

## **Coping with rising supply chain complexity: conceptualising a supply network map structure model to address that challenge**

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**Abstract:** The complexity in supply networks is increasing and influences the competitive position of the focal company. Traditional approaches like supply chain mapping only show the focal company's relationships with suppliers and customers along the vertical supply chain, but are not capable to map any horizontal buyer-supplier relationships with other companies. Hence, this paper introduces a new supply network map structure model that extends the multi-tier view towards suppliers and customers along the vertical supply chain also to the complementors and competitors across the horizontal supply chain. Thus, the model enables the development of the existing supply chain mapping theory further into a holistic supply network mapping method. The model has been conceptualised with the help of 13 semi-structured interviews and is based on relevant models from the strategic management and the purchasing and supply management (PSM) literature. According to design science, it has been refined in several iterations.

**Keywords:** supply network; supply chain mapping; supply chain complexity; conceptual research; theory development; semi-structured interviews; design science.

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## 1 Introduction: supply chain visibility, complexity and necessary tools

### 1.1 *Better visibility needed due to supply risks, supply market trends and legal obligations*

If companies aim to maximise their profits, they can either try to increase revenue by raising sales prices or by achieving higher sales volumes or they can try to lower their purchasing costs. An important pre-condition for the companies in this context – especially from the purchasing perspective – is to have a high visibility about the inbound supplier structure and the interrelated buyer-supplier relationships (Barratt and Barratt, 2011; Barratt and Oke, 2007; Jin et al., 2013; Tse and Tan, 2012). Influential authors of the industrial marketing and purchasing (IMP) group such as Hakansson and Ford (2002) have carried out research on these complex interactions between companies and networks in various contexts, e.g., purchasing, since the 1980s.

A high visibility is desirable for optimising supplier relations, but also mandatory to react to the occurrence of risk events such as the tsunami in Japan in 2011 or the major

fire at the production facility of the German filter supplier Hydac in 2015, which caused a damage costing many millions of euros. Risk management rises in significance as supply chain vulnerability grows due to the increasing integration of actors into supply chains and networks. This development leads to dynamics that might damage all of these actors simultaneously. Such integration trends include the alignment of business models and strategies, processes and IT integration approaches as well as a trend to reducing buffer stocks (Norrman and Jansson, 2004; Spahr and Schäfer, 2014).

Most industrial firms currently concentrate on their core competences. It is assumed that the low value creation share of 38% of OEMs in the automotive industry in 2017 will even further decrease to 35% until 2030 (Wyman and VDA, 2018). The affected companies only have sufficient information about their 1st-tier suppliers, because they carry out system or modular sourcing, but they usually know little about the lower tiers in their supply chains (Trimble and O’Kane, 2008).

Moreover, there is a trend towards the globalisation of the value-creating processes in the supply network, which allows manufacturers to profit from the cost advantages in low-cost countries but does reduce transparency. Furthermore, as a result of this development, manufacturers need to cope with the volatility of the various sourcing market currencies (Semmler and Mahler, 2007).

Another important driver why the focal firm should improve the transparency across its supply network is increasing legal obligations concerning supply chain transparency: the taxation law of the European Union requires a certification of preferential origin and is obligatory for all WTO members as a part of the GATT Agreement. The certificate must indicate the country of origin; if several countries are involved, the country of the last substantial material transformation is decisive (European Commission, 2019).

## *1.2 High variety of suppliers and other causes increasing the supply chain complexity*

Supply chain complexity is increasing significantly (Hamta et al., 2015) and managers need to respond to this severe challenge (Turner et al., 2018; Cagliano et al., 2009). The growing complexity results from several causes: globalisation, customisation, innovation, product complexity, flexibility, sustainability, volatile markets and unpredictable demands (Sun and Rose, 2015; Kavilal et al., 2017). The supply chain complexity drivers denote number and variety of suppliers, customers, products, processes and uncertainties which are highly inter-dependent (Kavilal et al., 2017). The growing supply chain complexity may result in negative consequences on cost, customer service and reputation. Organisational aspects of complexity are often reflected in process-related or structural deficits, bottlenecks, information gaps or further obstacles. Uncertainty in material planning due to supply chain complexity can lead to inaccurate forecasts that will result in overstocks caused by bullwhip effects (Blecker et al., 2005) or in late deliveries (Wilding, 1998).

Furthermore, Choi and Hong (2002) differentiate between horizontal, vertical and spatial characteristics of upstream supply chain complexity. Horizontal complexity is characterised by the number of suppliers in each tier while vertical complexity is characterised by the number of tiers and spatial complexity is finally specified by the extent of the dispersion among members within the network. The three complexity drivers intensify the effects of the other two complexity drivers mutually. Complexity

usually consists of a static element concerning the variety of supply chain actors and behaviour as well as a dynamic aspect regarding the interactions between these actors (Bode and Wagner, 2015). The combination of the vertical and horizontal direction including indirect relationships is termed an industrial network (Miemczyk et al., 2012).

### *1.3 Suitable tools required to cope with low visibility and rising supply chain complexity*

As inbound risks and supply chain complexity increase while the overview of value creation architectures declines, purchasing managers need suitable tools to achieve visibility about the actors in their supply network and their relationships with each other in order to help make strategic sourcing decisions. The existing supply chain mapping approach is no longer sufficient for this task as it only addresses the linear, vertical supply chain, but competing supply chains rather look like overlapping networks (Lambert, 2008; Bellamy and Basole, 2013; Choi and Wu, 2009). Consequently, the research goal of this paper is to design a supply network map structure model to support the strategic sourcing process according to the following research questions:

- RQ1 What are the requirements for and objectives of a supply network map structure model from the focal company perspective?
- RQ2 Which structure, actors and directions of relationships are needed to meet these requirements?

This introduction will be followed by an overview about existing models in strategic management as well as purchasing and supply management (PSM) literature to guide model conceptualisation. In the first step, the existing models are analysed before defining the term supply network mapping and explaining the relevant attributes of supply network maps. In the following part of this paper, the exploratory research approach is described. After explaining the methodology, requirements and objectives of the supply network map, we present our findings, which are relevant for the model conceptualisation. The main body of the paper is based on the theoretical and exploratorily gained findings and explains all the elements of the Supply network map structure model in detail: supply network structure, supply network actors and supply network directions. Finally, the paper ends with conclusions including the theoretical contributions, managerial implications as well as the limitations and the need for future research.

## **2 Theoretical foundations: relevant strategic management and PSM models**

Strategic management and PSM literature examine a focal firm within its environment. Hence, we decided to search in both disciplines for relevant structural models in preparation for the supply network map structure model to be conceptualised. Figure 1 provides an overview of the existing models, which have been identified as influential for the new supply network map structure model, sorted by discipline and publication chronology.

Figure 1 Relevant models for structure model conceptualisation

Strategic Mgt. Literature	<p><b>Five Forces Model (Porter, 1979)</b></p>	<p><b>Business Ecosystem (Moore, 1996)</b></p>	<p><b>Value Net (Nalebuff/Brandenburger, 1997)</b></p>	<p><b>Cluster Map (Porter, 1998)</b></p>
PSM Literature	<p><b>Structural Supply Chain Map (Lambert et al.; Wilding, 1998)</b></p>	<p><b>Geographic Supply Chain Map (Lambert et al., 1998)</b></p>	<p><b>Complex Supply Chain (e.g. Smirnov et al., 2006)</b></p>	<p><b>Supplier Pyramid (Becker, 2007)</b></p>

## 2.1 *Relevant models in strategic management literature covering other actors*

In strategic management literature, the five forces model by Porter (1979), the business ecosystem by Moore (1996) and the value net by Nalebuff and Brandenburger (1997) took a structural approach to investigate actors in the environment of the focal company influencing the firm's business. As this environment is characterised by a high degree of transparency and continuously evolving relationships between the actors, the ecosystem stream of strategy knowledge is relevant (Jarzabkowski and Wilson, 2006). In contrast to these structural analyses, the cluster map by Porter (1998) is a geographic approach to investigating local concentrations of makers, subcontractors and raw material suppliers within a certain industry in a defined area.

The overlap of these four strategic models lies in the focal company and its direct suppliers. Moreover, the strategic models show customers and competitors as important actors. While competitors directly influence the focal firm's business in the five forces model and the value net, they only appear on the periphery on the third layer of the focal company in the business ecosystem. Cooperation with competitors without violating compliance regulations might in certain business cases lead to a 'coopetitive advantage' (Nalebuff and Brandenburger, 1997; Sroka, 2013).

Complementors are another important group of actors in the value net and in the extended enterprise on the second layer of the business ecosystem. They are regarded as the mirror image of competitors (Brandenburger and Nalebuff, 2011). Complementary products are connected with the product delivered by the focal company and make the offering more attractive to the customer, whereas products of competitors make it less valuable and less unique to the customer. Subcontractors are considered in the cluster map and the extended enterprise of the business ecosystem as well as customers' customers who are included in the ecosystem, but appear on the same layer as the other actors.

In the new supply network map structure model, stakeholder interests play an important role. As the structure model is conceptualised for application in strategic purchasing, all actors who are part of complex networks to plan, source, make and deliver products need to be involved (Millar, 2015). This analysis leads to the conclusion that the scope of the value net and the cluster map should be fully covered by the new model. The threat of new entrants and of new substitutes according to the five forces model are subordinated to the group of competitors in the model conceptualisation phase as new or substituting products enhance the rivalry between the focal company and its competitors (Porter, 1979). As the following regulatory and enabling forces in the business ecosystems are not directly related to the above mentioned product sourcing and delivery, they are neglected in the new model, but might be added if needed in response to stakeholders' demand in future as in a later self-renewal evolutionary stage of the ecosystem (Moore, 1996): contributors, trade associations, standard and public bodies, universities, research institutes, trade unions, stakeholders and investors.

## 2.2 *Relevant models in PSM literature showing multi-tier interactions*

The authors of the PSM literature like Harland et al. (2003), Jarillo (1993) and Lamming et al. (2000) concentrate their work on supply networks. Hence in PSM literature, we identified again three structural models presented in the overview in Figure 1 as influential for the design of the new supply network map structure model: the structural

supply chain map (Lambert et al., 1998), the complex supply chain (Smirnov et al., 2006), the supplier pyramid (Becker, 2007) and the geographic supply chain map (Lambert et al., 1998). While the models from the strategic management literature have mainly been taken into account to help select the relevant actors to form the nodes in the new supply network map structure model, the PSM models have primarily been considered concerning the links between these actors. When analysing these models, a remarkable finding is that these relations reach across many tiers. Up to three levels are included in the structural supply chain map with each tier being a new branch point for multiple links. Other authors such as Wilding (1998) with his supply chain complexity triangle as well as Kaufmann and Germer (2001) with their supply chain map suggest models with very similar structures compared to the structural supply chain map. While the above mentioned models show relationships being complex but parallel, other complex supply chain maps allow complex overlapping links. Within these illustrations of complex supply chains, small simplified units consisting of a producer and his 1st-tier suppliers can be highlighted and serve as configuration patterns (Smirnov et al., 2006), as illustrated in Figure 1.

An additional important insight is provided by a modified version of the conventional supplier pyramid. In this pyramid, suppliers are sorted according to their degree of value creation (Becker, 2007). The shape not only describes the closeness to the OEM at the top of the pyramid, but also the number of suppliers at each level of the pyramid. Starting at the bottom of the pyramid, part suppliers manufacture standard parts and hardly perform any research and development or provide any assembly service. At the next level, suppliers deliver modules and possess high technological competence but do not execute much assembly work, either. Finally, at the 1st-tier level, suppliers deliver assembled systems or components and have high technological and logistics competencies, so that the OEMs collaborate with them via modular or system sourcing (Appelfeller and Buchholz, 2011). The recent version of the supplier pyramid by Becker (2007) shows that deliveries do not only take place directly between an actor and its direct higher or lower tier, but that single or several tiers can also be skipped and so direct relationships between part suppliers and OEMs, for instance, can be established (Präuer, 2003). This behaviour is also referred to as climbing up the supply chain from a supplier's perspective or as stepping down it from the focal company's point of view (Wan and Wu, 2015). As suppliers have realised that the lower they are classified in the supplier pyramid, the easier they are to replace, they now strive to extend their product scope and to system integration (Wolf et al., 2010).

### *2.3 Supply network maps having a more complex geometry than supply chain maps*

The supply network is more complex than the vertical supply chain. Therefore, a definition for the mapping approach should emphasise the focus on the new processes and dependencies resulting from this complexity. Moreover, complementors and competitors will need to be added to the mapping approach following the literature review. Consequently, we derive the following definition of the purpose of the new supply network mapping approach from the supply chain mapping definition: "strategic supply network mapping focuses on goods, money and information flows and the corresponding processes and dependencies into all directions of a company's

environment: upwards towards the suppliers, downwards towards the customers, to the left towards the complementors and to the right towards the competitors.”

Supply network maps are characterised by several features that are classified into the main attributes of geometry, perspective and implementation. We adapted these attributes from chain to network scope in Table 1, based on the attributes for supply chain maps defined by Gardner and Cooper (2003).

**Table 1** Supply network map attributes

<i>Main attribute</i>	<i>Sub-attribute</i>	<i>Definition</i>	<i>KPIs / characteristics</i>
Geometry	Tiers	Sequential actors leading to the initial supplier / final customer, most distant complementor / competitor	# tiers # layers
	> Direction	Coverage up or down / left or right	Supplier-orientation / customer-orientation Complementor-orientation / competitor-orientation
	> Length	Tiers / layers in each direction	# tiers up / # tiers down # layers left / # layers right
	Width	Interchangeable actors within a tier or layer	# tier-x suppliers / # tier-x customers # layer-x complementors / # layer-x competitors
	Spatiality	Geographical representation	Yes / no
Perspective	Focal point	Company or industry	Company / industry
	Scope	Scope of the perspective	See below
	> Product breadth	Breadth of product coverage	Commodity group / product / component
	> SC perspective	Inclusion of SCM processes	Yes / no
	> Process view depth	Extent to which the map incorporates processes	# processes
> Cycle view	Inclusion of return channels and other feedback loops	Yes / no	
Implementation	Information density	Amount of information in the visual display	High / low
	Link to database	Link to preexisting corporate or supply chain database	Yes / no
	Delivery mode	Communication medium towards the users	Paper / electronic / web

Geometry describes the shape of the map. The tiers on the vertical axis as well as the layers on the horizontal axis are determined by direction and length. Direction means the upwards supplier-orientation, the downwards customer-orientation, the complementor-orientation to the left or the competitor-orientation to the right. Concerning the length in each direction, the number of tiers or levels can be calculated. The width is characterised by the number of interchangeable actors within one tier or layer (Pawellek, 2012). Yet, this understanding differs from the definition given by



Gardner and Cooper (2003) who regard the degree of specificity within a tier as the map's width. Finally, the element of spatiality distinguishes between structural and geographical maps.

The most important decision in terms of the perspective for a supply network map is to choose the focal point: this is the heart of the map and may either be a single company or a whole industry, depending on the relations that will be shown on the map. Moreover, the scope of the map needs to be narrowed down to an adequate product breadth, supply chain perspective, process view depth and cycle view. The product breadth ranges from a single component, to a whole commodity, to a whole end-customer product right up to the whole product portfolio of one focal company. For model implementation, it is important to define a suitable object to be mapped, implying a certain pattern within the supply network structure. If a whole system of a focal company would be mapped, the complexity would be very high and a visualisation could hardly provide a precise overview. Furthermore, the investment of time and resources would be very high (Doorey, 2011; Marshall et al., 2016) and probably not all the necessary information would be available. Therefore, it is necessary to choose a subsystem that will be mapped, such as a single commodity group (Heimbrock, 2001). Sometimes, an object cannot be decoupled easily from the rest of the network due to multiple relations and dependencies. As a result, it is mandatory that any partial entities can clearly be integrated into the whole network again (Jehle, 2005). Moreover, a map must incorporate the relevant perspective, including processes such as procurement, manufacturing, packaging and distribution. Such processes can be mapped in varying depths. Another attribute of supply chain maps is whether the cycle view with return channels and feedback loops are part of the map.

Finally, the implementation of the map is crucial for its acceptance and use within a company. Thus, the information density may vary from high to low, depending on the amount of information that is shown on a visual display. If a link to a database such as Microsoft Access exists, this may allow real-time data processing. Finally, the creator of a map can choose a suitable delivery mode depending on the user's preference, such as paper, e-mail or the internet.

The literature review and subsequent deduction of a definition and attributes for supply network maps has enabled us to get a first idea of the required structure of the model to be conceptualised. However, it is important to explore the requirements and objectives of the buyers who will carry out supply network mapping and use our model in strategic purchasing. Therefore, an additional exploratory empirical research approach defined below is required.

### **3 Research methodology: model requirements and objectives identified through exploratory research**

#### *3.1 Exploratory empirical research approach to create and refine the model*

Qualitative research is a suitable methodology to examine rarely explored questions and objects (Lamnek, 2005). As the approach is used to reveal reasons lying beyond the surface, the exploratory empirical research approach is an appropriate way for investigating the requirements and objectives of supply network mapping that are not yet visible to a purchasing organisation (Bortz and Döring, 2006; Flick, 2007).

For data collection, we carry out semi-structured interviews with experts from relevant departments in an agricultural machinery manufacturer and other firms in the same industry, because a complex, multi-tier network including various actors is characteristic of the agricultural machinery sector. This type of interview allows variation in the use of questions in order to involve a participant deeply into the study. Each interview has been linked to the purpose of the study to try to uncover the requirements and objectives of supply network mapping (Galletta, 2013).

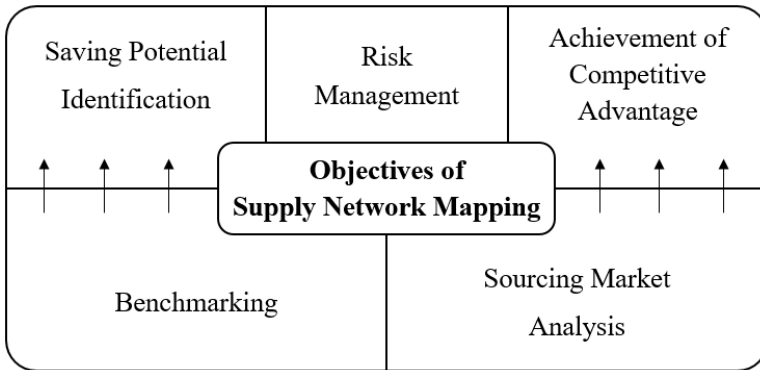
The sample size for these qualitative interviews is typically small. All in all, 13 interviews – 12 physical sessions and one webinar – with 16 people were conducted over half a year, including 11 employees of the agricultural machinery company and five people from companies in the same industry and software providers. The order of the interviewees was chosen according to the most promising research progress (Galletta, 2013). That is why the interviews started with the heads of corporate purchasing and spare parts purchasing as well as the global sourcing coordinator in order to achieve a broad understanding of the underlying objectives as quickly as possible. Interviews with employees who are responsible for more specific areas such as product management, customs and foreign trade, product cost optimisation and logistics purchasing were carried out later. In addition to this, brainstorming sessions with several purchasers of product-related material were conducted to capture the model requirements for an application in their daily work.

According to design science, the model has been conceptualised in several iterations with various model stakeholders. Following this methodology, the results of one interview or brainstorming session serve as an input for the next interview or brainstorming session (Johannesson and Perjons, 2014). Based on the stakeholders' requirements, a first draft of the supply network map structure model was created. Different commodities were selected for a test case to verify if the created model is suitable for application. Following the application experience, the model was again refined in several iterations.

### *3.2 Model requirements and objectives being important for model conceptualisation*

Several model requirements have been decisive for the creation of the supply network map structure model. The purchasers of product-related material highlighted during their brain-storming sessions that the model needs to lead to a good market transparency for tenders, renegotiations and cost optimisation projects. Moreover, the model shall be able to provide a geographic view by comparing local with global sourcing scenarios or by illustrating alternative purchasing options. Margin structures in the assembly of a component should be visualisable by the structural view of the model. Further results concern the actors in the supply network. Not only should the upstream vertical supplier network be mapped, but also the various layers of complementors and competitors in order to lead to benchmarking findings.

Supply network mapping can be a promising tool for achieving the three main objectives arising from the expert interviews and the brainstorming: saving potential identification, risk management and the achievement of competitive advantage. These objectives are supported by sourcing market analysis and benchmarking, both contributing as a foundation to the achievement of the main goals, as shown in Figure 2.

**Figure 2** Objectives of supply network mapping

A component can be split-up into its single parts to identify cost saving potential. The OEM can negotiate the volume on 2nd-tier parts directly with module suppliers in order to achieve lower prices. He can even switch to the 2nd-tier supplier to source the volume directly from him if it makes sense from a total cost of ownership perspective. The second objective is the management of external, uncontrollable risks. Although these risks are difficult to quantify, the occurrence probability and the severity of such risks, such as a natural disaster in Japan, can still be predicted and monitored by calculating suitable risk KPIs (Borghesi and Gaudenzi, 2013). As the third objective, it is important to analyse the potential for the achievement of competitive advantage which is also subject to the important related literature stream of social network analysis (Barney, 1991). Competitive advantage can be achieved by being a preferred customer of shared 1st-tier suppliers (Pulles et al., 2016; Schiele et al., 2012). The sourcing market analysis is a subordinate target to support the three main targets above. The country of origin where a part has been manufactured plays an important role for the supplier's sales price in the context of both structural and geographic supply network mapping and is of a high interest for the customer in times of an increasing consumer awareness for a local, sustainable and ethically correct production of the goods that they consume (Kraft et al., 2018). The targets of benchmarking as a further subordinate objective of supply network mapping include: to evaluate the competitors' successes and to improve the knowledge improvement on his existing and future suppliers, competitors, customers and complementors in line with a strengthening of the own market position (Büsch, 2013).

#### 4 Model conceptualisation: capturing the structure and relationships in a company's environment

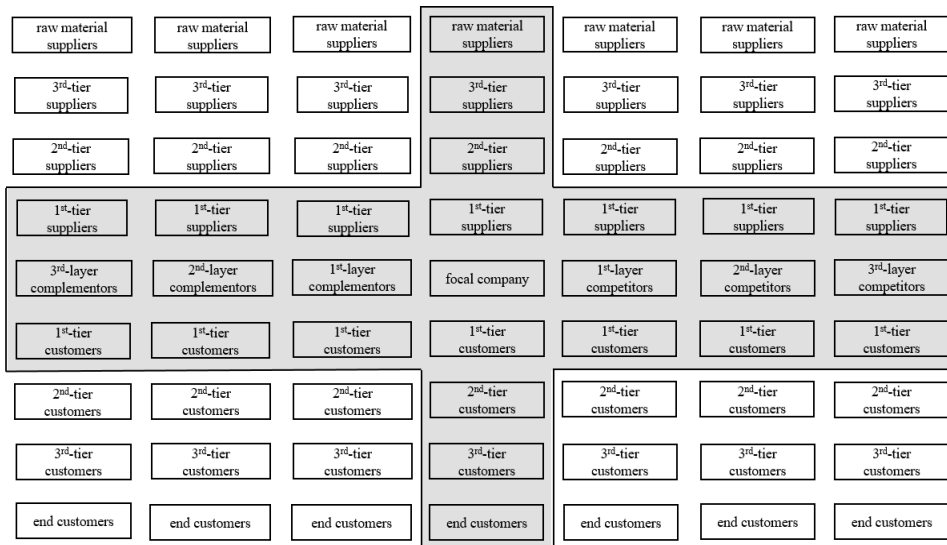
##### 4.1 Supply network map structure model visualising a company's environment

The supply network map structure is based on the structural mapping for the upstream purchasing network through all supplier tiers and the downstream distribution network passing through all customer tiers (Gudehus and Kotzab, 2009). We supplemented this vertical order by the same horizontal triple layer structure towards the competitors and complementors. There is no  $n^{\text{th}}$ -layer competitor or complementor as there is no initial source of competition or complementarity.

In order to create the model in Figure 3, the following abstraction and idealisation of the real company environment was carried out (Jebeile and Kennedy, 2015): the vertical supply chain is no longer than four tiers consisting of 1st, 2nd, 3rd-tier and raw material suppliers. All boxes have the same distance between them not representing the real geographic distance, each box signifies one type of actor rather than the real number of actors and every actor only plays one role within the supply network. Due to this idealisation, the following business cases are left out of consideration: the focal company can be both OEM and supplier, joint ventures between the focal company and competitors, suppliers with creditor and debtor accounts and suppliers who also act as complementors or competitors.

To turn the supply network structure into the supply network map structure model, a zone in the form of a cross shape has been drawn into the model. This cross marks the target zone of transparency achievement for the focal company, because reaching 100% visibility and knowledge about all actors in the supply network requires too much effort (Doorey, 2011; Marshall et al., 2016). The focal company should know in detail the tiers within its own supply chain. In contrast to the upstream supplier network, this knowledge usually exists on the customer side as the company is actively choosing and influencing this structure. Furthermore, the company should be aware of the competitor's 1st-tier supplier and customer structure. On the complementor side, the transparency about customers will already be there because both companies have a mutual interest in increasing their sales together. On supplier side, research should be done on 1st-tier suppliers if the products share common parts, which will mainly be true for 1st-layer complementary products.

Figure 3 Supply network map structure model



#### 4.2 Relations with suppliers, customers, competitors and complementors to be managed

The idea behind the new supply network map structure model is that a company should supervise its relations into all four directions within the supply network: towards suppliers, competitors, customers and complementors. The following four definitions highlight the basic idea of the relationship management.

Supplier relationship management is described as the IT-based design of strategic and operative procurement processes and of supplier management in line with the overall procurement strategy (Appelfeller and Buchholz, 2011). As a mirror image to the supply side, customer relationship management is presented as “the initiation, enhancement and maintenance of mutually beneficial customer and partner long-term relationships through business intelligence-generated strategies” [Baran et al., (2008), p.10]. The term complementor relationship management has been characterised by Günther (2015) as the ideal integration of the focal company and its complementors concerning product ranges and resources. Finally, we introduce the new term competitor relationship management in this paper to complete the management of interactions towards all actors chosen as relevant in the supply network, although it might appear self-contradictory at first sight. Competitor relationship management represents the IT-based collection of knowledge about competitors concerning their supplier and customer relations that leads to a mutually beneficial alignment of activities between the focal company and its competitors.

**Table 2** Supply network map actors

<i>Suppliers</i>	<i>Customers</i>	<i>Complementors</i>	<i>Competitors</i>
<i>Supplier relationship management (SRM)</i>	<i>Customer relationship management (CRM)</i>	<i>Complementor relationship management (CoRM)</i>	<i>Competitor relationship management (CompeRM)</i>
<i>1st-tier suppliers</i> = system suppliers	<i>1st-tier customers</i> = distributors, importers	<i>1st-layer complementors</i> = vendors of end-product-related products that cannot exist without the end-product	<i>1st-layer competitors</i> = end-product competitors
<i>2nd-tier suppliers</i> = module suppliers	<i>2nd-tier customers</i> = contract dealers	<i>2nd-layer complementors</i> = vendors of end-product-related products that complement the end-product	<i>2nd-layer competitors</i> = single end-product / market competitors
<i>3rd-tier suppliers</i> = part suppliers	<i>3rd-tier customers</i> = independent dealers	<i>3rd-layer complementors</i> = vendors of customer-related products	<i>3rd-layer competitors</i> = single part / spare part competitors
<i>raw material suppliers</i> = steel suppliers, rubber suppliers,...	<i>end-customers</i> = agricultural contractors, farmers	<i>no equivalent</i>	<i>no equivalent</i>

All these four types of relationship management are summarised in Table 2. Moreover, we suggest definitions for all the actors in a supply network. Definitions for the various layers of complementors and competitors are proposed in this paper for the first time.

Starting with supplier relationship management, according to the supplier pyramid by Becker (2007), system suppliers are regarded as 1st-tier, module suppliers as 2nd-tier and part suppliers as 3rd-tier suppliers. Raw material suppliers represent the  $n^{\text{th}}$ -tier in this order and deliver primary material, such as steel.

The relevant customer tiers can be clarified by analysing a focal company's sales structure: The distribution channel via subsidiary distributors or importers in foreign countries is regarded as the 1st-tier customer level. One level lower, contract dealers can be listed who distribute products on behalf of the focal company. As the counterpart to contract dealers, independent dealers who sell products of several brands enlarge the sales capacity of the focal company. Finally, the goods are sold via dealers to the end-customers in the supply network.

Regarding complementors, the paper distinguishes between the subject and the extent of complementarity. While complementary products of 1st and 2nd-layer complementors are tied to the products of the focal company, complementors are classified on the 3rd-layer if their products are related to the customers of the focal company. Concerning the extent of complementarity, products of 1st-layer complementors cannot exist without the product of the focal company whereas 2nd-layer products only complement the other product. 3rd-layer complementors provide products fitting to the interests and needs of the customers of the focal company in order to offer them a complete product range.

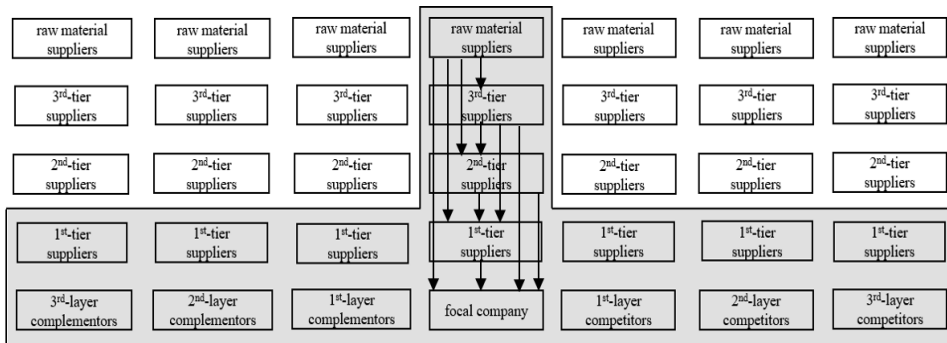
Finally, the various layers of competitors need to be defined based on the subject and the extent of competition regarding the product portfolio (Hefti et al., 2014). 1st and 2nd-layer vendors compete concerning end-products whereas 3rd-layer competitors try to gain market share for spare parts. 1st and 3rd-layer competitors are in competition with the focal company over nearly the whole product range. However, 2nd-layer competitors either only serve selected markets or only have a few competing products for product quality and/or pricing reasons.

### *4.3 Mapping of a company's relationships being necessary in three directions*

#### *4.3.1 Vertical supply network mapping: analysing value creation in the vertical supply chain*

Vertical supply network mapping according to the wording used by Choi and Hong (2002) is the first of the three directions to be presented. This type of mapping focuses on the length of the vertical supply chain of the focal company and is visualised by the vertical arrows in Figure 4. This prompts the core question: how many tiers does the vertical supply chain include upstream in the chain?

However, the goal of vertical supply network mapping is not only to determine the number of tiers but also to gather as much information as possible on countries, value creation by the various suppliers and supplier names. As mentioned in previous paragraphs, the target of the focal company should be to achieve at least transparency within the zone marked by the cross shape, which includes the whole vertical upstream supply chain.

**Figure 4** Vertical supply network mapping

As the identification of cost saving potential is one of the main objectives of supply network mapping, vertical mapping can help to ease the direct negotiation of indirect volume by the focal company. Indirect volume describes modules or parts that are delivered by 1st-tier suppliers to the focal company or needed for their assembly process of systems, but have been manufactured by lower-tier suppliers. This means that the purchasers take charge of the direct negotiations with 2nd or 3rd-suppliers without having direct contracts or delivery agreements with them. In this case, the purchasers step down the supply chain towards lower-tier suppliers (Wan and Wu, 2015). Once the purchasers of the focal company have made their price agreements with these lower-tier suppliers, they communicate their prices to the 1st-tier suppliers who can then place their orders by referring to these price agreements. As an alternative to this approach, the purchasers of the focal company can also offer to their 1st-tier suppliers to bundle their volumes in order to negotiate better prices from sub-suppliers, termed chain sourcing (Schulte in den Bäumen, 2009).

Another aspect in the context of vertical supply network mapping is the strategic supplier classification, segmenting suppliers into preferred, alternative, restricted and phased-out suppliers or comparable classes (Appelfeller and Buchholz, 2011; Helmold and Terry, 2016). Usually, such classifications only consider the direct spend volume and suppliers are developed or phased-out based on the result. However, in order to evaluate the actual total volume, the classification would have to be enlarged to the 2nd- and 3rd-tier levels, because if a supplier is phased-out by the focal company but continues as a sub-supplier of 1st-tier suppliers, the supplier does not disappear from the focal company's supply network.

In the context of risk management, vertical mapping should reach beyond 1st-tier supplier risks and risk management should be expanded to the sub-suppliers. However, the transparency that the focal company may achieve on the sub-supplier structure is limited, especially for financial monitoring. Therefore, in future, 1st-tier suppliers will have to be involved in a strategic risk management with sub-suppliers.

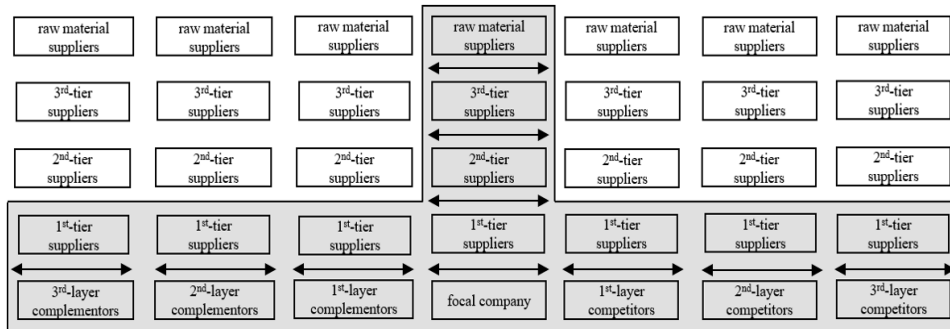
#### 4.3.2 Horizontal supply network mapping: capturing the number of interchangeable actors

Horizontal supply network mapping according to the wording used by Choi and Hong (2002) explores the number of interchangeable actors within one tier or layer, termed supply network width. Consequently, the main objective of horizontal supply network

mapping is market analysis. The core question arising from this mapping relating to horizontal supply chain complexity is: how many suppliers are there in every tier of the supply chain?

Horizontal relationships are deemed ‘more informal and invisible’ (Bengtsson and Kock, 1999). Usually, there is no horizontal flow of goods, money or information. The actors just co-exist. Co-existence describes a rather passive state without explicit interaction between the parties but still potential dependencies (Bengtsson and Kock, 1999).

**Figure 5** Horizontal supply network mapping



Nevertheless, horizontal relationships are just as important as vertical relationships. They are an indicator of respective market power. According to the taxonomy of supply networks by Harland et al. (2001) focal companies can actively manage their supply networks if they have a high supply network influence and only cope with the networks if they have a low supply network influence.

The width describes the number of interchangeable actors, which influences the supply risk according to the Kraljic (1983) matrix. Thus, the width is very low in the case of a monopolist who manufactures complex components that are protected by intellectual property rights and very high in case of standard material suppliers. The number of interchangeable actors also has an effect on the overall supply network complexity. If all competitors and complementors use the same 1st-tier supplier for a certain component, there is just one vertical flow of goods and the pressure to increase the satisfaction of this one supplier in order to improve the own customer status is very high for the buyers. A preferred customer status would lead to beneficial treatment and thus to competitive advantage (Vos et al., 2016). However, if there are many interchangeable suppliers, what if-scenarios can be simulated. The effects can be measured in purchase prices and logistics costs. With the help of a suitable IT tool, the simulation can be done quickly and various paths can be illustrated, that are linked to several supply network mapping scorecards with KPIs for the various objectives.

The findings for the suppliers also hold true for the focal firm. The more complementors and competitors that exist, the more important it is to look into the whole supply network and all dependencies within it. In contrast to this, focal companies who do not have any competitors can concentrate only on their supply chain. However, they should never stop observing their competitive environment as new entrants can emerge quickly according to Porter (1979).



### 4.3.3 Hybrid supply network mapping: unveiling the suppliers of competitors and complementors

Finally, hybrid supply network mapping combines horizontal and vertical mapping. The perspective towards competitors or complementors is the horizontal aspect of the term whereas the emphasis on sub-suppliers represents the vertical element.

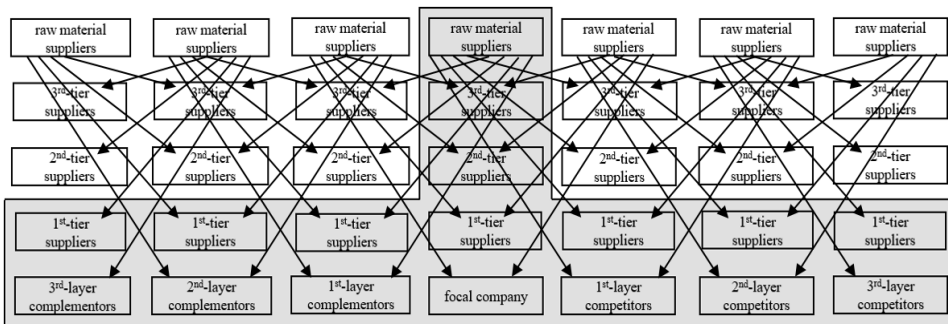
Referring to the cross shape representing transparency in the supply network map structure model, hybrid supply network mapping will help to find out: who are the 1st-tier suppliers of the complementors and competitors? Out of the mapping objectives, hybrid mapping contains mainly a benchmarking view to support the achievement of competitive advantage.

The arrows in Figure 6 show that the complexity of hybrid supply network mapping reaches far beyond the cross shape. On the one hand, suppliers at all levels of the vertical sub-supplier structure might also supply to competitors or complementors. On the other hand, suppliers at all levels of the competitors' or complementors' sub-supplier structure might also supply to sub-suppliers or to the focal company directly. If a supplier is supplying a competitor or a complementor with high quality products, this supplier might also be an attractive partner for the focal company.

If the focal company and 1st or 2nd-layer complementors or competitors share the same supplier-base at one or more of the above levels, several activities can be recommended to the purchasers of the focal company:

- Projects involving shared suppliers and complementors or competitors should be monitored to profit from price decreases during increasing project volumes.
- In particular cases, it can make sense to bundle purchasing volumes with complementors (cooperative sourcing) or competitors (coopetition sourcing) in order to achieve better prices (Schulte in den Bäumen, 2009).
- The monitoring of the business that shared suppliers make with other customers can also help to improve the risk management system: if the suppliers' capacity is restricted, supply chain disruptions can be anticipated.
- Confidentiality agreements should be closed or intensified with shared suppliers in order to protect intellectual property of the focal company from its competitors.

Figure 6 Hybrid supply network mapping



If suppliers also supply 3rd-layer competitors with parts, this will typically not be appreciated by the focal company. That is why purchasers usually consider this aspect in audits before making their supplier choices and why they will strive for exclusivity agreements.

Finally, the focal company and 1st-layer or 2nd-layer complementors or competitors might not yet have common suppliers. In that case, hybrid mapping enables market research including the performance of potential new suppliers in their relationships with other customers.

## **5 Conclusions: supply network mapping contributing to literature and helping purchasing managers**

### *5.1 Considering the complex relationships in a company's environment*

Supply network maps show the material, information and money flows in all directions of a focal company's environment: towards suppliers, customers, competitors and complementors. They can either show the structural or the geographical view of the relations. Supply network mapping can support the decision making process of strategic purchasers in the following main areas: identifying cost saving potential, risk management and achieving competitive advantage.

The result of this paper is a new supply network map structure model. The model is based on the relevant actors that appear in several well-known strategic management models and combining these with the analysis of multi-tier network links from relevant PSM models. The core of the new supply network map structure model is a cross-shape that implies that a focal company should gain visibility about all actors with a direct link to this company: the whole vertical supply chain as well as all complementors and competitors with their 1st-tier suppliers and customers. With regard to flows and interactions in the network, vertical, horizontal and hybrid directions of supply network mapping have been identified with the help of semi-structured interviews and the application of the model in various test cases.

### *5.2 Closing a gap between PSM and strategic management literature*

This research contributes to both the strategic management and the PSM literature. It is closing a gap between these disciplines by adopting the multi-tier interactions analysis regarding suppliers and customers, which is known from supply chain maps, complex supply chains and the supplier pyramid as discussed in the PSM literature (Becker, 2007; Lambert et al., 1998; Smirnov et al., 2006) to integrate further actors like competitors, complementors, sub-contractors and customers' customers as discussed in the strategic management literature (Nalebuff and Brandenburger, 1997; Porter, 1998, 1979; Moore, 1996). In terms of the PSM literature, this transfer leads to a network-like understanding of the focal company's environment, fitting well into the continuously evolving roles and relationships in an ecosystem instead of the antecedent linear chain interpretation (Jarzabkowski and Wilson, 2006). Competition between several companies' supply chains is a scenario often described in the literature but rarely illustrated in a structural model approach until now (Lambert, 2008). Considering the strategic management literature, a visualisation of actor relationships via multi-tier links is a new, valuable

addition. Using the example of competitors, it would be very helpful not only to group all competitors into one node in the business ecosystem or value net, but also to map all links to other actors in order to analyse the subject and the extent of the competition. Moreover, in the geographic sense it would be of a great interest to analyse whether all actors located closely to each other in a regional cluster really have intensive relationships with each other.

Caused by the extension to competitors' and complementors' supply chains, many complex overlapping interactions result that will take research on current buyer-supplier-supplier triads and possibly new supply network patterns to a higher level and require further analysis. Such new triad constellations are among others: buyer-competitor-supplier, buyer-complementor-supplier, buyer-competitor-customer, buyer-complementor-customer, competitor-supplier-2nd-tier-supplier, complementor-supplier-2nd-tier-supplier, competitor-customer-2nd-tier-customer and complementor-customer-2nd-tier-customer. The new term supply network map that we introduced in this paper is linked to this evolution from chain-like structures towards network-like structures' visualisation. In terms of spatiality, the model can be used both structurally and geographically. These two approaches reflect the existing literature on supply chain mapping and take this field further on network level.

### *5.3 Supply network map structure model as a tool to facilitate strategic purchasing*

The supply network map structure model gives a shape and framework to the actors and links of supply networks and can consequently be considered as a tool to facilitate strategic purchasing decisions and processes. As a result, the model leads to more transparency about a focal company's network.

The model has been conceptualised from the requirements of an agricultural machinery company. However, its suitability for other industries can be assumed due to the basic structure of the model. Taking a look into the three economic sectors, the supply network map structure model covers the primary sector, because fishermen act as raw material suppliers to the food industry. Furthermore, the model is suitable for businesses in the secondary craft sector, such as carpentries, and in the industrial sector, such as road vehicle manufacturers, because these businesses execute purchasing and selling activities and are involved in value creation. The model might also be transferable to the tertiary services sector in the future. For that sector, the bottom part of the supply network will be of particular interest because it is focused on customer-orientation.

Following the three directions of supply network mapping, the model contributes to the achievement of all five supply network mapping objectives. While vertical supply network mapping aims at the identification of cost saving potential and risk management, horizontal supply network mapping focuses on market analysis assisting hybrid supply network mapping that can help to achieve competitive advantage supported by new benchmarking findings. However, these are only the most significant objectives for each of the directions, but there are also weaker relations, such as those between hybrid supply network mapping and risk management. Regarding the timeframe, the model cannot only help to realise medium and long-term improvements through its strategic use but also support the identification of short-term cost savings in its operative application.

#### *5.4 Further testing of the model in various business contexts required*

Our paper proposes a new supply network map structure model to achieve a holistic structural understanding of a focal company within its complex environment. However, the supply network map structure model presented in this research is an abstraction and idealisation of the real company environment, which is often considered to be a misrepresentation of its target system (Jebeile and Kennedy, 2015). The model contains a triple-tier structure into all directions and a congruent cross-shape marking the zone of transparency. This basic shape might be refined according to the requirements of strategic purchasers of various commodities. Furthermore, an investigation of the actors on the vertical model axis and their continuously evolving roles and relationships in an ecosystem might require to modify the shape. Consequently, the current structure will probably be further developed towards both larger and smaller basic structures with thicker and thinner cross shapes.

Regarding the directions of supply network mapping, only the upstream part of the supply network has yet been explored in detail. However, the customers of the various supply network tiers have also been defined, so that future research on the downstream part of the supply network can be carried out by sales experts. Once the supply network mapping application is extended to the downstream supply network, experience needs to be gained with regard to the model application in sales. A follow-up study could take place concerning correlations between the upstream and the downstream part of the supply network. Such research might contain the influence of supplier deliveries to 3rd-layer competitors on end consumer sales for the focal company or the consumer demand for complementary products depending on the alignment between complementors and the focal company.

The scope of this paper concerning the commodities to be mapped is limited to product-related material covering components, modules and single parts, while non-product related material and services were excluded from this research. Therefore, future researchers are encouraged to investigate the structure of the supply networks and the applicability of the supply network map structure model for non-product related material and services. Moreover, the model might also be tested for other logistical applications, such as stock control at all levels in the supply network and the transport optimisation in operations research.

An important result of this study is that it is important to define a suitable object to be mapped, implying a certain pattern within the supply network structure. If a whole system of a focal company would be manually mapped, the complexity would be very high and a visualisation could hardly provide a precise overview. Therefore, it is necessary to choose a sub-system such as a single commodity (Heimbrock, 2001). Nevertheless, we are aware that the real advancement in supply network mapping will happen with the help of big data analysis. If supply network information could be gathered and processed automatically, it would be possible to map the whole supply network of focal companies. This paper can be regarded as the conceptual basis for this approach and future researchers are encouraged to further explore the antecedents, usage and effect of big data in supply network mapping.

Moreover, success factors for information gathering and finally supply network mapping success need to be further investigated and are expected to lead to important theoretical and managerial implications. Despite the general model applicability, costs and benefits analysis are a major limitation of the supply network mapping opportunities

and need to be evaluated for every application. A linear relationship between the supply network's complexity in terms of the net's length, width and dependencies and the benefit through the mapping work is assumed. The more complex and dynamic a supply network is, the more stressed it is (Kaufmann and Germer, 2001) and the more optimisation potential exists.

Finally, the procedure how to create a supply network map in a concrete business case remains unattended in this paper. This broad research field remains to be investigated and includes the mapping responsibilities, information sources, requirements, procedural steps, determinants and obstacles. Publications in the field of supply chain mapping and related research streams, such as supply chain complexity or vertical integration, often do not distinguish clearly between a supply network map as the output of the mapping activity and the supply network mapping procedure that is necessary in order to achieve such visualisation.

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