Development and application of a maturity measurement framework for supply chain flexibility

Jan-Hendrik Fischera,*, Antônio Márcio T. Thoméb, Luiz Felipe Scavardac, Bernd Hellingratha, Roberto Martinsc

aEuropean Research Center for Information Systems, University of Münster, Leonardo-Campus 3, 48149 Münster Germany
bPontifical Catholic University of Rio de Janeiro, Rio de Janeiro, RJ, Brazil
cFederal University of São Carlos, São Carlos, SP, Brazil

* Corresponding author. Tel.: +49-251-8338022; fax: +49-251-8338009. E-mail address: fischer@ercis.uni-muenster.de

Abstract

Today’s supply chains (SC) are acting in an ever more complex, dynamic and uncertain business environment. Increased customer expectations regarding product variety, shortened product life-cycles and volatile demand motivate the need for supply chain flexibility (SCF) in the face of stiff competition and environmental changes. Flexibility processes implementation in supply chains varies according to companies and SC, due to several factors. The level of awareness of the need for flexibility, the proactive or reactive plan and use of flexibility; and the focus on the SC as a whole or in single companies are examples. The concept of process maturity assumes that the implementation of procedures is carried out in multiple evolutionary and successive stages, which are explicitly defined, managed and measured. Maturity models give companies indicators as well as guidance to analyze and subsequently improve their processes. Despite several SC maturity models in the literature, there is not a model focusing on the maturity of SC flexibility processes, like the one intended in this paper. The levels of the maturity of SCF are (1) none, (2) inter-firm, (3) SC reactive, (4) SC proactive, and (5) SC paradigmatic. Each level has five dimensions: (1) Collaboration, (2) Information Technology, (3) Information flow, (4) Internal flexibility types and (5) Performance measurement. A toy case drawn from the automotive industry illustrates the application of the model from a dyad perspective. Based on the findings, SC flexibility maturity levels are measured in each of the analyzed links and areas for improvement are identified.

Keywords: Flexibility; Supply Chain Flexibility; Maturity

1. Motivation

Today’s supply chains (SCs) are acting in an ever more complex, dynamic and uncertain business environment. Increased customer expectations regarding product variety, shortened product life-cycles, and volatile demand patterns motivate the need for supply chain flexibility (SCF). SCF enables companies and supply chains to adapt their structures, processes, resources and steering mechanisms to uphold their performance in face of environmental changes [1,2,3].

Over the last three decades, the debate on flexibility was extended from manufacturing flexibility [4,5,6] “beyond the organisation’s boundaries to other nodes in the supply chain” [2,7]. Cross-functional and cross-company flexibility efforts are required to create a competitive advantage [8]. To establish flexibility at the SC level, a meaningful integration and coordination of and between SC partners is vital [9].
The implementation of processes for the management and utilization of flexibility in supply chains varies according to companies and supply chain. As an example, flexibility implementation differs due to the level of awareness of the need for flexibility. It also differs due to the company’s proactive or reactive plan and use of flexibility. The focus of the analysis on the SC as a whole or a single company also differentiates flexibility implementation types.

The concept of process maturity assumes that the implementation of procedures is carried out in multiple evolutionary and successive stages. The maturity level of a process describes to which extent the process is explicitly defined, managed and measured. Maturity models or frameworks define these different developmental levels and give companies indicators as well as guidance to analyze and subsequently improve their processes.

Maturity models have been developed to describe the maturity of the SC management processes [10], various different business practices such as Sales and Operations Planning [11] or IT inter-organizational collaboration (Plomp and Batenburg, 2010), among others. Currently, there is a gap in the literature for models that measure the maturity of SCF.

To fill this gap, the goal of this paper is to offer a model to measure the maturity of flexibility in inter-organizational supply chains. A toy case in the automotive SC illustrates the application of the model.

This paper has multiple parts. Section 2 presents the research design for maturity model development, literature review, and case study research. Section 3 gives the results of the literature review on SCF and maturity models. The developed framework is explained in section 4 and applied to industrial cases in section 5. Section 6 concludes the paper and provide an outlook for both practitioners and researchers.

2. Research Design and Methodology

The development of the maturity model is based on the procedure for developing maturity models of Becker et al. [12]. They propose seven requirements for the designing process of maturity models: (R1) Comparison of existing maturity models, (R2) Iterative procedure, (R3) Evaluation, (R4) Multi-methodological procedure, (R5) Identification of problem relevance, (R6) Problem definition and (R7) Targeted publication of results.

The development of the maturity measurement framework resort to multiple methodological procedures. A research synthesis of maturity measurement models for SC and manufacturing flexibility was conducted, in order to compare existing maturity models. The six-step process offered in [11] and [13] to select studies for inclusion in literature reviews was conducted. Eight SC maturity models were identified and analyzed from the literature base. These form the basis for the comparison and definition of dimensions and maturity levels, further discussed in multiple workshops to develop the maturity model of SCF.

A toy case was developed for the application of the model, based on the empirical study of the automotive industry. This industry is included because it is considered a benchmark for SC management [14]. The toy case uses multiple case study design, which allows for comparison of different sources of information and corroboration of findings [15]. Data were gathered utilizing interviews with executives of various stakeholders and local visits for direct observation. Triangulation has been sought both within firms, by comparing the interviews responses and observation visits, and across firms, by comparing the responses of firms. A member checking process was also conducted with the same managers in order to validate the researchers’ results, findings and analysis [13].

3. Literature Review

3.1. Supply Chain Flexibility

Flexibility from a manufacturing stand point is a well-known topic by operation management scholars. One can group the key aspects of flexibility into: types - product, mix, volume and delivery [4,6], dimensions [4,6], timeframe [6], uses [16,17] and the ability to change or react [6, 18]. Ability to change refers to flexibility that can also be used to seize opportunities in the marketplace without waiting to react to a stimulus [16,6,17].

Currently, scholars have focused their attention to look beyond the flexibility from a single firm perspective (i.e., the traditional manufacturing flexibility) incorporating in their studies the supply chain perspective [3,19], extending the flexibility debate beyond one firm’s flexibility borders. [20], [3] and [4] identify a number of SCF types as re-configuration, relationship, logistics, postponement, and sourcing flexibilities.

3.2. Maturity Models

The concept of maturity, however, is not new in the industrial engineering and management field. Crosby was among the first to propose, in 1979, a quality management model with fives levels of maturity [21,22]. Probably the most disseminated maturity model is the Capability Maturity Model (CMM) developed by researchers at the Software Engineering Institute of the Carnegie Mellon University. This model supports the management of the software development process [21]. Bowersox et al. [23] emphasize integration and collaboration in mature SC. Done [24] focuses on collaboration in six different processes, although the author calls them dimensions. Ayers and Malmberg [25] concentrate on enabling elements for implementing IT to support SCM better. [10] propose an SC management maturity model based on Business Process Orientation (BPO) maturity model, Capability Maturity Model (CMM) and Supply Chain Operations Reference Model (SCOR). The objective is to emphasize the positive correlation between SC maturity and performance of supply chain. The authors argue the essence of SC is the processes, and they should be managed from a process maturity perspective. The SC maturity model has five stages, which show the progress of activities toward effective SC integration. The stages are ad hoc, defined, linked, integrated, and extended.
Cohen et al. [26] present the PRTM stages of SC maturity. The SC Maturity Model developed by PRTM and The Performance Measurement Group, LLC (PMG), has four stages – functional focus, internal integration, external integration, and cross-enterprise collaboration. The objective is to measure how companies apply strategic, organizational, collaborative, and performance management practices to manage their supply chains.

Wadhwa and Rao [27] propose the only identified maturity model for manufacturing flexibility in this literature review. They state “the objective of the flexibility maturity model is to provide a direction for the organization to improve their flexibility maturity”. The seven levels are Qualitative understanding, Quantitative Understanding, Reactive Control, Managing Flexibility, Proactive Flexibility Management, Managing FlexAgility and Managing Flexibility of Flexibility. The authors equally envision other futuristic manufacturing maturity levels.

Despite the manufacturing flexibility maturity model, there is no comprehensive maturity model for flexibility that includes aspects relevant to SC management found in the literature review.

4. Maturity Model for Supply Chain Flexibility

This paper proposes a maturity framework for SCF, with five levels of maturity comprised of five dimensions each. The following section explains the dimensions of the framework and how these characterize the different maturity levels. Table 1 provides an overview of the maturity model or framework.

4.1. Dimensions

The dimensions indicate the shift from one level of maturity to the next. Each dimension has five different maturity levels.

- Collaboration Dimension describes how and to which extent internal functions and SC partners are integrated into flexibility management.

- Information Flow Dimension prescribes the data and information that is shared between SC members. The more information is shared and visible to SC members, the more flexibility can be established [28].

- The Information Technology Dimension relates to the Information Flow Dimension but measures how the information systems of partners are integrated to support flexibility management.

- The Internal Flexibility Types Dimension indicates which flexibility types are used in the SC to provide external flexibility to end customers. More mature internal flexibility types demand more collaboration with partners, i.e. such as the new product flexibility.

- The Performance Measurement Dimension indicates how the flexibility performance of the SC is measured, with which dedicated key performance indicators across functions and partners to support the respective maturity level.

4.2. Maturity Levels

The framework focuses on the flexibility of SC as a whole and not from the viewpoint of an individual focal organization. This focus is necessary to capture the notion of inter-organizational flexibility. The quality of processes regarding the integration of partners increases with every maturity level; starting from no flexibility and ending by full end-to-end SCF. The maturity levels include the differentiation in reactivity and proactivity proposed by [27] as the second differentiation feature besides inter-organisational collaboration.

A given SC is not necessarily at the same maturity level for all dimensions. Depending on the setting, an SC can be situated in different stages, according to different dimensions. However, it is probable that maturity levels measured in different dimensions would be at least close together.

The five maturity levels are as follows.

- Level 1 (No flexibility) - Flexibility is of no concern to the company. A silo culture prevents collaboration and information flows. IT systems do not support the planning or performance measurement of flexibility.

- Level 2 (Intra-firm flexibility) - Flexibility is only used internally and to react to flexibility needs. There is cross-functional collaboration to create the flexibility at the level of the company. The IT systems enable the in-house flexibility. Internal data is shared among functional units (e.g., inventory level and sales forecast). Possible flexibility types are machine, routing, material handling and labor flexibility. Performance measurement is conducted for intra-firm functions and processes to control the intra-firm flexibility across the functions.

- Level 3 (Reactive Flexibility) - The SC can react flexibly after a flexibility need occurred. Flexibility potentials are not planned and created ahead of time. Collaboration with SC partners for communication of flexibility needs and determination of the flexibility level exists. Inter-firm IT-Systems are enabling information exchange and eventually joint re-planning among customers and suppliers. External SC data is partially integrated with internal data (e.g. capacities, orders, sales, forecasts). Flexibility types can be, for instance, logistics flexibility, sourcing flexibility or relational flexibility. Performance measurement is concerned with inter-firm functions and processes.

- Level 4 (Proactive Flexibility) - The SC manages flexibility proactively through structured preparation and utilization of flexibility potentials. Inter-firm regular collaboration occurs to prepare flexibility and to determine the level of flexibility jointly. Internal and external functions are connected to key SC partners. Flexibility consideration is designed into functions and processes. IT-systems of key SC partners are partially integrated to enable flexibility planning in ERP/APS. Planning information are exchanged among key partners (e.g., capacity investments, promotions, product launches), enabling the development of partially joint plans. Possible flexibility types are for example postponement, expansion or new product flexibility. Performance measurement covers internal and external functions and processes with key SC partners to improve the flexibility proactively.
Level 5 (Paradigmatic Flexibility) - On this level, flexibility is leveraged through end-to-end flexibility planning with the integration of all partners. Regular inter-firm collaboration is implemented along the entire supply chain. Internal functions are connected with external functions of all SC members. IT systems are fully integrated along the supply chain. Information is exchanged in the SC on an ad-hoc basis. All internal flexibility types can be used to provide external flexibility. Performance measurement is conducted for all processes and functions of the SC with the purpose to plan, control, and improve all processes and functions of the entire supply chain proactively.

5. Case studies

The maturity model has been applied in a toy case within the automotive industry towards illustrating its application based on a dyad perspective. To embrace different perspectives of the supply chain, one representative link between different supply chain tiers was chosen. Link A embraces a multinational vehicle manufacturer (VM) and one of its main car distributors. Link B embraces same VM with one of its main first tier suppliers, in this toy case the engine manufacturer. Link C embraces this engine manufacturer with one of its main component supplier (i.e. a second tier supplier), as displayed in Figure 1.

| Level | Level 1: No flexibility | Level 2: Intra-firm flexibility | Level 3: Reactive flexibility | Level 4: Proactive flexibility | Level 5: Paradigmatic flexibility |
|-------|-------------------------|-------------------------------|-----------------------------|-------------------------------|--------------------------------|
| Definition | Flexibility is of no concern. | Flexibility is only used intra-firm. | No planning of flexibility ahead of time. | Structured preparation and utilization of flexibility potentials. | Regular inter-firm collaboration implemented along the entire supply chain |
| Collaboration | No collaboration | Silo culture. | Inter-firm Collaboration with partners in case of flexibility needs. | Inter-firm regular collaboration to prepare flexibility. | Connection of partners’ IT systems |
| Information Flow | No information flow on flexibility | Internal data shared among functional units (e.g., inventory level and sales forecast) | External SC data partially integrated with internal data (e.g., capacity, orders, sales, forecasts) | Planning information exchanged among key partners (e.g., capacity investments, promotions, product launches) enabling the development of partially joint plans | Information exchange in the SC on an ad-hoc basis |
| Information Technology | IT systems not concerned with flexibility | Intra-firm IT-Systems enabling in-house flexibility | Inter-firm IT-Systems enabling information exchange and eventual joint re-planning among customers and suppliers. | Integration of flexibility planning into ERP/APS systems of key SC partners | IT systems fully integrated along the SC |
| Internal Flexibility Types | None | Machine, routing, material handling, labor | Logistics flexibility, sourcing flexibility, relational flexibility, among others. | Postponement, expansion, new product, information systems, among others | All internal flexibility types can be implemented |
| Performance Measurement | PM is not concerned with flexibility | The purpose is to control the intra-firm flexibility across the functions | The purpose is to control the inter-firm flexibility and to improve reactively the inter-firm flexibility | Internal with external functions and processes with key SC partners | The purpose is to plan, control, and improve proactively all processes and functions of the entire SC |

Jan-Hendrik Fischer et al. / Procedia CIRP 41 (2016) 514 – 519
Fig. 1 - An overview of the studied supply chain

If an SC is classified at the lower maturity level of the links among companies, probably most SCs will be at Level 1 of maturity. There could always be a link that has no flexibility at all (even if it is between a third and a fourth tier supplier). It should be even more true of large and complex supply chains. The absence of flexibility can be a negative aspect, for instance in cases where the SC did not improve towards developing / implementing the required flexibility. However, the model does not posit that supply chains necessarily need to seek the highest maturity level. Moreover, SCs may have links that demonstrate flexibility and others that do not, as found in the developed toy case.

Link A is under a significant influence of the VM, where an exclusive contract determines the downstream relationship. Usually, plans are defined by the VM with almost no interference from the distributor. There is a well-defined information flow in which data such as production capacities, sales orders, sales forecasts and order delivery times are shared, based on the existing inter-firm IT systems. Flexibility is not planned ahead of time, and whenever it is required (e.g., current sales higher than expected) the SC reacts to avoid disruptions (e.g., increasing production levels). There is no structured preparation and utilization of flexibility potentials to use flexibility proactively. However, some internal types of flexibilities can be identified. An example is the postponement of the assembly of customized items from the VM final assembly plant to the distributors’ point of sale (e.g., air-conditions and alloy wheels). From this dyad perspective, one can classify this SC link on level 3 of SCF maturity.

Link B contains a partnership example, where the VM invested in the construction of the engine plant, as well as in its machinery. It invites regularly the supplier in the early stages of the car product design (following the early supplier involvement approach) with some functions integrated between the firms (e.g., production and research & development). The link provides many examples of internal flexibility types as relational, sourcing and logistics flexibilities. Flexibility across functions in both plants are well-developed, and performance measurements to control inter-firm flexibility have been recently implemented. This link also has well-integrated IT-Systems and plans, although it does not design for flexibility ahead of time, being only reactive, and the flexibility requirements are communicated on an as-needed basis. As Link A, Link B of this SC can also be classified in Level 3 of SCF maturity.

Link C is located upstream the SC and embraces a first and second tier supplier. Flexibility is only used intra-firm with no inter-firm collaboration and IT-Systems. Just internal data is shared among functional units, and flexibility types are limited within the confines of the single firms. The performance measures and intra-firm IT-Systems hardly contemplate manufacturing flexibility issues. Despite being considered important, flexibility is only a minor concern, resulting in a Level 1 maturity grade. It is not a surprise that this SC link offered many bottlenecks to the entire SC from an end-customer perspective, which was reinforced downstream by many other SC members (i.e., VM and dealers).

6. Conclusion & Outlook

This paper offers a framework to measure the maturity of SCF. Although the literature offers different maturity models for SC [29] and for manufacturing flexibility [30], there is no model measuring the maturity of SCF. Given the growing importance of SCF in the academic literature, a first contribution of this paper is to propose such model. Moreover, with the application of this model to the automotive industry from a successive dyad perspective, this research contributes to fill another gap in the literature, highlighted in Stevenson and [31] and [13]. There is a lack of empirical multi-tier studies investigating the inter-organizational components of SCF. In addition to advancing the academic debate on SC maturity models from a flexibility perspective, the research findings are also relevant to practitioners. With the increasing importance of dealing with flexibility beyond the manufacturing walls, an understanding of how to assess the current level of SCF is crucial for SC managers across industries. The proposed framework can help as a guide for practitioners to understand their current SCF maturity level and to define a flexibility target to be achieved in the future. It is paramount, as not necessarily the highest maturity level is the desired one. There can be cases where there is no need for flexibility, or cases for which a low maturity level could be best. The SCF maturity model accommodates different requirements for flexibility, and hence it comes handy for researchers and practitioners alike.

Acknowledgements

The authors of this paper acknowledge the research agencies CAPES and DAAD for their support in the PROBAL project entitled “Development of a Maturity Measurement Framework for Supply Chain Flexibility”, CAPES (PVE 401522/2014-8) and CNPq for the support with a research grant.

References

[1] Moore, D.; Subash Babu, A. (2009): Supply chain flexibility: a state-of-the-art survey. In: International Journal of Services and Operations Management 5 (1), S. 29–65.
[2] Fatemi, M. (2010): Supply Chain Flexibility: Definition and Review. In: European Journal of Economics, Finance and Administrative Sciences 20, S. 141–147.
[3] Thomé, Antonio Márcio T.; Scavarda, Luiz Felipe; Pires, Silvio R.I.; Ceryno, Paula; Klingebiel, Katja (2014b): A multi-tier study on supply chain flexibility in the automotive industry. In: International Journal of Production Economics 158, S. 91–105. DOI: 10.1016/j.ijpe.2014.07.024.
[4] Slack, Nigel (1987): The Flexibility of Manufacturing Systems. In: International Journal of Operations & Production Management 7 (4), S. 35–45.
