

Combining Qualitative Reasoning and Balanced Scorecard to model future behavior of a company

Torben Huegens, Stephan Zelewski

Institute for Production and Industrial Information Management, University of Duisburg-Essen
Universitaetsstr. 9
45141 Essen, Germany
{torben.huegens | stephan.zelewski@pim.uni-due.de}

Abstract

Using the management technique “Balanced Scorecard” in a company means to deal with several objectives that are only qualitative or partially quantitative. These objectives have to be sorted into a framework, the so-called perspectives. Kaplan/Norton say that the objectives of the perspectives are causally linked between each other and that this causality is desirable because with these causal links it is possible to make assumptions about the future performance of a company. In contrast to this statement, their description of techniques to causal link the objectives is unspecific, based on intuitive and subjective knowledge. Due to this a company does not know the effects of taken actions onto the objectives. Using a Qualitative Reasoning technique like Qualitative Simulation a company has the opportunity to get an overview over possible future developments of the company. The strategic management of a company can then be grounded on the Balanced Scorecard.

Introduction

In the well-known management technique “Balanced Scorecard”, the objectives of the different perspectives and the links between them play an important role. Kaplan/Norton say that the objectives are causally linked and this causality is desirable because with these links it is possible to make assumptions about the future performance of a company. Through this it becomes feasible to give a company clear advices how to achieve the desired objectives and explain how the objectives interact. In particular, causal knowledge about interactions between the objectives of a company is of great economic relevance. For the complex, i.e. not linear networked interaction links between the objectives it can be followed that non intended effects can occur, which have an impact on the intended achievement of the objectives. In extreme cases the intended effects can be inverted.

Currently the identification of the causal links is done by management teams. The identification process is based on subjective and intuitive knowledge. In addition, the correlation analysis, structural equation or “path” analysis, neuronal networks and other quantitative techniques are used to validate the made assumptions. These techniques suffer

a strong problem caused by using only quantitative information. A large number of objectives are measured not quantitative but qualitative and so there can be only a qualitative link between them, too. For these objectives, it is not possible to validate the causal links with the above mentioned purely quantitative techniques. A technique is needed to validate these assumed causal links, because the knowledge of the management team is limited and may be wrong. Therefore, a new way of validating the causal links is needed.

A possible approach is to combine the Balanced Scorecard with Qualitative Reasoning. Using Qualitative Reasoning, it is feasible to predict future behaviors of purely qualitative models of objectives. For this Qualitative Reasoning provides a clear method to make explicit the links between parts of the considered model (with qualitative equations or graphically). Furthermore a simulation of future behavior of the model can be done. Thus the modeler can learn about possible influences on the system of modeled objectives and how the model will react on this.

For the Balanced Scorecard, Qualitative Reasoning gives the opportunity to qualitatively model the assumed causal links between the objectives and validate these links through the simulation of the future behavior of the model. The company gets the opportunity to know how it can influence the future behavior through actions that are undertaken to improve one or more objectives simultaneously. In Addition, it gets to know how to handle possible non intended side effects that result from the assumed causal links between the objectives.

The Balanced Scorecard

Beginning in the early 90’s Kaplan and Norton introduced a new Performance Measurement System called the Balanced Scorecard (BSC: Kaplan and Norton 1992; Kaplan and Norton 1993; Kaplan and Norton 1996). The BSC is an instrument for the top-management presenting all needed information about the company at a glance in a so-called “management cockpit”. Figure 1 shows the typical visualization of the BSC.

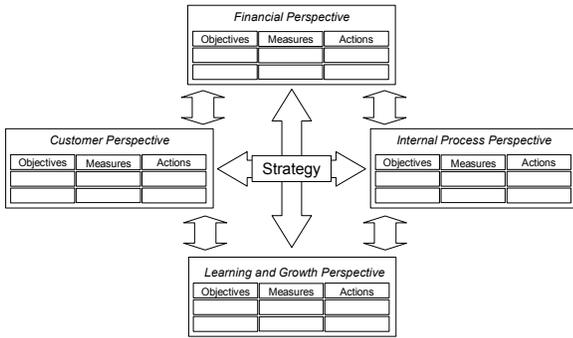


Figure 1: BSC-overview

The generic perspectives of a Balanced Scorecard are (Kaplan and Norton 1992):

- Financial Perspective – How do shareholders see us?
- Customer Perspective – How do customers see us?
- Internal Process Perspective – What must we excel at?
- Learning and Growth Perspective – Can we continue to improve and create value?

These perspectives are filled with objectives, measures and actions. Beginning with a strategy objectives are developed in detailing and refining the strategy into objectives for the perspectives. The attainment of the objectives has to be measured using corresponding measures. To improve the attainment of the objectives actions are needed, which focus on one objective and try to improve these objectives. The “management cockpit” aggregates all these information into a traffic light illustration. Showing green if an objective is reached and showing red if an objective is not reached.

Since the first publication the Balanced Scorecard has been undertaken a constant development (Kaplan and Norton 2000; Kaplan and Norton 2001a; Kaplan and Norton 2001b; Kaplan and Norton 2004). From first focusing the objectives, measures and actions, the focus changed to strategy formulation, and visualization of the strategy and objectives using the so-called strategy map (figure 2).

In the strategy map, the objectives are connected through arrows basing on the intuitive and subjective knowledge of the development team. Using this kind of illustration, it should become clear how a company is influenced through the approach or fail of all or some objectives. To create a complete strategy map the objectives and the connections between the objectives have to be identified. In the example (figure 2) of a strategy map, the following connections between objectives have been identified: E.g. on the lowest level, the Learning and Growth Perspective, three key objectives are identified: Attract and retain quality personnel, Improve knowledge management and Develop leadership capability. The following level, Internal Process Perspective includes the objectives Better research, New products and Increase partners.

The objectives in the “standard” strategy map are connected using arrows, which only explain that the objectives are connected. There is no statement possible about the strength of the influence from one objective on another. If causal maps or cognitive maps would be used to model a

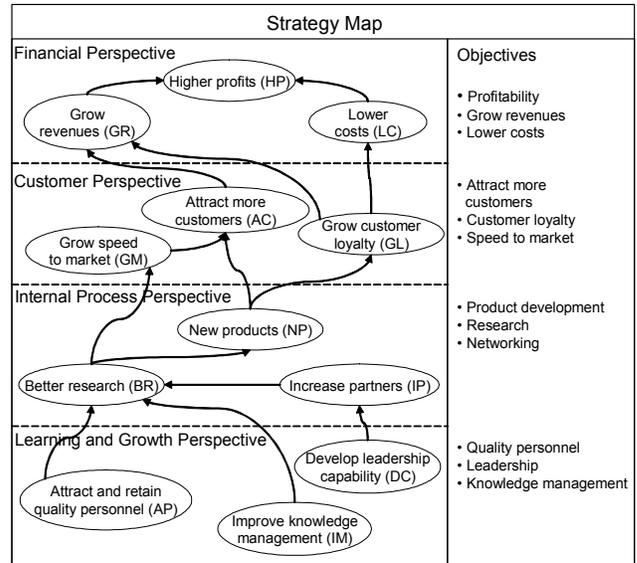


Figure 2: Example of a strategy map

strategy map, the direction and the strength of the influence could be stated. Traditionally the identification process is done in management meetings using intuitive and subjective knowledge about possible objectives and connections. A validation is only possible in using the objectives and introducing new actions. After some time the behavior of the model can be identified and it becomes clear that the connections and objectives are right or wrong. The correctness of the assumed causal links between the objectives can be proved using correlation analysis, structural equation or “path” analysis, neuronal networks and other quantitative techniques. These techniques use only quantitative data and only quantitatively described objectives can be validated. So a new technique is needed, which can handle qualitative and quantitative data, because the objectives, which are identified, are mostly qualitative, only the underlying measures are partly quantitative. In this approach a Qualitative Reasoning (QR) technique, namely the qualitative simulation technique developed by Kuipers is used (Kuipers 1986; Kuipers 1989).

The development of Qualitative Reasoning has traditionally focused on the usage in the origin area of qualitative physics (Berleant and Kuipers 1997; DiManzo, Tezza, and Trucco 1988; Forbus 1984; Weld 1990). In the mean time, Qualitative Reasoning has not been solely used in qualitative physics, but also in areas like ecology (Rickel and Porter 1992), continuous processes (Leitch, Freitag, Shen, Struss, and Tornielli 1992), engineering (Hogan, Burrows, Edge, Woollons, and Atkinson 1991; Dague 1988; Rehbold 1989; Kiriyama, Tomiyama, and Yoshikawa 1991), and medicine (Kirby and Hunter 1991).

Some attempts have been done to use Qualitative Reasoning in the areas of economics and business administration. Berndsen/Daniels used Qualitative Reasoning to analyze dynamics and causality in Keynesian models (Berndsen and Daniels 1990). Farley/Lin and Steinmann showed some applications of Qualitative Reasoning to analyze

economic models (Farley and Lin 1990; Steinmann 1997). Examples of Qualitative Reasoning in business administration provide Hinkkanen/Lang/Whinston. They use Qualitative Reasoning to analyze accounting systems, using a specialized Qualitative Reasoning technique, named Rules Constrained Reasoning (Hinkkanen, Lang, and Whinston 2003). Even the forecast of Cash Flows has been done using Qualitative Reasoning techniques (Bailey, Kiang, Kuipers, and Whinston 1993).

An attempt that is similar to the approach presented here is the model-based diagnosis of the business performance of companies (Daniels and Feelders 1991). In this attempt, only quantitative objectives are focused and the connections between them are analyzed. The approach presented here is different, because it focuses on links between qualitative objectives.

Construction of the constraint model

Using the above shown strategy map of a hypothetical company the graphical constraint model in figure 3 can be formulated. Due to the ambiguity of the strategy map further assumptions have to be made:

1. Every connection between the objectives is monotonically increasing meaning that every objective has a positive influence on the connected objective.
2. If more than one objective is connected to an objective the influence has to be added up, because the aggregated influence on the objective must not be equal to the sum of the parts. Due to this, the construction using influences, which are monotonic increasingly connected to the objective, is used. These influences are added up and

the amount is equal to the influence on the objective. This approach is used due to the consideration that always compensation-effects can be measured, even if one objective is not achieved. It would be possible to connect the objectives using the MULT-constraint, and then there would be no compensation-effect if one objective is not achieved.

3. A Higher profit has an influence on the rate of change of Attract and retain quality personnel. Due to a better image of the company more quality personnel can be attracted and retains in the company.

To reduce the complexity of the model in a first attempt a smaller model is used for the qualitative simulation (see figure 4). For the simulation of this small example additional assumptions had to be made:

1. Every objective has reached a distinct landmark value marked with a star at time-point t_0 .
2. At first only the time-points t_0 and t_1 are considered as relevant.

The goal of the qualitative simulation is to determine which behavior is possible from the given initial state t_0 , when a new action is launched.

The following figure 5 shows the reduced model of figure 4 as a QSIM description (basing on Qualitative Differential Equations (QDE)).

The model in figure 4 and 5 connects with a monotonic increasing function the objective "Attract and retain quality personnel" (AP) with the influence of AP (influenceAP). Equally the objective "Improve knowledge management" (IM) is connected with the influence of IM (influenceIM) using a monotonic increasing function. These influences are added as influence on the objective "Better research".

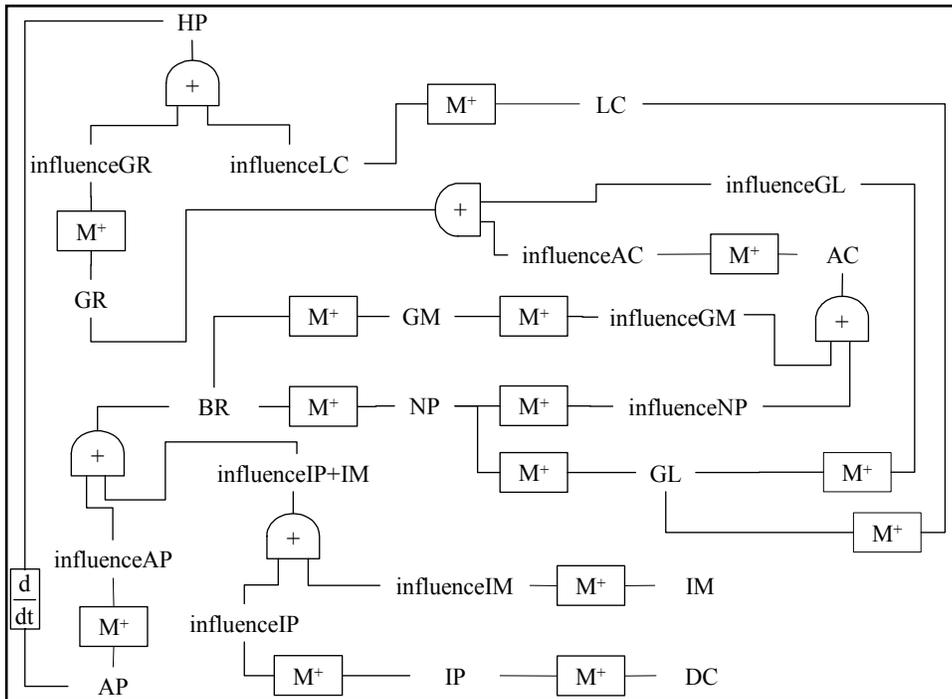


Figure 3: The strategy map as constraint model

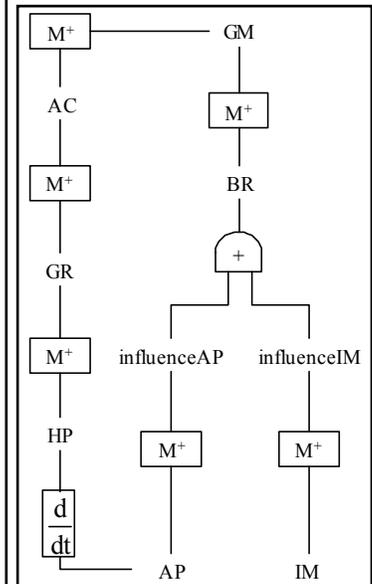


Figure 4: Example model

The following objectives “Grow speed to market” (GM), “Attract more customers” (AC), “Grow revenues” (GR) and “Higher profits” (HP) are connected using monotonic increasing functions. To generate an impact in the model over time, the objective “Higher profits” is connected to “Attract and retain quality personnel” using the partial derivative d/dt .

Model: Balanced Scorecard	
Quantity Spaces:	
IM	(minf...0...im*...inf)
AP	(minf...0...ap*...inf)
BR	(0...br*...inf)
GM	(0...gm*...inf)
AC	(0...ac*...inf)
GR	(0...gr*...inf)
HP	(0...hp*...inf)
influenceIM	(minf...0...inf)
influenceAP	(minf...0...inf)
Constraints and Corresponding Values	
influenceIM = M^+ (IM)	(minf minf), (0 0), (inf inf)
influenceAP = M^+ (AP)	(minf minf), (0 0), (inf inf)
BR = influenceIM + influence AP	
GM = M^+ (BR)	(0 0), (gm* br*), (inf inf)
AC = M^+ (GM)	(0 0), (ac* gm*), (inf inf)
GR = M^+ (AC)	(0 0), (gr* ac*), (inf inf)
HP = M^+ (GR)	(0 0), (hp* gr*), (inf inf)
AP = d/dt (HP)	

Figure 5: Description of the Qualitative Structure

For a complete description of the Qualitative Structure the initial state has to be added (figure 6):

The actual value of GM is gm^* and the direction is increasing due to a new action that has been launched. It is assumed that the new action has a positive influence on the qualitative value of GM and so changing the qualitative direction to increasing. The actual value of IM is im^* and the actual value of AP is ap^* , in both cases the direction of change is not known. Two possible initial states generated by QSIM are shown in figure 6. The initial value is given through the pair of qualitative value and qualitative direction.

Objective	Initial state	
	1	2
IM	(im*, dec)	(im*, inc)
AP	(ap*, inc)	(ap*, inc)
BR	(br*, inc)	(br*, inc)
GM	(gm*, inc)	(gm*, inc)
AC	(ac*, inc)	(ac*, inc)
GR	(gr*, inc)	(gr*, inc)
HP	(hp*, inc)	(hp*, inc)
influenceAP	(I-1, inc)	(I-1, inc)
influenceIM	(I-0, dec)	(I-0, inc)

Figure 6: Initial states of the QSIM model

Using the above shown model to simulate the future behavior the QSIM software generates at least fifteen possible initial behaviors. The following figures 7 and 8 show the results for example behaviors of the same initial state.

Interpretation of the results

Normally one would expect that all objectives increase due to the increase in “Grow speed to market”. Nevertheless, the first behavior plot (figure 7) shows that the objective “Improve knowledge management” decreases at first and afterwards returns to its initial-value. The influence of AP is strictly increasing. Equally, the influence of IM first goes down and the direction is unspecified, afterwards the starting value is reached again and the direction of change is increasing. This behavior can be explained through the huge ambiguity. QSIM only predicts all possible behaviors using the P- and I-Transitions.

A company with this strategy map can see from the qualitative simulation that the improvement of the objective “Grow speed to market” improves all other objectives, despite “Improve knowledge management”. “Improve knowledge management” seems not to change focusing on the time-points t_0 and t_1 . Though it has to be analyzed in the company why the objective “Improve knowledge management” is at first negatively influenced and afterwards reaches its starting value.

The second behavior plot (figure 8) shows that the influence of AP is strictly increasing, too. The influence of IM strictly goes down and reaches zero. The direction is still decreasing. All other objectives behave in the same direction, they increase and reach inferior. The direction of all objectives is still increasing.

Considering this second behavior a company can see that the improvement of the objective “Grow speed to market” improves all other objectives, despite “Improve knowledge management”. “Improve knowledge management” decreases and reaches at time-point t_1 zero.

In both cases the top-objective “Higher profits” is influenced positively, in the second behavior plot it even reaches infinity (this behavior needs further research, because normally it is impossible that an infinite profit can be reached). The success of the company seems not to be influenced through the objective “Improve knowledge management” that is not reached.

Due to the huge ambiguity of the example strategy map, the small example qualitative model shows equally an ambiguous behavior. In a “real” company, more knowledge can be represented in the model to reduce ambiguity and the number of different behaviors.

Conclusions

The model presented here shows only a first attempt to combine Qualitative Reasoning and Balanced Scorecards to allow companies to get a clue of the change in the com-

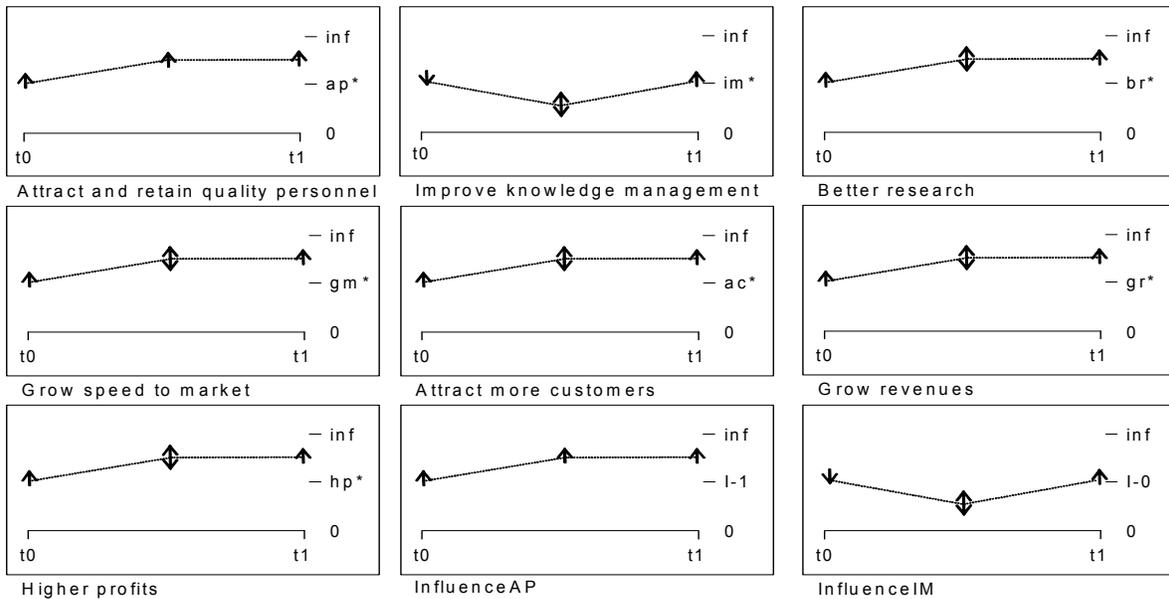


Figure 7: Qualitative behavior 1 on the basis of initial state 1 for the small example – Time t_0 to t_1

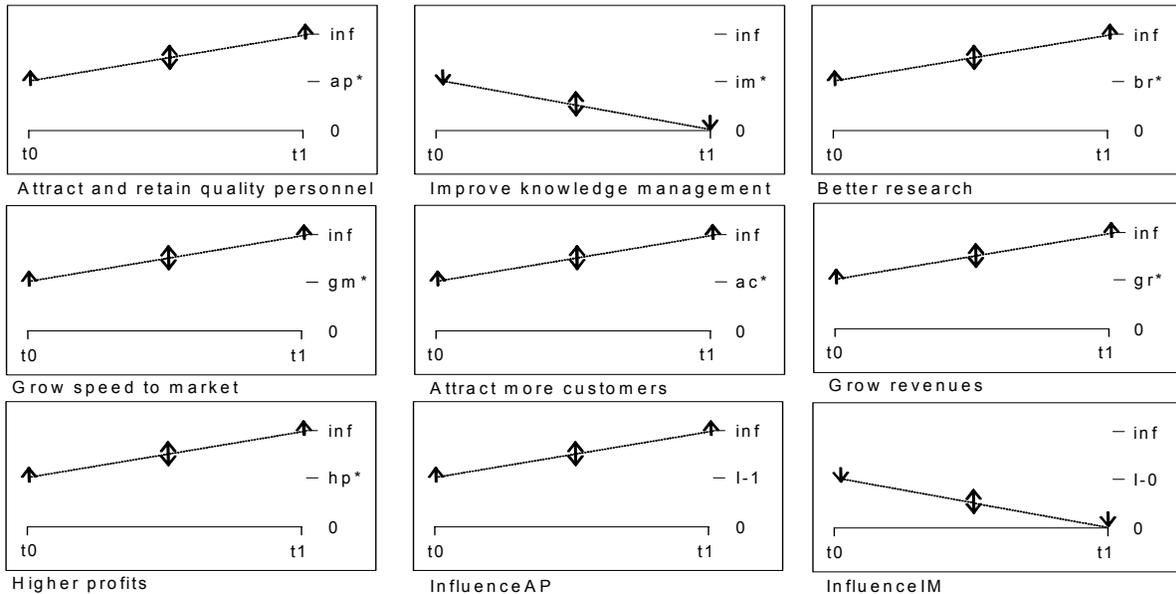


Figure 8: Qualitative behavior 2 on the basis of initial state 1 for the small example – Time t_0 to t_1

pany, if a new action to reach a higher value of one objective is launched.

Using Qualitative Reasoning the financial success of a company can be explained. The management gets the possibility to understand which influences taken actions can have on the financial success. Furthermore, using Qualitative Reasoning it can be shown, that even in small networks of objectives the type of impacts of one action on different objectives cannot always be uniquely defined. It can be ambiguous as long as the effects of objectives cannot be exactly quantified (which is common in corporate practical experience due to side-effects and estimation de-

fects). This should lead management teams to more attention against actionism.

The further development of Qualitative Reasoning and Balanced Scorecards may comprise:

- The qualitative simulation of the whole strategy map with all objectives and influences;
- more connections between objectives including both increasing and decreasing connections and
- further refinement (knowledge enrichment) of the model to predict fewer states.

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