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Increasing Profitability Using a Simulation of the Cause and Effect Relationships between Key Variables in a Supply Chain

Erhöhung der Profitabilität durch Simulation der Ursache-Wirkungs-Beziehungen zwischen Schlüsselvariablen in einer Supply Chain

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Abstract: The model creation of complex systems requires the reduction of complexity. This paper illustrates an approach to build a cause-and-effect model in a case study with a retailer. The focus is first on the model conception, starting from vague goals, and second on the impact of the model use in a change process. The findings in the project are stated and a reflection of the approach is given.

1 Introduction

The challenge in retail business is to get the right products to the right place just when the customer is willing to buy them. To do so, a broad range of methods, tools and techniques have been developed such as

- a range of alternative flows of goods (direct, stock, transit, etc.),
- collaboration tools such as VMI (Vendor Managed Inventory) or cross-docking,
- process cost accounting and internal cost allocation mechanisms,
- logistic platform concepts with highly automated distribution centres,
- goods management and logistics systems,
- sound performance measurement systems and
- the use of TQM etc.

Since the sixties, when record companies discovered that they could promote their musicians in the charts by pushing their records into the shops, merchandise density has become a common rule of thumb used by retailers. Of course, it not only increases sales, but inventory levels also.

One of the key performance indicators to control supply chain performance is the out-of-stock rate of items in the shops. Most firms say it is crucial to minimize this rate, as it indicates a lost chance to sell something and satisfy a customer (cf. Torell 2008).

A large retailer can face a quite complex challenge to optimize his supply chain: he must bear in mind the optimization parameters and areas of influence, the tens of thousands of articles he sells, his multiple suppliers, his dozen or more retail shops and finally the changing combinations, whether they be seasonal or throughout the year.

Although numerous simulation-based investigations of retail supply chains have been carried out, an approach for the optimization of such a complex and somehow indistinct situation is hard to find in the literature and all the more so for this industry.

The purpose of this paper is to add some experiences and make some recommendations

1. to promote a change process in a company working with paradigms and unwritten rules
2. to cope with complexity in conceptual modelling and
3. to explain some of the findings for an increase in profitability.

2 The Case

Manor, a subsidiary of Maus-Frères AG in Geneva, is the leading multi-specialist in the Swiss retail trade sector. With 11,500 people employed in 70 department stores, the company achieved a turnover of approx. CHF 2.9 billion in 2007, representing a market share of approx. 58% of the department store market segment. Manor operates in a saturated market characterized by intense competitiveness. This market has been stagnating for many years and is set to continue stagnating in the long term despite recent growth caused by a blip in consumer behaviour. Manor's strategic objectives assume a sharp rise in profitability. Achieving this will be a huge challenge in which all divisions (purchasing, supply chain management, department stores) will have to play a part. The importance of supply chain management as a factor in the company's competitiveness was recognized by the management over 15 years ago. This led to the creation of a modern supply chain which had won several awards in the past.

Over 6,500 suppliers from around the world deliver around 750,000 items which are then offered for sale in dozens of different product lines, each with their own specific characteristics (even from a logistics perspective); whether it be women's clothing, multimedia, household goods or pet products. Added to this, every one of Manor's department stores retains its own characteristics, in terms of product range or consumer behaviour. In addition, this astonishingly high number of products is not all on sale throughout the year. Instead, new products and collections are constantly appearing on the sales floors, making this sector hugely dynamic.

Since there was no precise data on variables within this environment, Manor's supply chain was run by unwritten laws and paradigms which, whilst proving their worth in the past, are not necessarily appropriate today:

- A good example of this is the mix of flow of goods. Since its introduction years ago, there has been a feeling that suppliers make too many direct deliveries to the department stores.
- Another example is the rhythm of deliveries. Many of those involved in the supply chain felt that there were too many journeys to the stores, causing high in-store transportation and logistics costs.
- A third example concerns the issue of whether to open up packaging units at the distribution centre or at the department store.

There were many other areas where hidden assumptions and the absence of any holistic view meant that decisions were not being taken on a sound basis. There was also uncertainty over which influencing factors did in fact exist and how important they were in relation to the overall optimization of Manor's profitability.

Thinking about how to achieve new and challenging profitability targets, Manor realized that further significant optimizations in the supply chain could only be achieved if they took a holistic view. It became clear that – given the already high performance levels – it was no longer enough simply to look for further impact using simple solutions. Instead, contributions to the supply chain management system would need to be made via cross-divisional projects and innovative, original pathways.

The overall project purpose was, therefore, formulated as: "to bring about strategic decisions and introduce or implement efficient and effective measures aimed at optimizing the supply chain overall as a contribution to increasing Manor's profitability."

The project was executed in 2006 to 2007. Currently decisions are being put into action.

3 Promoting the Change Process

Authors who investigated change processes in the company all pointed out the importance of integrating affected key persons in the conceptualization process. The company, therefore, did not intend to appoint a renowned consultancy firm just to listen to their recommendations, although they might be elaborated and already proven. The main concern was to generate long-term improvements by gaining a company-wide understanding of the complex interrelationships between the variables in the complex supply chain, with time restrictions for such aim taking second place.

Instead an approach was chosen that combined a consultant with internal experts in the process of analyzing and taking decisions. This led to the following advantages, which were observed in the project:

1. In-house professionals were integrated in the project and promoted it.

2. Those involved benefited from skills development as a part of the project.
3. Interrelationships were investigated in cross-divisional teams and a sound understanding of those were developed.
4. Confidence in the solution grew, speeding up the decision and implementation process due to the support of the involved persons.

For the analysis, it was agreed to use participative modelling, a process in which the consultant and the client together develop a model of the object in question. This is a common approach in system dynamics (e.g. Vennix 1996) and proved to be applicable to support the points made above.

The goal to develop a simulation model within the analysis phase instead of employing diagramming techniques as it is common had a number of advantages:

- A comprehensive simulation system allows the widest range of scenarios to be computed and decisions can be taken on this basis.
- The effects of changes can be quantified; installing the model allows alternatives to be compared at low cost.
- Installing a comprehensive simulation model and applying it to decision-making was a novelty for the firm and its environment (including direct competitors and federation fellows), thereby meeting the company's claim to be innovative.
- By far the most important point is that a great deal of knowledge is condensed in the model and by showing the outcome of decisions in numbers as a result of simulation scenarios – supported by internal experts of each division – has an enormous convincing effect on senior management. This was the key to open the field for projects dealing with themes that had never been put in question before.

Supply chains simulations have become a common technique. A vast number of specific supply chain problems are addressed by different solutions and documented in literature (see Cope et al. 2007 for an overview). But still, to understand problems, phenomenas, results and mechanisms of processes in a company is an adventure which cannot necessarily be solved by predescribed simulation tools or models as long as the occurrence of those points is not defined enough to confirm the match. Neither discrete event simulation, decision or planning support tools, nor process simulation methods were found applicable. On the other hand, the widely open system dynamics approach based on cause and effect relationships was found suitable for investigations in this case.

As a software tool, *Vensim* was chosen as its notation in the form A → B ("if A increases, B does also") is very easy to understand and can be interpreted even by people who are not accustomed to these kinds of tools.

An often reported disadvantage of simulation models is the effort needed to design and verify them. Clearly, there is much work to do and it should be judged in each case if it is worthwhile. In this case, the knowledge gained by the participants and the savings resulting from the decisions made surpassed by far the efforts.

4 Coping with Complexity in Conceptual Modelling

Conceptual modeling is almost certainly the most important aspect of a simulation project (Robinson 2006). System complexity (an often used but not commonly defined concept) sets high demands on an insightful representation of model elements, both for the analyst and the stakeholders as domain experts (Van der Zee and Van der Vorst 2007).

Questions arose e.g. how to deal with the fact that there are some 750,000 different products (including variants in size and packaging) with different characteristics like price, seasonality, in/out vs. stock keeping and so on. How should the 6,500 different suppliers from Europe and the Far East be taken into account with their diverse ways of delivering goods? What impact do the 73 (different, of course) department stores in all parts of the country have, where consumers partly show disparate behavior in making their purchasing decisions?

It is known that a number of principles are suited to reduce complexity. Following a short summary, we will demonstrate how we applied these principles to the challenge of building a simulation system for the situation outlined above.

- Decomposition: breakdown of a system into semi-independent components (Van der Zee and Van der Vorst 2007).
- Classification: grouping of similar types of objects (Van der Zee and Van der Vorst 2007).
- A basic background is given by system theory (boundaries, elements, subsystems etc.).
- Aggregation Levels of Models (Ulgen and Gunal 1998)
- Goal orientation, which provides guidance for reducing non-relevant aspects.

Another aspect we like to add is derived from our definition of complexity. The following points contribute to complexity and can be adjusted, if applicable:

- number of elements: all as-is ↔ some relevant
- number of relationships between elements: all as-is ↔ some relevant
- nature of relationships between elements: determined ↔ chaotic
- number of subsidiary systems: all as-is ↔ some relevant
- temporal change: static ↔ dynamic

4.1 Detailing Project Goals and Defining Subsystems

Certainly, each project has to start with detailing the goals. The benefit regarding the reduction of complexity is that the goals lead to perimeters for the system (or criteria for decomposition). In our case, the goals derived from the clients questions as follows:

- What is the best combination of goods flows?

- How do efforts to compact goods in containers and trucks correlate with costs and service quality induced by the frequency of deliveries from distribution centres to stores?
- What are the effects of merchandise density and how can we get control regarding an optimization?
- What are the driving forces behind building stock in the stores and what measures effectively lead to reductions while not affecting sales?
- What is the effect of the number of articles in an assortment and how can we evaluate the current situation?
- As rotation of goods was a proven performance indicator in the Toyota Production System (and in retail by discounters): how can we apply this concept to a firm which claims to be a specialized dealer in almost each product line?

The decision to build a model based on causes and effects made things easier when compared with a model based on material flow for example because from these goals we could simply define topics for further investigation that served as subsystems. Figure 1 gives an example.

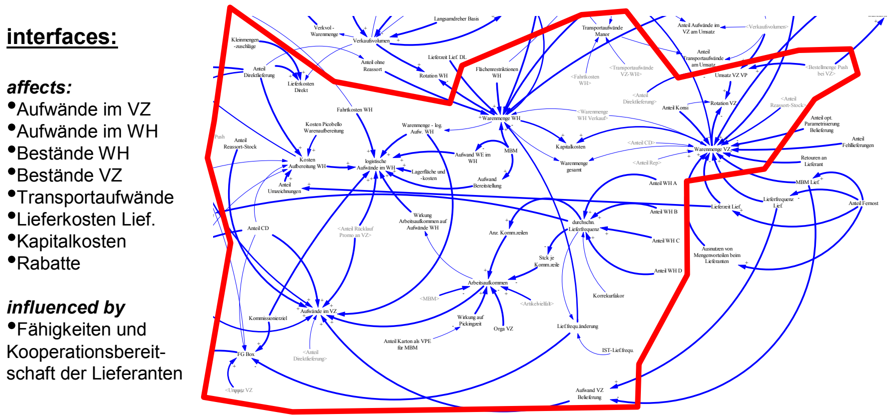

Figure 1*: A Subsystem from the Cause and Effect Diagram for Discussion by the Expert Group*

The topics also gave way to the formation of expert groups: any number of professionals could be involved in subprojects with the connections between thematic areas remaining transparent at all times.

4.2 Setting Constraints for the Subsystems

Having defined what subsystems were to be investigated was a big step forward. But, still the framework for defining model entities had not been set. For this, our list of complexity drivers appeared to be helpful:

- *Number of elements*: In a cause and effect model, there is no need to have those elements mentioned above (articles, suppliers, department stores etc.); we need their characteristics only. When characteristics are formed by several different elements, we strive to calculate them as an average whenever possible. In this sense, classification and aggregation is used to minimize complexity.

- *Number of relationships between elements*: There might be some chance to separate the more important from those, which have only the slightest impact. But, generally there was no limitation.

- *Nature of relationships between elements*: The relationships – if not known exactly – were described by basic mathematical functions: linear, exponential, saturation, logistic growth. In our experience, in models with many relationships, these few elementary functions are sufficient to get the kind of results that can be expected in business dynamics.

- *Number of subsidiary systems*: As the overall goal was an increase in profitability, we decided to look at the monetary aspects, only, and to describe all relationships either in Swiss francs or factors of those.

- *Temporal change*: The only possible dynamic in our system could come from feedback loops. Such loops can only be thought of as coming from decisions made within the system. However, the investigation of decision making was not included in our goals; we just wanted to prepare for the decisions. Thus, our model could be designed as stable.

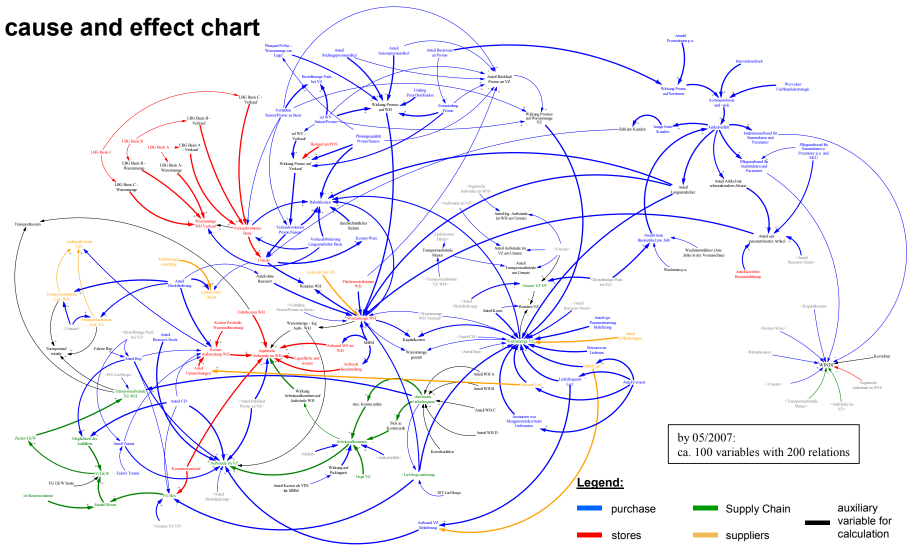

Figure 2: *Representation of the Influencing Factors in Manor's Supply Chain from Supplier to Customer in the Cause and Effect Diagram*

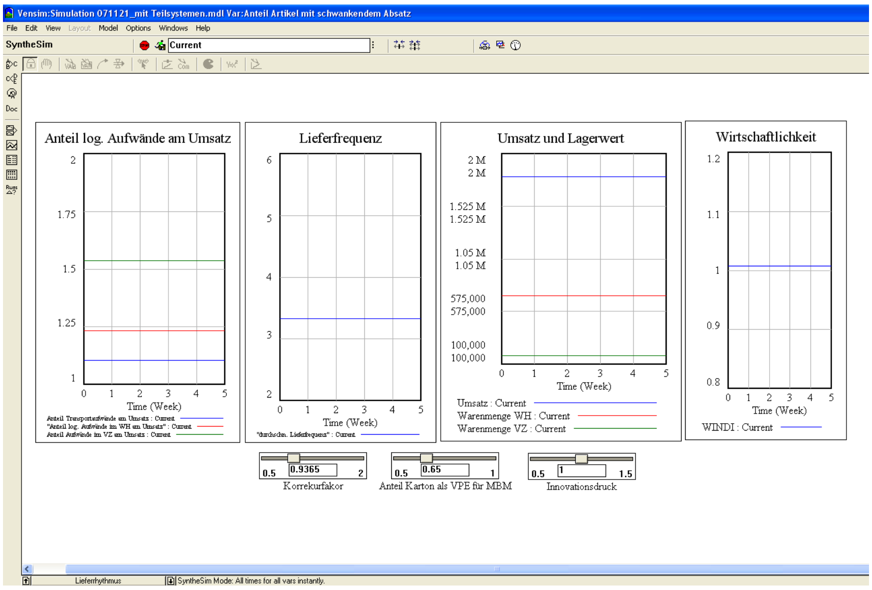

Figure 3: *Cockpit Display of the Simulation Tool: Effect of delivery frequency ("Lieferfrequenz") on Key Variables, mainly Share of Logistics Costs per Turnover (left) and Efficiency (right)*

With this groundwork at hand, the work on the model can start. The rest is part of the challenge for the analyst working with the interdisciplinary expert groups. For the results of the case study, please see figure 2.

5 Findings in the Project

5.1 How the Model Works

An exemplary demonstration of the results shall give an insight as to how the simulation model works and what kind of results one expect from it.

The subsystem "Delivery Rhythm" was build by continually asking questions like "what are the determining factors for the frequency of store deliveries" and "what causes a higher or lower frequency?" until the chain of causation satisfied analyst and experts. The next step was to describe the relationships of all elements in terms of costs or factors. The resulting figures can be displayed in the simulation while variable inputs can be changed by using the scroll bars as shown in figure 3.

The simulation showed that an average reduction of 0.5 delivery days per week and article category in B and C stores (which is 12% for B and 14% for C stores respectively, where A and B are categories by turnover)

- reduces handling costs by CHF 200,000 at the distribution centres and department stores respectively,
- reduces transport costs by approx. CHF 750,000,

- raises stocks in the department stores by approx. CHF 4m whilst reducing it in the distribution centres by CHF 3.5m,
- leads to total savings of CHF 1m.

These results were tested and confirmed in pilot trials and have been put in effect, meanwhile.

Of course, this is an example of easy-to-calculate relationships. A different matter is the adjustment of out-of-stock rates.

This requires further explanation. The argument that missing articles on the shelf lead to missed sales and is a potential loss for the company must be seen in a wider context of statistical meaning. We can observe that the effort to keep out-of-stock rates low leads to larger amounts of quantities ordered. As it not possible to exactly foresee sales in the different stores, ordering more of everything is the only way to reduce them. For this reason, out-of-stock is not only a matter of a single unit not available on the shelf. It is also linked to a large number of articles ordered, filling up stocks in the department stores. Obviously, a differentiation of articles by their chance to be sold would lead to higher efficiency. But the initial situation was found to be vice versa: A-articles had an out-of-stock rate of 1.5 %, C-articles of 0.3 % - whereas stocks have a range of several weeks.

The findings of our investigations suggest to not always stock basic range items which are rarely in demand and so are not necessarily expected to be available by the customer. This gives the chance to then adjust replenishment and management processes accordingly and should lead to the following results for an increase of out-of-stock C-articles:

- a significant reduction in stock levels at the department stores of CHF 80m and in the distribution centres of CHF 16m,
- reduced discounting costs of CHF 2.5m,
- slight reductions in costs at distribution centres of CHF 0.3m and at the department stores of CHF 0.15m.
- and an overall bottom line increase of over CHF 5m.

Certainly, the relationships in this example like "out-of-stock rate of C-articles in dependence of stock level" or "sales in dependence of out-of-stock rate" are not known. Therefore, those numbers stated above cannot be claimed to be exactly true. All we can do here is to analyze the data available, discuss opinions with experts and change the described relationships within the range of assumptions to see if results are stable. On the other hand, all the client needs to make a decision is that the direction is the right one; not necessarily that the proposed results are exactly right.

5.2 Leverages of Main Actuating Variables and Decisions made

One of the main goals of the project was to determine the variables which Manor can influence and to map their effects on Manor's overall profitability for the pur-

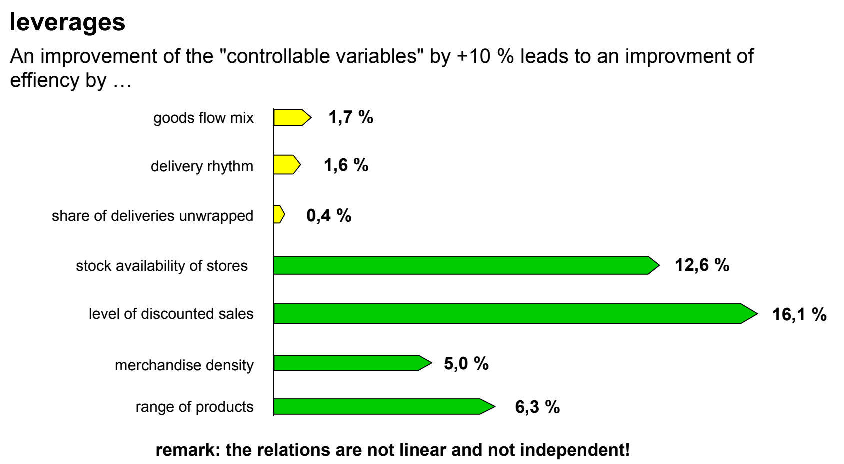

***Figure 4**: Comparative Significance of Central Influencing Variables for Profitability*

pose of deriving the most efficient measures. The following conclusions resulted from applying the simulation system (please refer also to fig. 4):

Different aspects can be classified by the effect on Manor’s overall profitability.

For all intents and purposes, the following variables cannot be influenced:

- level of discounts
- fill rates of trucks and boxes

These two aspects are influenced by other aspects and are, therefore, resultants. With respect to discounts, it should, however, be pointed out that discount costs are a crucial area. If the right adjustments could be made here, reductions in these costs stand to make the highest gains in terms of Manor's overall profitability.

The percentage of deliveries made at packaging unit level (instead of breaking open packaging units at distribution centres) has a marginal effect, only.

These aspects have a slight effect on Manor’s overall profitability:

- delivery rhythm (number of deliveries from distribution centres to department stores per week)
- mix of flow of goods.

These aspects have a large effect on Manor’s overall profitability:

- merchandise density
- range of products

A high merchandise density is only profitable if combined with (as a minimum) a modest quality of planning (the latter expression is used to describe how good purchasing met the customers’ expectations for the articles; one indicator is the level of discounts on sales).

These aspects have a very large effect on Manor’s overall profitability:

- stock availability at the department store (->out-of-stock rates)
- quality of planning

To give an idea of the importance of this model for the future direction of the company we can provide a short list of actions:

- change the mix of flows of goods towards less direct and stock and introducing a new kind of cross docking
- adjust the frequency of store deliveries
- adjust the service levels in department stores (“out of stock”) for each category of item and drastically reduced for C items.
- define a promotion strategy fine-tuned to the needs of Manor’s overall supply chain.
- base purchasing no longer on the in-store merchandise density of a product but on the principle of “relative product availability”.
- lower initial allocations for remaining stock from distribution depot during discounted “push” sales.
- optimize product range breadth and depth.
- conduct a clearer division of responsibilities and competences between the Purchasing Division and the department stores.
- rework and communicate the liquidation policy.
- optimize supplier management: contract design (service level), delivery terms, supplier evaluation, numbers of suppliers.
- define detailed purchasing processes to improve planning quality, discounting and relative product availability incl. product costing analysis; revision of existing purchasing processes: cost-optimized for basic products, time-optimized for the latest products (e.g. fashion).
- review performance indicators and introduce control indicators and incentive systems to assist in presenting the success of the measures referred to and the development of causes and effects.

6 Conclusion and Future Works

The chosen approach for model creation has proven its applicability in the described example. It shows some similarity to the works of Van der Zee and Van der Vorst (2007) and can be described as analogical to the aforementioned authors as:

1. Domain analysis: The setting of goals for the simulation results in the definition of the simulation approach (cause and effect, discrete event etc.), the system boundaries and the subsystems (decomposition)

2. Framing (framework for defining model entities, activities, relationships, and their dynamics). Principles for complexity reduction have to be chosen for each subsystem: aggregation through classification of elements / filter to reduce the number of relations between elements / simplification methods for describing unknown or tricky relations between elements / limitation of subsidiary systems to investigate / dynamics to consider or to blind out.
3. Grammar: Definition of techniques for analysis, documentation and the simulation system itself.
4. Model building

Future work will have to prove and refine this approach by the application to further projects in business dynamics. Comparisons with different kind of model creation projects will show mutuality and differences between business dynamics, manufacturing simulation and others.

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