Integrating System Dynamics in a Strategic Foresight Process for Firms in Production Networks

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Abstract

Firms have long used strategic foresight to adjust to fast changing business environments and increasing uncertainties. While strategic foresight on a corporate level is rather common, approaches addressing the network perspective are still rare. Documented attempts within the last few years to combine different foresight methods indicate a need for integrated approaches. Methods to communicate and discuss future thoughts between strategists and decision makers engaged in foresight processes gain importance. The goal of this paper is threefold. First, to present a strategic foresight approach that evaluates key drivers of future changes. This evaluation is conducted based on a firm's business model by considering the network perspective. Second, the application of the approach is shown with focus on the development of a system dynamics model during a group model building process. Third, a generic system dynamics model for performing strategic foresight in production networks is introduced.

Keywords

Strategic Foresight; Production Networks; System Dynamics; Group Model Building; Foresight Methods;

1 INTRODUCTION

Since the 1970s different approaches for single firms have been developed to cope with environmental changes (Duncan, 1972). Ansoff’s concept of weak signals marks the introduction of strategic foresight as primary step in the strategic management process of firms (Ansoff, 1975). In the past two decades a large amount of literature focusing on the performance of strategic foresight has been published (Frishammar, 2002), (Tsoukas *et al.*, 2004), (Horton, 1999), (Slaughter, 1998), (Slaughter, 2002). Moreover, many firms adapted their strategies by cooperating within business networks (Jarillo, 1988), (Jarillo, 1993). Firms within networks specialize on their core competencies and build dynamic capabilities to better address fast changing global market demands (Teece *et al.*, 1997). Production networks are complex and dynamic structures which often evade a single firm's strategic perspective (Zheng *et al.*, 2002). A firm can understand the influence of the business environment on its strategy through evaluation of dependencies between other network actors. This evaluation process, however, is difficult and requires a methodological sophisticated approach (Haag *et al.*, 2011). Over the past few years various ideas to integrate different foresight methods, e.g. how to combine scenario analysis and road mapping (Rohrbeck *et al.*, 2011), were explored. Therefore, the main focus is the systematic integration of existing methods, e. g. system dynamics, into a foresight process for production networks. As Blackman et al. pointed out, the role of doubting in foresight activities is very important (Blackman *et al.*, 2004). Hence, group-model-building aspects are integrated to ensure visualization of the underlying mental models.

Voros proposes a generic process with five sequential steps to gain a profound input for a corporate strategy process (Voros, 2003). Here a recently published expansion of this process shown in Figure 1 will be further explored.

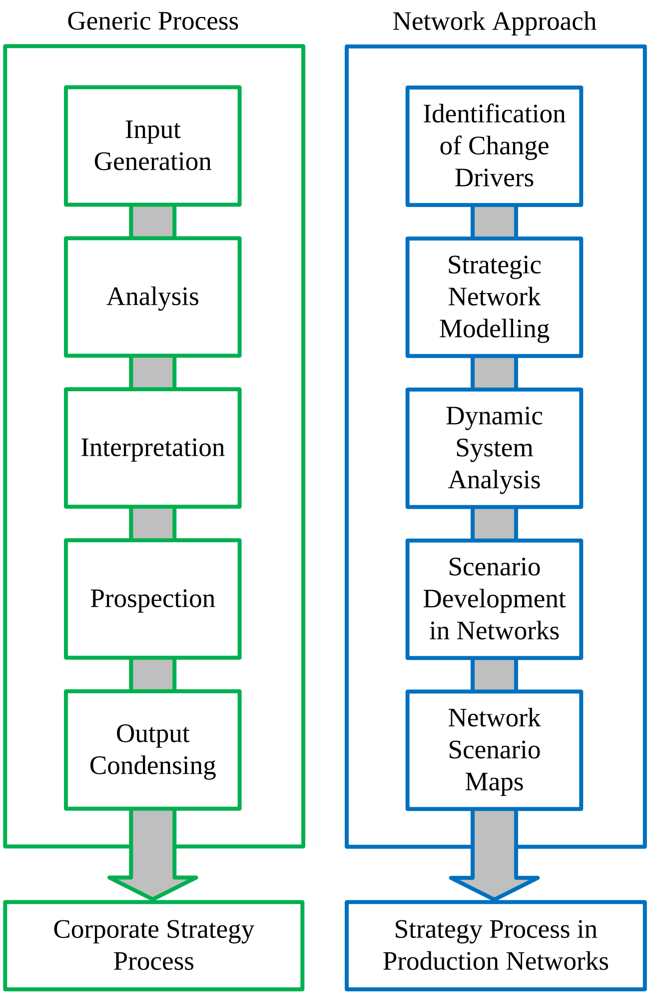

Figure 1: Strategic foresight in production networks (Haag *et al.*, 2011).

This paper introduces a network approach while focusing on the integration of group modelling aspects. This approach assumes that system dynamics serves as a method to systematically elicit and share mental models on the future course of the business model of a firm (Vennix, 1996). This is especially applicable for firms in production networks. Production networks have many diverse actors leading to increased complexity and uncertainty. The entire approach is designed like a group model building process (Rouwette *et al.*, 2002; Rouwette *et al.*, 2011; Andersen *et al.*, 1997). One of the major concepts of group model building is group facilitation (Richardson *et al.*, 1995). Here, a method expert facilitates a group of client representatives from different departments of the firm.

This paper shows the application of the approach in one firm as part of a three year research project. During the application of the whole approach, the representatives of the firm remained the same. The firm representatives include three members of the product management department, five of the marketing department, and a single member of the production department. A method expert guiding the process facilitated the application of the approach. No details of the client firm are revealed within this work.

2 FORESIGHT APPROACH FOR FIRMS IN PRODUCTION NETWORKS

2.1 Identification of Change Drivers

At the beginning of a strategic foresight process, environmental scanning helps to identify change drivers (Slaughter, 1998). A PESTLE-Analysis identifies change drivers of strategic relevance. Figure 2 shows the environment of a single firm in a production network divided into a general environment and a task environment. A PESTLE-Analysis identifies change drivers from the political, economic, social, technological, legal and ecological fields (Johnson *et al.*, 2000).

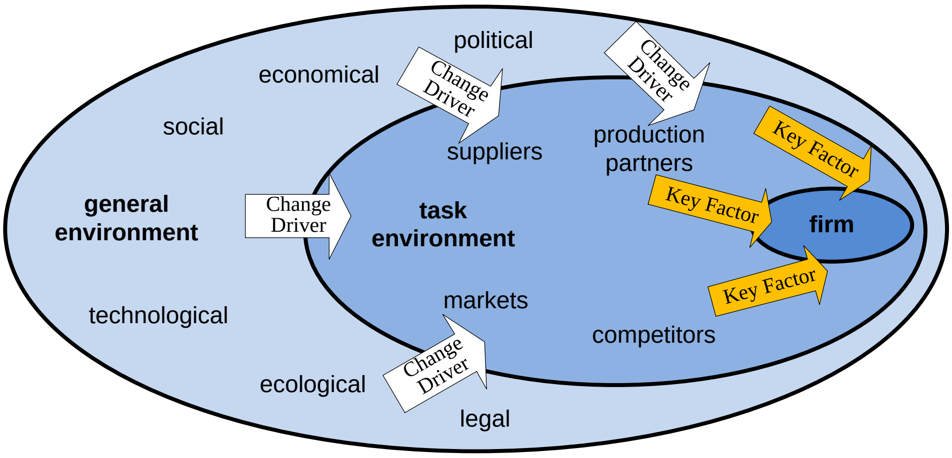

Figure 2: General environment and task environment for strategic foresight in production networks (Haag *et al.*, 2011).

PESTLE-Analysis is a well-known method, and will therefore not be further explained. However, it is extremely important to decide upon a proper length for the strategic time horizon, that will remain constant for the entire foresight process.

2.2 Strategic Network Modelling

In order to deduce key factors with important impact on a firm's business model, the structure of the production network is modelled. These models help to develop a qualitative impact analysis. Each change driver (d) identified in step 1, has a chain of impact through the network along the network relations (Figure 3). A set of key factors defines the change drivers that end at strategic business units (comp. Figure 2).

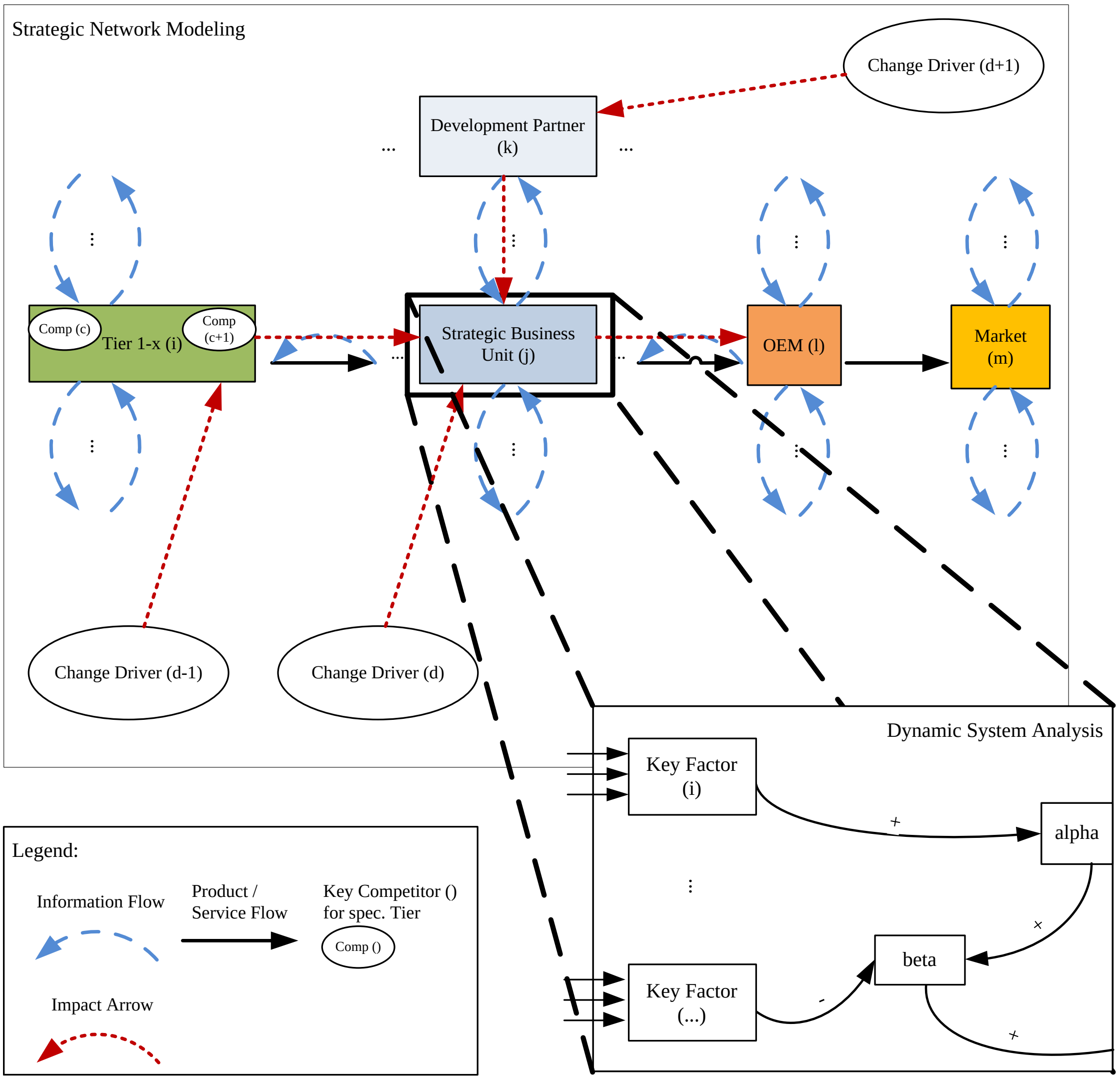

Figure 3: Strategic Network Modelling (Haag *et al.*, 2011)

The set of key factors builds the basis for the next step, the dynamics system analysis. From a methodological point of view, strategic network modelling is the first step of the approach where role models gain importance. A group model building process distinguishes five roles (Richardson *et al.*, 1995):

- the facilitator, functions as group facilitator and knowledge elicitor,
- the content coach, focuses on the model content formulated,
- the process coach, focuses on the building process,
- the recorder, documents, and
- the gatekeeper, holds the internal responsibility for the success of the project.

Therefore, a method expert ensures for the rest of the approach, that all five roles or functions are properly assigned.

2.3 Dynamic System Analysis

Dynamic system analysis aims at building a simulation model to evaluate the impact of the key factors on the business model of a firm. Therefore, three tasks are performed. Initially, the set of available key factors identified through strategic network modelling is compared to a generic business model. This comparison ensures that all areas of importance for the future of the business unit are included. Figure 4 shows a generic business model (Johnson *et al.*, 2008), which includes the four elements: "customer value proposition", "profit formula", "key resources" and "key processes".

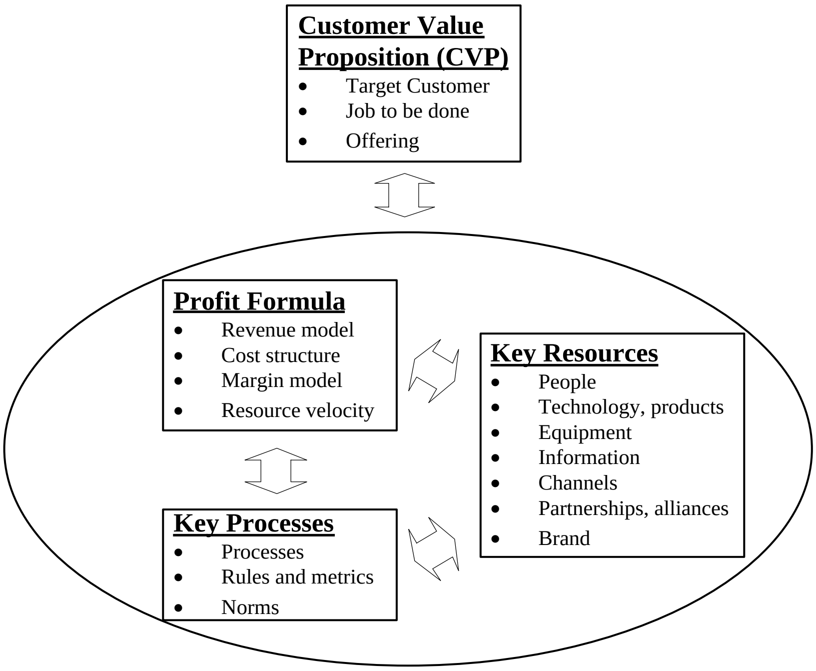

Figure 4: Example of a possible generic business model (Johnson *et al.*, 2008).

Key factors are named according to the rules for variable naming found in system dynamics literature (Sterman, 2000). The first task creates a set of variables which serve as a basis for the development of a system dynamics model. Secondly, a qualitative system dynamics model is built according to group model building concepts summarized in (Vennix, 1996) like the use of group memories, workbox etc. The model's purpose is to visualize the future changes of the business model resulting from the impact of change drivers transformed by the network or directly affecting the business unit of the firm. However, such modelling efforts always have an additional goal. They also make the various mental models of strategists and decision makers on the future course of the firm explicitly available. This enables a firm wide discussion about the firm's future and helps to communicate the firm's strategy. As a third task of the dynamics system analysis, a quantitative system dynamics model is established.

2.4 Scenario Development

Scenario-based planning first emerged from military war games. In the civil world, Herman Kahn first developed the use of scenarios in the late 1960s. For about three decades, a rational approach was propagated, referred to today as forecasting. In 1994 Mintzberg published an overwhelming work about the rise and fall of strategic planning (Mintzberg, 1994). He disagreed with the old Planning School and proposed that strategy developing should concentrate on the invention of new categories and not the forecasting of old ones.

Based on group learning, modern scenario development tries to foster double-loop-learning (van Heijden, 2007) well known from system dynamics literature (Sterman, 2000). In accordance with strategic management literature, van Heijden extends the goal of scenario development to understand the environment. He started to compare scenarios with business ideas to address key competencies and business choices (van Heijden, 2007). He further introduces causal loop diagrams as a way to enhance system learning.

Within the given approach, scenario development has two goals. First, it aims to create different possible future scenarios. This is accomplished through scenario development based on the key factors. In comparison to other inductive methods form literature, setting up a consistency matrix as a deductive approach reduces scenarios from the theoretically possible combinations of values of key factors to a couple of consistent value sets. This is done by commercial software, programmed for scenario techniques. Secondly, scenario development strives to evaluate the scenarios on a single firm level. This is achieved by simulating discrete value sets of the impact factors within a scenario to better interpret the scenarios with a simulation model. In achieving the second goal, most of the benefit of the structured approach can be found. As the simulation model explicitly shows the mental model of the group, discussing the simulation runs of different scenarios helps to reflect on the assumptions made.

2.5 Network Scenario Maps

Strategic network models together with the system dynamics model serve as a strong basis for communication regarding output information within the clients firm. Verbal scenario descriptions and scenario interpretations provide a comprehensive view of the meaning for the organization. Network scenario maps enable a firm to use the resulting scenarios in addition to the underlying models when considering the network structure during strategy making.

3 AN ILLUSTRATIVE EXAMPLE

3.1 Introduction

The approach introduced in Chapter 2 has been developed during a national research project in Germany. As part of the project the approach was applied in four industrial partners. Due to the strategic relevance of the results, no details are given in this sequel. However, relevant aspects of the results are shown from a case to further explain the approach and underline its practical relevance. The next two sections explain the application of the approach, in this specific example, Section 3.2 shows in detail special segments in the establishment of the system dynamics model. Section 3.3 provides a general overview of the utilization of the model for simulation and interpretation of the scenarios.

3.2 From Change Drivers to a Simulation Model

Identification of Change Drivers

For the purpose of this paper only one business unit was considered. The evaluated approach can however be applied to other business units. The application of the foresight approach was assigned a five-year strategic time horizon. Under consideration of the time horizon, about 30 different change drivers were identified through PESTLE-Analysis. Each change driver was assigned to a field. The identified change drivers are listed with a short description explaining their importance for the future of the company.

Change Driver	**Description**	**Field**
Shift in purchasing behaviour	End-Customers are concerned about long-time solutions and therefore looking for high quality (economical uncertainty); or End-Customers try to get things as cheap as possible since money purchasing power is getting low (economic crisis)	Social
Increase of raw material shortages	What happens if there is no oil available? Which are the raw materials on which we depend?	Ecological
...		

Table 1: Example list of change drivers

Table 1 shows two examples of change drivers associated with a specific PESTLE-field and explained by a short description to understand and communicate the ideas behind.

Strategic Network Modelling

This step deduces key factors through visualization of strategic inter-organizational relations within production networks. The change driver "shift in purchasing behaviour" affects the up-stream side of the network. The business unit is affected along the value adding chain and over the direct customer. The effect for the business unit is represented by a possible change of the three customer-segments "part of price-oriented end-customers", "part of quality-oriented end-customers" and "part of price-performance-ratio oriented customers". The change driver "increase of raw material shortages" affects the down-stream side of the production network. It affects the "variable costs of the products" and the "delivery time of plastic films" over the supply chain of the business unit. Figure 5 shows the production network as well as two examples of change drivers including the effected key factors.

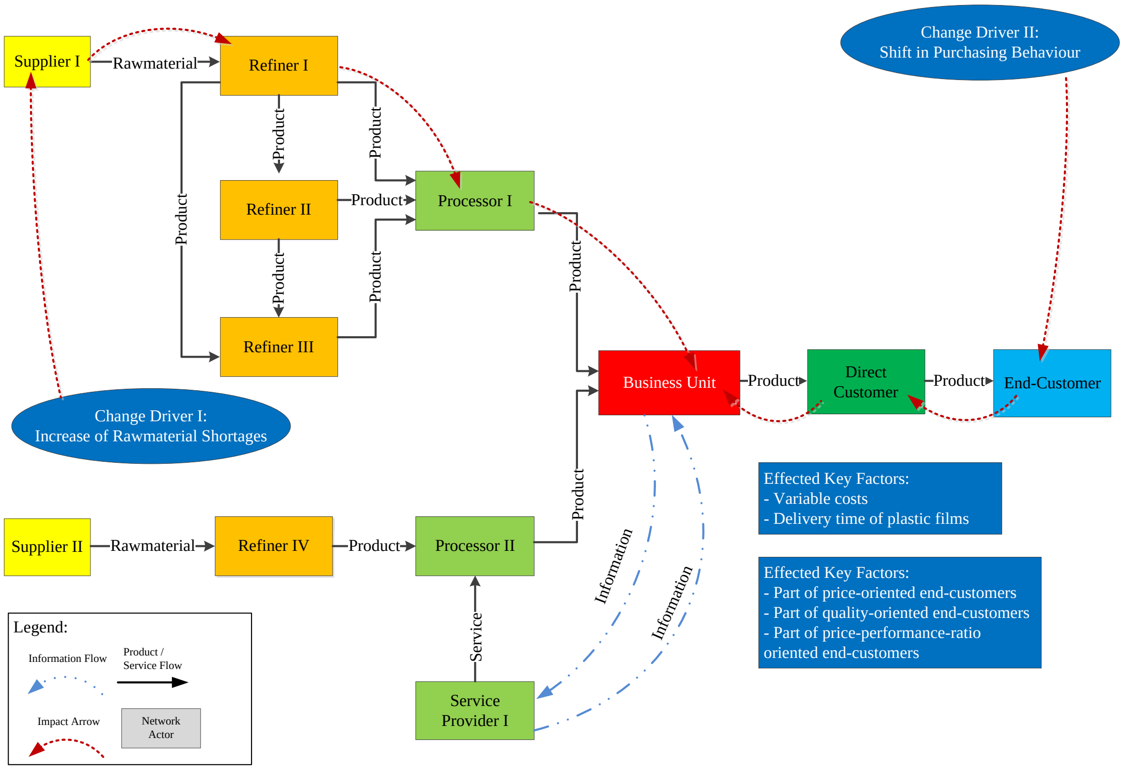

Figure 5: Illustrative Example for Strategic Network Modelling

All change drivers were evaluated using the illustrated procedure. Change drivers for which no key factor could be found or the chain of arrows ended at another actor of the network were sorted out. After evaluation only 15 change drivers remained associated with 20 key factors by a chain of impact arrows.

For this network modelling step, a method expert from the university functioned as a group facilitator and content coach. Another university employee not familiar with System Dynamics functioned as a process coach. A student assistant recorded. The product manager, who was responsible for the business unit of the client firm, functioned as a gatekeeper. The production manager was highly motivated to gain the results of this approach and held the internal responsibility of the project. The representatives remained the same with the exception of the recorder position, which was filled by several different students.

Dynamic System Analysis

As explained in Section 2.3, the dynamics system analysis consists of three sequential tasks. The first task inspects the completeness of the key factors through consideration of the generic business model given in Figure 4. Although this task seems rather simplistic, it is beneficial. For many participants it was new to view the business unit from a generic perspective. Questions about the development of market share and customer value proposition were raised within the group and first dissensions between marketing and product management were identified. Nevertheless, a set of 35 variables was developed with all four fields of the generic business model represented and a common understanding of these variables.

The second task was to develop a qualitative system dynamics model. The group facilitator introduced a preliminary model by performing a literature review called "Share from Spreading Fixed Costs" from (Sterman, 2000) (Figure 6). This preliminary model was introduced to the group and used as a starting point to develop the system dynamics model. The "Spreading Fixed Costs"-Model, models the very basic effect of fixed and variable costs and the simple idea how sales are influenced by market share and industry demand. The fact that the price affects product attractiveness and that product attractiveness is decisive for market share were both apparent to every participant.

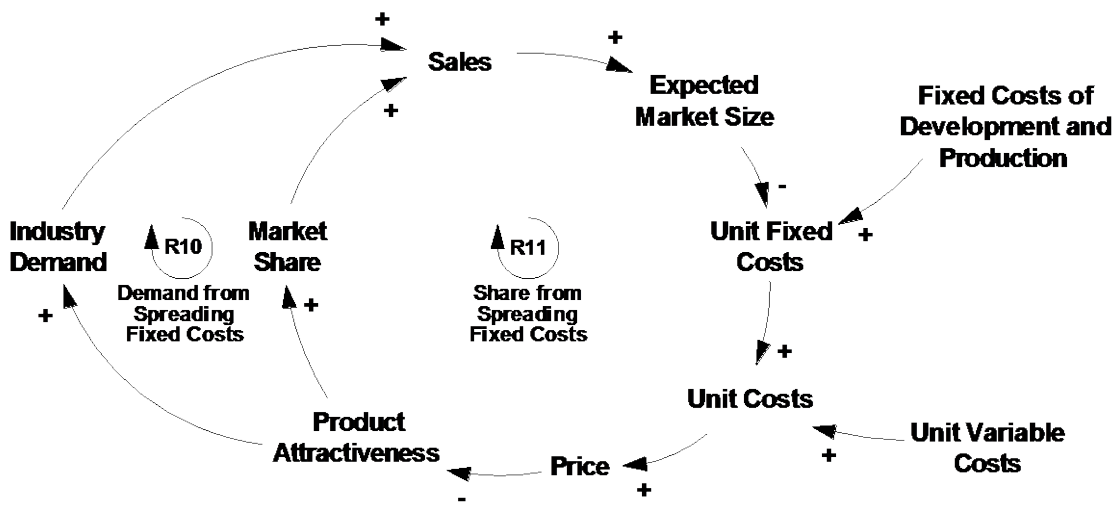

Figure 6: Preliminary-model for dynamic system analysis (Sterman, 2000).

Figure 7 shows the main loops of the resulting system dynamics called "growth machine" and "pricing loop". The effective product attractiveness is increased through either an increase in attractiveness for end-customers or an increase in the attractiveness for direct-customers. The relevance of the end-customer for effective product attractiveness is defined as a constant in simulation. Product attractiveness for end-customers depends mainly on the price as well as on other factors, which are described in a model sections later on. The market share results by comparing the attractiveness of the competitors with the attractiveness of the client firm, while sales depend on the market share times demand minus demand restrictions. The pricing loop balances the growth loop, the higher the price the higher the profit. With higher profits the price can be lowered depending on the pricing strategy of the firm (compare Sterman, 2000).

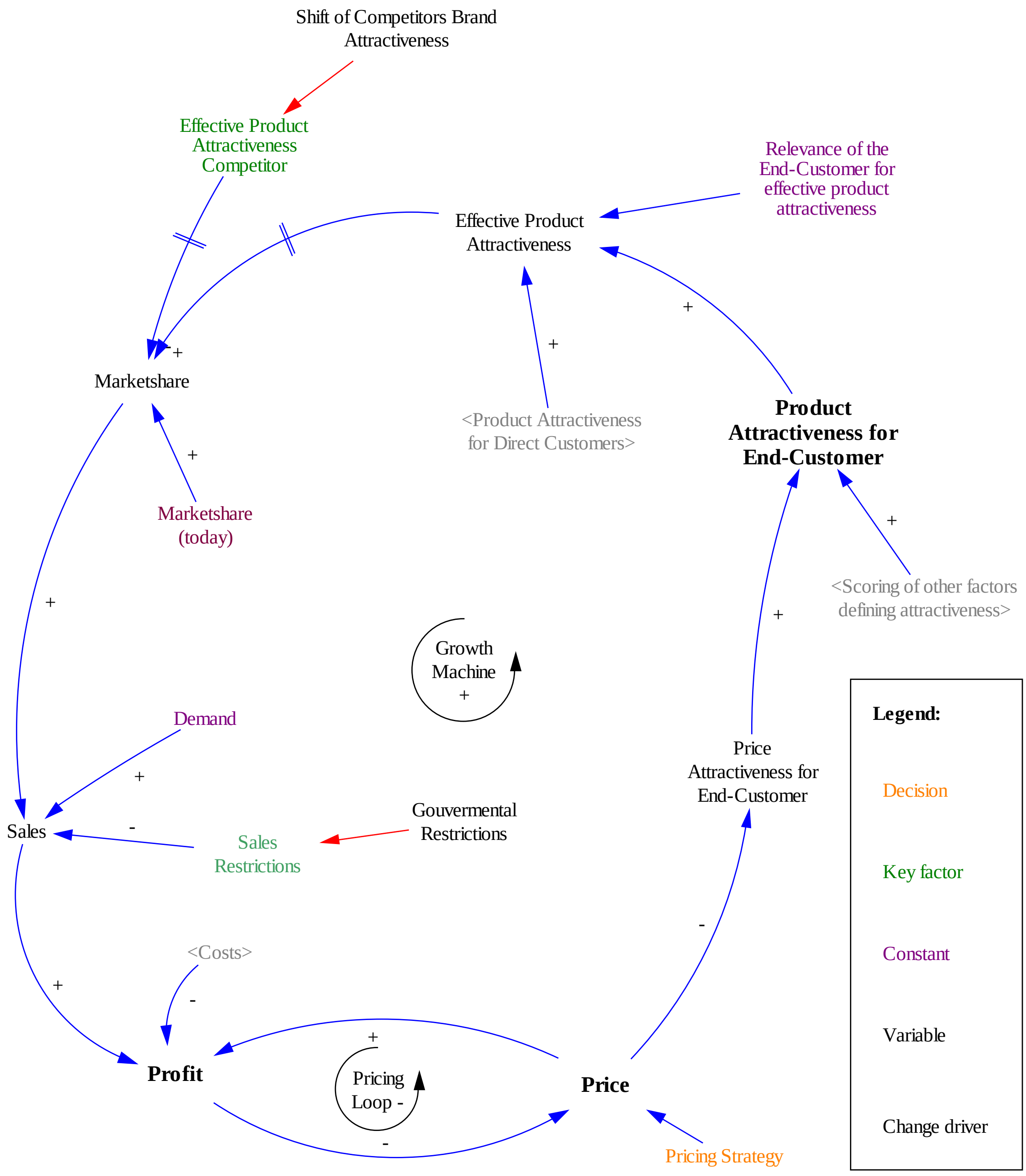

Figure 7: Model segment with the main loops of the application example.

From a methodological point of view, the model consist of key factors which are marked with green colour and defined within a scenario. The constants were added during the quantification (task III) but are already shown at this point. The change drivers are connected over a red doted impact arrow, indicating that there is an impact that cannot be determined with loop polarities according to the rules of system dynamics. However, it is important to see link between the change drivers identified in step 1 and the key factors resulting from strategic network analysis in step 2. Finally, possible decisions of the firm are included as orange variables.

A detailed example of the previously described change drivers is represented in Figure 8. It shows the model segment, representing the product attractiveness for end-customers. Four factors influence the product attractiveness for end-customers. First, the scoring for the price, second the performance of the product itself, third the brand attractiveness and fourth the point of sales attractiveness. The future course of attractiveness for end-customers depends mainly on the development of the factors themselves. However, much more important are the weights of each of the four factors defined over the end-customer segments. That is where the change driver "shift of purchasing behaviour" introduced in step 1 has its impact on. Together with a second change driver called "shift to more purchasing powerful end-customers", the three key factors representing the market segments are calculated. According to these three segments, the weights representing the importance of the four factors defining product attractiveness for end-customers are defined.

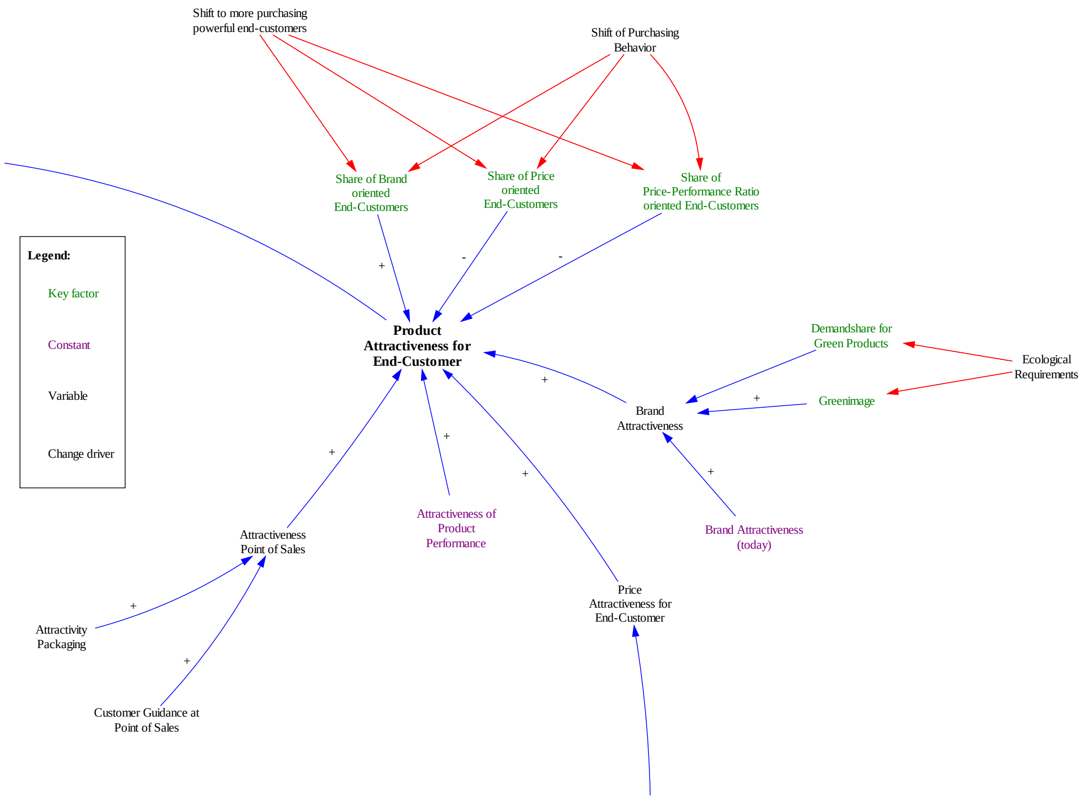

Figure 8: Example of a model segment representing the product attractiveness.

Finally a simulation model is created to quantify the system dynamics model. This was done during an iterative process of model improvement by the facilitator and workshops with the clients firm. The quantification was mainly done during a workshop opening the quantification process with all participants of the foresight approach. Thereby the crucial task was the evaluation of soft factors like the weights to calculate product attractiveness for end-customers. Table 2 shows the weights as one result of the quantification workshop. The columns are sorted according to the market segments while the rows are sorted according to the factors directly influencing the attractiveness.

	Price-orientation	Price/Performance-orientation	Performance-orientation
Attractivness Price-Scoring	90%	50%	0%
Attractiveness Point of Sales	0%	30%	10%
Brand Attractiveness	0%	10%	40%
Product Performance Attractiveness	10%	10%	50%

Table 2: Weights for calculation of product attractiveness for end-customers

By the use of weights in the equation for product attractiveness for end-customers, the three segments define the attractiveness of the product during simulation time. If the weights are given in a matrix T, the share of each segment is given in a vector S and the attractiveness of each attractiveness factor is given in a vector A, the product attractiveness for end-customers reads as:

$$PA = \bar{A} \cdot \bar{\bar{T}} \cdot \bar{S}$$

In the illustrative example the attractiveness factors were given a fictive scale from 1 to 10, 1 was unattractive and 10 very attractive. Through variation of the end-customer segments, with constant attractiveness factors, the attractiveness values varied between scores from 3 till 9.

Through the quantification process, a simulation model was developed, which was calibrated on basis of a base-run. For the base-run, all key factors were set to the present-day values. The base-run was calibrated to stay at its value for a five years simulation period as defined in step 1 of the approach. The simulation model was based on 13 key factors with 38 independent values and included two quantified decisions. Key factors and decisions were represented by up a maximum of three different possible future values, which were defined in scenarios developed in the following step.

3.3 Scenario Development and the use within a Strategic Foresight Process

Scenario Development in Production Networks

A consistency matrix was developed based on the key factors and their possible future values defined in the previous steps. The 38x38 matrix was completed during a one-day workshop in small groups of two or three participants. Table 3 shows an illustrative example with fictive values and five value sets for future scenarios. The values given in percent indicate the degree of consistency of the corresponding value in a 'value set X'. For example 'key factor 1' value 'a' is 90% consistent with 'value set 1'; and 'key factor 1' value 'n' is 10% consistent with 'value set 1'. This means that for 'value set 1' the 'key factor 1' value 'a' is very consistent with all the other values of key factors in 'value set 1' and all other values of 'key factor 1' are very inconsistent with 'value set 1'. The difference between value sets and scenarios is the ambiguity. Through interpretation of the value sets the group must decide which value a key factor has for each scenario. This interpretation is done based on the value sets resulting from the scenario-software. An example is displayed in Table 3. In the present example the group decided to define seven different scenarios based on five unambiguous value sets, in order to represent all possible futures of the environment of the firm.

	Value Set 1	Value Set 2	Value Set 3	Value Set 4	Value Set 5
key factor 1, value a	90%	100%	0%	30%	0%
key factor 1, value b	0%	0%	100%	0%	0%
⋮					
key factor 1, value n	10%	0%	0%	70%	100%
key factor 2, value a	20%	90%	0%	0%	10%
key factor 2, value b	80%	10%	0%	20%	70%
⋮					
key factor 2, value m	0%	0%	100%	80%	20%
⋮					
key factor 11, value a	30%	0%	0%	90%	0%
key factor 11, value b	20%	100%	90%	10%	0%
⋮					
key factor 11, value o	50%	0%	10%	0%	100%

Table 3: Illustrative example of a consistency matrix

By simulating the scenarios, the conducting group had the possibility to reflect upon their mental model. Figure 9 shows an illustrative example of three simulation runs for the market share of the firm. While the middle line represents the base run which simulates values of today, 'scenario 1' represents a positive effect while 'scenario 2' a negative one.

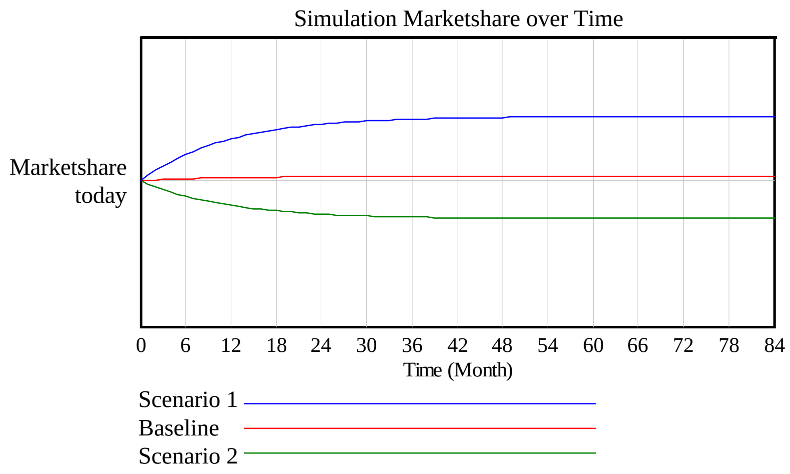

Figure 9: Illustrative example: Simulation runs for market share over time.

Network Scenario Maps

For the given example the results of each step of the approach are documented. Hence, a list of change drivers, the corresponding key factors, and the defined scenarios exist. A Vensim model is available to simulate the scenarios by importing the values from the list. Furthermore, the network models show the change drivers' affect on the network structure and influence on the key factors. A combination of verbal descriptions for each scenario as well as the simulation runs help to re-evaluate later the future course of the strategic business model under consideration.

The firm utilized the scenarios to decide upon the integration of a value-adding step to increase flexibility. Therefore, it was important to understand the information flows to partners and identify the impact of future changes.

4 A GENERIC SYSTEM DYNAMICS MODELL FOR PERFORMING STRATEGIC FORESIGHT IN PRODUCITON NETWORKS

The introduced approach has been applied to different firms within the research project Vertumnus. A comparison of the resulting system dynamics models reveals a pattern from which a generic structure can be deduced, shown in Figure 10.

The model consists of four loops. The smallest loop, is the price adjustment loop which was previously described in literature, has a balancing behaviour (e.g. Sterman, 2000). The biggest loop is "success to the successful". If the profit increases the price can be lowered under the assumption of a fixed profit target. If the attractiveness increases, sales increase, and thus profit increases. This creates a reinforcing loop. A third loop "spreading fixed costs" is part of this model and was part of the preliminary model shown in Figure 6 as the "share from spreading fixed costs loop". The spreading fixed costs loop is also a reinforcing loop and therefore empowers the success to successful effect. Finally, a fourth loop, "network power", is included in the model. This loop represents the effect of power within the network on the costs per unit. Besides the market share, many other factors influence these variables. Due to their complex nature these factors are not included in the generic model structure. Simplified, the greater the market share of a firm, the greater the power within the network, the lower the costs per unit. This again, is a reinforcing loop.

Besides the model structure itself, the variables can be assigned to the business model from (Johnson *et al.*, 2008) presented in Section 2.3. Figure 10 highlights the classification of the variables to the four categories: Customer value proposition, profit formula, key processes and key resources. This classification provides further insight. All of the variables belonging to the key resources and key processes are not part of the four loops. These variables influence the customer value proposition of the business model. Moreover, many of the critical success factors of a firm operating in a production network are determined by variables influenced by network actors.

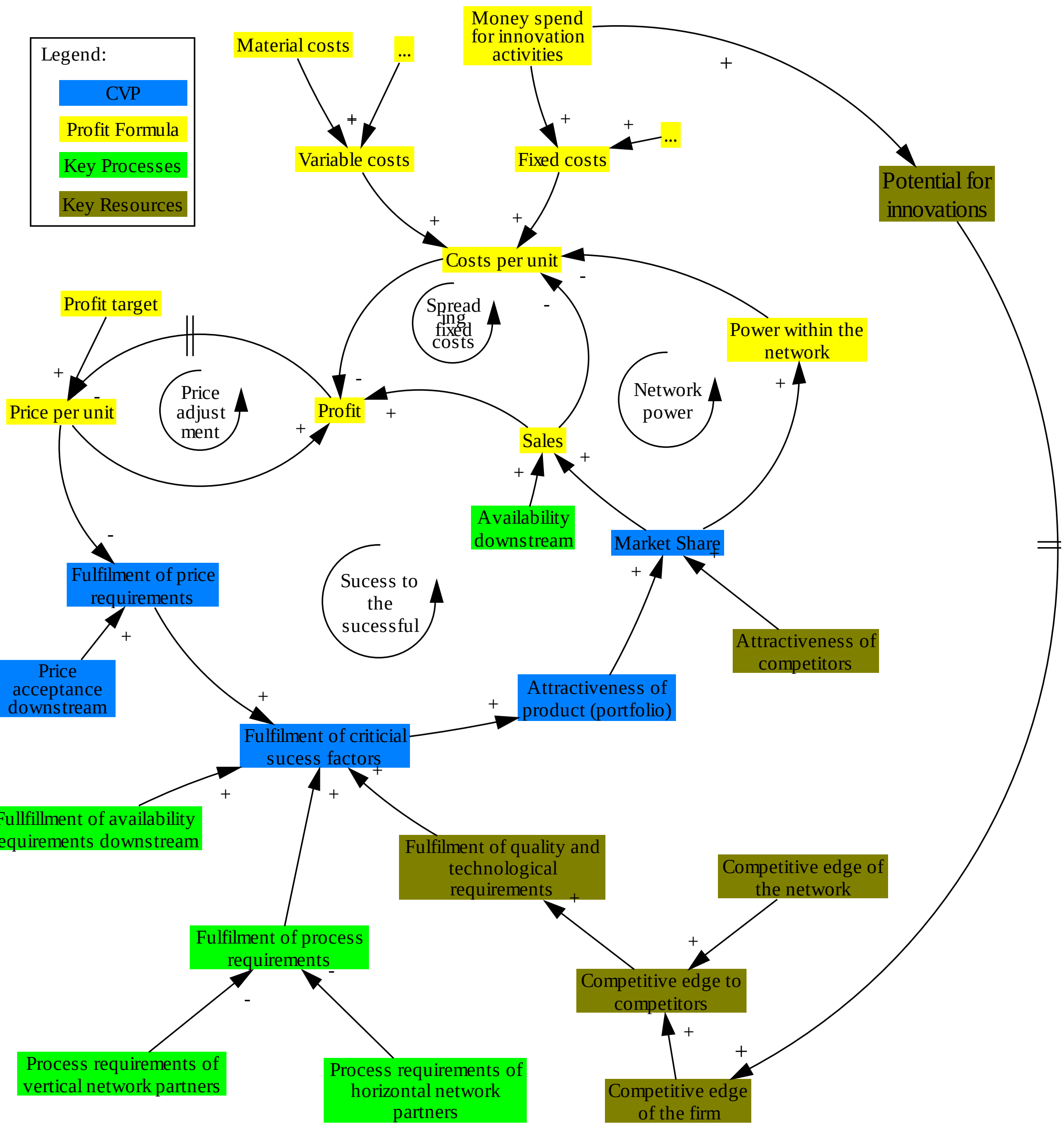

Figure 10: The Generic Structure of a System Dynamics Model for Strategic Foresight in Production Networks.

5 DISCUSSION

Firms organize their production processes within production networks to increase flexibility and gain competitive advantages. However, the complexity of production networks makes the development of appropriate business strategies difficult. Therefore, methods, which enable decision makers to visualize and discuss future changes on firms' strategies, are needed.

The integration of system dynamics into the strategic foresight process for firms operating in production networks helps decision makers and strategists develop coherent future views. The introduced approach finds the change drivers and deduces their impact through the production network on the business model represented by key factors. The development of a system dynamics model based on these key factors to simulate future scenarios help firms to handle the prevailing complexity of production networks.

This paper integrates system dynamics in a systematic foresight approach for firms in production network. It further explains the application of the approach through an illustrative example gained during a research project. Finally, this paper introduces a generic system dynamics model as the result of an explorative study to increase feasibility for further applications.

6 ACKNOWLEDGMENTS

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