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A CONCEPTUAL MODEL OF PRODUCT VARIETY

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ABSTRACT

More individual customer requirements and increasing competition due to the Internet technologies are just a few of the reasons that force manufacturers to react accordingly, e.g. by providing a higher product variety. Managing product variety is a great challenge that manufacturers have to address to be successful. The associated complexity makes product variety difficult to manage, although adequate management is essential to guarantee revenue and profit. Before making the decision to broaden the product range, it is recommended to check whether the profit of product variety outweighs the effort. There is also the question regarding the optimal product variety that enables the maximum net benefit for the manufacturer. Moreover, decisions on product variety are far-reaching due to their interconnectivity to almost all other managerial decisions. If manufacturers were capable to understand and oversee all the drivers and enablers of product variety, they would be in a better position to weigh all the pros and cons before arranging changes in the product portfolio. How to support decision-makers in this process? The approach presented in this paper addresses challenges by creating a unified framework of the factors impacting product variety. This is achieved by systematically studying management literature and integrating the found mechanism in a conceptual cause-effect model created with Garp3 – a workbench which offers meaningful visualization and simulation opportunities. After selecting appropriate literature, the relevant concepts are represented in a knowledge graph using the Garp3 software. The consequent preparation of the concepts enables deliberate decisions on wordings (types), number of model fragments, and level of abstraction. The simulation tool works without any numerical information, but still enables users to start from different scenarios (e.g. manufacturer with a single product starts to increase its portfolio) and observe the behavior of the system and its underpinning explanation in terms of cause-effect relationships.

Keywords: *complexity, conceptual model, causality, Internet technologies, product variety*

1. INTRODUCTION

Managing product variety, this is the number of variants within a specific product group (Lancaster, 1990), is essential for the success of manufacturing companies (Kahn, 1998). Identifying the drivers of product variety is just as important as knowing the enablers of product variety and finding ways to deal with the complexity (Schleich et al., 2007) of a broad product variation. In this regard, e.g. Technology can be seen as driver as well as enabler of a manufacturer's product variety (Gao et al., 2004). By conducting a broad keyword research on this topic, we found a range of papers which are worthwhile for further analysis. A deeper look at these papers shows that nothing is as divergent as it seems at first sight. In part, the literature shows quite significant differences in wordings. Therefore, it is not clear whether the authors relate to the same story. For instance, when talking about Information Technology (IT), some authors refer to internet and internet technologies (e.g. Brynjolfsson et al., 2010) while others (e.g. Gao et al., 2004) refer to software on the computer like computer-aided design or flexible manufacturing technology.

Besides technology and product variety, some authors find other important influencing factors that are worthwhile considering. One example is complexity (e.g. Schleich et al., 2007), which actually plays a significant role in a product-rich business environment. One of the reasons is that product variety generates complexity and to manage this is one of the goals of some researches. By studying other researches (e.g. Kahn et al., 1998), we read about ways how to deal with this complexity. Some authors show an interest in impacts of product variety, for instance the manufacturer's revenue and profit as being dependent on product variety. Others investigate a small product variety in addition to a broad product variety. This allows for a comparison of these two product strategies. Economies of scale (e.g. Zhou et al., 2017) could be a reason for the manufacturer's concentration on a single product instead of managing a wide variety.

The divergent approaches to deal with this topic pose a great challenge. In our opinion, it is important for future research to provide a unified picture on this topic by following the integrated approach. Our concurrent approach pursues the goal to create clarity by excluding initially suitable researches which have a different orientation. By integrating various papers, we provide a more comprehensive view on the topic, the relevant concepts are represented in a knowledge graph using the Garp3 software which enables us to observe the behavior of the system. The paper is organized as follows. Section 2 presents the Garp3 workbench for developing qualitative models. Section 3 focusses on a manufacturing company which faces technology-induced changes of stakeholder requirements and therefore shows the initial situation as well as possible mechanisms for this firm. Section 4 presents the simulation results of our scenario. Section 5 summarizes the main conclusions.

2. GARP3 REPRESENTATION TECHNIQUES

Garp3 (Bredeweg et al., 2009) uses entities, agents, assumptions as well as configurations to describe the physical system structure. In comparison to that, quantities, quantity spaces, magnitudes and derivatives, direct influences, proportionalities, correspondences, and inequalities are used to describe the system behavior. Therefore, quantities are the relevant properties of entities that may transform under the influence of processes. Quantities consist of a quantity value which in turn is comprised of magnitude and derivative. The range of possible values that a quantity can have is referred to as quantity space. The derivative represents how a quantity changes. The magnitude indicates the current value of a quantity. The notion I+ is used to model positive influences, which denote direct relations between two quantities. The notion I- is used for negative influences. By the use of proportionalities (P+ or P-), the derivative of the target quantities can be determined depending on the derivative of the source quantities. Correspondences are used to model the relations between qualitative values of different quantities. Inequalities are commonly used for indicating that one quantity value is different (or equal) to another quantity value.

Scenarios are applied to model the initial state of a system and serve as input for the qualitative simulator. Model fragments are required to describe the structure of a system and consist of conditions and consequences. Each model fragment represents part of knowledge of the domain that may apply to a certain scenario. The engine searches for model fragments that are applicable to the selected scenario and infers the system behavior. With the mentioned inputs, different simulation outputs can be generated, including states, behavior graphs, value history diagram, equation history and causal model. States depict a qualitatively unique behavior in the modelled system. Several states together form a behavior graph. The value history shows how quantity values change within a behavior graph.

3. TECHNOLOGY-INDUCED CHANGES OF STAKEHOLDER REQUIREMENTS

We first construct a conceptual representation of the mechanism that determines basic company behavior regarding product variety. The qualitative model provides a picture of how technology-induced changes of stakeholder requirements constrain the behavior of a company; the simulation results provide information about how the company reacts to changing requirements.

3.1 Initial situation

At this point, we model the initial situation of a company having the key characteristics of a dynamic manufacturing company which faces changing stakeholder requirements. The initial scenario (see Figure 1) starts with stakeholder requirements being bigger than the company's product variety (shown by the bigger-than equation between *requirements* and *product variety*). *Product variety* is bigger than *modularization* and *production scale*, but smaller than technology in the initial state. *Technology use*, which is associated to the agent *technology*, is represented as an exogenous quantity (denoted by the exclamation mark in Figure 1) and, therefore, shows exogenous behavior. Thereby, the quantity reflects some sort of uncontrollability. The increasing behavior, one of the possible behavior patterns for exogenous quantities, is highly suited to demonstrate the rising use of technology in today's information age.

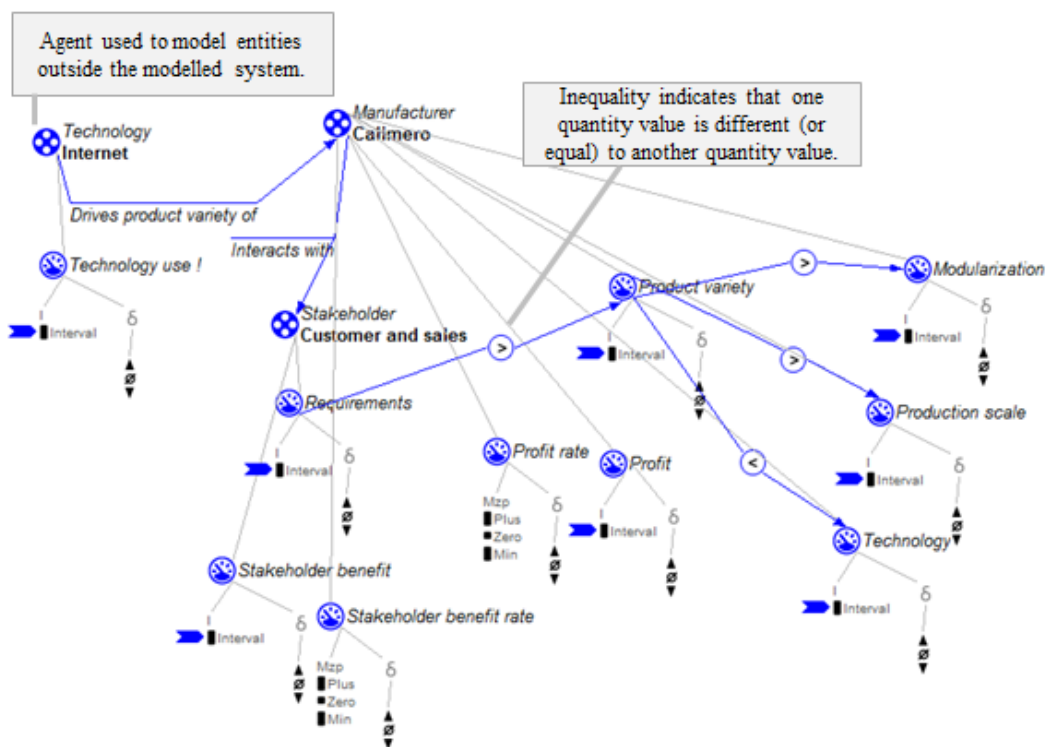


Figure 1: Scenario for a manufacturing company facing changing stakeholder requirements
 Source: own research

3.2. Basic mechanisms

The next challenge is to identify the mechanisms that cause changes in the enterprise behavior.

3.2.1. Mechanism 1: Technology-induced changes

We identified the studies of Brynjolfsson (Brynjolfsson et al., 2010), Hinz (Hinz et al., 2011), Rathnow (Rathnow et al., 1993), Bednar (Bednar et al., 2015) and Salvador (Salvador et al., 2002) to deliver valuable insights concerning possible drivers of product variety.

While Brynjolfsson et al. (2010) distinguish between technological and non-technological drivers of product variety, Hinz et al. (2011) focus on the Internet and related technologies as drivers of large assortments of products. The afore-mentioned enumerate Database and Search Technologies, Personalization Technologies as well as Social Networks and Online Communities as tools that have changed how consumers find the products they buy. Information technology is changing consumer needs, in the Internet consumers learn about new products and services, and they find a remarkable product variety. This of course puts the provider under pressure to offer a wider range of product varieties. In comparison to that, Hinz et al. (2011) highlight the improved search technologies. A different insight comes from Rathnow et al. (1993) who identify the sales department as a driver of product variety. According to Bednar et al. (2015), mass customization, a strategy that focuses on individual customer requirements but uses the advantages of mass production, can be seen as a driver of product variety. Salvador et al. (2002) see the heterogeneous customer needs as a driver of product variety. To put all these insights about drivers of changing stakeholder requirements together, we use the quantity *technology use* which is associated to the entity *technology* (see Figure 2). The positive influence (I+) between *technology use* and *requirements* is used to express information regarding causality and shows that *technology use* has a positive effect on *requirements*. We assume a quantity space {Interval} for both quantities.

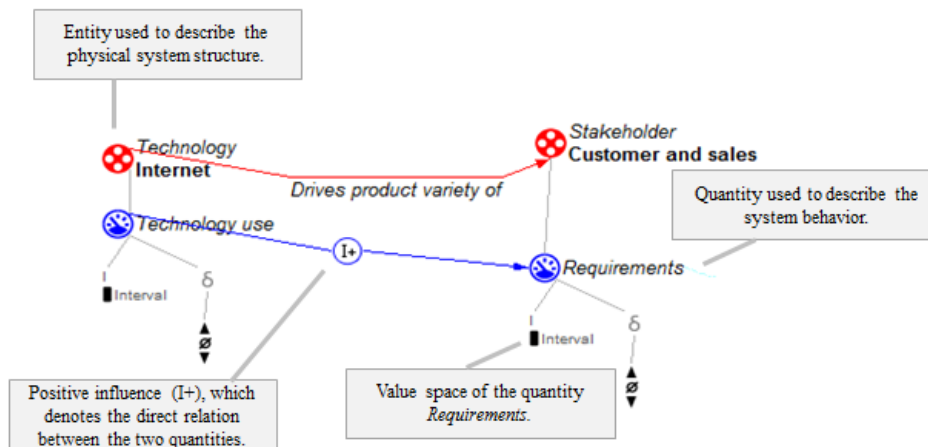


Figure 2: Changing requirements
 Source: own research

3.2.2. Mechanism 2: Fulfilment of stakeholders' requirements for high variety

As Kahn (1998) states, a high-variety strategy increases the possibility of fulfilling each individual consumer need. If *requirements* and *product variety* are in balance (*requirements* equal to *product variety*), we expect the *stakeholder benefit rate* to be stable. From a customer perspective, this is the optimal situation because customers find all goods and services required in the manufacturer's product portfolio. No action on the part of the manufacturer is required. If the quantity *requirement* is bigger than the *product variety*, we expect the manufacturer to increase the product variety to bring the system back into balance. If *requirements* are smaller than *product variety*, we expect the manufacturer to decrease the product variety to balance requirements and product variety, since the quantity *requirements* is external and thus cannot be influenced. This corresponds to (Kahn, 1998) who points out that too much variety causes too much confusion or overload. Figure 3 captures these insights by satisfying the equation "*requirements* minus *product variety* is equal to *stakeholder benefit rate*" (see Figure 3). If *requirements* are bigger than *product variety*, *product variety* has to be increased (denoted by the I+ from stakeholder benefit rate to product variety) and this in turn decreases the *stakeholder benefit rate* (denoted by the P- from product variety to stakeholder benefit rate).

The entity *stakeholder* on the left-hand side of the model shows an inverse behavior to bring the system in balance (I- from *requirements* to *stakeholder benefit rate* and P+ from *stakeholder benefit rate* to *requirements*). Different to the quantity *requirements* and *product variety* that assume the quantity space {Interval}, *stakeholder benefit rate* has quantity space {minus, zero, plus}.

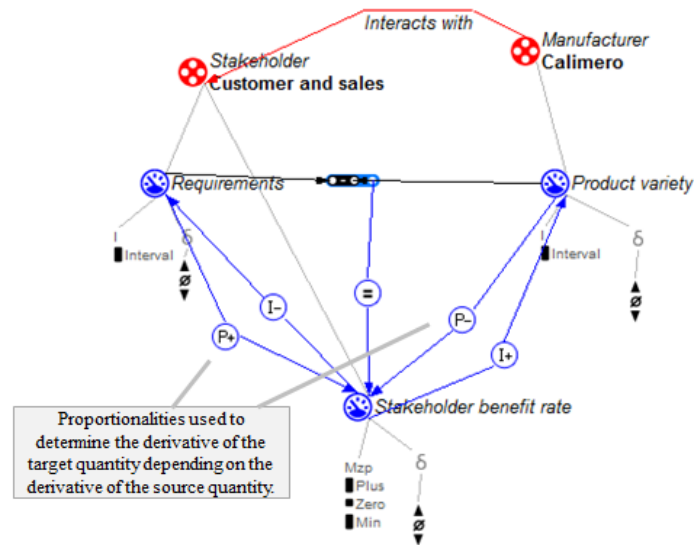


Figure 3: Fulfilment of stakeholders' requirements for product variety
 Source: own research

3.2.3. Mechanism 3: Modularity enables product variety

As Holmqvist et al. (2004) states, a constantly increasing product variety generates more complexity. The concept of modularization can be used to deal with this complexity by disassembling existing products and then integrating the components into modules that can be used for other products; this process thus helps to generate product variety. Kahn (1993) states that the modularization approach makes product variety strategies affordable by standardizing as much of the product as possible, and only varying those parts that provide an added value to the customer. Figure 4 shows the mechanism that summarizes these insights between *product variety* and *modularization*. If *product variety* is bigger than *modularization*, *modularization* has to be increased (denoted by the I+ from *profit rate* to *modularization*) and this in turn decreases the *profit rate* (denoted by the P- from *modularization* to *profit rate*). The quantity *product variety* on the left-hand side of the model shows an inverse behavior to bring the system in balance (I- from *profit rate* to *product variety* and P+ from *product variety* to *profit rate*). *Profit rate* has quantity space {minus, zero, plus}.

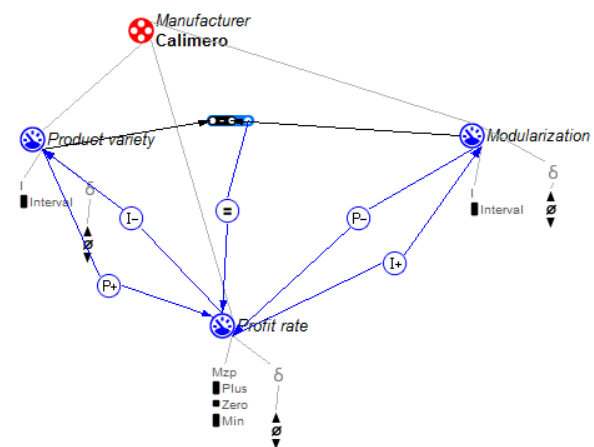


Figure 4: Modularity enables product variety
 Source: own research

3.2.4. Mechanism 4: Generation of scale economies

Missing Economies of Scale is understood as a barrier of product variety (Brynjolfsson et al., 2010), since more variants mean higher unit production costs. This economic effect is more likely to be achieved with concentration on a single product. As Schleich et al. (2007) state, a trade-off has to be found between the benefits of a higher product variety like increased market share and sales volume and the reduced economies of scale.

In our opinion, if we find a balance between *product variety* (production scope) and *product scale* (see Figure 5), the efficiency benefits from economies of scale and scope are guaranteed (equation “*product variety minus production scale is equal to profit rate*”). The quantity *profit rate* has quantity space {minus, zero, plus}.

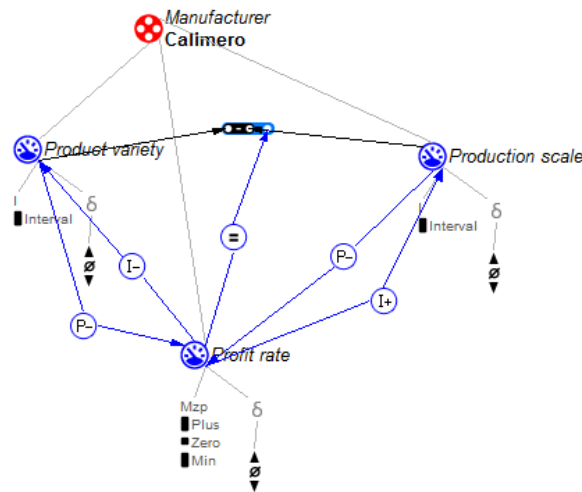


Figure 5: Generation of efficiency benefits in production
 Source: own research

3.2.5. Mechanism 5: Technology and product variety as complements

Gao et al. (2004) investigate IT as a driving and enabling force of product variety. They describe IT and product variety as complementarities. By combining these two, firms can generate higher value than other firms. Brynjolfsson et al. (2010) mention the IT-enabled markets which increase producers' incentives to focus on a niche market. For instance, technology modifies the cost of stocking products. By having these insights, we model the mechanism *product variety* and *technology* (see Figure 6). The quantity *technology* has quantity space {Interval}.

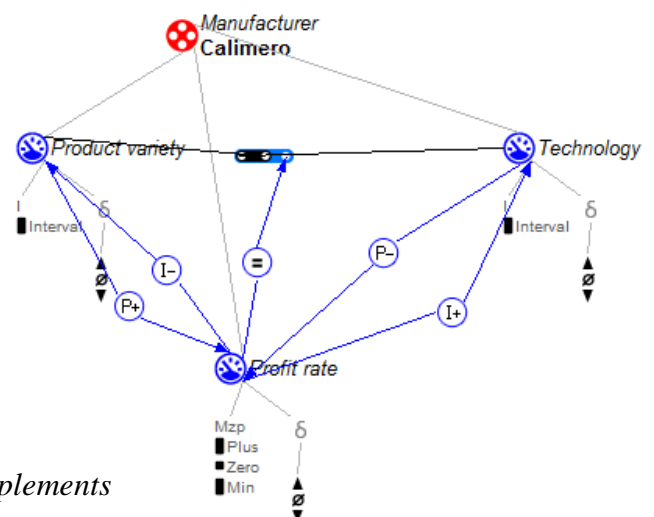


Figure 6: Technology and product variety as complements
 Source: own research

4. SIMULATION

Simulating the scenario „manufacturing company facing changing stakeholder requirements“ (Figure 1) produces a state graph with 6 states (see Figure 7), including one stable end-state (state 6). We select the behavior path [3->2->1->4->5->6] path for further analysis with the value history diagram (see Figure 7). The value history diagram represents the values of magnitude and derivative each quantity assumes in each state during the simulation. It enables us to follow the changes a quantity undergoes during the simulation. As shown in Figure 7, *modularization*, *production scale*, and *technology* follow *technology use*, meaning that all these quantities increase in states 3, 2, 1, 4 and 5. *Modularization*, *production scale*, and *technology* stabilize in state 6. *Stakeholder requirements* decrease in states 3, 2, 1, 4 and 5 and stabilize in state 6. This behavior can be explained by the fact that expectations decrease if parts of them are already fulfilled by a broader product variety. The quantity *product variety* decreases in states 3, 2 and 1, increases in state 5 and is stable in states 4 and 6. The decrease of *product variety* in states 3, 2 and 1 can be explained by the fact that besides *stakeholder requirements* also the quantities *modularization*, *production scale*, and *technology* have effect on *product variety*. In our model, the manufacturers’ *profit* decreases in all states except end state 6. It should not be forgotten that the increases in the quantities *modularization*, *production scale* and *technology* represent investments for the manufacturer. The quantity *stakeholder benefit* is stable in states 2 and 6.

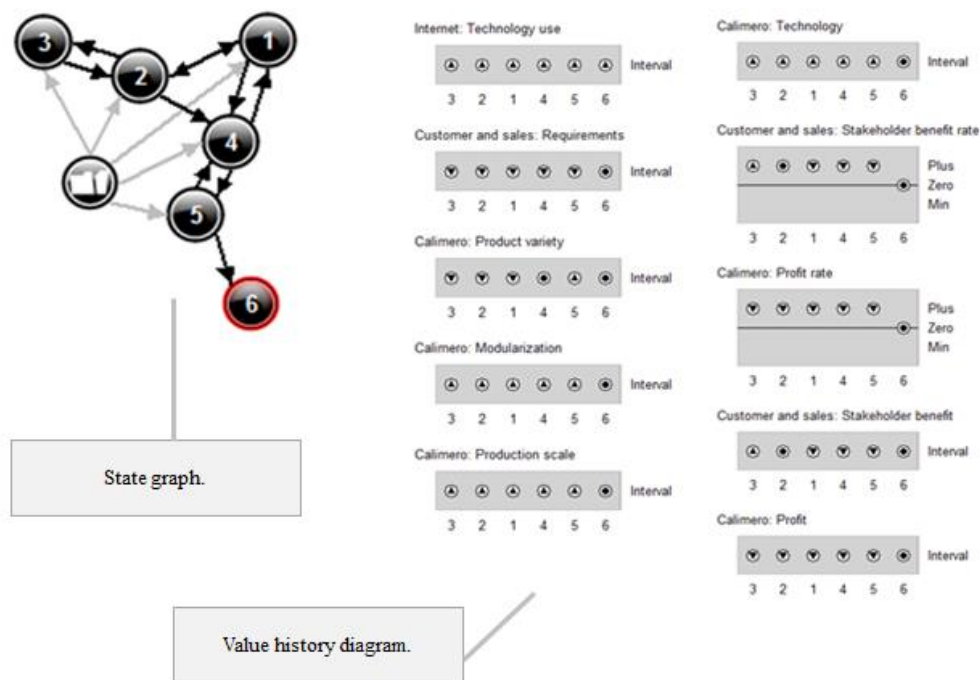


Figure 7: State graph and value history diagram for scenario “manufacturing company facing changing stakeholder requirements”
 Source: own research

5. CONCLUSION

Increase in product variety is a trend in many industries around the world. One of the reasons for the demand for higher variety can be found in changes in technology use. Garp3 provides a meaningful visualization of the investigated business scenarios. As Lancaster (1990) states, it is of big importance for a manufacturing company to think about the “optimal” degree of product variety. The study of selected research enables to draw a picture about driving as well as enabling forces of product variety.

The insights are presented in a knowledge graph using the Garp3 software, which in our opinion is well suited to demonstrate possible company behaviors due to changing stakeholder requirements. The demonstration in the form of models facilitates the explanation of domain knowledge gained from selected literature. In our current research, we enrich the models by further domain knowledge of cost behavior (e.g. a mechanism that balances costs and benefits to find the cost-optimal degree of product variety).

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