Value network analysis and configuration within turbulent environments using simple vector-based modeling approaches

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ABSTRACT

Since current market developments often show a high volatility and uncertainty as well as a strong interconnectedness between a growing amount of companies, adequate means for the design and analysis of economic value networks have gained high relevance in academic and practical fields. In this context, a specific difficulty for a company is, to quickly identify the critical influence factors within the surrounding network of suppliers, customers, competitors etc. that should be analyzed in-depth and subsequently be handled with high management attention and effort. In particular, the attribute ‘critical’ might be assigned to multifaceted dimensions such as performance complexity, risk, flexibility or others. These dimensions strongly depend on the individual company context and may change often and unexpectedly, according to market developments. Thus, the purpose of this paper is to propose a conceptual model together with a respective managerial method that facilitates the quick and nevertheless adequate identification of ‘critical’ value network locations. In order to enable the representation of multiple dimensions, a vector-based approach is used that considers as well several different dimensions as the ability to model individual network topologies.

Keywords: economic value network management, value network assessment, value network analysis, critical network path, network boundary spanning

MODELLING THE VALUE NETWORK TOPOLOGY IN TURBULENT ENVIRONMENTS: A SENSITIVE BALANCE BETWEEN SIMPLIFICATION AND FEASIBILITY VERSUS VALIDITY OF PARTIAL ANALYSES RESULTS

Typical performance requirements, a company has to fulfill under current business conditions, are regarding short lead and reaction times and a competitive cost position in spite of high product variety, a distinct operational flexibility (Stevenson and Spring 2007) and a proficient capability to adapt to structural changes (van Hoek 2004). Relevant value network design issues usually concern the amount, the capacity and the location of manufacturing plants, the supplier selection and the alignment of market regions to production facilities (Chopra and Meindl 2004). As a consequence of intensive outsourcing initiatives, industrial value creation is more and more based on a highly fragmented division of labor between legally independent companies, each concentrating on their specific core competencies. The coordination of value networks is reliant on accurate and exhaustive information (Holweg and Pil 2008, Caridi et al. 2010). However, an increasing network complexity extends the required amount of information to describe the system and its current state (Sivadasan et al. 2006) and causes a growing intransparency. With a rising number of companies that are involved into joint value creation processes, a firm's dependence on the behavior of other companies increases as well as the necessary coordination efforts. This applies especially, when information is incomplete, opportunism is a usual occurrence (cp. Coase 1988 or Jensen and Meckling 1976) and objectives can't be assigned to other value chain participants (companies) by implication.

As a matter of fact, an exhaustive analysis of the relevant influences that originate from changing customer demands, and / or from a company's supplier flows, is not possible with existing resources and within the available amount of time, before an action has to be taken or an enquiry has to be answered. Therefore, the identification of 'critical' network participants or segments is essential for a company in order to concentrate analysis, planning, steering and optimization efforts on the most effectual means. We preliminary define a 'critical' network segment as one single company or a bundle of several companies – e.g. suppliers or customers – that have a strong impact on the acting company's performance and, thus, have to be treated with distinct management attention. The basic assumption of the present paper is that as well practical applicability as result validity can be remarkably improved through partial analyses that are focused upon those critical areas.

A value network consists of convergent, linear or divergent material and information flows (in practice a mix of these generic topological types). Depending on the respective product range, capacity base, purchased parts and geographic actualities, a dynamic operational network topology evolves. This network topology is determined through three main factors: customers, suppliers and company-internal capabilities. Accordingly, Mentzer et al. (2004) classify "logistics capabilities" into demand- and supply-management capabilities and emphasize the importance of interface and information management proficiency, herewith distinguishing between internal functions and cross-company cooperation. Likewise the main uncertainty sources are stated to be the suppliers, the own production, and the customers (Davis 1993). Hence, also a network topology model should be set-up according to this three-tiered configuration logic.

The academic literature provides several generic supply chain models (for a detailed overview and review see Meixell and Gargeya 2005). For example, Lambert et al. (1998) have proposed a converging supplier structure towards the focal company, followed by a successively diverging customer structure. This generic topology model simplifies, but raises complexity at the same time: simplification is applied insofar that neither competitors nor m:n relations between multiple vendors and buyers are respected. On the other hand the model is usually too voluminous already at a tier_1 supplier and customer level, because the high number of even tier_1 value network partners exceeds the feasibility of exhaustive analysis in a real industry setting. This applies even more, when extending the focus on a tier_2 to tier_n level. Another model that considers the impact of competitors has been proposed by Gosling (2003), who assumes the existence of 'middlemen' (representing the role of competing companies). However, the model is restricted to tier_1 suppliers and customers. Apparently a topology that includes ideas from both models, more precisely a multi-stage tiered value flow structure and influences from competitors, would establish a more realistic value network map. Further, additional links would have to be considered for the case of m:n relationships or other links that extend the pure tree-structure of typical theoretic models.

Altogether, a real-world network topology is likely to be a more detailed and complex specification of this generic network model structure. However, on the other hand, complexity reducing adjustments have to be made in order to ensure the feasibility of logistics analyses: first, a clear selection has to be done at each tier-level, which suppliers (which customers) to include and which to exclude in the analysis. Second, also influential companies have to be integrated into the value network topology that don't have a direct contractual relationship with the focal company, nor are a customer or a supplier. The resulting balance between feasibility and validity of a value network topology model is difficult to obtain in the face of sudden, erratic changes and low transparency. Figure 1 illustrates the generic value network structure conceptualization that results from these considerations:

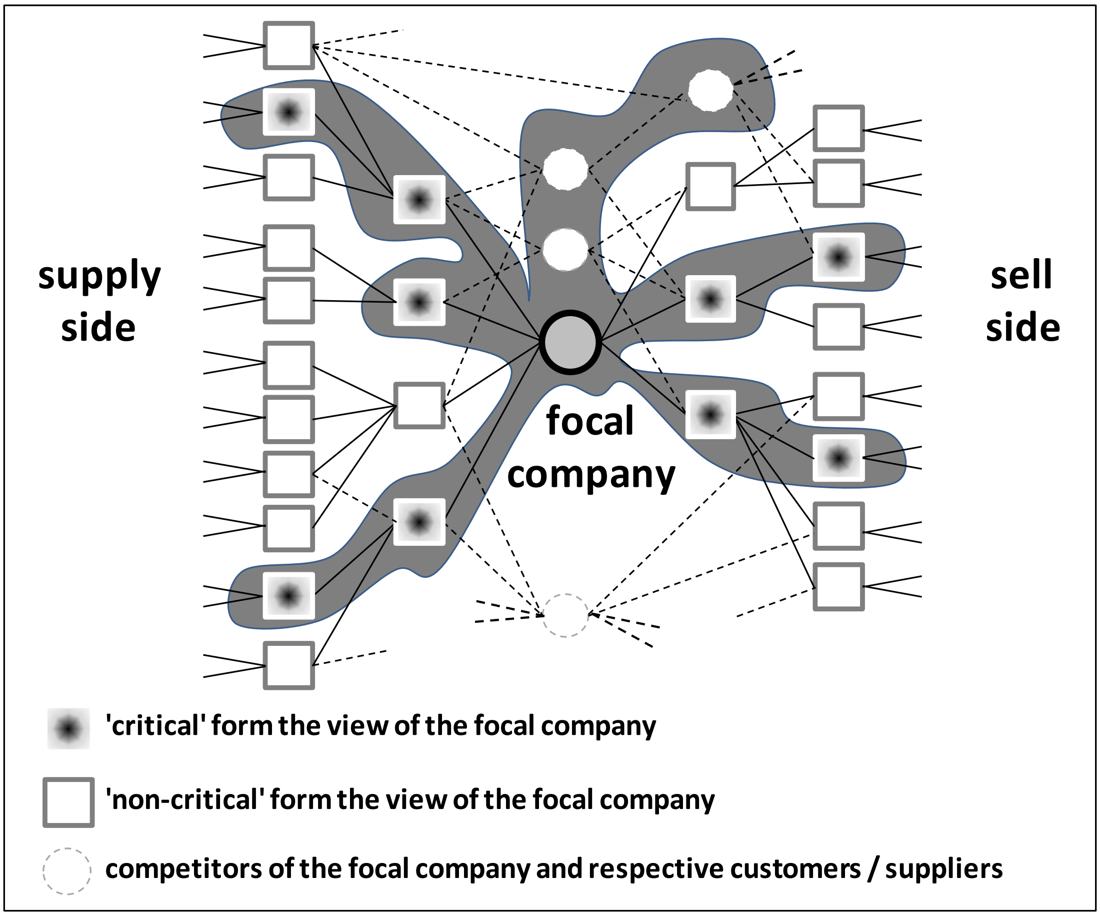


Figure 1: generic value network structure model

The dark grey shaded area indicates the 'critical' network knots and paths from the perspective of the focal company – here three tier$_1$-suppliers, two tier$_2$-suppliers, two tier$_1$-customers and two tier$_2$-customers. Also two competitors and one of the competitor's customers are regarded as critical.

Further, a more detailed inspection of the focal company has to be included in the modeling process: as supply chain management is an internally driven activity, the focal company may not be modeled as a 'black box knot' like all other companies in the modeled system. Figure 2 shows the perspective of the focal company within its value network in detail:

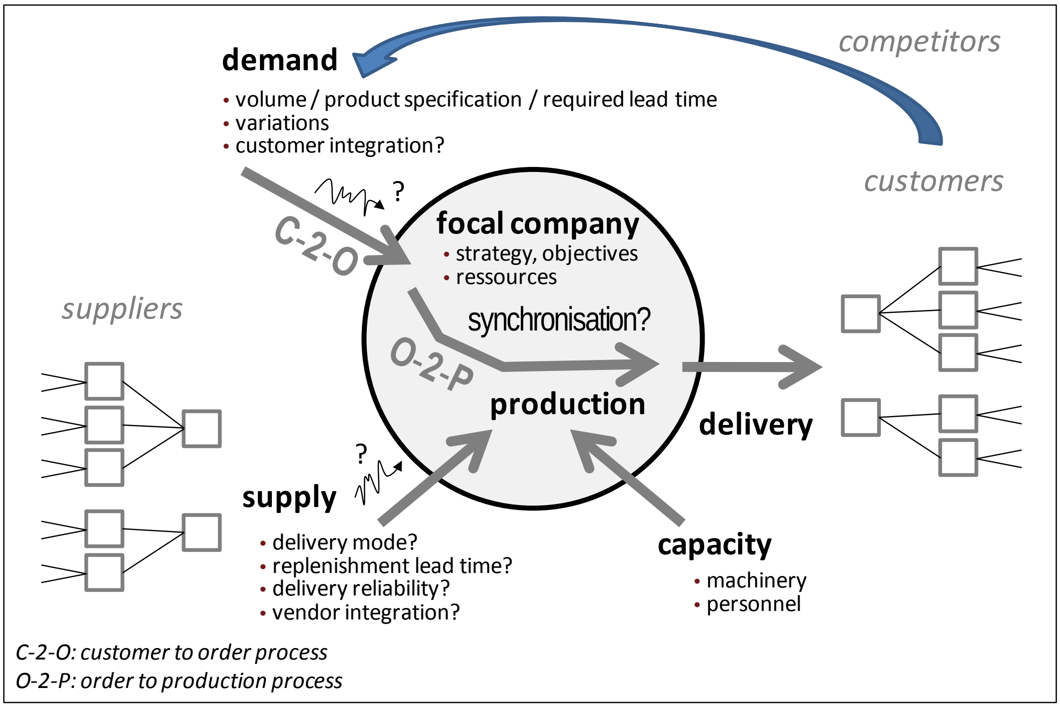


Figure 2: value network integration from the view of the focal company

Value network integration – more often referred to as supply chain integration (e.g., Frankel et al. 2008 or Chen et al. 2009) – has to be understood as the streamlining of a company's operations in service of a proficient customer service (see Fabbe-Costes and Jarre 2009). Thus, in addition to network topology issues, the accommodation velocity of the internal order fulfillment and production capability, together with the delivery capability of the enclosed suppliers, becomes an important matter according to the customer requested lead time and flexibility requirements. Whenever this accommodation velocity is too low to serve changing market requirements, and neither pre-production nor negotiation for delivery postponement is possible, a network knot – either the focal company itself or an associated supplier – becomes a performance bottleneck and therefore critical in the aforementioned sense.

Supply chain management in this regard can be interpreted as a synchronization issue, especially within a customer-specific business that serves a lot of customers with multiple product variants (Thonemann and Bradley 2002), most probably also influenced by competitors that could attract orders at the expense of the focal company's revenue and market share. A distinct coordination challenge will arise particularly, if two conditions occur in coincidence with each other: firstly, the customer requested lead time is shorter than the time required by the focal company to coordinate order fulfillment, parts supply, production and shipment. Secondly, the forecasting horizon is too short to pre-produce finished goods (make-to-order setting).

Taking into account that each company (each network knot in figure 1) has got a different and over time varying influence on other network participants (as exemplarily shown for the focal company in figure 2), a heterarchic system evolves (Ahlert et al. 2009), consisting of actors (companies) with subjectively differing mutual conceptualizations of their business environment. An important conclusion from figure 2 is that a harmonization of processes, interfaces, used technical terms and interpretations is essential in order to jointly advance the value flow performance. This is also supported in the literature. For example, Brock et al. (2005) are claiming flexible, ideally even dynamic means of description in order to enable individual parties to construct their own particular views and to facilitate the interoperability between them. In this regard, logistics theory could provide a beneficial ontological framework (Mentzer et al. 2004). In particular, process modeling techniques are assumed to contribute integrated business rules, processes and organizational enterprise views for this purpose (Presley and Liles 2001). However, the authors in their contribution emphasize lacking capabilities to apply multiple enterprise views as a relevant shortcoming in a cross-company context.

In addition to the fact that standardization is desirable, but nevertheless not widely achieved, a highly fragmented value network topology causes the need of intensive cross-company negotiations, tightly integrated with planning and order fulfillment processes (figure 2) and, therefore, requiring appropriate decision-support. Although, such a supply chain integration is often stated to be favorable in the literature (e.g. Flynn et al. 2010), practical experiences shows that most companies are far from a cross-network term standardization and process integration. At best, certain dyadic vendor-buyer relationships are integrated in such manner.

Altogether, the discussion shows that the issue of figuring out the relevant (‘critical’) network participants on a tier_1 – tier_n level including sell-side, buy-side and potential other influencing companies is a relevant but difficult managerial task. The importance of this matter originates from the force to operate efficiently under rapidly changing conditions and economic performance objectives. In fact, the dark-shaded critical value network area in figure 1 is not a static entity, but will change over time. In many industry sectors, customer-caused changes are occurring ‘overnight’, whereas most vendor- or raw material market-related changes at least can be suspected over weeks, e.g., disadvantageous weather conditions or political disturbances. Usually the accommodation velocity of internal capacity or associated supplier flows is notably lower than market variations. Consequently, Flynn et al. (2010) in their recent study have observed that “internal and customer integration were more strongly related to improving performance than supplier integration” (p. 58).

Difficulties to determine the critical value network issues for managerial intervention are arising from several factors, especially from the high number of network participants, from time restrictions for analysis and measure definition in the face of unpredictable environment changes, from restricted data availability and accuracy and from differing mutual network forces and objectives.

As Christopher and Holweg (2011) have recently summarized, the development of supply chain management and respective models or concepts is rather new and has taken place during a period of comparably high economic stability. For this reason the authors in their paper postulate the capability of a company to develop a structural flexibility regarding the supply chain design as a critical success factor far beyond the bare ability to cope with oscillating customer demands. This emphasizes the claim of the present paper to propose a managerial method that is easy to apply and provides for fast execution to enable repeated, iterative application, nevertheless, carefully regarding the complex nature of value network coherences (Jain 2008).

Regarding the presented value network conceptualization and the discussed need for means to facilitate the identification of critical value network knots or segments, the paper is subsequently structured as follows: the next section introduces and further enhances a supplier network model that encloses two interesting attributes: the ability to represent a specifically configured network topology and the use of vectors to represent a bundle of relevant value network parameters. Besides, a five-step configuration and implementation approach is proposed, to facilitate practical application. The third section subsequently discusses measurement and parameterization issues and presents possible parameter bundles for value network assessment, herewith also discussing thinkable notions of the attribute ‘critical’. The paper finally concludes with an outline on the academic significance, managerial insights and possible limitations of this paper and indicates future research needs.

VECTOR-BASED VALUE NETWORK MODELING

Vector- or matrix-based approaches are widely used in a logistics or value network context within field like operations research (OR). For example, queuing network topics (in particular, optimal topology-, optimal routing-, and optimal resource allocation problems, cp. Kerbache and Smith 2004), or network equilibrium discussions (e.g. Li et al. 2008) are frequently applying graph theory including matrix algebra. Therefore, the idea to represent a system with multiple entities and attributes through the use of a vector-based approach is common, but has – to the best knowledge of the authors – only rarely been proposed for a simplified, more practitioner-capable use as evaluation means. In a company-internal context, for instance, Windt et al. (2008) propose to examine the complexity of a production system using a feature vector due to the multi-facetted nature of complexity. A further example that is already in closer coherence to the context of value network management is a supplier network model proposed by Müssigmann (2007), who has set-up a supplier structure that converges towards the focal company, similar to Lambert et al. (1998), but explicitly excluding the sell-side. This model in its derivative configuration, proposes to apply rather operative key performance figures, such as lead time, cost, delivery reliability or product quality (p. 233ff). Though, sharing the same basic idea, the two exemplarily mentioned approaches show differences regarding the following aspects: whereas Windt et al. assume a vector comparison of two different systems based on an ordinal scale and using one vector only, the Müssigmann model establishes a network structure (knots = companies and edges = co-operative relationships between two companies) and assigns evaluation vectors to each knot and each edge. A further difference is that Müssigmann proposes to also use additional weighting vectors in order to model varying importance of particular parameter values, according to the company-specific situation. Finally, Müssigmann doesn’t restrict his model to a purely ordinal comparison.

Shortly described, the modeling procedure is as follows (Gerschberger et al. 2010): the focal company is used as the starting point (singular root and entry point of the network). Subsequently the supplier flows are assigned building a tree-like structure with clear 1:n relationships. Each tier$_1$ is directly linked to the focal company. Each tier$_2$ is directly linked to a tier$_1$ (and so on). During this first stage of modeling an evaluation vector is assigned to each knot and to each edge that is part of the developed supplier network. Having completed the network topology design, a further evaluation vector is added on a condensed level that is derived through the aggregation of all singular vectors, preferably done through the use of mathematic means (e.g. summation, multiplication,, maximum / minimum calculation or similar). Next, a weighting vector is proposed in order to be able to model a different importance of singular vector values. Finally, a position index can be used for prioritizing certain network segments.

The basic idea of the present paper is, to compile the existing approaches into a comprehensive value network assessment approach that allows for a better identification of critical network locations. Since it will most probably depend on the given business scenario which approach is applicable (e.g. according to the way the used parameters are operationalized and measured and also depending on the available data), this compilation is done in the form of a modular procedural configuration and implementation approach.

Phase 1 – modeling purpose and analysis objectives definition

As the intention to 'identify critical network segments' can be motivated by rather different intentions, as a first step a company has to define its analysis objectives. This could be multiple issues, including supply chain design questions (e.g., regarding the question of the appropriate supplier number, geographical location or structure) and supply chain execution questions (e.g., determining the inevitable, desirable and at the same time affordable amount of flexibility towards short-term order changes).

Phase 2 – determining the model parameters and scale definition

Based on the defined objectives, the model can be parameterized. This is a mainly individual task that depends on the requirements of a specific company or business scenario as well as on enabling factors such as the data acquisition capability. Anyway, our recommendation is to facilitate the parameter determination through appropriate literature, available empiric findings or evidence from (best practice) company projects. A strong relation can be stated between the degree of operationalization, the used metrics, the applicable scales and the later aggregation mode and model applicability.

Phase 3 – iterative network topology building and data acquisition

In the face of a possibly high amount of network participants, it is most important to keep the data acquisition effort as low as possible. Therefore, in a first step, only tier_1 customers and suppliers should be analyzed, according to the defined intentions and using the selected parameters. If applicable, existing segmentation means should be included to save time and effort and to ensure consistency with other logistics issues. In a second and third step, value network participants should be investigated that are not directly contracted to the focal company, in particular, tier_2 suppliers and -customers as well as competitors (or other relevant parties) that have a strong impact on the focal company, regarding the analysis objectives. Since, for these cases the data availability is usually poor, the information asymmetry tends to be high and the number of tier_2 participants is likely to be much higher, compared to tier_1 participants, a careful selection has to be done, regarding the question which network knots to include and respectively exclude during this modeling step. Especially, when applying a quantitative aggregation approach, a sensitivity analysis (according to Poh and Ang 1999 a valuable means for the purposive application of any quantitative decision model) will provide advantageous support: if, for example, the aggregated vector doesn't change much with a singular parameter change for a tier_2 (and respectively a later tier_n), it is not necessary, to include this knot into the further analysis; the respective effort can be prevented in advance. This step is iteratively applied on following tier-levels until sensitivity analyses indicate the end of reasonable analysis. Thus, the dark grey shaded area according to figure 1 could be determined. There are, however, two potential shortfalls that may inhibit the execution of phase 3: firstly, in most cases, the data availability gets worse with an increasing tier-level. Therefore, in theory as many iterative steps might be indicated as appropriate according to the sensitivity analysis; in practice, a bad ratio between benefit and effort might give evidence to finish at a prior stage. Secondly, the described iterative process is kind of “greedy”, comparable to greedy heuristic algorithms, used in the field of operations research: if a tier$_2$-knot indicates to not further examine subsequent steps, still the case might occur that a later knot, surprisingly, implies a high impact on the aggregated vector. A typical practical example for this would be a raw material shortage: even, if, such incident occurs at a tier$_3$ (or higher) level, it can cause huge impacts on the whole network, eventually even touching the end-customer, although, not being indicated as ‘critical’ according to the iterative topology building process. Thus, the here proposed model does not deliver ‘perfect’ results, but may on occasion have to be adjusted manually.

Phase 4 – model validation and verification

Since the basic modeling process is now finalized, subsequently, the question has to be answered, whether the model delivers valid findings that could be used as a base for managerial decisions. The appropriate means to be applied within that step strongly depend on the specific context. Again, a sensitivity analysis could facilitate the evaluation of result robustness towards measurement errors of singular parameters. Since, the model at this stage might already contain a huge amount of parameters, an automated computation is recommended – assuming the use of metrics and scales that are feasible for computation.

Phase 5 – definition of management measures and continuous model application

All analysis efforts are inefficient, if there is no managerial implication. Thus, in phase 5 appropriate optimization measures have to be deduced from the executed value network assessment. In order to best possibly exploit the model benefits, a continuous application cycle should be installed. In particular, this means that a periodic ‘network topology test’ should be done: the assumption that a certain knot is regarded to be critical may change over time, leading to misleading results. As mentioned above, the frequency of such iterations will also depend on the efforts for data acquisition. Figure 3 summarizes the proposed approach:

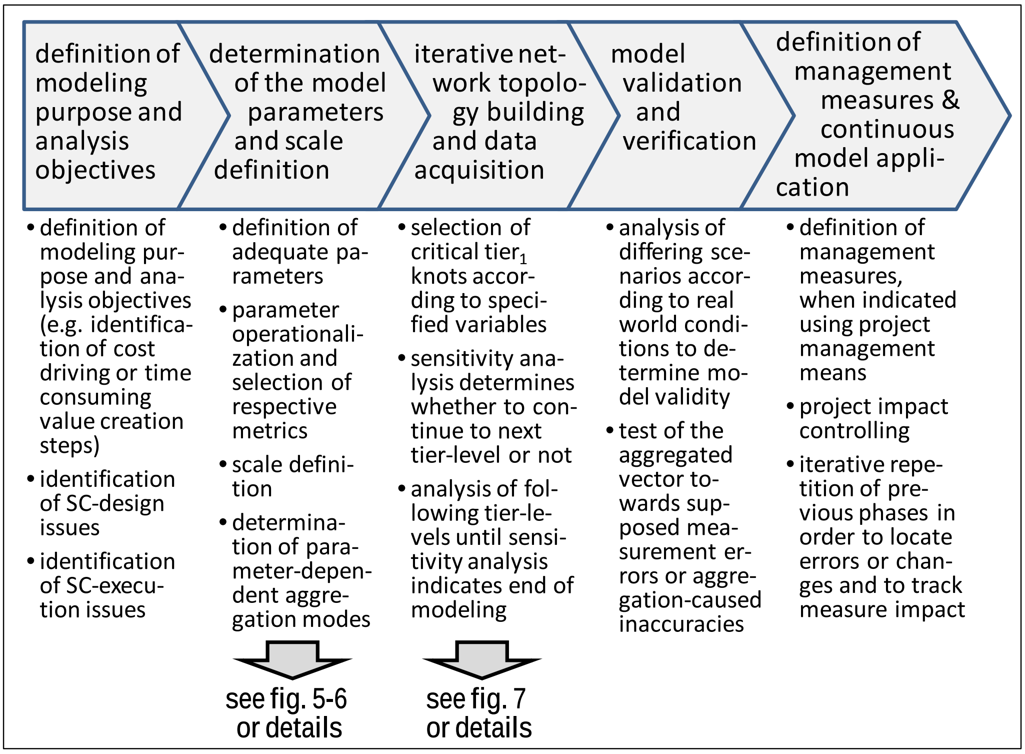


Figure 3: proposed configuration and implementation approach

MEASDSUREMENT AND PARAMETER OPERATIONALISATION ISSUES: THE TRADITIONAL CONTROL-APPROACH VERSUS THE HOLISTIC VIEW OF COMPLEX ADAPTIVE SYSTEMS

Christopher and Towill (2001) have proposed four performance measures as most important in a supply chain management context on a condensed level: quality, cost, lead-time and customer service. More detailed performance measurement issues have been frequently investigated within a meanwhile conceivably huge body of literature that as well encloses comprehensive approaches (for instance, based on the balanced scorecard concept; see exemplarily, Bhagwat and Sharma 2007 or Gunasekaran and Ngai 2009) as the investigation of specific issues (such as, measuring the impact of supply chain management practices; e.g., Li et al. 2005 or performance-based resource allocation in supply networks; cp., Ross 2000) as concretely industry- or company-specific case studies (e.g., Forslund and Jonsson 2007 for the topic of delivery service or Gunasekaran et al. 2000 in a small company setting).

Last recently, Estampe et al. (2010) have reviewed 16 models related to the evaluation of supply chain performance on a tactical and an operational level. This rather exhaustive analysis clearly indicates that respective models and metrics are reliant on a company's supply chain related maturity, herewith shifting the choice of the applicable measurement approach and metrics towards a company-dependent decision. Additional company-specific adjustments will require further specification. However, the individual or case-based metric application that is reported in the literature is manifold and diverse, up to an impermeable degree, inhibiting an exhaustive or at least representative review. In addition to that, data availability and the capability of currently used IT-systems are absolutely company-specific conditions that are further determining the ability to measure the operational performance. For those reasons, the present paper follows the proposition of

Christopher and Towill (2001), grounding performance considerations on the four basic categories quality, cost, lead-time and customer service, thus leaving it on a company’s disposal to further particularize, extend or weight these measures individually if required.

An important strategic decision regards the positioning of the decoupling point (see Olhager 2010 or cp. Sun et al. 2008 regarding multiple decoupling points in a network), since a company should align its operations differently before (make-to-stock orientation) and after (make-to-order orientation) this point, in each case defining other objectives. Subsequently, also the parameters used in a model that intends to identify critical value network segments have to be set-up accordingly. If, for instance, a company purchases an expensive part individually for a certain customer and with low chance to use or sell it elsewhere, the supply flow has to be well-timed and reliable in order to allow for a short storage period, low capital lockup and inventory risk nevertheless avoiding stock-outs. In this case, unexpected demand fluctuations can seriously threaten the company performance. Contrary to that, a low-prized commodity part could be scheduled less elaborate and hedged through safety stocks.

In addition to the previously discussed selection of performance metrics, further arguments have to be considered in current turbulent market conditions: it can be assumed that variability, especially regarding demand changes, causes disadvantageous effects on cost, delivery reliability and capacity utilization (Christopher and Holweg 2011). This impact is further worsened, if accompanied by unpredictability and uncertainty regarding the decision parameters (see e.g., Agarwal et al. 2006). Variability and uncertainty, and the frequently recommended ‘company answer’ for these issues, flexibility, have been extensively researched. In this regard, Agarwal et al. (2006) have developed a framework for the analysis of variables that are affecting supply chain performance related variables, justified through extensive literature research, expert interviews and the use of the Analytic Network Process technique (ANP) for evaluating the influence of multiple dimensions on supply chain objectives. In doing so, the authors specified four supply chain performance dimensions, in particular “market sensitiveness”, “process integration”, “information driver” and “flexibility” (p. 215). Although, the objectives of this research were clearly different from the objectives of the present paper, the underlying framework can also be used as an initial point here, though, not as an independent framework, but assigned to the value network conceptualization that has been explained in the figures 1 and 2. Figure 4 visualizes this transfer consideration:

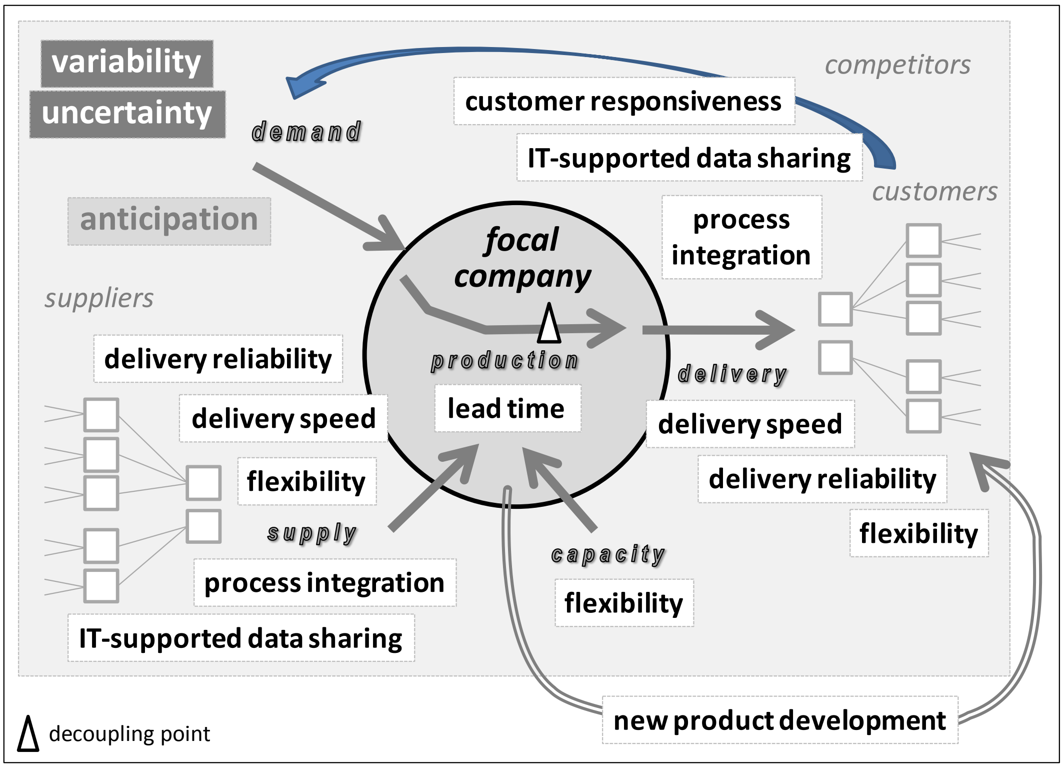


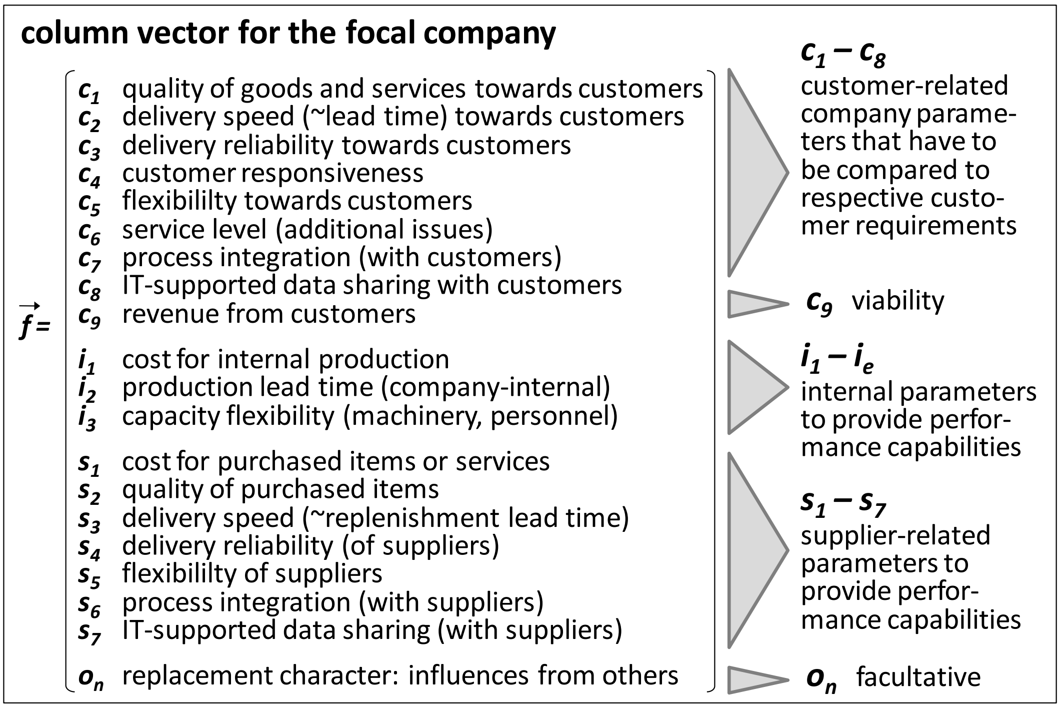
Figure 4: dimensions to assess value networks in turbulent environments

Depending on the degree of variability and uncertainty (partially reducible, using anticipation means, such as prognosis and forecasting), a total of 14 dimensions was selected to be used for the purpose of model parameterization within the vector model that was introduced above. These 14 dimensions are clearly assigned to the three generic categories buy-side, company-internal production, and sell-side:

- *sell side*: customer responsiveness, delivery reliability, delivery speed (~replenishment lead time), flexibility, process integration and the maturity of IT-supported data sharing
- *buy side*: delivery reliability, delivery speed (~replenishment lead time), flexibility, process integration and the maturity of IT-supported data sharing
- *company-internal*: lead time and flexibility of the installed capacity

One additional dimension could not be assigned to these categories and, thus, was positioned outside of the applied scope: the development of new products introduction and development time. It depends on the analysis purpose, whether to include or exclude this parameter; is there a clear supply chain execution or optimization focus, in most cases, it will not have to be regarded. In contrast a value network assessment on a long-term strategic level, might evaluate this parameter with high priority, indicating the innovative potential of a company and its network partners.

In contrast to the framework that has been proposed in Agarwal et al. (2006), the present paper applies a network view. Therefore, the dimensions, though in principle taken as proposed in this contribution, have to be sorted according to the three generic categories also for the purpose of vector definition. The variable ‘revenue’ ($\boldsymbol{c}_9$) is additionally appended, in order to represent a company’s overall viability and economic position. Assuming these coherences as a valid option to assess critical network constituents, the aggregated column vector for the focal company could be constructed as follows (cp. also phase 2 in fig. 3):


column vector for the focal company

$\vec{f}=$

c_1 quality of goods and services towards customers
c_2 delivery speed (~lead time) towards customers
c_3 delivery reliability towards customers
c_4 customer responsiveness
c_5 flexibililty towards customers
c_6 service level (additional issues)
c_7 process integration (with customers)
c_8 IT-supported data sharing with customers
c_9 revenue from customers

i_1 cost for internal production
i_2 production lead time (company-internal)
i_3 capacity flexibility (machinery, personnel)

s_1 cost for purchased items or services
s_2 quality of purchased items
s_3 delivery speed (~replenishment lead time)
s_4 delivery reliability (of suppliers)
s_5 flexibililty of suppliers
s_6 process integration (with suppliers)
s_7 IT-supported data sharing (with suppliers)

o_n replacement character: influences from others

$c_1 - c_8$ customer-related company parameters that have to be compared to respective customer requirements

c_9 viability

$i_1 - i_e$ internal parameters to provide performance capabilities

$s_1 - s_7$ supplier-related parameters to provide performance capabilities

o_n facultative

Figure 5: exemplary definition of the aggregated column vector for the focal company

If required, the single parameters $\boldsymbol{c_n}$, $\boldsymbol{i_n}$ and $\boldsymbol{s_n}$ could also be weighted according to their relative relevance for a company's business conditions. The parameters $\boldsymbol{o_n}$ are facultative, in case a company has to respect other critical influences, e.g., from competitors, political institutions or legal authorities that are not directly impacting the other parameters, but nevertheless have to be taken into account. Similarly, the issue of new product launching could be included with an additional parameter set $\boldsymbol{n_n}$. Besides, a company can anytime modify or extend this vector, in order to achieve a more representative conceptualization of the individual business environment. Also, further simplification is possible for the case of insufficient data availability, however, at the expense of result validity, if critical issues have to be neglected. As figure 6 shows, the aggregated vector is determined through three different streams of variables that have to be aggregated across the value network. Whereas internal variables ($\boldsymbol{i_n}$) can be surveyed in the company itself, e.g., using the existing IT-systems, the influences from customers ($\boldsymbol{c_n}$) and suppliers ($\boldsymbol{s_n}$) have to be assessed according to data that is retrieved from external sources.

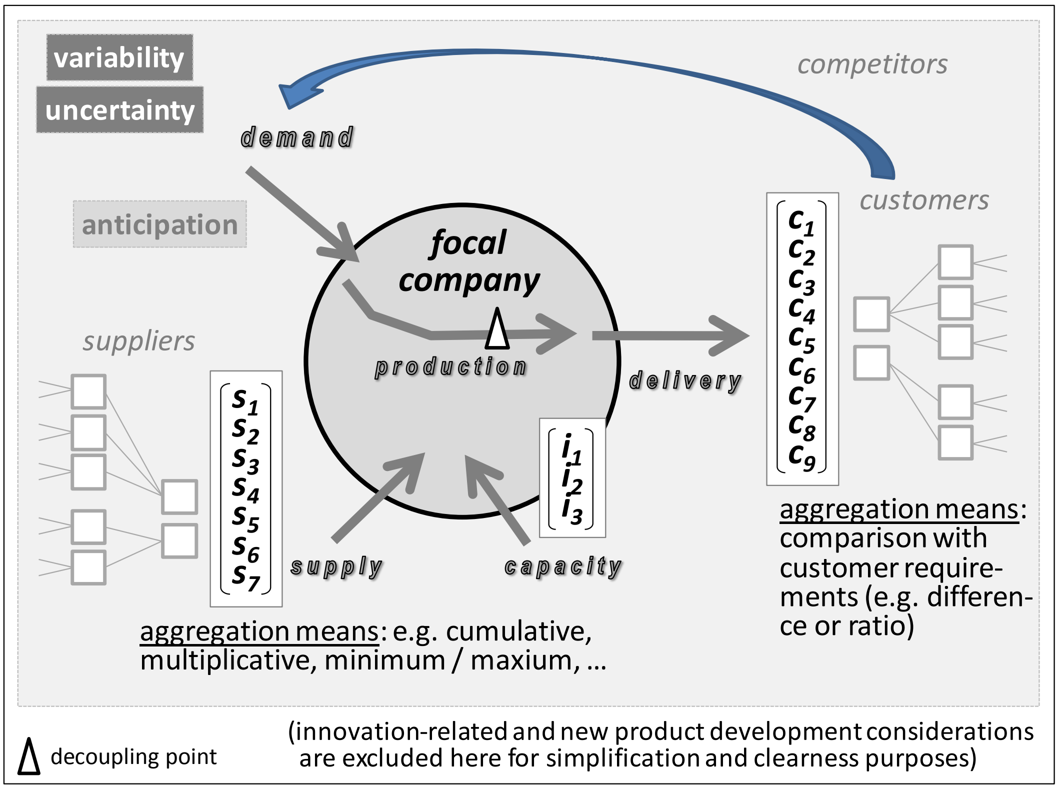


Figure 6: assignment of parameters to categories (inbound – internal – outbound)

In particular, the procedure to evaluate a company's customers according to the variables c_n, can be closely assigned to existing customer segmentation approaches. Methods that are widely used anyway, such as for instance, ABC- or XYZ-classification or portfolios for customer assessment, can be also applied to execute this evaluation, however, with extended parameters (c_n). In this regard, it is most important to operationalize the included variables in a way that allows for a later comparison between customer requirements and the focal company's performance capabilities. This comparability is easy to achieve for quantifiable indicators, such as 'delivery speed', 'delivery reliability' or 'quality'. Other variables, e.g., 'customer responsiveness' or 'process integration' must be subjected to elaborate scale development, for example, using scoring schemes or similar. Whenever possible, metrics such as the coefficient of variation advantage should be used, since they are normalized and scale-free, therefore allowing for a comparison of influence factors from heterogeneous nature (Christopher and Holweg 2011). Finally, the results of the comparison between customer requirements and realized performance can be mathematically aggregated into the column vector for the focal company ($\vec{f}$).

A similar situation regarding metrics definition and data acquisition applies for the supplier-related variables (s_n). As also supplier evaluation approaches are wide-spread in theory and practice, the access to appropriate assessment data should be good in principle. Scale development issues that have come up at the customer side, have to be respectively regarded, also at the supplier side, to ensure a consistent cross-network consolidation (e.g., for variables such as 'process integration'). The main difference regarding the final vector $\vec{f}$ compared to the customer-related variables is the calculation mode: here, an aggregation (e.g., cumulative, multiplicative, maximum or minimum determination) has to be done, instead of a comparison between customer requirements and company capabilities.

The measurement and aggregation of company-internal variables ($\boldsymbol{i_n}$) follows different principles: whereas cost issues have to be summed up together with supplier-related cost to calculate the total amount of costs, lead time- and replenishment lead time issues have to respect bottlenecks and task parallelization in order to figure out the total lead time that is needed within supply flows and production processes in total. Since, the underlying logistic coherences are following existing laws of production logistics and queuing theory (e.g., the coherences between lead time, capacity, utilization and cost), respective formulas will have to be applied for figure aggregation. In most cases, a company will be able to retrieve the required data from the installed ERP-system.

Altogether, three calculation streams are resulting that are finally influencing the column vector of the focal company $\vec{f}$ from customer-side, internal conditions and supply-side. Figure 7 illustrates the aggregation:

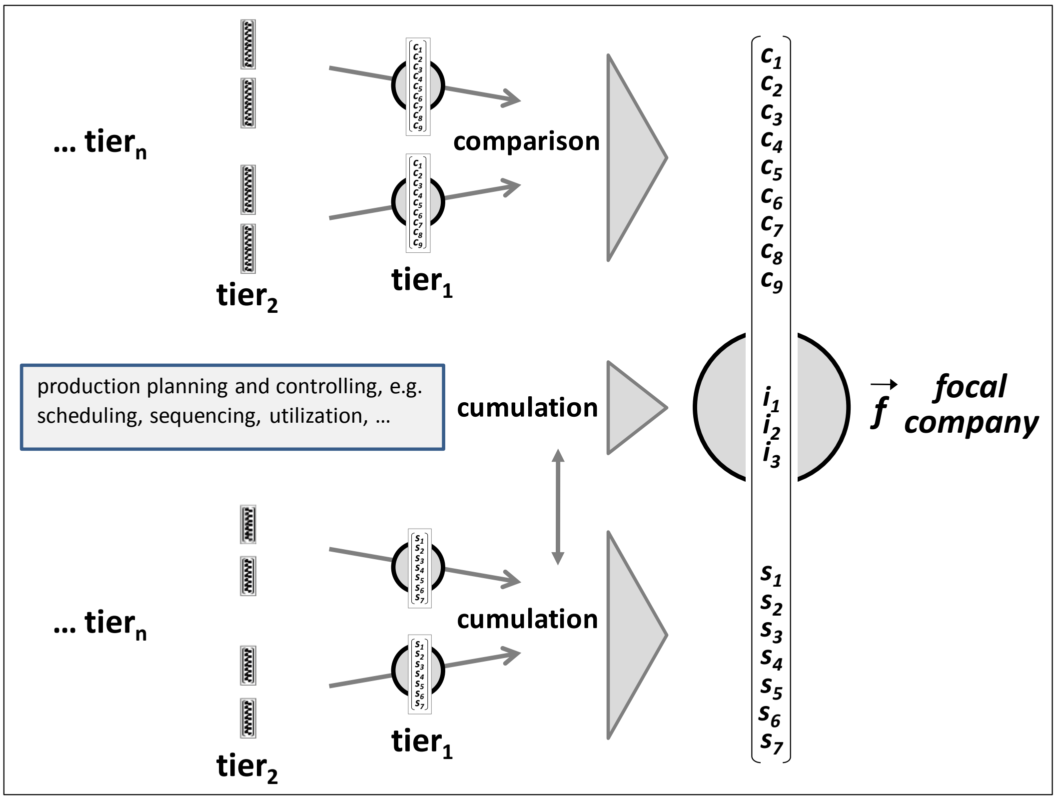


Figure 7: calculation of the column vector for the focal company

Thus calculating all three constituents of the aggregated vector $\vec{f}$, the tier$_1$ customers and suppliers can be distinguished into ‘relevant’ (=’critical’) and ‘not relevant’ (=’non-critical’). As the next step is now, to additionally model the relevant tier$_2$ – tier$_n$ network segments, a sensitivity analysis has to identify these tier$_1$-knots, that are modified through the behavior of previous tier$_2$-knots to an extent that remarkably influences the values of the aggregated vector $\vec{f}$. In doing so, the respective aggregation means have to be applied analogously on each tier-level to obtain aggregation consistency, although, sometimes in practice, lacking data availability might cause the necessity to use approximations. Though, a broad practical model application has not yet been done, we assume a more difficult modeling process under the following circumstances: a rise of the total amount of critical edges and knots across the entire modeled network in general, as well as an increasing number of $tier_2$ – $tier_n$ edges and knots, in particular (indicating a missing contractual relationship with the focal company and therefore difficult data access).

Summarizing the results of this chapter so far, a generic set of parameters to identify critical value network locations has been proposed and operationalized, together with a corresponding procedural approach. As mentioned above, the variables to be calculated during the configuration of singular vectors may have to be modified. Also, further vectors might be included, e.g., to weight single knots against others, regarding their relevancy for the aggregated vector $\vec{f}$ or to assign evaluation vectors also to edges, not only to knots.

CONTROLLABILITY VERSUS SELF-ORGANIZATION – HOW TO USE PARTIAL ANALYSIS APPROACHES WITHIN TURBULENT MARKET ENVIRONMENTS

Prior to practical model implementation, a further general measurement issue has to be discussed that is in particular important in the absence of stability. In principle, there are two central paradigms for the assessment of value networks that have to be clearly distinguished from each other (see e.g. Hodgson 2000, Christopher and Holweg 2011): the traditional, mechanistic reductionist and ‘control’ approach versus the holistic view that assumes a value network to be a complex adaptive system (CAS).

The traditional approach towards variability is, to best possibly predict and smooth occurring turbulences. Respective management concepts (e.g., vendor managed inventory or collaborative planning approaches, e.g. Holweg et al. 2005 or order-smoothing, e.g., Balakrishnan et al. 2004), try to improve information availability and value network transparency (Christopher and Holweg 2011) in order to achieve a better controllability. As Christopher and Holweg state for supply chains that are exposed to remarkable turbulence, and also from a CAS point of view (Hodgson 2000), this kind of control-based managerial interventions can be counterproductive in volatile environment, due to an inopportune degree of rigidity within the network structure and the corresponding interactions. As a consequence of lacking predictability and controllability, respective management attempts are often causing frustration, if applied to dynamic and complex networks, especially. if the (even more intransparent and less influenceable) $tier_2$ and $tier_3$ participants have a remarkable impact on the focal company (Choi et al. 2001). If, the here proposed model is applied in a reductionist setting, a similar frustration is most likely to occur, due to the reason that given incomplete information and high volatility the chance is low to achieve a “perfect” perception of the critical network settings under certain business conditions.

In contrast to controllability-oriented thinking, last recently approaches from the theory of complex systems or from the field of CAS and related disciplines have experienced a rising interest, also, in the field of logistic and value network management (e.g., Anderson 1999, Manson 2001, Bar-Yam 2003, Surana et al. 2005, Tielebein 2006, Shahabi and Banaei-Kashani 2007). In congruence with other authors, e.g., Surana et al. (2005) are enforcing the study of CAS in order to identify commonalities among complex systems (e.g., investigating biology, physics, chemistry, but also social systems or ecology) and to better understand respective laws of nature. Surana et al. recommend the application of CAS concepts to characterize and model supply-chain networks. Also, decentralized approaches, e.g., the theory of loosely coupled systems (Orton and Weick 1990), have gained attention. Major issues in this regard are the huge number of inter-dependencies between network participants, the often non-linear nature of developments within the network and the occurrence of self-organizing behavior. As a complex system is also adaptive, if the system elements change their behavior subsequently to events that arise from the interaction of elements in a self-organizing manner, a value network can be regarded to be a CAS. A main difference to mechanistic thinking is that “the whole determines the parts, and that these and their relations are defined in relation to the whole” (Tarride and Zuniga 2010, p. 1116). According to CAS-principles, decisions and developments will often depend on the prior progression and the actual situation of each individual company. Also, unexpected developments may occur that are not necessarily caused by external impacts, but can emerge as an inherent part of the internal system behavior (Hodgson 2000, Choi et al. 2001). Therefore, Surana et al. conclude that “managers must appropriately balance how much to control, and how much to let emerge” (p. 4236), a claim that complicates managerial intervention.

The two mentioned perspectives are remarkably different: whereas reductionism intends to simplify a coherency through the application of general laws, based on the assumption of linear causalities and supposing a given external controllability, a holistic, CAS-oriented approach, sets a stronger focus to the relations of a system, also regarding circular causalities (Tarride and Zuniga 2010). The main difference compared to mechanistic approaches, originates from the fact that the mentioned emergent nature is not reducible to the characteristics of the network elements (Hodgson 2000). Therefore, emergence phenomena can be explained ex post, but are not predictable ex ante. Thus, even the most accurate and valid partial analysis can’t cover more than an actual snapshot – eventually valid during a longer period, but possibly ‘expired’ unexpectedly. If applicable, a continuously repeated application could enable the necessary course corrections, given the presumption that data acquisition and computational efforts are kept respectively low.

Consolidating the mentioned arguments – the diversity and the singular nature of measurement issues and metrics definition, and the two contrary approaches within reductionism and holistic system thinking – our conclusion is as follows: partial reductionist analysis has its significance and is inevitable, despite incidental limitations regarding the accuracy of initial assumptions, the result validity and the practical applicability. However, a manager must be aware of the fact that the insights gained from the application of such means are an actual and eventually fuzzy or misleading snap-shot that may be unfeasible the day after.

CONCLUSION

Shortly summarized, the argument of the present paper is that current turbulent business environments are demanding for a consequent concentration of managerial efforts on the most critical network segments that are exposed to constant change. Since, an exhaustive value network analysis or assessment is merely possible, a means is required, to conduct respective partial analyses upon these critical network locations. To serve changing conditions, a corresponding method must provide for fast execution and frequent, repeated application. In the course of identifying critical network areas (a procedural approach that may also be referred to as ‘network boundary spanning’), the underlying network topology is important: as many knots as possible should be excluded from in-depth analysis to minimize efforts. Nevertheless, all relevant impacts on the focal company’s business should be respected, even, when occurring at a tier-level 2 and further. Altogether, a value network is a complex adaptive system of heterarchic nature. Although, the smooth integration of network participants based on common standards is claimed as desirable, the given reality rather shows heterogeneous individual companies that are on occasion enforcing certain dyadic buyer-vendor relationships.

In this regard, the attribute ‘critical’ applies to multifaceted dimensions that have been discussed in detail above. According to changing environment conditions, also the criticality of a network segment may change anytime. Major attention should be paid to the obtainable accommodation velocity of the internal order fulfillment and associated supplier performance capabilities compared to the customer requested flexibility, here regarded as the ‘synchronizing function’ of value network management.

Thus, the objective of the present paper was to propose a conceptual model together with a respective managerial method that facilitates the quick and nevertheless adequate identification of ‘critical’ value network locations (in other words a proficient value network boundary spanning). In order to enable the representation of multiple dimensions, a vector-based approach was used, further extending two existing approaches (in particular, Windt et al. 2008) and Müssigmann 2007), here, extended through a five-step configuration and implementation approach.

Next, basic parameters for the aggregated vector as well for its single variables and the associated network aggregation process were proposed. According to the nature of measurement in turbulent environments, the differences between a reductionist and a holistic application approach were discussed shortly.

Altogether, the resulting model and method provides as well the ability to model individual network topologies as the parameterization with multiple dimensions to indicate criticality.

Possible limitations are resulting from two major issues: firstly, this approach has not yet been broadly validated in practical use; an currently ongoing case study will provide professional industry implementation and most probably yield into advances regarding the model, the parameter proposals and the procedural configuration and implementation approach. Secondly, the selection of parameter values for the vector $\vec{f}$ and subsequent partial vectors could be discussed divergently. This indicates future research needs. Therefore, as a next step a prototypic model implementation and validation is planned in the research team, in order to further advance the results that have been achieved so far.

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