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Coordination mechanisms and software in industrial networks – a literature review

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Abstract This paper groups recent supply chain management research focused on organizational design and its software support. The classification encompasses criteria related to research methodology and content. Empirical studies from management science focus on network types and organizational fit. Novel planning algorithms and innovative coordination schemes are developed mostly in the field of operations research in order to propose new software features. Operations and production management realize cost-benefit analysis of IT software implementations. The success of software solutions for network coordination depends strongly on the fit of three dimensions: network configuration, coordination scheme and software functionality. This paper concludes with proposals for future research on unaddressed issues within and among the identified research streams.

Keywords: Supply chain management, literature review, network type, organizational design, coordination mechanism;

1 Introduction

Research in the field of supply chain management touches multiple academic disciplines in light of ambiguous definitions. In this literature review organizational proposals and their IT system support is focused. Relevant articles are classified in three major groups.

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First, management or organization science analyses the influence of network characteristics and organizational parameters on the supply chain performance. This kind of research seeks for empirical evidence about the diffusion of Supply Chain Management (SCM) technologies or best practices and observable success factors or enablers.

Second, a large number of papers predominantly from operations research deal with the development of novel planning algorithms and business process models. New methods shall improve commercial supply chain software functionalities or increase implementation efficiency. Regarding novel planning algorithms, either the classic centralized approach is extended in order to better reflect real word conditions or decentralized coordination schemes are proposed.

Third, researchers from production and operations management develop methods for the evaluation of software investments. Particularly interesting are contributions that deliver information about organizational cost and benefits.

The contributions are sorted by research approach, validation method applied, the organizational concept regarded and the objective of software use under study. The classification based on these criteria characterizes briefly each paper within one of three major groups. In the next section these research streams are presented before in chapter 3 findings are summarized and conclusions are drawn.

2 Identification of research streams

All papers are grouped in one out of three major research streams.

Within the considered research papers network and organizational characteristics are discussed (section 2.1) which influence the utility of SCM software. Mainly empirical data from surveys is used to study the performance increase due to the use of SCM software within hierarchical organizations. For decentralized, collaborative concepts often contracts are discussed instead of software functionality. Other authors address coordination schemes (section 2.2) mainly based on analytical deductive research. A wide range of methods such as simulation and stochastic optimization have been developed which can enhance SCM software functionality in the future. Some researchers propose economic evaluation models (section 2.3) concerning the use of SCM software following a theoretical descriptive approach. In all research streams hierarchical as well as collaborative concepts are of interest.

Table 1 provides an overview of all reviewed articles. In the sequel listed papers are briefly discussed.

Table 1 Characterization of relevant literature

Ch.	Source	Approach	Method	Organization	Purpose
2.1	Bichescu and F. (2009)	Analytical deductive	Numerical analysis	Hierarchical & Collaborative	SCM software benefit
2.1	Chan and C. (2010)	Analytical deductive	Simulation	Collaborative	SCM software benefit
2.1	Dale and M.(2009)	Empirical inductive	Survey	Hierarchical & Collaborative	SCM software benefit
2.1	Kim et al. (2011)	Empirical inductive	Case study	Collaborative	Operational performance
2.1	Teller et al. (2012)	Empirical inductive	Survey	Collaborative	Operational performance
2.1	Wong et al. (2011)	Empirical inductive	Survey	Collaborative	Operational performance
2.2	Almeder et al. (2009)	Analytical deductive	Hybrid models	Hierarchical	SCM software functionality
2.2	Gupta and G.(2011)	Analytical deductive	Stochastic optimization	Hierarchical	SCM software functionality
2.2	Sodhi and T. (2009)	Analytical deductive	Stochastic optimization	Hierarchical	SCM software functionality
2.2	Albrecht (2009)	Analytical deductive	Deterministic Optimization	Hierarchical & Collaborative	SCM software functionality
2.2	Jung et al. (2008)	Analytical deductive	Deterministic Optimization	Hierarchical & Collaborative	Operational performance
2.2	Zhao and S. (2011)	Analytical deductive	Simulation	Collaborative	SCM software functionality
2.3	Arshinder and D. (2008)	Theoretical descriptive	Literature review	Hierarchical	SCM software benefit
2.3	Blankley et al. (2008)	Theoretical descriptive	Survey	Hierarchical	SCM software benefit
2.3	Hvolby and S. (2010)	Theoretical descriptive	Case study	Hierarchical	SCM software functionality
2.3	Kaipia (2009)	Theoretical descriptive	Survey	Collaborative	Coordination cost
2.3	Mittermayer and R. (2013)	Analytical deductive	Simulation	Hierarchical & Collaborative	Coordination cost & benefit

2.1 *Network types and organizational fit*

Real world network configurations and organization characteristics are frequently subject of empirical research. Within this group predominantly surveys and case studies are conducted in order to quantify organizational performance and software benefits.

For the characterization of networks so called contextual factors are crucial. The organizational proposals typically imply the organization structure, coordination mechanisms to interact among the units and an IT system to support the processes.

Contextual factors have been studied by Bichescu and Fry (2009). They confirm that the distribution of decision rights among supply chain partners influences strongly the SCM performance. Particular settings of cost parameters, such as penalty and holding cost, also have considerable impact.

Based on a survey among senior managers Importance-Performance Analysis (IPA) has been performed by Teller et al. (2012) in order to identify major improvement opportunities for the execution of SCM. The study revealed that favorable internal SCM conditions have the strongest positive impact on SCM execution but these conditions rarely are found in industrial practice.

The statistical analysis of a survey among managers of automotive manufacturing plants revealed that high environmental uncertainty affects dimensions of SC integration and operational performance distinctively (Wong et al. 2011).

SC integration efforts in a high uncertainty environment do not always lead to desirable operational performance outcomes. The paper demonstrates the need of conceptualizing SC integration and operational performance as multidimensional constructs.

These findings are confirmed by Chan and Chan (2010) who compare the performance of different decentralized coordination mechanisms regarding cost and order fulfillment objectives. The authors find out that high capacity utilization generally calls for ‘adaptive’ coordination while the ‘flexible’ approach is particularly recommendable in case of low demand uncertainty and low capacity utilization.

The relationship between IT capabilities and firm performance has been discussed controversy. Dale and Muhanna (2009) argue that aggregate data lead to mixed results and therefore propose to separate internal from external IT capabilities and to examine the influence of industry-specific environmental conditions (dynamism, munificence and complexity). They identify a strong influence of contingency factors (and even of combination of them) on the financial performance regarding different IT capability types.

Social network analysis has been recently applied to study three automotive supply networks (Kim et al. 2011). Several centrality and complexity metrics at the node- and firm-level help to determine specific roles in a supply network. Although no concrete recommendations are presented, requirements for system integration or supply risk management can be derived from the network metrics.

2.2 Novel planning algorithms and coordination schemes

Today SCM software still employs deterministic optimization models based on a strictly centralized, hierarchical organization concept.

Within the last years practitioners as well as scientists have been recognized that deterministic optimization models do not represent adequately real world complexity. Important extensions to the basic model consider uncertainties either using stochastic programming or a combination of analytical and simulation modeling techniques, so-called "hybrid models" (Almeder et al. 2009). Probably the most important critics on SCM software address the difficulty to establish a central decision unit that will be accepted by all actors. Therefore partially centralized or decentralized organization forms have been developed as alternatives to hierarchical planning.

Stochastic programming is applied to increase planning quality by incorporating uncertain demand and obtain improved expected values for service level and cost. Basically, some of the parameters defining a problem instance are random (e.g. demand or yield). After decision making now (stage 1) corrective action can be taken in the future, after revelation of the uncertainty on further stages (Gupta and Grossmann, 2011). Recently, Georgiadis et al. (2011) consider time varying demand uncertainty in the stochastic program for the optimal design of supply chain networks. Other model extensions incorporate financial supply chains: Sodhi and Tang (2009) include cash-flow optimization taking into account borrowing limits in their SC model. Additionally, adapting the Value-at-Risk (VaR) measures from financial risk management, they introduce demand-at-risk, inventory-at-risk and borrowing-at-risk measures that quantify the probability of violation of financial constraints.

To reduce the calculation time and complexity, solution strategies recently are developed (Gupta and Grossmann, 2011). The primary reason why stochastic programming is not widely applied in industrial applications is the complexity of the method and its low comprehensibility. "Selling the superiority of optimization-based risk-management approaches to managers is a challenge facing researchers." (Sodhi and Tang 2009, p. 737).

One of the mayor problems with decentralized planning approaches is that involved parties are not willing to share local information. Private data may be sensitive (especially capacity data) and constitute a strategic advantage for bargaining, which is lost after revelation.

Albrecht (2009) develops several coordination schemes that define the type and sequence for the exchange of private information. Different mechanisms for surplus sharing of the system-wide benefits are proposed that encourage truthful information exchange among the actors. In a similar manner,

Jung et al. (2008) show that with decentralized coordination acceptable performance levels are achievable compared to the fully centralized form if quantity information is shared.

Recently the competition among supply chains moved in the focus of research interest. For example, Zhao and Shi (2011) examine several influence factors such as market competition (i.e. the degree of product substitution between supply chains), the number of suppliers, the contract type and the decentralization grade.

2.3 Cost-benefit analysis

SCM system´s complexity is considered the major reason for the slow propagation and its limited use. At the same time benefits of these systems increase with the planning complexity to deal with (Hvolby and Steger-Jensen 2010).

The operational and financial impact of SCM software implementations have been studied by Blankley et al. (2008). Apart from first-order operational effects also second-order, financial impact can be observed – but after a significant time lag. Those benefits, such as sales growth, reduction in administration cost or the increase of firm value are more difficult to capture.

SCM research focuses in a large number of cases only on the benefits of software implementations. Kaipa (2009) remarks that information gathering and analysis results in important organizational cost. Therefore the optimal level of (costly) information sharing shall be determined according to the capability to react to changes on the material flow level.

Several organizational forms and IT support levels have been evaluated in different network types by means of simulation (Mittermayer and Rodríguez, 2013). For each network configuration specific business process architectures have been proposed.

3 Summary and future research opportunities

The first group of researchers carried out empirical studies on the experience with SCM and supporting IT systems.

There is no doubt that contextual factors such as firm size, production system properties, demand uncertainty or power balance among partners have strong influence on the appropriateness of different organizational designs. However, very few papers have discussed coordination mechanisms and their proper implementation. Arshinder and Deshmukh (2008) highlight the lack of empirical studies on the "conditions under which sub-type of coordination mechanism" shall be employed. They also remark that "there can be situations where two mechanisms are required to reduce the SC costs" and that "models are required to evaluate the degree of coordination" (Arshinder and Deshmukh 2008, p. 325). Social network analysis used by Kim et al. (2011) provides centrality and complexity metrics but the study is realized on a high aggregation level. Within this research stream, we propose to detail contextual factors, organizational designs and software functionalities and study the fit among the three elements. Higher resolution of the research scope will allow more concrete recommendations for industrial practice.

The second research group can be split in those authors who further improve centralized optimization algorithms considering uncertainty either by means of stochastic programming or ‘hybrid’ models and others who focus on decentralized coordination procedures. Within the latter community, relatively simple coordination schemes have been presented which achieve near-optimal results if at least some uncritical information is made available to the SC Partners. Future research within this stream shall focus on the identification of coordination mechanisms required for the beneficial use of collaboration-focused SCM modules. This is important because the success of decentralized concepts depends strongly on the willingness of SC partners and the dynamic interaction of organization units. Therefore prerequisites – i.e. favorable conditions for the implementation of particular coordination schemes shall be described.

The third group of Scientifics focuses on benefits and costs of SCM software implementations. The list of benefit and cost categories is much longer than might be expected at first sight. Apart from positive direct operational effects, the use of SCM software might suppose indirect, long term benefits such as sales growth or an increase in firm value. The evaluation of SCM software success depends on uncontrollable contextual factors, but also on controllable organizational design parameters. In general, few methods have been developed for the a-priori evaluation of SCM software benefits. Organizational costs are not considered with sufficient concern and available methods in many cases do not allow the comparison of different organizational designs and IT solutions. For example, decentralized planning approaches might offer acceptable results using relatively simple, low-cost software solutions.

Apart from the above mentioned proposals, results from one research segment shall be exploited in other fields. For instance, observations from empirical studies about organizational fit and network characteristics can be used as basis for decision support tools regarding SCM software investments. Furthermore, real world conditions should be taken into account when evaluating the efficiency of SCM software because success probabilities depend largely on the representation of complexity. Available off-the-shelf SCM software packages do not incorporate stochastic methods as described in section 2.2. However, these sophisticated prototype algorithms can be applied in experimental scenarios for the identification of (un)favorable contextual factors, leading to improved software investment decisions.

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