One size fits all? An analytical approach how to make use of process modelling techniques for different fundamental supply chain types

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Abstract: Process orientation is considered a key driver for the efficiency and effectiveness of modern supply chains. It is recognised in science and practice that the modelling of logistics processes is the first step in their optimisation. At the same time, well-known process modelling techniques are not suitable for every type of supply chain. This article uses two established frameworks to make recommendations regarding which modelling technique fits to which supply chain type. For example, BPMN or BPMN light can help lean processes, while flexible and collaborative supply chains more likely require BPM 2.0 and case management techniques. Practitioners can use these findings to apply the most promising process management technique for their business purposes. From the scientific point of view, this article focuses on the integration and process orientation of supply chains and fosters with it the necessity of corporate customer-centricity.

Keywords: process management; supply chain management; process modelling.

Reference to this paper should be made as follows: Lederer, M., Quitt, A., Büsch, M. and Avci, R. (2020) 'One size fits all? An analytical approach how to make use of process modelling techniques for different fundamental supply chain types', *Int. J. Supply Chain and Operations Resilience*, Vol. 4, No. 1, pp.1–20.

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1 Introduction

Modern business science and management practice state that many business challenges of nowadays can be overcome by means of consistent and customer focused, i.e., value adding, process orientation (Page, 2016). Studies show that international markets, shorter lifecycles, and individual customer expectations can often only be handled with an internal enterprise configuration that thinks less in functions (e.g., sourcing department) than in workflows (e.g., production process) (Singh, 2012; Aggarwal, 2004).

As one of the major corporate core processes, supply chain management (SCM) in particular faces the challenge of integrating several departments and coordinating multiple processes (Marchesini and Alcantara, 2016). Studies as well as individual case studies show clear evidence that positive effects within supply chain processes can only emerge when all required parties – internally as well as externally (e.g., suppliers, production and assembly, sales and warehousing) – are integrated into one fundamental process. Optimisation driven individually by departments or isolated target systems (e.g., focus on costs vs. customers) weaken the entire supply chain (Vanathi and Swamynathan, 2016). Through its various interfaces to other processes (e.g., CRM and PLM), such negative effects also spread to other business processes (Oh et al., 2015).

The consideration of the process orientation along the SCM has already been investigated extensively (Bae and Seo, 2007), since science and business practice have been focusing on the value chain for years. Thereby, the integration of different partners (e.g., within sourcing networks, supplier partnerships, and joint ventures) as well as the design (i.e., the modelling), optimisation (e.g., reengineering), and execution (e.g., monitoring by means of KPIs) of cross-functional and cross-company value chains has been of major interest (Azmi et al., 2017).

Current and well-founded research contributions show that many authors try to model SCM processes in order to optimise individual aspects. For example, Bae and Seo (2007) attempt to use the modelling of SCM processes to achieve flexibilisation, while Tiruta-Barna et al. (2016) use process models to shorten cycle times (e.g., in the warehouse). In general, it is noticeable that previous applied research either pursues very specific business targets or only examines special modelling techniques. For example, Drzymalski and Odrey (2008) show an application of Petri nets and Lin et al. (2000) demonstrate the optimisations using a proprietary tool from IBM.

However, the general desire to model SCM processes is clearly observable, as are attempts to build general recommendation systems that are limited in terms of modelling technique or SCM application (Groznik and Maslaric, 2012).

It is noteworthy, that the approaches of both, SCM practitioners and scientists, focus only on a few modelling and optimisation forms. Thus, processes are usually represented as a SIPOC diagram (supplier, inputs, process, output, customer), swim lane chart, time function map or value stream map (Mishra and Sharma, 2014; Patig, 2011). These techniques, mainly coming from logistics experiences, focus on the flow of physical products (e.g., inbound and outbound logistics) and often still neglect the importance of information flows for increased customer responsiveness. As the degree of digitisation as well as the efficiency requirements of supply chains increases constantly, it becomes more and more relevant for companies to be open to new modelling methods.

The domain-independent business process management (BPM) discipline developed numerous paradigms of how business processes can be modelled to support underlying business objectives such as competitiveness and efficiency (Mishra and Sharma, 2014; Lederer, 2016). State of the art modelling techniques are, in contrast to the methods mentioned above, for example BPMN, eEPCs or case-driven modelling (e.g., adaptive case management). Since these notations show major advantages (e.g., can be model-checked and transferred in software code) (Patig, 2011; von Rosing et al., 2014), this paper will provide recommendations, which process modelling technique may support SCM in its further development.

In SCM, fundamental different process types can be observed: e.g., lean vs. agile vs. cooperative supply chain designs (Hines, 2004). Coming from a process-oriented view on these paradigms, they have fundamentally different workflow characteristics (for example standardisation vs. flexibility, pre-definition of processes vs. experience-based ad hoc decisions). Based on this differentiation, each supply chain type requires corresponding modelling techniques to successfully create added value for its customers.

Therefore, the following research question will be answered in the context of this paper:

- Which modelling notations are most suitable for different supply chain types?

In Section 2, the state of the art referring to the research question is described. It turns out that modelling is an important task in SCM and that much research is already available. In Section 3, a classification table is designed to assign the most appropriate modelling techniques to fundamental supply chain types. For this, the fundamental classification of

Gattorna (2015) is used as one dimension to describe different supply chain designs. The process criteria of Lederer et al. (2017) serve as second dimension. They define which modelling techniques are fundamentally suitable for which fundamental process properties. The combination of both dimensions will be presented as part of a Delphi study. In the discussion, the three modelling techniques most suitable for each supply chain design will be presented. Section 4 concludes this article with a summary and critical appraisal as well as implications.

2 Related work

Today, companies have realised that they are not interacting as individual players on the market but rather as stakeholders within a globally spanned value chain network, (Lavastre et al., 2014). Maximise customer satisfaction by simultaneously reducing costs and increasing quality has become a corporate imperative (Usui et al., 2017). Following for example the total quality management (TQM) approach, quality is not only formally understood (e.g., 'no technical defects'), but also concerned about participation, i.e., among others the capability of customer responsiveness. It is proven that TQM and customer satisfaction are positively related (Tanninen et al., 2010). But how can an innovation-driven, dynamic customer be satisfied when the value creation process is driven by a transactional supply chain that focuses primarily on standardised, lean processes? The customer experience will not be congruent and hence value creation cannot be maximised. Therefore, smart global sourcing and supply chain strategies contribute a significant share to reaching the major corporate goal (e.g., customer value creation).

Traditionally, supply chain management has been focused on efficiently coordinating all activities from sourcing, logistics, operations to sales and even reverse logistics (Simamora et al., 2016). However, strategic SCM has become a competitive advantage (Melnyk et al., 2009). Characteristics such as resilience, flexibility and reliability determine nowadays in addition the success of supply chains (Gunasekaran et al., 2015; Kamalahmadi and Mellat-Parast, 2016) by focusing on their operating performance. But also customer responsiveness has become key as current research on customer-focused supply chains has shown (Madhani, 2017; Deshmukh and Mohan, 2016; Kibbeling et al., 2013).

Since the complexity of market requirements increases constantly, forming different types of customer groups – especially in the age of customisation – the one-size-fits-all supply chain is not competitive any more (Alicke et al., 2017; Melnyk and Stanton, 2017). Not only sales and marketing need to segment their target customers, but also supply chain management has to be able to respond to diverse customer needs and to structure the resulting complexity (Alicke et al., 2017). Supply chains need to segment as well, since a fully flexible, innovative customer does not primarily care as much about the on time and cost delivered product, but rather on a close, innovation-seeking relationship with the supplier.

For successful market-oriented supply chain segmentation, firstly, the role of supply chain management towards the customer has to change: It is now used to be passive and indirect, as the marketing or sales department interacts directly with the customer and communicates all relevant information to supply chain and operations management. Supply chain management, however, has to get into immediate contact with the customer, forming a communication triad together with sales/marketing (Melnyk and Stanton; van Hoek et al., 2014). Secondly, strategic and corporate alignment has to be granted as well (Alicke and Forsting, 2017). Van Hoek et al. (2014) discussed drivers of SCM's value creation potential, concluding, that its perception primarily depends on the cross-functional collaboration and integration of the supply chain function. This means, the better SCM is actively involved in customer-facing processes and works cohesively together with other supply chain participants the higher is its value creation (Stank et al., 2011; Gattorna, 2015). However, internal supply chain integration is oftentimes still a neglected issue in many organisations (Wieland et al., 2016).

Major prerequisite for effective cross-functional work is the organisational process design as well as the underlying techniques supporting collaboration. So far, research has not yet focused on analysing adequate process modelling techniques that foster the alignment of the internal as well as external supply chain. However, scientists as well as practitioners already claim SCM to be proactive in the digitisation movement and take advantage of methods such as big data analytics, which require a clear process model (Roth et al., 2016).

Therefore, the research focus of this article lies on identifying the best fit between BPM methods and individual supply chain types, which consider the entire corporate setting and business model alignment, to create the basis for meaningful big data analytics.

3 Mapping modelling techniques to supply chains

In this section, a classification scheme is developed that combines certain supply chain types with existing modelling methods.

The supply chain types as the first dimension (subsection 'supply chain types') come from the recognised publication of Gattorna (2015), who outlined in his studies and considerations that in business practice, five fundamental supply chain processes exist. They are based on different buying behaviours and hence differ in their basic design, way of cooperation, flexibility, structure and goals (subsection 'Gattorna's supply chain types').

These essential process properties come from a study by Lederer et al. (2017). They evaluated, which state of the art modelling technique fits best to certain processes according to these properties (subsection 'process build time techniques').

3.1 Existing frameworks

3.1.1 Gattorna's supply chain types

Gattorna (2015) defined the modern supply chain as "any combination of processes, functions, activities, relationships and pathways along which products, services, information and financial transactions flow in and between enterprises, in both directions, end-to-end" (Gattorna, 2015). Besides the classic hard assets, such as warehouses and technology, he calls for customer-centricity along the supply chain to create value in today's volatile environment. He identified five prevailing consumer buying behaviours. Based on these, he defined five corresponding supply chain layouts also aligning business strategy, leadership and culture which will be used in this contribution to assess process modelling techniques (Gattorna, 2015):

- Customers of *collaborative supply chains* are interested in close integrated relationships with their suppliers fostering mutual gain. This type of supply chain is adequate for mature products and mostly predictable demand. The customer is open for innovation – granting a high degree of trust – but also requires high quality and consistency. The aim is to serve the customer as flexibly and consistently as possible, thereby mitigating any risk by means of transparent communication. The corporate incentive system is key, as it has to encourage teamwork and individual participation for maximum reliability and service culture towards the customer.
- *Lean supply chains* are adequate for price-sensitive and transactional buying behaviour. Surplus in general is not really appreciated, but routine and reliable products at lowest cost possible. Demand is predictable. Therefore, supply chain design focuses on continuously increasing efficiency of operations to process large quantities, raise standardisation, and realise the maximum degree of economies of scale. Lean supply chains have to be robust to minimise supply risk and clearly structured to avoid any waste. Therefore, the culture is hierarchical and rule driven, incentivising employees to perform repetitive tasks economically.
- *Agile supply chains* primarily focus on speed, which customers expect in a structured and cost-efficient way. Demand is unpredictable and market conditions highly volatile. Therefore, customers are price sensitive, but aware that flexibility leads to a premium. The dynamic organisation can be described as 'collaborative individualism' [Gattorna, (2015), p.287], since cross-functional, customer-specific teams have to respond in real time to unforeseen individual demand at a suboptimal information level. Good processes – if feasible – are important, however, especially in the volatile surrounding fewer by definition. Dynamic process reengineering occurs and risk aversion decreases since the main goal is to perform.
- *Campaign supply chains* are mainly applied for capital construction projects, which require a tailor-made supply chain design due to its individual complexity. Customers require precision and controllability, think long term and are risk-averse. It is relevant to supply on time, on demand, and on quality in order to meet the project budget. Solid planning and forecasting along the entire supply chain are hence critical methods that also require collaboration. All supply chain parties need to be tightly aligned and managed demand-responsively to achieve precise delivery. Despite its uniqueness, such large-scale projects also show repetitive components regarding structure and process. Those elements can be organised in a lean manner. However, individual, ad hoc demand requires agile responses.
- *Fully flexible supply chains* are relevant in case of unforeseen business disruptions as well as in emergency or humanitarian cases. All customers expect high responsiveness and speed from the supply chain, which needs to be activated instantaneously. Therefore, risk management for quick but resilient solutions is key. It is often required to set up so far non-existing supply chains – short term and even cross-country. Customer behaviour in all cases of crisis will evolve after stabilisation of the situation into more natural buying behaviour as described above.

Table 1 Process characteristics (PC), properties and scaling number

Process characteristic		*1*	*2*	*3*	*4*	*5*
PC_1	Structuring	Structured	Structured with ad hoc exceptions	Structured with pre-defined exceptions	Loosely structured	Unstructured
PC_2	Process representation	Activity oriented	Rule oriented	Artefact oriented	Ø	Ø
PC_3	Process implementation	Workflow engine	Rule engine	Program control flow	Ø	Ø
PC_4	Trend orientation	Data-driven	Case-driven	Social-driven	Ø	Ø
PC_5	Process participants	Person to person	Person to application	Application to application	Ø	Ø
PC_6	Knowledge intensity	Knowledge-intensive	Automated/repeatable	Ø	Ø	Ø
PC_8	Interrelatedness	Linked explicitly	Inferred link	Ø	Ø	Ø
PC_9	Collaboration intensity	Collaborative	Semi-collaborative	Non-collaborative	Ø	Ø
PC_11	Value repetition	Ad hoc	Administrative	Collaborative	Production	Ø
PC_16	Implementation	Big bang	Step by step	Ø	Ø	Ø
PC_17	Process instantiation	Automated	Semi-automated	Manual	Ø	Ø
PC_23	Process cycle time	Long-running	Medium	Short running	Ø	Ø
PC_7, 10,12, 13, 14, 15, 18, 19, 20, 21,22		High	Medium	Low	Ø	Ø

Source: Lederer et al. (2017)

Table 2 Domain-independent classification of modelling techniques

Characteristics / Modelling techniques		P_1 S-BPM	P_2 uBPMN	P_3 BPMN Plus	P_4 Deontic BPMN	P_5 BPMN Gamification	P_6 Ad hoc BPMN	P_7 BPMN light	P_8 AC-BPM	P_9 ArC-BPM	P_10 BPMN4RS	P_11 BPMNDiffViz	P_12 BPMN choreography diagram
PC_1	Structuring	1	1	3, 4, 5	4, 5	1 to 5	4, 5	1, 2	1	1	1, 2, 3	1 to 5	1
PC_2	Process representation	3	1, 2, 3	1, 3	1, 2	1, 2	1	1	1	3	1, 3	1, 2	1
PC_3	Process implementation	3	1, 2, 3	1, 3	1, 2	1, 2, 3	1	1	1, 3	3	1	1, 2, 3	3
PC_4	Trend orientation	1, 3	1, 2	1, 2	2	2, 3	2	2	1	1	1, 2	1	1, 2
PC_5	Fixation	2, 3	2, 3	2, 3	2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2 ,3	2, 3	2, 3
PC_6	Knowledge intensity	2	2	2	2	2	1	1	2	2	2	2	2
PC_7	Diversity of information	2	2	1	2	2	1	2, 3	1, 2	1, 2	2	2	3
PC_8	Interrelatedness	1	1	2	2	1, 2	2	1	1	1	1	1, 2	1
PC_9	Collaboration intensity	1	1, 2, 3	1, 2, 3	1, 2, 3	1, 2	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3
PC_10	Value	1	1	1	1	1	1, 2	1	1	1	1	1	1
PC_11	Value repetition	4	4	4	4	4	1, 3	4	4	4	4	4	4
PC_12	Predictability	1	1	1	1	1, 2, 3	3	1, 2	1	1	1, 2	1	1
PC_13	Flexibility	3	3	1	1	1, 2, 3	1	2, 3	3	3	2, 3	3	3
PC_14	Model-ability	1	1	1, 2	2	1, 2, 3	3	1, 2	1	1	1, 2	1	1
PC_15	Complexity	3	2	2	3	1, 2, 3	1	2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3
PC_16	Implementation	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2
PC_17	Process instantiation	1	1, 2	1, 2	1, 2	1, 2	2, 3	1, 2, 3	1, 2	1, 2	1, 2	1	1, 2
PK_18	Robustness	1, 2, 3	1, 2	1, 2, 3	1, 2, 3	1, 2	3	1, 2, 3	1	1	1, 2	1	1
PC_19	Adaptability	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	2, 3	1, 2	2	1	1	2	1	1, 2
PC_20	Adaptivity	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	2, 3	1	1	1, 2	1	2, 3
PC_21	Selection	1, 2	1, 2, 3	1, 2, 3	1, 2, 3	2, 3	1, 2	2, 3	1, 2	1, 2	2	1, 2	2, 3
PC_22	IT needs	1	1	1	1	1	1	1	1	1	1	1	1
PC_23	Process cycle time	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3

Source: Lederer et al. (2017)

3.1.2 Process build time techniques

In their study, Lederer et al. (2017) present a collection of available modelling methods known in the BPM discipline. Among the 31 notations and methods, there are classical and well-known approaches such as BPMN or case management. Likewise, however, the list also includes rather unknown methods such as uBPMN and CCM, but their application appears very promising in very normative respectively flexible supply chains.

In addition to this classification, the authors follow the underlying idea in this article that these methods are particularly well or not well suited, if a process to be modelled has certain process characteristics. For this, the authors have created a state of the art list of process properties based on recognised publications. The characteristic values also come from current scientific contributions. This list of characteristics including their possible features is shown in Table 1.

Table 2 presents the evaluation table, which combines known state-of-the-art modelling techniques (columns) with fundamental process characteristics (rows). As a classification scheme, it shows which properties of processes can be satisfactorily supported by which technique. An entry in the table cells indicates that the technique can be used when a process holds this value of the characteristic. For example: The cell 'P2_uBPMN/PC_6: knowledge intensity' contains '2', i.e., 'automated/repeatable' (from Table 1). This means uBPMN is suitable for processes attributed with this property in the respective process characteristic.

The study results of Lederer et al. (2017) will be used as a list of possible modelling techniques for this article. In a representative study using the method of a systematic literature review, this article has collected well-known as well as rather unknown modelling techniques. In addition to scientific databases, also practical publications (e.g., case studies and whitepapers) were taken into account. The mapping to the individual process properties is - in contrast to other studies on this subject - objectively and proven by literature. Other publications often only evaluate which notation is usable when based on personal opinions (for example in the textbook) or on the basis of (possibly not evaluated) field tests. The used mapping has been developed using the target activity grid method. For more details, the interested reader refers to the primary study.

In summary, the mapping shown in Table 2 can be considered a general and universal recommendation. It is only supplemented by case-specific features (e.g., specifications in the company or particularities in a project/organisation). Lederer et al. (2017) also describes how to consider such specific factors.

For this contribution, it has many advantages for answering the research question:

1 In contrast to other studies, well-known as well as rather unknown techniques are listed. This makes new scientific findings for SCM possible.

2 The classification scheme can be used as a recommendation system. This has already been demonstrated in two field studies from other domains (Lederer et al., 2017, 2018), but not yet for SCM.

3 The given list of modelling techniques is domain-independent and can therefore now be applied to the SCM domain in this contribution.

3.2 Methodology

In order to come to a recommendation as which modelling technique is suitable for which SCM type, the two dimensions described above need to be combined. Such an assignment of methods and process types is possible with different approaches and visualisations. In science and practice, among other things, Ishikawa diagrams and matrices are known as typical solutions. However, while the first ones have the disadvantage that they are not understandable in a large number of types and methods and do not allow multiple assignments (Best and Weth, 2009), matrices are characterised by a high degree of traceability for many entries. Furthermore, this contribution does not consider the interactions between properties and does not add any additional grouping within the dimensions. The assignment, therefore, follows the matrix approach of (Greischel, 2003), which represents the process properties and notations on the axes of a matrix.

Table 3 Process characteristics (PC) properties (numbers) for the supply chain types

		Lean	*Collaborative*	*Agile*	*Campaign*	*Fully flexible*
PC_1	Structuring	1	2	2, 3	3	3, 4
PC_2	Process representation	1	2	2	2	3
PC_3	Process implementation	3	1;	1	1, 2	2
PC_4	Trend orientation	1	3	3	2	2
PC_5	Process participants	1	2, 3	1, 2	1, 2	1
PC_6	Knowledge intensity	2	1	1, 2	1, 2	1
PC_7	Diversity of information	3	1	2	1, 2	1
PC_8	Interrelatedness	1	1, 2	1, 2	1, 2	2
PC_9	Collaboration intensity	3	1	2	1, 2	1
PC_10	Value	1	1, 2	2	1, 2	3
PC_11	Value repetition	1, 2	1, 2	1, 2	1	1
PC_12	Predictability	1	1, 2	2, 3	2	3
PC_13	Flexibility	3	2	1	2	1
PC_14	Model-ability	1	2	2	1, 2	3
PC_15	Complexity	3	2	1	1, 2	1
PC_16	Implementation	2	1	1	1	1
PC_17	Process instantiation	1	2	2	1, 2	3
PK_18	Robustness	1	2	2, 3	2, 3	3
PC_19	Adaptability	3	2	1	1, 2	1
PC_20	Adaptivity	3	2	1, 2	1, 2	1
PC_21	Selection	3	2	1	1, 2	1
PC_22	IT needs	1	2	1, 2	2	2, 3
PC_23	Process cycle time	3	3	3	1, 2, 3	3

In order to use the matrix as a classification and recommendation system, it has to be evaluated which of the methods described in Lederer et al. (2017) is suitable for which SCM type of Gattorna (2015). From the number of matches per notation, tendencies can be identified which modelling technique makes more sense and which one is less suitable. Although this contribution is not quantitative research, the number of true occurrences should be used as an indication.

From 23 process properties, 16 strategic dimensions, five SCM types and a total of 69 characteristics of the process properties, 126,960 evaluation decisions are needed. The actual evaluation was logically based on a multi-method approach which combines a three-stage target activity grid method based on Best and Weth (2009) in the context of a scientific Delphi study (Kaplan and Norton, 2009):

i For this purpose and in the sense of an introduction, two SCM experts were introduced by the author of the primary study to the meaning and semantic of the factors. In order to ensure objectivity despite the multitude of evaluations, two designated SCM experts with more than 35 years of SCM research and practical experience have made the assessments. Both were proven experts in the field of process orientation and SCM optimisation. In addition to years of experience, their competences have been proven by publications, international projects, industry work and key notes in relevant committees in the past. This introduction took about 1.5 hours and consisted of a frontal lecture followed by an interactive panel discussion on the exact interpretation and common understanding of the factors.

2 The experts then had several days to fill a formal table in a Delphi study. They evaluated separately which SCM types fulfil which criterion. Questions to the author of the first study were only allowed to describe the content of the factors. The experts made assessments with the help of their experience and their own desk research. Deviations in the assessment based on the filled tables were discussed in a joint final round. As there were less than 5% discrepancies and clarification was possible within a half-day appointment, no renewed Delphi round was started as a separate assessment. Table 3 shows the resulting assignments.

3 The number of matches per SCM type gives a sequence of notations as to their suitability. This means that taking the given experts' assessment as well as the general study into consideration, the number of appropriate fits (reflecting suitable notations) can be counted for the different SCM types. In order to avoid foolish inaccuracies and to continue the claim of a qualitative study, a simple scoring algorithm (i.e., applicable properties increase the score by one point at a time) was used.

Although, as described above, there are no exact and quantitative sequences for calculations, particularly suitable modelling techniques can still be identified efficiently.

3.3 Results

The expert evaluation results in the following recommendation model (see Table 4). According to the generic model and based on the scaling, the notations described are the top three for each SCM type.

Table 4 Process modelling recommendations for the different SCM types

	Rank	*Modelling techniques*	*Number of true criteria occurrences*
Collaborative	1	Social BPM	25
	2	BPMN gamification	23
	3	BPM 2.0	22
Agile	1	Social BPM/process design thinking	31
	2	BPMN gamification/BPM 2.0	28
	3	Ad hoc BPMN	26
Lean	1	BPMN choreography diagram	28
	2	Simulation-based BPMN/BPMN4CP	26
	3	uBPMN	25
Campaign	1	BPMN gamification	39
	2	Social BPM	38
	3	Design thinking	36
Fully flexible	1	Collaborative BPM/process design thinking	26
	2	Ad hoc BPMN/adaptive case/mgt./collaborative case mgt.	24
	3	Emergent case management	23

The advantages and limitations of using the recommended notations for the different SCM types are discussed in the following sections.

3.3.1 Collaborative

As shown, in collaborative supply chains, customers are highly integrated into the value chain and their demand is hence predictable. These two central features are especially supported by the recommended process modelling notations.

Social BPM stands for a general trend in business processes to give more participation to teams and stakeholders. This is done, for example, by using tools for group decisions. Instead of prescribing the decisions with the help of business rules and regulations, the human competences are used by people who work every day in the process. For SCM processes, the managers and operators involved in sourcing, production planning and distribution know best what the customer expects. Therefore, for example, in the approach of subject-oriented business process management (S-BPM) not end-to-end processes are defined by the management or process consultant, but rather the behaviour of individual actors (e.g., the freight forwarder who plans first, then informs the customer in advance, then drives the tour and finally arrives at the customer). The complete recording of all behaviour (e.g., the customer gets the preliminary information, prepares the warehouse and then receives the freight on the factory premises), gives a detailed picture of individual goals and their interdependence (so-called interaction diagram). Collaboration, which was perhaps previously given implicitly in the process, can thus be explicitly documented and even planned. The notation thus strengthens the desired collaboration by capturing dependencies based on the behaviour of individual actors. This also serves the common understanding of value chains – an important prerequisite for success in this SCM type.

A similar way is *BPM 2.0*, which is the third-ranked recommendation of the model. The idea of this notation is that not only the behaviour of individual actors is modelled, but involved persons can model the processes themselves. For example, Web 2.0 tools (e.g., processes as wiki entries) are made accessible to all parties involved in a workflow. Every actor (e.g., suppliers, partners and customers) can contribute ideas to the process. In SCM, physical storage, transport and handling play the central role in identifying process improvement. Therefore, people on-site might have the best ideas for optimisation compared to a (possibly central) process documentation. Following the idea that the know-how of the crowd produces the best results, this approach offers the opportunity to gain a high degree of integration while balancing all the requirements of the various roles. SCM is characterised by many conflicting objectives (e.g., customer demand for fast delivery versus cost reduction desire of the supplier through centralisation of warehouses). The resolution of such conflicts significantly contributes to the success of a collaborative supply chain. BPM 2.0 contributes to integration in two ways:

1 Efficiency can be increased by allowing people to share ideas quickly and efficiently (e.g., in chat rooms/forums instead of modelling ideas in complex documents).

2 Furthermore, the direct involvement of many people instead of focusing on a process modeller allows more ideas to be exchanged.

Thereby, innovation is fostered that will perhaps resolve several conflicting goals.

BPM gamification as an approach to process modelling and optimisation can be used in addition to the two described methods. Persons or organisations involved in value creation processes are rewarded formally (e.g., monetary) or informally (e.g., levels of status) for meaningful contributions. Such contribution may be an improvement of the process model (including the activities, roles, documents and IT systems) as described above. But it can also refer to affirming the desired behaviour of the participants (e.g., more collaboration, more data sharing, and reduction of mistakes). Relevant for the use in the SCM will be to unite the different goals and partners in a uniform incentive system, so that the entire value added chain profits from gamification. This is especially true for SCM, since the consideration of only one process step or for only one participating organisation would not lead to sustainable optimisation in process orientation.

3.3.2 Agile

The recommended modelling approaches for agile SCM are very similar to those of the collaborative type. The essential distinction of the types lies in the fact that in agile processes, the collaboration needs to be realised on a very individual basis. For the methods to be used, on the one hand, this means that no great investment should require for the documentation and design of the processes. As in classical BPM, for example, extensive actual modelling with complex analyses is often necessary. This may not justify the expense for a one-time process, which runs only for one specific customer. On the other hand, the techniques must be capable of handling spontaneous and short-term exceptions. For SCM, this flexibility may results from customers demanding a short-term plan adjustment (e.g., different quantities or delivery times). Likewise, changing the required goods (e.g., quality, size, or special conditions such as cooling) can have a major impact on the process.

The fact that the recommended notations support collaboration in the process has already been discussed in the previous section. Therefore, the question should be discussed to what extent the modelling approaches also supporting the described requirements for individuality and flexibility.

Design thinking in processes is a rather new method that helps to sustain the customer perspective in processes. In interdisciplinary teams, optimal processes are created through intensive discussions. Since this approach is usually organised in workshops, it is questionable whether it is suitable for very agile processes. After all, a design thinking workshop generates effort for all organisations involved in SCM processes. Where *social BPM* and *BPM 2.0* provide a more cost-effective approach through IT support, design thinking may be more appropriate for creating templates. If basic decisions are documented in templates (e.g., in which cases the customer prefers which delivery conditions in general), detailed decisions for agile individual cases can then be defined as part of BPM 2.0 or social BPM.

Ad hoc BPMN describes a possibility, how in processes documented with the extensive business process model and notation (BPMN), also short-term adjustments become possible. So-called light versions of the notation define a selection from the large set of possible model elements. This reduction in modelling scope could be made in the SCM, when the involved companies agree in such a complexity reduction. By doing so, the effort of modelling can be reduced.

3.3.3 Lean

Lean supply chains can be observed in stable environments, where process optimisations are only possible through intensive and data-driven analysis (e.g., Six Sigma). Since the participants or at least the interfaces between them need to be defined in great detail, completely different modelling notations are to be expected in comparison to the previously discussed SCM types.

In fact, the model does not recommend collaborative or agile SCM methods. All recommended modelling methods have their central advantage in the combination of process scheduling with a detailed design of entities. This information density is used in SCM practice for incremental process improvements. While radical (large but high-risk) innovations are possible using the agile and collaborative methods (e.g., complete reengineering in design thinking workshops), the recommendations for lean SCM rather support data-driven incremental improvements.

The *BPMN choreography diagram*, for example, is a further development of the established BPMN 2.0 standard, in which not only the professional but also the technical background of the process is documented. Similar to social BPM, partners' interactions are modelled in the supply chain, but their internal states and requirements are not presented. Choreography diagrams do not replace the actual extensive process description (these contain all detailed activities), but instead enriches these models through communication channels. Therefore, they have the potential to support complex supply chains by displaying not only the control flows of the goods (activities) but also the flow of information (data, e.g., digital currencies in the future). Especially in times when genuine optimisations can still be achieved in established value chains only through high data integration, this approach is forward-looking. It lays the foundation for well-known ideas such as vendor managed inventory, predictive production or intelligent forecasting.

If such a data-driven understanding of value chains exists, simulations become possible. For established processes, for example, new workflows, routings, storage strategies or even deliveries can be tested in the model before they are actually rolled out in practice. In lean process optimisation (e.g., loss function, Six Sigma), simulation and observation data is often used extensively to balance between process alternatives. Due to the ongoing trend of globalisation in value creation (e.g., global sourcing, outsourcing) simulations can also be used to simulate new partners in the supply chain in advance. In a nutshell, *simulation-based BPMN* offers a clever combination to link modelling processes with incremental innovation opportunities.

BPMN4CP is an extension of BPMN, which was originally developed for hospitals. However, the idea behind it also fits for modern lean supply chains. In essence, four major adjustments are made:

1. There is the possibility to model goals of different actors explicitly in one single diagram. Originally intended for the balance between doctors and the hospital's financial management, the approach can be transferred very well since a large number of partners are involved in a lean supply chain. Moreover, quality indicators are modelled in the control flow, which can be used directly for quantitative lean principles.
2. In addition to the control flow, there is a data and document view. It shows what data is available and what dependencies occur (e.g., generalisation between documents such as contracts). The first advantage for SCM is that quality department can model quality data (e.g., scrap, on-time delivery, etc.) in the process right in the planning stage. As modern supply chains are sometimes often quite complex, the whole presentation helps to identify the source of poor quality more quickly in distributed networks. Completely new approaches such as deep learning in production or future-oriented new deliveries will be strengthened.
3. Activities in the control flow are divided into three types: diagnosis, therapy and support. In fact, there is a similar distinction in operational logistics. Decisions are made (e.g., for or against a supplier), material/data is processed (e.g., loaded/stored), and some activities are just enablers (e.g., maintenance). In this way, the complexity of a supply chain can be reduced visually. At the same time interesting new simulations and tests become possible. For example it can be investigated which operative activity causes most errors.
4. Resources are bundled in BPMN4CP. This phenomenon is also known in SCM in the form of coupling (e.g., transport), packaging (e.g., paths), and commission (e.g., picking).

uBPMN, another recommended modelling notation, is also an extension of BPMN. It was originally intended for ubiquitous computing. However, it can, as BPMN4CP, be used optimally for supply chains, because systems that have to be permanently present (even in concurrency) can be explicitly modelled and connected.

In modern supply chains, IT systems are constantly collecting data (e.g., for tracking and tracing). These applications are mostly encapsulated as services (e.g., EDI interfaces) and should be permanently available. However, such concurrency issues cannot be represented in known SCM-specific modelling such as value stream maps.

In summary, the recommendations all have the potential to contribute to the lean supply chain. They support the analytical approach of optimisation, as it makes sense in this type. Although some notations were not primarily designed for SCM, their application could lead to new process insights.

3.3.4 Campaign

From process modelling point of view, campaign supply chains have the central advantage that the actual modelling and design may create effort. For large and important projects, complex and unique SCM processes have to be created.

The recommendation of *BPMN gamification*, which was transferred from the gaming scene to process domain, initially is surprising. After all, it has also been shown in the last sections that gamification can be used to persuade individuals to communicate their ideas for process optimisations (e.g., design thinking) or even to explicitly model them (e.g., BPM 2.0). Another considerable aspect of gamification is that people within the process can also be rewarded for services. Reward can be can either be offered for general process loyalty (e.g., adherence to the modelled control flow) or to special or excessive engagement (e.g., evaluation of more suppliers than required). The second reward style can convince in this SCM type: The campaign supply chain lives from the motivation of the persons involved. While lean processes are more likely to manage the mass and number of process instants, in large projects all individuals must work together in a trusting manner. At the same time, champions must be sufficiently incentivised. Motivation is enhanced by this approach by meaningfully combination of BPMN activities to badges. For example, not only the identification of suitable suppliers, but also their selection and commissioning (i.e., several activities) are connected as a badge. If one actor of the process is particularly prominent, he/she can reach a higher level (measures progressively the success in the game) by points for successfully managing the bundle of activities. In this way, the motivation and commitment of individuals/individual organisations in major projects can be rewarded. This extension of BPMN provides a suitable approach. It would be conceivable, for example, to award the budget of a major project for this form of incentivisation. The developers of this process modelling idea describe as a great advantage that assessment guidelines can be explicitly modelled. In evaluations, they also show the benefits of explicit rules in heterogeneous process teams. Especially in important and large projects (such as construction projects) policy decisions (for example, local sourcing) cannot or should not be modelled directly in BPMN (e.g., due to compliance). Nevertheless gamification can reward decisions and behaviour in line with the big goals of the entire supply chain. Especially in the political-social environment, which lives from individual heroes in a project, the notation can thus make a valuable contribution. However, it should be emphasised that gamification must be planned very well, because simple gamification approaches often fail in practice.

The benefits of *social BPM* were already discussed above. The advantages and limits of this approach also apply to this type of SCM. Chances arise from the efficient goal and opinion alignment in heterogeneous groups involved in large-sized projects.

The described effort of *design thinking workshops* can be worthwhile with this SCM type. Especially with heterogeneous process teams, but with one specific customer, this customer-centric process modelling can be used. An application can also make sense when rough processes are already in place for the large-scale project, but a more intensive focus on the customer should is needed with radical innovations.

3.3.5 Fully flexible

Fully flexible supply chains represent a type of processes that faces many unforeseen exceptions. Often, basic process patterns must be quickly adapted.

It is therefore not surprising that the model of this article mainly offers notations and methods of *case management*. All sub classifications (e.g., *adaptive*, *emergent* and *collaborative case management*) all have in common that processes exist as templates and not as detailed diagrams. In the traditional process management, processes are first modelled. Then they are explained to the people involved (humane resources), rolled out in IT systems (IT as a resource) or equipped accordingly (machines as resources). These resources are used when the process is instantiated and executed. In short, this means that process execution is only possible after modelling.

For the particular type of SCM, however, it is crucial that not all features and exceptions can be modelled in advance. If people make mistakes (e.g., serious wrong order picking) or major errors (e.g., completely wrong quality of an important component) are discovered, the process (e.g., packing and shipment) must be quickly adapted. This means that process steps, especially those where skilled workers with competences have to assess new situations, are redesigned during execution. The modelling and execution take place simultaneously. Case management offers a convincing approach: process instances are managed as a case. This means that for every new process instance (for example, a delivery) there is a basic template for the case (for example, in the steps of picking, packaging, route planning, and customer reception). If unforeseen events occur (e.g., packaging errors), the details within the basic steps (e.g., obtaining other packaging material) may be adjusted by experts.

This basic principle is shared by all sub-forms of case management. They combine good practices (templates) with the flexibility for major changes (exceptions). Thus, they support so-called knowledge workers, as experts can react flexibly to changes in a professional manner.

Adaptive case management focuses on the idea of reusing cases. Solved cases, that is, those that have sensibly responded to exceptions with new process entities (for example, changed actions, roles, and documents) are archived. If known exceptions occur, the known procedural solution can be used again as a template. This approach is particularly appropriate if the process contains both highly standardised (e.g., picking) and less standardised (e.g., supplier negotiation) steps.

Emergent case management tries to integrate approaches of BPM 2.0 into this approach. Web 2.0 tools are used. For example, if exceptions occur, skilled workers can contribute to the case in forums, wikis, chats, and other groupware tools (meaningful adjustments to the process model).

Collaborative case management supports when the activities with degrees of freedom need to be decided in a group. Applications are better known in the area of product lifecycle management (PLM). Nevertheless, examples from the SCM are also conceivable. The template of the case may include, for example, the ‘selection of a suitable supplier’. However, if many and complicated criteria (such as those that are difficult to quantify) are taken into account, the team can include an additional process exception. For example, the team decides to organise a new tender. All process members decide as a team (group decision support system) about which suppliers to engage.

4 Summary and outlook

Process orientation within the supply chain is becoming increasingly important for companies within global value networks. Nevertheless, it often remains questionable with which methods (for example notations) certain supply chains should be modelled. Especially given the different value chains in different industries and fields, managers and SCM practitioners are constantly faced with the challenge of meaningful process design. This contribution tried to give answers to this challenge by providing a general recommendation model.

This article is based on the approved and evaluated publications by Gattorna (2015) and Lederer et al. (2017). The first publication has described five major types of supply chain as stereotypes. The second study shows in an assignment model using process properties, in which situations, which modelling technique makes most sense. In a qualitative study, both results were combined within this contribution. In the results discussion, it emerges that SCM practitioners can benefit from the advantages and opportunities of various modern process notations. In each, the reasonable design alternatives differ greatly by SCM type.

Further research is needed to evaluate existing results in quantitative or case study-based investigations. Of course, the results are limited to the application fields of the studies used. For example, Gattorna (2015) as well as the resulting model of this contribution, right now, mainly focus on the customer and the buying behaviour. Therefore are no market-driven behaviour but also product-driven and hybrid characteristics are included. In addition, in practice, there are more hybrid SCM types appearing, which combine different stereotypes. The analysis of the appropriate notations is thus also dependent on the specifics of individual partners, opposites and situations. Furthermore, the described characteristics are generally valid – this shows the conceptually application in the discussion. Nevertheless, operational (e.g., notation requirements) as well as strategic (e.g., advancement of SCM) internal specifics are to be considered during productive use. Thanks to flexibility, the developed model can thus be used by SCM practitioners simply by adding their constraints to the given characteristics, classification or process types.

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