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Modelling Complex Planning Processes in Supply Chains

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Martin Wallner, Uwe Brunner and Helmut Zsifkovits

Modelling Complex Planning Processes in Supply Chains



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Demand planning has become a key issue for the performance of supply chains. However, the right quantity is dependent on many factors. Besides market influences, like changing demands, there are also inner-company variables such as the availability of resources. Decision makers often lack a clear picture of what influences their decisions and perceive a state of complexity.

There are several theoretical models for managing complexity, but they are not designed to identify the complexity in demand planning. The aim of this paper is to establish a methodology for visualizing and reducing the complexity in the demand planning process.

The first result is a model for visualizing the complexity in the planning process. The model shows the factors which influence planned quantities in a chronological order, and, makes cause-effect relations regarding time, responsibility and system support visible.

The second result is a structured compilation of methods and tools to actively influence the complexity in the demand planning process. The identified approaches are either assigned to complexity design – reducing complexity by simplifying the supply chain – or complexity control – reducing complexity by decreasing the uncertainty in planning.

Keywords: Complexity Management, Demand Planning, Supply Chain Management, Visualizing Complexity

1 Complexity in Supply Chains

Within the last decades, markets for products and services have undergone profound changes. New product features and design variations have increased the variety of offers visible on traditional and electronic markets. Sophisticated technologies have driven the need for specialization and thus, the division of work. Supply chains have come to span more players in the processes of value creation, with a need for more coordination, and they have become more globally connected.

Links between businesses have changed from simple transactions to much more sophisticated collaborative relationships. Suppliers are becoming strategic partners who are fully integrated in their customers' development. Processes cross company borders and thus have to connect technology and people in multiple enterprises.

The reasons for the growing complexity of products, structures and processes are manifold. From a demand perspective, heterogeneous customer preferences, variety-seeking and transaction cost minimizing efforts drive the complexity of market offers. From a supply-side view, the trend towards more complexity is motivated by technology innovation, globalization, and the attempt of keeping new entrants out of the market.

We will not discuss whether a certain degree of variety is efficient or useful. The question whether there can be too much choice in buying or other decision processes is investigated by Iyengar (2011), among others. Here, we take the present complexity on markets, within and between enterprises as a fact.

The large and steadily increasing variety of product offers and the resulting complexity of organizational structures and processes pose strong challenges on the effective planning and control of supply chains.

The majority of businesses is suffering from the complexity, not only in terms of technical complexity of the products and the variety of products offered, but also in terms of internal processes, organizational structures and production facilities. As an example, a large-series manufacturer of high-tech products needs more than 40 different process chains to ensure the material supply to a production area.

This diversity is expensive and neither wanted nor documented in the process standards; it has simply grown over time. This results in production processes with different manufacturing technologies and orders, fluctuating production times, complex provisioning processes and sophisticated internal and external control requirements. Mastering the complexity of the supply and manufacturing processes is the key challenge to internal operations and supply chains. Due to its interdisciplinary nature, logistics in many cases has to deal with the effects of increased complexity, without being able to influence their causes directly.

Variant management is aiming to manage and control diversity in products and processes. This means to reduce the company's internal diversity which is a cost driver, while increasing external diversity which creates customer value. Variant-related costs are a significant portion of "complexity costs". The methods of variant management are aimed at prevention, control and reduction of diversity.

Complexity has monetary and non-monetary consequences on all processes, in all phases of the product lifecycle. The following table gives an

overview of the effects of increased variety on development, procurement, manufacturing, sales and service processes. Some of these occur in the product market cycle (i.e. from product introduction to product phase-out), but also the effects in the pre-market and after-market phase have to be taken into account.

Higher product variety increases costs in all these phases. This increase often cannot be fully compensated via higher sales prices. So, there should be a methodological approach to all the planning and control processes of logistics in order to handle complexity, aiming to improve efficiency and eliminate waste of any kind.

Table 1 Effects of higher product variety on supply chain processes

	Before	Market Cycle	After
Development	Additional engineering drawings, BOMs, tests	Adaptation of variants due to engineering changes	Data cleaning
Procurement	Additional suppliers, selection processes	Reduced order quantities Loss of price reduction	Phase-out planning
Manufacturing	Additional tools Additional work schedules	More complex manufacturing control	Equipment/ tools disposal

	Before	Market Cycle	After
		Increased setup times Higher inventory levels (WIP) Quality control	
Sales	Staff training More sophisticated pricing	Higher inventory levels (finished goods) Higher frequency of errors in order management	Phase-out planning
Service	Service documentation Staff training	Lower customer satisfaction („Fix-it-right-first-time rate“)	Provision of spare parts over 5 to 10 years

2 Complexity Drivers in a Supply Chain

Regarding the need for a methodology to manage complexity in demand planning, certain complexity drivers within a supply chain lead to planning problems. In order to provide a more structured approach, the complexity

drivers are divided into internal and external complexity drivers influencing the demand planning process.

Based on a literature research, the drivers were categorized after the aforementioned structure. This was done in case internal complexity drivers could be compared with structural complexity drivers (Denk/Pfneissl, 2009, p.22 and Kirchhof, 2003, p.62-64) and external complexity drivers could be transferred from economic trends and challenges (Brunner/Schweiger, 2014, p.308), which are connected to supply chain management.

For a common understanding of the complexity drivers and their influence on demand planning it is necessary to discuss them in detail. To support managers, this section also provides an evaluation of the complexity driver's relative influence.

2.1 Internal Complexity Drivers

Internal complexity drivers can directly be influenced from the company. The complexity roots in the various operations that support the business model. The most apparent internal drivers are outlined in the following table.

Table 2 Internal complexity drivers

Segment	Complexity driver
Product/Customer structure	Lot sizes
	Customer structure
	Production structure
	Brand policy

Segment	Complexity driver
Supplier structure	Number of suppliers
	Value added depth
	Supplier contracts
Organization	Supply chain responsibility
	Organizational structure
	Process structures

2.1.1 Product/Customer Structure

Lot sizes are extremely relevant for demand planning. Nearly every industrial enterprise tries to optimize lot sizes in production and along the supply chain and that causes a long-term goal conflict between production and sales managers. An integrated, but independent logistics department could try to balance the different objectives in their role as production planners. In addition to lot sizes, the customer structure itself influences the demand planning process. The more customers you have, the more orders you need; the smaller order sizes there are, the more complex is the demand planning process. This also interferes with the product structure, when standardized mass products could be planned more clearly than individualized products in a serial or single-item production (production structure). Moreover, the brand policy of a company could indirectly influence demand planning. If more brands need to succeed on the market, there is a wider range of products (materials/articles) – each requiring individual management.

2.1.2 Supplier Structure

Demand planning is not only focused on the customer side of the supply chain, it also correlates with supplier aspects. The more suppliers a company has, the more consideration must be given towards different delivery dates and differences in quality. Companies with a deeper value-added depth can more easily plan their production, because they merely have to coordinate internal suppliers and do not require a multitude of external suppliers for a lot of items, which must be purchased. Additionally, some standardized supplier contracts for material supply could give a company an opportunity to decrease the complexity in planning.

2.1.3 Organization

First it is important to know who is really responsible for the logistics processes. The main issue is, if there is a Supply Chain Manager with an overall responsibility for all logistics processes. Only an overall responsibility of the supply chain processes in a company could lead to excellence in supply chain and demand planning. In practice some companies have developed their former transport or logistics departments into real supply chain departments. For example, there are companies, in which the production department as part of the general supply chain reports to the supply chain department. This possibly represents the future of organizational integration. And this leads to optimized processes with an ideal process structure. However, no company can possibly perfect all processes, and, hence continuous improvement has to be implemented.

Table 3 External complexity drivers

Segment	Complexity driver
Market	Price fluctuations
	Demand fluctuations
	Urbanization
Optimization needs	Lead time variances in SC
	Stock level vs availability
	Appropriate IT for planning

2.2 External Complexity Drivers

External complexity drivers root in market dynamics and can only be indirectly influenced by a company. The table below contains the most apparent drivers.

2.2.1 Market

The market is the most important complexity area regarding the field of demand planning. Demand fluctuations are very common in economically and politically uncertain periods, the reasons for which are manifold and diverse. One such reason could be price fluctuations on the market itself. There are products which are more price sensitive than others. As an example from the field of logistics, the prices for diesel in recent years have shown that price fluctuation only has a minimum impact on the current

consumption for trucks and vehicles, because they are needed, and equivalent alternatives in terms of cost and availability were rare. Other examples show that there are products with more sensitive market reactions. And also other factors than price may lead to demand fluctuations. The construction industry provides yet a further example. If there is an economic crisis and the government must save money, public spending will decrease with a parallel strong impact on the construction business.

Urbanization as a global megatrend influences the demand situation. Future city centers will be places to live and work at the same time. This will have a big impact on supply strategies. Companies need to adapt their city logistics concepts.

2.2.2 Optimization Needs

The last subset of complexity drivers deals with the extended needs for optimization in the last years. Companies were forced to decrease their stock levels although the lead time variances in the supply of a company were still high. This happens especially due to high imports of products from countries with lower salary costs, mainly situated in Asia. A company therefore has to decide about the appropriate stock levels to be available on the market. Customers very easily intend to change the supplier or source.

The last aspect of external complexity is found in corporate IT systems. The main issue is to check, if the "appropriate" IT systems are used for the demand planning. There are a lot of systems available on the market, but not every system is ideal for planning. In business there are a lot of examples, in which complex planning situations are covered via an isolated Microsoft

Excel toolset. Excel in general could be an excellent tool, but not in the case of complex planning.

2.3 Evaluation of Influence

All these factors are generally important for a company, yet all companies are unique and therefore the complexity drivers must be evaluated by the respective management team. To see how strongly the complexity drivers could influence demand planning, an expert group has conducted a neutral evaluation to give managers an indication of their relative influence (see figure below).

Regarding internal complexity "Production structure", "Lot sizes", "Value-added depth" and "Customer structure" are the main complexity drivers. These factors are closely related to the product and the general business model of the enterprise in question.

For the external complexity "Price fluctuation", "Demand fluctuation", "Stock level vs availability" and "Appropriate IT for planning" are the main complexity drivers. These are factors which are mainly driven by the market and its uncertainty.

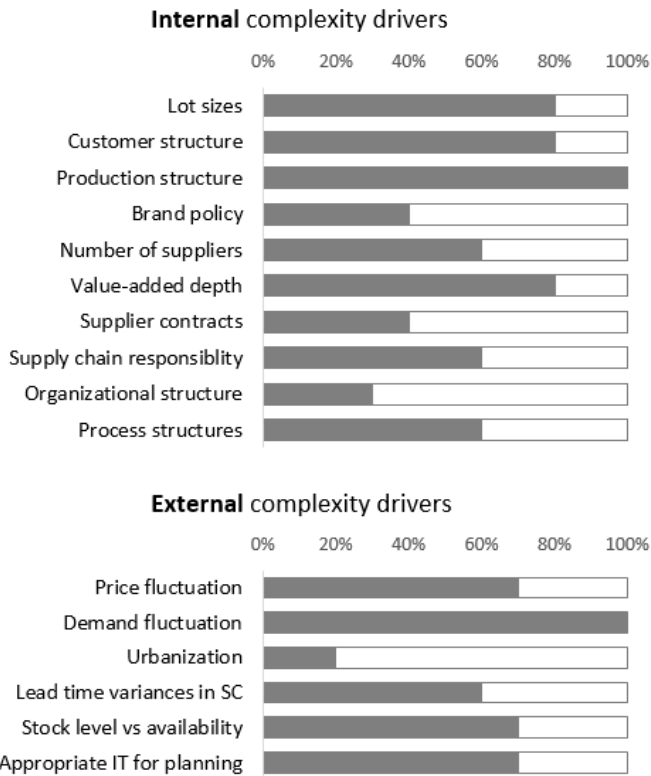


Figure 1 Evaluation of complexity drivers (relative influence)

Having clarified the root causes for complexity in demand planning processes the next chapter will provide a methodology to make this complexity visible, and consequently manageable.

3 Visualizing Complexity

Through visualization the complexity of a planning problem becomes understandable for the decision-making managers (Schwinghammer, 2011, p.112). Thus, gathering the required information to feed a model is often the first step in reducing the (perceived) complexity (Meyer, 2007, p.35). This chapter will explain the logic of building the model.

3.1 Methodology and Model

The model in figure 2 is designed to visualize the complexity in a demand planning process, but can identically be applied to other processes. The layout is based on the precedence diagram method (PDM). PDM connects activities and events in processes in chronological order and also reflects on the relationship of activities (Leutert, 2007, p.24-26). There could be arrows indicating variants to a path, for example.

In detail, the model shows the flow of decision-making processes. The vertical axis (from left to right) represents the chronology of the process split into planning phases (columns), each containing one or more decisions. The horizontal axis (from top to down) contains information that is relevant for decision-making.

The grid system enables the allocation of decisions to mutually exclusive planning phases. Decisions are either in sequence or happen simultaneously, there are no overlaps. The coordinates help reference identified potentials for improvement. The markers (e.g. "1") highlight the parts of the model that will be explained in detail.

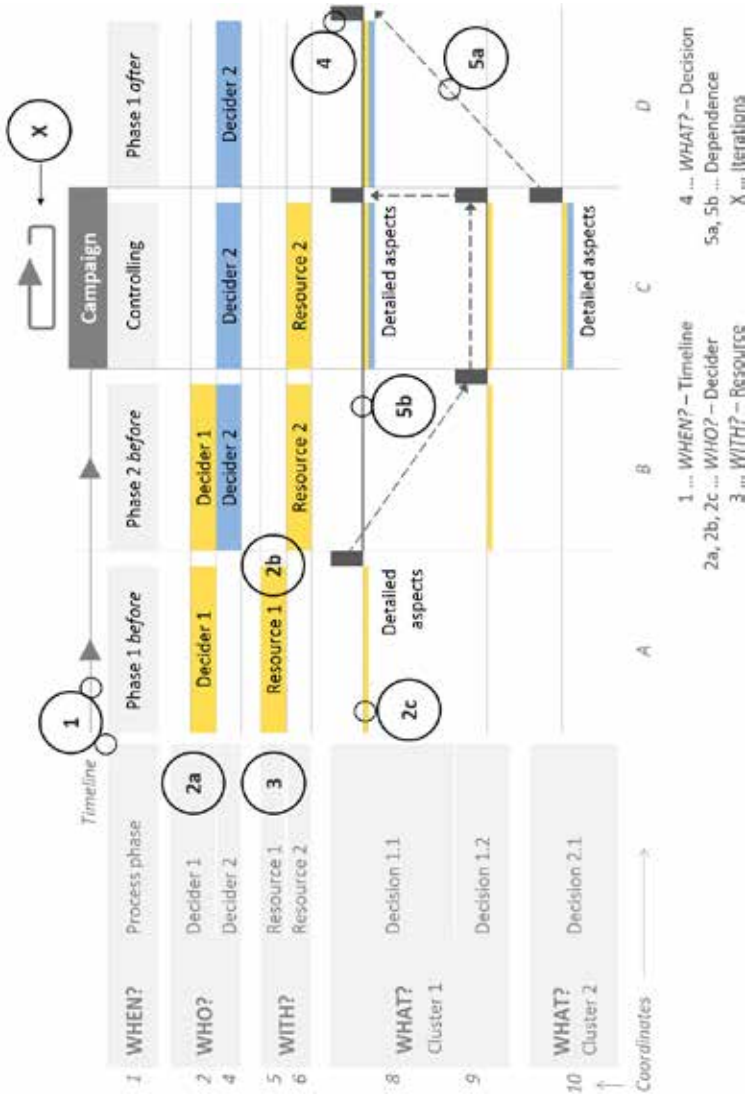


Figure 2 Visualizing complexity in demand planning

Besides PDM, the model also has strong influences from Systems Engineering, a methodology for (re-)designing systems in a project approach. In the following list selected recommendations are outlined (Geiger et al., 2009, p32-33):

- Analyze the system step-by-step (project management)
- Take care of formal logic (notation)
- Use appropriate tools (for modelling)
- Make system borders visible (e.g. between departments)
- Visualize only essential cause-effect relations
- Identify interplays and system patterns
- Consider subjectivity

A single phase (When?) contains one or more decisions (What?) that are taken in this phase. Besides the chronology of decisions the model also shows the decision-makers (Who?), relevant resources (With?) and the relationship of the decisions (Dependence).

The dependence visualizes two kinds of information. On the one hand, it shows the relationship of a decision to its predecessor(s) and its successor(s) by arrows, and, on the other hand, the decision's deadlines indicated by a change in the timeline of each decision (strokes change from dotted to full) become visible.

Table 4 contains a detailed description of the model's components and references the markers set in figure 2. The circle arrow highlighted with "X" indicates that this very phase has several iterations. This could be true for marketing campaigns with weekly controlling updates.

Table 4 Description of the model

	Examples	#	Model
When?	Point of time	1	Timeline
		2a	Horizontal Swim-lanes
Who?	Person, Organizational Unit	2b	Responsibility for resources (With?); color coding
		2c	Responsibility for decisions (What?); color coding
With?	Software, Tool, Key Figure	3	Horizontal Swim-lanes
What?	Decisions	4	Decisions and detailed aspects
Dependence	Predecessor(s) and Successor(s), Deadlines	5a	Arrows
		5b	Deadlines; change in stroke style

3.2 Analysis

The structure of the model enables various possibilities for visual analysis. The visual identification of irregularities is the first step in managing complexity. The main levers are presented here.

3.2.1 Identification of Gaps

As presented in figure 3, there are two possible directions for identifying gaps: horizontal and vertical. Horizontal gaps (1) could reveal that a decider is not taking part in a certain decision, but then again in the following. Vertical gaps (2) could show if a phase misses resources or maybe uses too much.

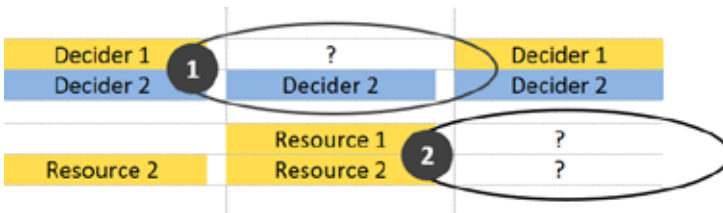


Figure 3 Identification of gaps

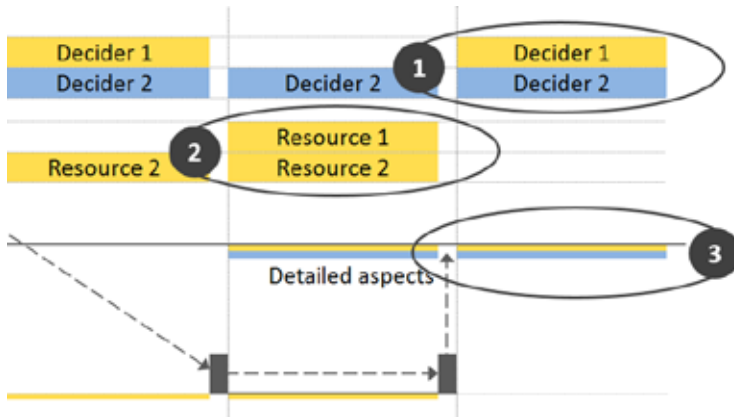


Figure 4 Identification of redundancies

3.2.2 Identification of Redundancies

Redundancies are another key aspect of visual analysis. The model shows (see figure 4) if a decision is over- or understaffed (1) and if a planning phase unnecessarily uses two resources of the same type (2). It also reveals inconsistencies between official responsibility and the role in decision-making (3).

3.2.3 Chronological Allocations

In figure 5 the arrows (1) indicate if decisions – considering their deadlines – can be moved to another phase; or even excluded.

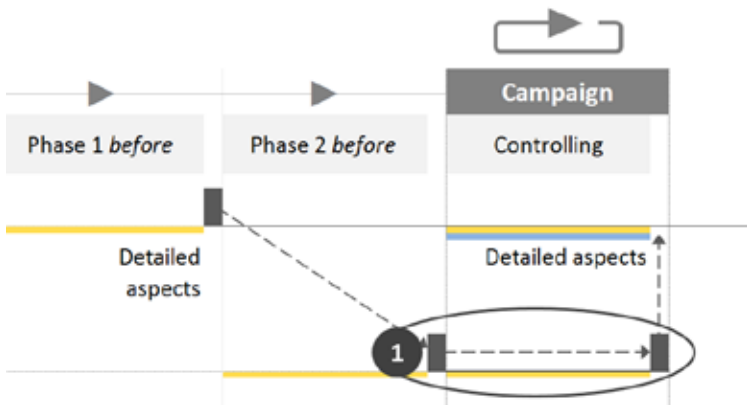


Figure 5 Chronological allocations

4 Methods to Reduce Complexity

This chapter provides methods to reduce complexity in a supply chain. The characteristics of complexity are plurality, variety, ambiguity and variability (see table 5). Additionally, the table identifies appropriate strategies to change or reduce complexity (Betge, 2006, p.80-81).

Table 5 Characteristics of complexity and appropriate strategies

Character- istic	Description	Strategy
Plurality	Number of system elements and relations	Dimensioning
Variety	Different types of system elements and relations	Differentiation/Adaption
Ambiguity	Different interpretations of system elements and relations	Specification
Variability	Frequency, strength and continuity of changes of system elements and relations	Stabilization

As a result of their focus, the strategies are either assigned to complexity design or complexity control (table 6). Complexity design leads to a substantial change in the supply chain, Complexity control aims for the most efficient way to manage it. The assignment is based on a doctoral thesis about managing complexity in the automotive industry (Maune, 2002, p.14-42). The methods will be explained in detail in the following two sections of this chapter.

Table 6 Methods to change/reduce complexity

Complexity design	Complexity control
(Plurality)	(Ambiguity)
Dimensioning	Specification
(Variety)	(Variability)
Differentiation	Stabilization
Product/value analysis	Project planning
Equal parts management	Changing demand
Classification and prioritization	IT as an enabler
Order penetration point	Logic of communication
Supply chain design	

4.1 Complexity Design

The goal of complexity design is to (re-)design the objects in a supply chain. In detail, the plurality and the variety of objects shall be reduced.

4.1.1 Product/Value Analysis

Value analysis is an effective method to reduce complexity in products or processes. Its goal is to improve the ratio of cost and function, defined as value. To gain a higher customer value, either improve the function or reduce the costs (Arnolds et al., 2013, p.120-123). If there is a predefined level

of maximum costs, the method enhances to Target Costing (Schröter, 2011, p.17). In the context of complexity the value of process steps is in scope. Failure to pass on information in an early phase may lead to unnecessary processing.

4.1.2 Equal Parts Management

Equal parts are components of a product, which are used in not only one product (individual parts), but in several (Thonemann, 2010, p.444). A higher usage of equal parts directly affects supply chain complexity; meaning less customized interfaces, templates, processes etc. Equal parts can be established through the integration of functions (Maune, 2002, p.24) – e.g. TV power adapters that can switch between 110 and 230 volts – or by (industry-wide) standardizations (Ehlers, 2006, p.140).

4.1.3 Classification and Prioritization

The classification or prioritization of products or processes – e.g. based on their value added – indicates if they have a proper level of complexity. Important methods are ABC analysis, for prioritizing objects from A to C (Zsifkovits, 2013, p.187), CONJOINT analysis, for evaluating multiple attributes of a product (Scholz, 2009, p.160), and Portfolio analysis, for clustering objects in two dimensions (Gärtner, 2013, p.253).

4.1.4 Order Penetration Point

The order penetration point (OPP) splits orders along their value chain regarding several aspects and therefore has direct impact on supply chain processes and their complexity. Two important aspects are the change

from push- to pull-production and the change in optimization targets (Schönsleben, 2011, p.41-43). Everything upstream from the OPP will be pushed as lean as possible. The products can run through highly standardized production processes without considering the specific order. Downstream from the OPP the customers will pull individual products that meet their specific needs (e.g. a car with outside rims); the processes have to be agile.

4.1.5 Supply Chain Design

Supply Chain Design (SCD) focuses on the (re-)design of supply chains in terms of efficiency and effectiveness (Hoppe, 2007, p.21). A simple map visualizing all stakeholders, resources and their associations could give valuable feedback on critical paths, potentials for IT and business models (Kummer et al., 2009, p.339). The display format and the level of detail depend on the desired outcome of the analysis.

4.2 Complexity Control

Complexity control aims for improving the planning and controlling of a supply chain. The main focus is on defining clear directions for communication to prevent or reduce ambiguity. Furthermore, it provides methods for avoiding temporal changes in planning objects.

4.2.1 Project Planning

Projects are time-limited and unique assignments (Burghardt, 2013, p.19). The planning characteristics and restrictions established on top-level are transferred to the associated work packages. The complexity is mainly

driven by the interplay between different planning and control layers. Milestones are effective control mechanisms to address this complexity and should be planned according to the costs-by-cause principle (Schreckeneder, 2010, p.64).

4.2.2 Changing Demand

Little changes in demand can have unpredictable effects on the scaling of a supply chain. For example, if the forecast predicts a certain rise in sales all stakeholders involved could – dependent on their planning algorithms – order a different quantity (including safety stock). Multiplying this effect upstream the supply chain could lead to large swings in inventory. Because of its characteristic curve the effect is also known as Bullwhip Effect (Zsifkovits, 2013, p.91-93). Information policies and technologies can reduce the implied complexity (misunderstandings, misinterpretations, lack of data etc.). A smart way to ensure forecast data feed from the customer is to provide incentives for sharing – i.e. better payment conditions.

4.2.3 IT as an Enabler

Many modern business processes are exclusively enabled by the usage of information technology (IT). This leads to substantial business process reengineering, often referred to as Efficient Consumer Response (ECR) in the context of supply chain management (Corsten/Pötzl, 2002, p.7). ECR's main goal is to have common standards and processes for controlling and optimizing the supply chain (Kummer et al., 2009, p.341-342). By integrating big data from social media like Facebook or Google, forecasts can immediately be readjusted according to the latest sales data (Schmarzo,

2013, p.167). Faster data access and integration are a key issue in preventing and controlling complexity. The degree of integration depends on the performance requirements of the supply chain (Melzer-Ridinger, 2007, p.29).

4.2.4 Logic of Communication

The quality of shared information is one of the most significant factors of complexity. It is of essential importance that receiver's understanding and interpretation of information is equivalent to the sender's (Ostertag, 2008, p.49). This requires mandatory regulations. The SUCCESS rules of Hichert provide clear instructions for data structure and display (HICHERT FAISST, 05.05.2015). The rules are also relevant for the model in this paper, since every project regarding Complexity Management begins with the visualization of complexity.

5 Concluding remarks

The model for visualizing the complexity in demand planning processes was applied to an industrial company. This was done parallel to literature research and helped understanding practical implications.

The model improves employee understanding and supports innovation processes. Like mentioned before, the visualization of complexity is often the first step of reducing it. The employees have a common process structure available and that makes discussions about improvement a lot easier. A very important aspect is to have a systematic approach. The project should start by analyzing systemic interfaces at a top level and gradually

move to the details. This also supports understanding cause-effect-relations.

In future Knowledge Management could play an important role in complex processes, because they often require a lot of collaboration. Appropriate IT systems will enable people to share their ideas in an organized way and the system will also "remember" what happened in the past.

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