well-established in strategic management research. Thus, with our paper we extend the technological perspective of cloud computing (CC), by shifting the focus from the purely technical viewpoint to a wider understanding for new business opportunities. Instead of focusing on the advantages of the simulation results that have already been widely discussed in literature, we will investigate the major actors, roles, and requirements for enabling and running such a business model. The paper uses a construction-oriented mixed research methodology based on a systematic literature analysis (Webster and Watson, 2002), design science (Hevner et al., 2004), and expert interviews (Cresswell, 2003). Thus, the underlying research questions are:

RQ1: How could an overall business model for cloud-based DES be structured?

RQ2: What are the general requirements for participating in the cloud-based DES?

The structure of the paper is as follows: In section 2, we discuss the theoretical background and the search for related work. Thereafter, we explain our mixed method research approach in section three. The section 4 outlines the underlying business model, consisting of actors and roles, including the important mediation role of an information broker. In section 5, we conceptualize the requirements for running such a business model. Finally, the paper discusses the evaluation in section 6 and concludes in section 7 with contributions, limitations and future research.

2 THEORETICAL BACKGROUND

To explore the status quo regarding the inter-organizational simulation of SC processes via CC, we conducted a systematic literature analysis (Webster and Watson, 2002). Knowing that the underlying research field is quite new and very specific, we consciously used a broad keyword range in order not to miss any pertinent research stream that might be helpful. The keyword based searching process started with using significant terms in various combinations: (operation* OR logistic* OR supply chain* OR value network* OR discrete event simulation) AND (cloud computing OR software-as-a-service OR grid computing OR service oriented architecture*). In order to identify relevant publications, we applied the searching process in four scientific databases (EBSCO, Science Direct, Google Scholar, Springer Link). With these searching parameters, we identified two broad fields of research: The first research field is not relevant for our research as it discusses simulation-based test environments for integrating cloud services, rather than providing simulation as a service for SC process optimization. As the consideration of this field may be fruitful in a more mature status of the underlying topic instead of for the actual conceptualization phase, we excluded it. And also the second field tackles our core topic only superficially in so far as it investigates the general advantages of cross-company cloud usage for operating real SCs (e.g., ordering by using cloud services).

Therefore, we expanded our literature searching procedure by seeking for exemplary papers that describe cloud-based value networks with related actors and interactions. We identified seven papers (cf. section 2.2) whose major insights have been transferred for our purposes of conceptualizing a value network through a cloud-based SC simulation tool. As this paper proposes a business model that integrates the fields of supply chain management (SCM), discrete event simulation (DES), and cloud computing (CC), we discuss these terms successively in the upcoming sub-sections 2.1 and 2.2 through the lens of strategic theory (Mintzberg, 1987).

Our upcoming business model includes various actors and therefore varying strategic perspectives may be taken, e.g., the perspective of service providers, integrators, or information brokers. We focus mainly on the strategic relevance of the integrated simulation for users, namely the SC members, as the users decide whether they accept the business model or not. The value-chain model by Porter (1985) is very suitable for the purpose of this paper. Porter sought to understand the relevant factors of competitive advantage and found that *rigorous control* throughout all activities within the value chain may enable organizations to utilize cost-saving and differentiation potentials. Moreover, he postulates that running organizations successfully is about to *reconfigure the value chains* successfully (Porter, 1985). Although Porter only considered value chains within one organization, his concept can easily be transferred to a SC network. Hence, rigorous control can be assured by modeling real live SC processes within a detailed simulation with controllable variables. Following this approach in integrated simulation environments with related SC partners may open new dimensions for value chain reconfiguration. This reconfiguration process leads to a *process-based view on strategy*, where the question is *how* SCs reach a particular performance (Mintzberg, 1987). We aim to answer this question in section 4. Moreover, simulating the SC network can be justified with the process-based research concept of the so-called "*intermediate outcome*" (Chatterjee, 1998). For the SC members, the integrated simulation does not represent a product or service that can be offered to the market place nor does it create competitive advantage per se, but it has the potential to draw valuable conclusions on real SC processes, which in turn may lead to higher profits, higher revenues etc.

2.1 Supply Chain Simunlation

In literature, SCM is defined as "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the SC, for the purposes of improving the long-term performance of the individual companies and the SC as a whole" (Mentzer et al., 2001). Contrary to many other definitions (e.g., Cooper et al., 1997b; Handfield and Nicols, 1999), this definition puts an important and realistic emphasis on the individual companies on the one side and the SC network on the other side, which means that there are pre-existent SC conflicts (more details in section 5). Moreover, Mentzer et al. (2001) determine SCM as a set of entities directly involved in the upstream and downstream of three flows: (i) products and services, (ii) finances, and (iii) information.

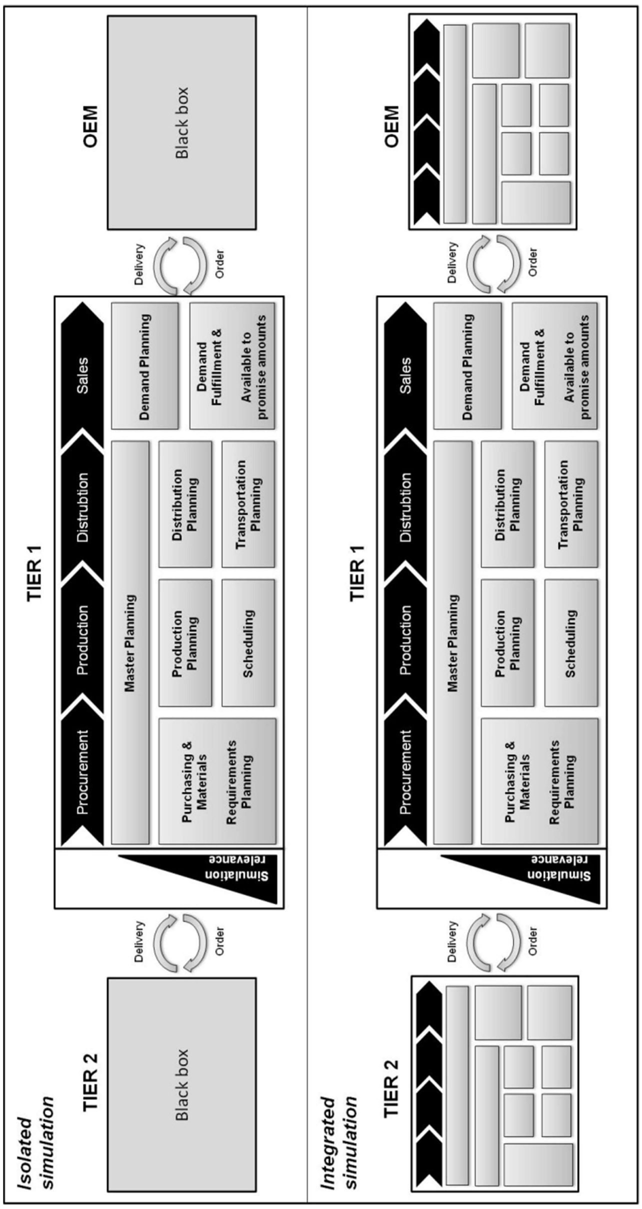
Supporting SCM processes, DES emerged in the late 1950s, modeling the operation of a SC system as a discrete sequence of events in time (Tako and Robinson, 2012; Agalianos et al., 2020). Each event occurs at a specific instant in time and constitutes a change of state in the system (Robinson, 2004). Hence, the SC system behavior and performance can be analyzed under various conditions (Sweetser, 1999; Sweeney, 2015). In contrast to other simulation methods such as system dynamics, DES is known to be useful at the tactical level by modeling a SC network of queues and activities, where randomness is created by statistical distributions (Brailsford and Hilton, 2001). Towards this end, this kind of incremental and tentative search for a better composition of the SC elements goes in line with *process-based view on strategy* that was introduced by Mintzberg (1987). Thereby, the pattern of action visible ex post makes up the "emergent strategy" (Mintzberg, 1987), which in the context of this paper may be derived from simulations.

In DES, entities (objects, people etc.) are modeled individually, where specific attributes are assigned to each entity. These attributes determine what happens to the entities during the simulation (Tako and Robinson, 2012). The relevant parameters and variables for simulating SCs have been investigated and discussed in literature intensively. Here we want to refer to some well recognized works such as Law and Kelton (2000), Fishman (2001), Min and Zhou (2002), and Chen et al. (2000) that provide a great amount of variables and parameters. There are divers DES software tools available for the simulation of SCs. Usually, they have a graphical user interface that supports the modeling process. Modeling modules/entities are mostly defined by locations, customers, production sites, resources, and links of storages, hubs, and transportations (Gutenschwager and Alicke, 2004). Also important is the integration of ERP functions such as planning and forecasting of production, procurement, and transportation. Due to the high requirements for data quality and the large amounts of data, assist functions are often advantageous, e.g., for checking the data consistency in the input or to import bulk data. In case of very large amounts of data, table-oriented approaches with a database may be beneficial. As mentioned before, the adequate use of such simulations is still quite expensive as they require specific knowledge and high performance systems. Moreover, we only occasionally found papers that applied DES in cross-company SCs (e.g., Dorsch and Hackel, 2012; Chien and Kuo, 2013; Turner et al., 2016). This is criticized by Pereira (2009), Demirkan and Delen (2013), and Sweeney et al., (2015) as well, who motivate research and practice to investigate cross-company analytics more in detail.

Following this motivation, we depicted our intention in figure 1. Acknowledging the SC planning processes, Meyr et al. (2002, p. 99) presented the SC planning matrices which involve long and mid-term aspects (e.g., "master planning") as well as short-term aspects (e.g., "transportation planning"). From the perspective of the

TIER1, we present an isolated simulation of the SC planning matrix in the upper case (which equals more or less today´s situation) and an integrated approach in the lower case. In the isolated case, the TIER1 has to estimate the current as well as forecasted order statistics from the OEM and the delivery statistics from TIER2 in order to analyze his own supply chain. In the integrated case, all members simulate their SC by themselves, by enriching the SC network with higher information sharing and optimization possibilities. In case of a fully transparent DES, all members of the SC (TIER 1, TIER 2, and the OEM) are in a position to see the data of the other members (e.g., order and delivery statistics). Herein, DES addresses especially the tactical or operational level, which we depicted with "simulation relevance". Of course it is possible to derive long-term strategic decisions from the simulation results.

Figure 1: Comparison of isolated and integrated SC simulations (adopted from Meyr et al., 2002)



2.2 Cloud Computing

The term "cloud computing" emerged in 2007 and is classified as a next development level of service-oriented architectures (Youseff et al., 2008). The National Institute of Standards and Technology (NIST) defines CC as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell and Grance, 2011). But CC does not represent a new technology. Rather, it stands for a new paradigm for IT processes (Youseff et al., 2008) by consistently linking individual, existing technologies (Leimeister et al., 2010). The majority of the research literature distinguishes between three major service models (Hoberg et al., 2012, Mell and Grance, 2011): "Infrastructure as a Service (IaaS)", "Platform as a Service (PaaS)", and "Software as a Service (SaaS)". Furthermore, there are four deployment types (public, private, hybrid, community). In terms of this paper, we only consider public CC, where an external provider offers services through the Internet. (With the other deployment types, the involvement of a pre-existing, neutral information broker is hard to realize.) Research and practice gain a lot from CC as it provides various advantages such as collaboration and coordination increases as well as costs and time savings (e.g., Meer et al., 2012; Cegielski et al., 2012; Ahmed et al., 2015; Bharany et al., 2022; Saratchandra et al., 2022), which consequently also assigns strategic relevance to CC (Marston et al., 2011).

Coming back to the seven papers that we identified during the literature search, Böhm et al. (2010) have developed a CC network, in which the interaction of service creation and mediation are presented. Their main contribution is the determination of eight generic roles. All involved participants are shown in relation to each other via a market platform. The authors evaluated their model by expert interviews that confirmed the interrelation between the different identified roles. The paper by Leimeister et al. (2010) is similar to the model by Böhm et al. (2010) and puts emphasis on the business perspective of CC. For this reason, similar to the work of Böhm et al. (2010), the article contributed to a systematic description of major actors entering the CC market and modeled their interactions by conceptually developing a value network of cloud actors. Walterbusch et al. (2014) built on the two models and created a CC business model by including actors such as a mediator and a consulter. Their principal contribution consists of the hybrid creation of cloud services via various related roles, which was confirmed by expert interviews. Moreover, they outline the importance of service transparency during the creation process. A completely different CC view on the cross-organizational collaboration aspect is discussed by Martens et al. (2011). They investigate the topic from an interdependency-driven perspective, which results in the determination of three collaborative CC environments. Thereby, the environments are constituted by *pooled* (public and community clouds), *sequential* (cloud chain) and *networked CC* (industrial cloud). This environment serves as a basis for a decision support process that includes risk and security factors for the selection of adequate partners. Also focusing on risk models, Keller and König (2014) asked how cloud actors can identify risks in cloud business networks and increase the transparency in network structures. Their real life application displays the dissemination of risks through the cloud network, where the actors are able to identify the impending risks. Lang et al., (2021) question whether or not free CC oriented discrete-event simulation software is an alternative to commercial tools for solving typical planning tasks in production and logistics. Herewith, they compare three open source solutions and two commercial simulation tools, including the supporting role of the IT-provider. Finally, the paper by Deng et al., (2021) explores via adaptive structuration theory how organizations attain organizational agility through IT-outsourcing appropriation. It examines the mediating role of IT alignment and the moderating roles of the adoption of cloud computing and knowledge transfer.

Grounding especially on the first three models, first we transfer empirically tested roles and the interactions of the roles on the subject of DES-based SC optimization.

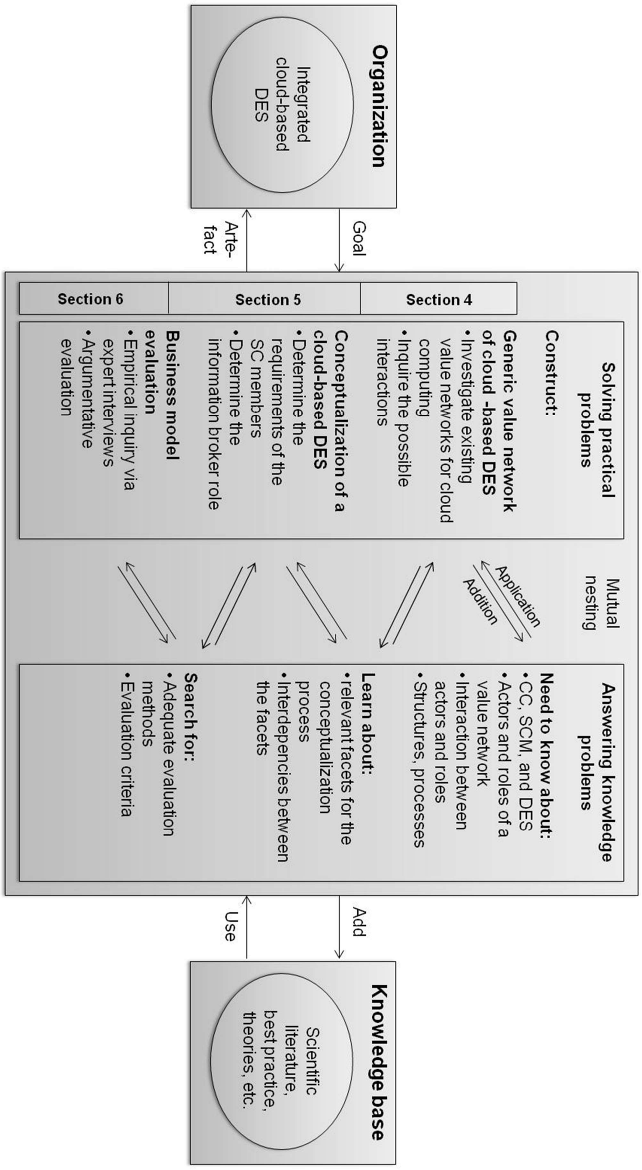
3 RESEARCH APPROACH

The underlying research approach is construction-oriented, because it involves "the construction of an information technology artifact and its evaluation" (Kuechler and Vaishnavi, 2011). Therefore, it is assigned to the design science research paradigm (Wieringa, 2010). Acknowledging Hevner et al., (2004), design science aims at the development of "technology-based solutions to important and relevant business problems". These solutions have to lead to an improved environment by means of creating innovative artefacts, which can be constructs, models, methods, or instantiations (Hevner et al., 2004). To provide a scientific methodology for the initially stated research questions, we adopt the nested problem solving strategy (Wieringa, 2010), which is based on the design science paradigm of Hevner et al., (2004). Herein, the problem solving process is conducted by the researchers iteratively, and both the space of alternatives and the final design is entirely open at the beginning. During the process of problem solving, the problem is decomposed into interrelated sub-problems. This decomposition is repeated until sub-problems arise, which are considered to be solvable by stakeholders. According to Wieringa (2010), the sub-problems can be sub-divided into practical problems and knowledge problems (cf. figure 2).

In order to solve a practical problem, a certain change in the current state is required. It describes the difference between the current state and the state as it should be. On the other side, a knowledge problem represents some kind of knowledge deficit, which can be resolved by adequately acquiring knowledge. In order to be able to provide the desired artifact and answer the paper's research questions, knowledge about CC, SCM, and DES as well as their interrelations is needed. Such knowledge deficits can be investigated for instance by means of a literature search like it was conducted in the second section of this paper. The research outcome, the generic value network (cf. section 4) and the conceptualization of the cloud-based DES (cf. section 5) will be presented one after another. Herein, we will use the e^3-method (Gordijn and Akkermans, 2001) as notation type.

Thereafter, the research outcome is evaluated in two ways (cf. section 6): through argumentative evaluation (Frank, 2006) and expert interviews (Cresswell, 2003). We conducted twelve semi-structured interviews with IT-experts from related business fields, all of them have at least two years of CC experience. Six of the IT-experts were from the SCM field of an industrial companies; three IT-experts are working for different CC service providers, and three IT-experts were from a SC simulation software company. All of them involved significant know-how and were able to contribute valuable feedback to the underlying paper. The interviews were conducted in December 2022 and took in average 45 minutes. With the approval of the interviewees, the interviews were audio-taped and transcribed by the researchers. The structure of the interviews consisted of three successively steps. In the first step, the questions covered the respective experiences of the interview partners with the CC and the SC network, their related job roles and their relationship amongst each other. In the second step, we included the presentation and discussion of our proposed value network. The IT-experts were also asked for their estimation of the value creation and the single value flows within an overall value network (cf. Figure 3). In the third step, we questioned the specific requirements for running such a value network (cf. section 5). In general, the valuable insights gained from the IT-experts led to an iterative construction of the paper.

Figure 2: Nested problem solving research approach (adopted from Wieringa, 2010)



4 ACTORS AND ROLES OF THE BUSINESS MODEL

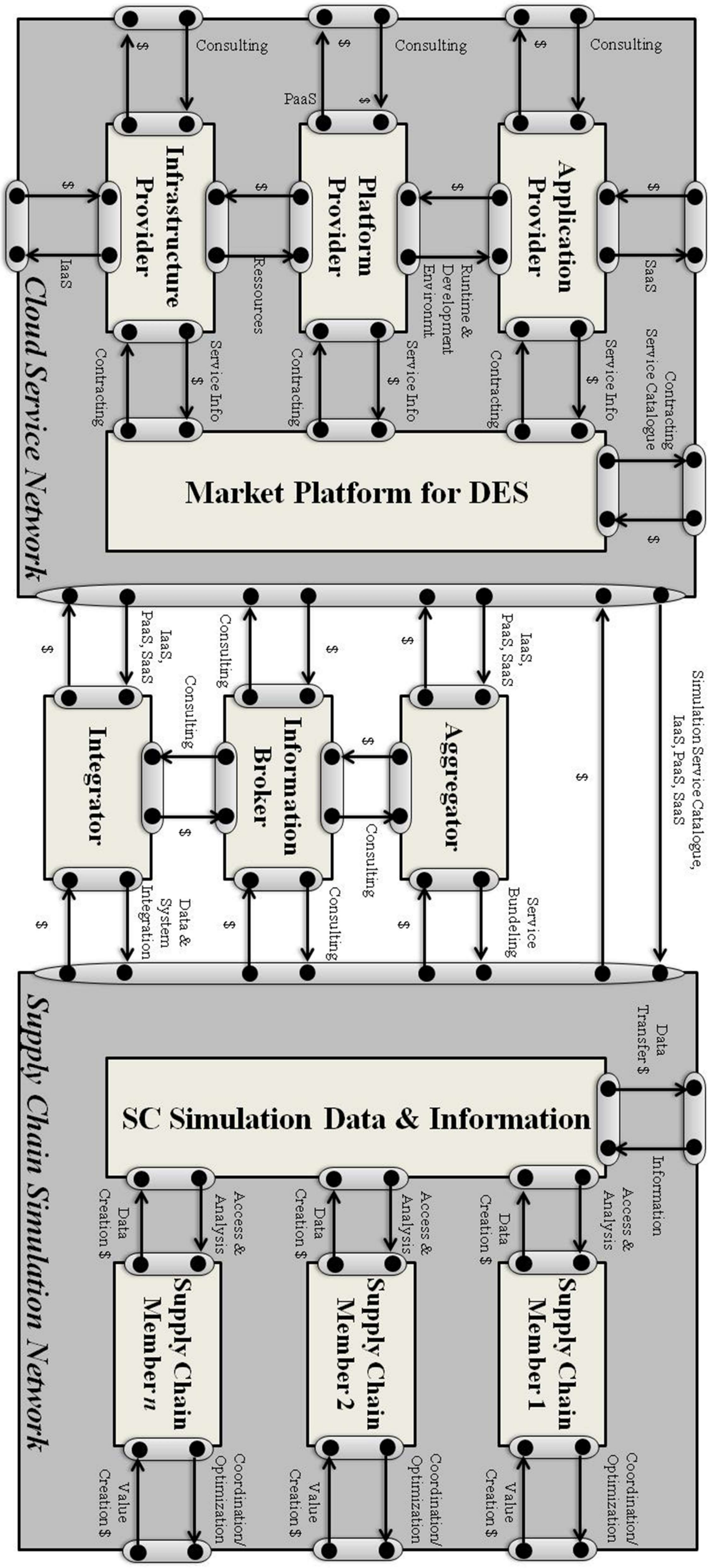
We follow the business model definition by Timmers (1998). Herein, a business model includes (i) a description of the various business actors and their potential benefits, (ii) a description of the sources of revenues, and (iii) an architecture for the product, service, and/or information flows. In order to meet the conditions (i) and (ii) we use the e^3-value method by Gordijn and Akkermans (2001). The third condition will particularly be specified in section 5. In general, the e^3-value method is a semi-formal conceptual modeling method that recognizes the creation, exchange, and consumption of economically valuable objects in a multi-role network. Within this network, value is generated by providing services (related to cloud-based DES) that are valuable for other related parties of the network. These services are exchanged in return of either money, which is the typical case, or other benefits that the participants value. Based on models by Leimeister et al. (2010) and Böhm et al. (2010), we extended the existing body of knowledge by combining the *value network of CC* with the *simulated value network of SCM*. In this context, it is important to mention that an actor may hold and act in various roles. Therefore, we take the abstracted viewpoint and speak of roles. In the following, we briefly discuss our understanding of the different roles emergent in the cloud-based DES ecosystem.

As mentioned before, CC literature generally differentiates between three service layers (Youseff et al., 2008; Mell and Grance, 2011; Marston et al., 2011), namely: infrastructure provider (IaaS), platform provider (PaaS), and application provider (SaaS). The ***infrastructure provider*** offers virtual hardware, network connections, and virtual storage for the cloud-based DES solution. The scalable nature of IaaS ensures enough infrastructure power, as additional machines can be instantiated on demand. The ***platform provider*** offers application programming interfaces and programming languages for developing, running, and testing DES software. And the ***application provider*** offers DES software via the web that runs on specific platforms and uses resources from the infrastructure provider. The modeling and simulation service can be perceived as a specific derivative of SaaS. The application provider ensures smooth operation of the DES software and provides new features and software improvements. The ***market platform*** constitutes a market place of different CC providers for SC customers, where suitable services may be combined. In addition, further services such as contracting, billing, and service level agreements may be offered to customers and providers (Leimeister et al., 2010; Walterbusch et al., 2014; Lang et al., 2021).

The ***aggregator*** is a DES cloud market expert, as he/she is able to aggregate various modular CC services into value-added DES-solutions in order to meet specific SC network requirements. Either the aggregator links existing services into a new service, or he/she adds value on top of a given service, creating certain features (Böhm et al., 2010). The ***information broker*** holds a central and trust-based position in our business model. The broker can provide a deep knowledge of the SC network´s business processes and can recommend the SC network using adequate services. The broker offers analytical services to the SC members based on the respective accessible data. Herein, the broker acts as a mediator between the members in order to increase overall efficiency. The information broker has to ensure the fulfillment of all user requirements (cf. section 5.1). More details on the function of the information broker role will be outlined in section 5.4. Having found the right DES-service, the ***integrator*** helps to migrate data into the cloud and develops clear interfaces for a seamless interoperability between the SC members, the system, and the cloud-based DES.

Finally, the SC network obtains the DES services from the cloud. The network consists of the single ***SC members***, whereby every member has to create certain data that is relevant for an adequate SC in the ***simulation model***. The SC network does not create value within the cloud service ecosystem, nor does the SC network offer cloud services to other networks. All CC activities have to be paid by the network´s members. In return, the gained information from the integrated DES simulation enable better coordination and optimization possibilities, which leads to value creation in the SCM ecosystem. The construction-oriented and literature-grounded business model is presented in figure 3. Herein, we extend the pre-existing body of knowledge by using existing business models (e.g., Böhm, 2010; Walterbusch et al., 2014) and breaking down their contained "user role" further into a linked network of users, namely the SC members.

Figure 3: Generic value network of cloud-based discrete event simulation



5 EMERGING CONCEPTUALIZATIONS OF THE CLOUD BASED DISCRETE EVENT SIMULATION

As mentioned before, the paper at hand focuses on requirements (*RQ2*), which have to be fulfilled in order to enable inter-company cloud-based DES, rather than presenting a specific and complete solution. Coming back to the presented business model´s roles, research has investigated the requirements of the cloud service network (e.g., Marston et al., 2011; Hoberg et al., 2012; Denk et al., 2021) as well as for the aggregator and the integrator role (e.g., Leimeister et al., 2010). Hence, we will focus in particular on the SC members and specify the information broker role. The upcoming sub-sections discuss the requirements of the SC members, namely (i) security and trust, (ii) authorization concept, (iii) scenario analysis, (iv) buyer-supplier conflict, (v) coordination and collaboration, as well as (vi) financial benefits. The discussion of these aspects is grounded in scientific literature and augmented by the insights of IT-experts during the interview phase. Derived from the discussions we will present 12 research directions.

5.1 Requirements of supply chain members for participating the cloud-based DES

5.1.1 Security and trust

Even in the very beginning of CC, various early studies report that ***security*** risks and a lack of ***trust*** are the primary concerns when using cloud services (Marston et al., 2011; Zissis and Lekkas 2012; Venters and Whitley, 2012). However, there is a strong link between “ensuring security” and the lagging effect “trust formation”, which is critical for building and using cloud services (Walter et al., 2014; Walterbusch and Teuteberg, 2014; Alouffi et al., 2021). Even if the company´s data that is transferred to the external provider is of “statistical nature” only, it may contain critical information with which SC competitors and other SC members may cause harm to the releasing company. Due to buyer-supplier conflicts, the SC members will certainly not share all their information with the related parties (e.g., information on production costs or resource utilization). Furthermore, compared with other encapsulated cloud services, the cloud-based DES trust issues are even more in the foreground, as by means of this service the SC members are brought together at a central place where they use the same data structures. This state of affairs makes it very interesting for SC members accessing and using unauthorized data. Hence, the cloud-based DES providers have to ensure secure data, information, and analytics. Looking at the business model, there is a trust issue of every SC member towards all cloud service providing parties, and there is a trust issue within the SC network between the members. Every SC member should be aware of who is providing which part of what service and at what security standards. Following the “strategic network” understanding of Gulati et al., (2000), long term buyer-supplier partnerships might have higher degrees of trust within SC simulations. That is because traditional and latest literature argues that particularly strategic SC networks need to offer the potential to share risks, enforce knowledge building, and facilitate learning processes (Katz and Shapiro, 1985; Pashaei and Olhager, 2015; Rezapour et al., 2015; Alouffi et al., 2021). For further investigations of trust issues within the SC simulation network, there already exists a valuable and transferable knowledge base in literature (e.g., Kleijnen, 2005; Pashaei and Olhager; 2015). Nevertheless, more research is needed with respect to cloud-based DES as well as the special role of the information broker.

Research direction 1: How can the security concerns of SC members in the cloud-based DES be understood and decreased in order to increase the level of trust?

5.1.2 Authorization concept for simulation tools

After having determined the SC processes with the relevant parameters, the SC members have to transfer their data into the cloud. Herein, the SC member individually determines who should have access to what specific event data. With public CC usage, SC members normally suffer from limited control over their data (compared to running own IT systems). Hence, the cloud-based DES providers have to establish specific authorization concepts which ensure data confidentiality and data integrity. These authorization concepts should also include that the cloud service providers do not have access to the data of the SC members in order not to lower the level of trust in case of sensitive data (Li et al., 2011). In accordance with the separation of actors and roles in section 4, neither the DES providers (in all three layers) nor unrelated parties (e.g., competitors) should have access to a SC member´s data. However, the data owners themselves can decide with whom they share their data. In other words, nobody in the SC has access to the data unless the data owner grants the access.

With cloud-based DES, there is an integrated simulation (cf. Figure 1), but it is not only one simulation for all members. Depending on their respective data access, the SC members may have separated fields of visible data. Hence, the integrated partial simulations run in parallel to each other and use data from each other so far as possible. Furthermore, it is of high interest for the SC network if there are potentials to carry out analytical evaluations for overall SCs using detailed data from different members, while still meet the limited data authorization of the individual members. Here, the authorization concept needs to ensure that the underlying model is not visible to the residual SC members and the “open” results do not allow statistical inference to unauthorized individual parameters. One way to increase the willingness for participation might be to consider relative changes, rather than absolute terms, e.g., financial values.

The research on CC provides divers authorization concepts (e.g., Wang et al., 2010; Li et al., 2011; Li et al., 2010; Cao et al., 2014; Alouffi et al., 2021). We found the works by Zissis and Lekkas (2012), Zhao et al. (2010), and Khan et al. (2013) to be suitable for our purposes. Especially the work by Zhao et al. (2010) serves as a valuable basis for an authorization concept.

Research direction 2: How can an intelligent authorization concept (including instruments and tools) be created in order to increase trust and participation willingness of the related members and to facilitate statistically relevant SC network analysis?

5.1.3 Scenario analysis

The cloud-based DES should fulfill an adequate degree of "what-if analysis" and "how-to analysis" possibilities (Russel and Norvig, 2009, p. 337 ff.). Towards this end, what-if scenarios are useful for evaluating SC optimization initiatives. They facilitate the selection of best suited alternatives from a portfolio of possible SC modifications. In contrast, a how-to analysis starts with the desired outcome and determines the adequate structure of the SC and the underlying processes through "backward inference". The optimization possibilities range from analyzing own data only (local optimization) to analyzing the entire SC across various members (global optimization).

Research direction 3: Which simulation environments, differentiating between individual parameters and overall statistical results from simulation models, are beneficial for improving local and global optimization possibilities?

If global optimization is envisaged, the various types of important and less important members may lead to a complete network simulation. However, due to the number of members added from tier level to tier level (Cooper et al., 1997a), the network becomes highly complex (Lambert et al., 2000) and overcrowded. It could be counterproductive, if not impossible, to involve and manage all process interactions with all members across the SC. It is crucial for the SC network to determine the critical members, processes and products (*simulation scope*), as well as the model's level of detail.

Research direction 4: What are typical and useful simulation scopes in terms of intercompany analyses with respect to the potentials of cloud-based DES?

The interrelation between the security and trust requirement (cf. section 5.1.1) is obvious. Basically, every member has access to his/her own data and if authorized to foreign data. Even though the concept postulates an integrated DES, the degree of integration is determined by the single SC members. When the trust level is low, the data (if any) might suffer from low quality and information sharing willingness might decrease. Research literature has impressively shown the importance between trust and information sharing (e.g., Prajogo and Olhager, 2012). Basically we hypothesize that the higher the trust and transparency willingness between the companies, the higher the information quality of the whole SC and the better the optimization possibilities. Moreover, the flexible and virtual nature of CC (Marston et al., 2011) with the standardized DES software enables easy addition of new members after the initial phase. It should also be possible to include adjoining members of the SC, which so far is modeled as a black box (cf. figure 1), in detail when providing respective data.

Research direction 5: How can the members' trust be increased in order to also increase the transparency and the information sharing willingness in the cloud-based DES?

5.1.4 Considering the buyer-supplier conflict

As mentioned before, there is a pre-existent buyer-supplier conflict. Stern and Heskett (1969) proposed three classic types of conflict causes within SCs: (i) differences between members' goals and objectives, (ii) disagreements over domain of decisions and actions, and (iii) differences in the perception of reality used in joined decision making. During the simulation phase, especially conflicts (i) may hinder members to join the CC service (e.g., customer wants the supplier to have a higher inventory stock for reducing lead times). When key members are missing in the simulation, it is much more difficult to run a global simulation and to achieve valuable results. If an important member in the middle of the SC (with direct upstream and downstream links to other important SC partners) declines to participate in the cloud-based DES simulation, the member might be modeled in the simulation chain as a black box, which means that the member´s processes are unknown. As the direct link is very important, also here statistics from historical data and further assumptions may be sufficient to fill the gap.

Research direction 6: How can a decline of members be handled, and what is the impact of declining members on the simulation results?

5.1.5 Coordination and collaboration

The next requirement is related to the interrelated fields of ***coordination and collaboration***. In research literature, there is no doubt that the right degree of coordination and collaboration can bring competitive advantage to the related SC members (Cegielski et al., 2012; Demirkan and Delen, 2013). In terms of this paper, the intermediate outcome (cf. section 2) *cloud-based DES* may serve as a standardized platform for simulating advanced coordination and collaboration behaviors, which may help members to draw needful conclusions. Hence, the simulation tool might constitute a kind of training for coordination and collaboration interactions. This requirement may have two linked dimensions, namely the technical and social coordination and collaboration. By means of the technical coordination and collaboration, we aim to improve the performance of the cross-company SC. From the social point a view, cloud-based DES may serve as a platform for discussions on common SC processes. Of course, this requirement cannot be seen loosely coupled from the prior mentioned requirements, as for instance a low level of trust within the SC network may hinder the collaboration intention.

Research direction 7: What is the impact of cloud-based DES on beliefs about collaboration and coordination initiatives in cross-company SCs?

Research direction 8: What is the impact of using cloud-based DES on real life collaboration and coordination in cross-company SCs?

5.1.6 Financial benefits

In the underlying business model we assume financial benefits for the SC members in terms of information acquisition through simulation analysis. Hence, the requirement is that the gained benefits of the SC network should overcompensate the costs for running such a cloud-based DES. At the same time we argue that the cloud-based DES might bring financial benefits to the cloud service network as well as to the integrator, the aggregator and the information broker, who all require compensation for their services. Herein, the SC network is the consumer of the obtained CC services and therefore, the SC network has to pay for the services as a customer.

However, the SC network is composed of various parties and thus does not represent a homogeneous unit. Therefore, the SC network needs to determine a fair allocation of the costs among the SC members, which is probably strongly linked to the expected benefits of the respective members. Moreover, it may occur that the overall SC can be improved by worsening single elements of related parties. The question of benefit allocation leads to game theoretical approaches (e.g., Colman, 1982; Myerson, 2013; Bharany et al., 2021; Greasley et al., 2022). It is unlikely that companies voluntarily simulate elements and share the data with others although they realize that the associated improvement of the overall SC will only come to effect when they put themselves at a disadvantage. Therefore, it is necessary to reach respective agreements that regulate such circumstances in advance. Hence, this might be a game theory issue with the dimensions of sharing a certain degree of data with others (including the information broker) on the one side and the allocation of expected benefits (such as compensation payments to the directly disadvantaged members) on the other side. It is also possible to aim pareto-efficient solutions only (evaluated be the information broker), in order to encourage companies for joining cloud-based DES simulation network.

Research direction 9: Have the value flows in the business model been considered correctly? How can the specific value proposition of provider related services as well as the specific SC member related gains be evaluated and how can respective financial benefits be allocated?

5.2 The role of the information broker

The idea of an information broker has been known for many years in scientific literature. Considering the description of the role, many classic papers define an information broker to be a trusted intermediary who conducts validation and evaluation in order to provide highly specific information (Boss, 1979; Niehans 1980; Budgen et al., 2007). The term information broker attracted great attention in the financial service industry in the 1980s (Niehans 1980; Ramakrishnan and Thakor, 1984). From the financial perspective, Niehans (1980, p. 167) stated that an information broker might bring borrowers and lenders together at lower costs than if the related parties would have made direct transactions. In this paper, we propose to transfer the basic logic on a cloud-based DES, meaning that the intermediation function might increase the efficiency in the SC processes. Acknowledging Porter´s (1985) value chain model (cf. section 2) and in order to achieve an efficient reconfiguration, it is needed to define the related strategic units, to identify critical activities, to define the critical items, and to determine the values of SC processes. Thus, this may constitute a procedure guideline for the information broker.

Research direction 10: How can the information broker be involved in an adequate manner?

The information broker is a neutral institution without own simulated SC processes. The broker´s basis is the access to authorized data from SC members. The broker´s incentive is an upfront defined service provision. As mentioned before, the cloud-based DES is an integrated simulation, where many interrelated simulations can be run in parallel, exchanging authorized data. This constitutes the local simulation analysis. As the information broker is a neutral institution, the global simulation analysis can be achieved when all members authorize the broker for all their data, meaning that the broker can run an overall and complete simulation. From a theoretical point of view, the broker is interested in optimizing the SC as a whole, which in an extreme case may disadvantage some members or events while the overall SC is benefitting. This leads to the already defined future research question of allocating the gains to the related SC members effectively. We associate four major functions with the information broker whereby the first two have company specific characters and the last two cross-company characters.

Firstly, prior research has shown that companies often tend to create an incomplete and/or incorrect picture of their SC processes due to restricted knowledge (Zee and

Vorst, 2005; Cimino et al., 2010). Hence, the broker with adequate expertise ***validates the defined cloud-based DES pre-conditions*** such as parameters or simulated processes for every SC member and provides the members with support for building models and experimentation plans. Along with that, the broker could make suggestions which key figures of the simulation experiments will be published for which members such that all authorization restrictions are met in case that data is needed from more than one participant of a SC. Within the validation, the broker may assist at the iterative reformulation of the simulation statistics and proposes alternative statistics that might provide additional, needful information and might better meet the member´s real world requirements.

Secondly, the information broker helps to ***discover inefficiencies in the SC of a member*** by analyzing processes via simulation experiments. Here, the information broker has to bear in mind the overall SC performance, which means that every company-specific optimization may have an influence on other members. Solving this conflict represents one of the future research directions. In general, discovering inefficiencies requires a deep understanding of the real underlying processes. In this function, the broker demonstrates opportunities for improvement for every member.

Thirdly, the information broker ***investigates the cross-company interactions*** and the impacts of the single elements on the whole SC. The broker thereby acts as neutral mediator between the related members and gives explanations of the rationale for the relevance of information, clustered by more or less related members.

And finally, the information broker may encourage the ***negotiation between the members*** in order to increase the overall SC efficiency. This negotiation is related to authorization/control issues as well as to adjustments of simulated processes. With regards to the authorization concept, the negotiation process is a dynamic interaction in which the broker might assist two members in order to increase their intercompany transparency (if this transparency is beneficial from the overall perspective).

Research direction 11: What is the impact of the information broker on beliefs about successful reconfiguration of cross-company SCs?

Research direction 12: What is the influence of the information broker on the ongoing participation activities in the cloud-based DES?

6 EVALUATION

The "nested problem solving" research approach constitutes a design science problem (cf. section 3). Research literature describes many evaluation methods for design science such as observational methods, analytical methods, experimental methods, or descriptive methods (e.g., Hevner et al., 2004). However, Frank (2006) noted that enough time is needed to allow innovative artefacts to be accepted by practice, which means that the evaluation of research approaches is often left to practice. Notwithstanding, the research approaches should be evaluated in an academic context during the early development phases as well. As already mentioned we carried out twelve interviews with IT-experts from related research fields (cf. section 3 for the three step interview procedure). Further, we used an argumentative descriptive way for indicating the validity of the paper.

The interviewees pointed out the pre-existing buyer-supplier conflict and emphasized the ongoing strong demand for suitable collaboration and simulation tools as proposed in our research approach. The experts agree that this paper proposes a new and promising business model for reengineering this issue. According to their assumptions, the benefit of creating these useful links to other companies in the SC via the cloud-based DES might lead to operational cost reductions and service improvements towards the end customers as well as resilicene. The experts´ deep practical background led to valuable contributions and iterative adjustments during the conceptual phase of the paper (determining relations and value flows in figure 3 and deriving specific requirements in section 4). In general, they indicated the validity of the generic model by emphasizing its clear and semantically correct structure. Moreover, the experts found the model to have reference character, namely by providing broad application possibilities and enforcing the understanding for the important link between CC and DES.

From the descriptive evaluation point of view, we follow Frank (2006) by assuming that validity of research is given, when three postulates are fulfilled: abstraction, originality, and justification. From the abstraction view point, the business model represents aggregated structures that focus on the determined requirements for running the cloud-based DES. With regard to originality, the new composition of the three different fields CC, SCM, and DES with predefined goals (cf. research questions in section 1) can be characterized as a novel approach. With respect to justification, we followed a methodologically sound research approach (cf. figure 2) and developed a plausible argumentative framework for running such an inter-organizational cloud-based DES.

7 CONCLUSION

It is not the intention of this article to present a complete cloud-based DES solution, as this research field is still in its infancy. We rather propose a first conceptual business model that benefits SC networks as well as the cloud service industry. Furthermore, we aimed to identify and investigate some critical issues within that constellation in order to enforce the development in this promising endeavor. In the upcoming sub-sections, we first summarize the main contributions of our work, then we discuss the limitation, and finally we structure the already mentioned future research directions.

7.1 Contributions to theory and practice

Although the numerous advantages of cross-company SC simulations are evident, analytical simulation tools that can exploit those advantages are scarce so far due to the complexity inherent in integrated simulation modeling. Furthermore, an adequate usage of DES is even today quite expensive when running company-specific simulations. Especially smaller companies with limited resources could experience a kind of technological breakthrough. CC has been established as the most flexible delivery service of providing IT. The scalability advantage of CC allows the cloud-based DES to be very detailed with further advantages concerning the overall runtime for experiments (Rosetti and Chen, 2012). CC is a predestinated basis for building a common simulation network with strong demands on expert knowledge, such as for DES. Furthermore, CC enforces the standardization process of DES by providing the same service to the whole SC network, which leads to harmonizing and simplifying cross-company simulations. However, combining the advantages of CC with the advantages of DES brings up a new business model that has so far not been studied in depth. Therefore, this paper takes a first step by systematically bringing together the cloud service network with the SC network, explaining major actors and roles. Furthermore, we outline the main requirements for a cloud-based DES for distributed cross-company SCs.

Within the presented business model, the information broker, also known to be useful in many other disciplines, has to ensure the validity of the simulated SC network and may constitute the key advantage in the SC network by acting as an intermediary in the optimization process. From an academic point of view, our business model framework has a strong impact, but also on practical business issues it has a major influence. We have no doubt that our concept constitutes a relevant part towards the need of "affordable analytics for the masses" (Demirkan and Delen, 2013).

7.2 Limitations

Considering the evaluation phase of the underlying research approach (section 3), we gained some first insights on value creation and value flow within our business model from the experts interviews. However, it is not yet possible to generate a comprehensive evaluation of the business model. As the proposed business model is a novel theoretical approach, the model is not in place in real life and the benefits are only assumed by the experts. Moreover, the provided underlying artifacts have not tested so far. Therefore, future research needs to investigate this business model in more depth and on a broader empirical basis. Further, the requirements may serve as general guidelines that have more conceptual character rather than application-ready instructions. Furthermore, we would like to add a general limitation of simulation models by stating that no simulation can involve all managerial real-world SC issues, because many soft facts such as individual behavior can hardly be modeled correctly.

7.3 Summarizing future research

As this paper provides a more generic concept, there is a great and fruitful basis for future, more detailed research in various related fields. During the construction process of this paper, various open research fields appeared which we mentioned in section 5 and which we structured into a research agenda (Melville, 2010) in table 1. We clustered the questions with the help of the *belief-action-outcome* framework of Melville (2010).

Table 1: Research agenda

Phenomena	Research questions	Recomm. research methods
Belief	• Research direction 1: How can the security concerns of SC members in the cloud-based DES be understood and decreased in order to increase the level of trust? • Research direction 7: What is the impact of cloud-based DES on beliefs about collaboration and coordination initiatives in cross-company SCs? • Research direction 11: What is the impact of the information broker on beliefs about successful reconfiguration of cross-company SCs?	Expert interviews, surveys, case studies, participative observation
Action	• Research direction 3: Which simulation environments, differentiating between individual parameters and overall statistical results from simulation models, are beneficial for improving local and global optimization possibilities? • Research direction 5: How can the members' trust be increased in order to also increase the transparency and the information sharing willingness in the cloud-based DES? • Research direction 4: What are typical and useful simulation scopes in terms of intercompany analyses with respect to the potentials of cloud-based DES? • Research direction 6: How can a decline of members be handled, and what is the impact of declining members on the simulation results? • Research direction 2: How can an intelligent authorization concept (including instruments and tools) be created in order to increase trust and participation willingness of the related members and to facilitate statistically relevant SC network analysis? • Research direction 10: How can the information broker be involved in an adequate manner?	Action research, prototyping, simulations, field and lab experiments,
Outcome	• Research direction 8: What is the impact of using cloud-based DES on real life collaboration and coordination in cross-company SCs? • Research direction 9: Have the value flows in the business model been considered correctly? How can the specific value proposition of provider related services as well as the specific SC member related gains be evaluated and how can respective financial benefits be allocated? • Research direction 12: What is the influence of the information broker on the ongoing participation activities in the cloud-based DES?	Action research, field and lab experiments, expert interviews, surveys

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