Management Accounting and Business Analytics

An example of System Dynamics Modelling’s use in the design of a Balanced Scorecard

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Abstract
This paper focuses on how System Dynamics Modeling (SDM) can contribute to an increased understanding of business in an ‘analytics’ setup. Such improved understanding is necessary to identify the variables that most effectively support a company’s strategy in a Balanced Scorecard (BSC). By combining the idea of a BSC as a causal loop system with systems thinking, the current paper aims to address not only the conceptual domain concept of ‘comprehensiveness’ related to BSC, i.e. the ‘scope’ (learning) and ‘differentiation’ (system dynamics causality and feedback), but also the methodological domain concept of ‘precision’ (solution by differential equations). We show that a company can improve its understanding of its business at a very early stage in the BSC design phase by using SDM such as causal loop diagrams.

1. Introduction
Within management accounting a frustration point has been that few research results have ever been used in the practical world (Merchant, 2012), even though management accounting is actually an applied and practical field that continually faces new challenges from the business world in real life (Kasanen et al., 1993; Kaplan, 1998, 2012; Otley, 2001; IMA, 2008; CIMA, 2009; Merchant, 2012). Having research contribute to new theories does not suffice; rather researchers should try to advance the body of knowledge. This means developing theories and approaches that specify both the behavior and the context required for achieving specified outcomes (Kaplan, 2011; Merchant, 2012; Ahrens, and Chapman, 2007). In other research areas, there has been intense discussion about the concept of ‘analytics’ and its practical implications for areas such as marketing, logistics and human resources (Liberatore and Luo, 2010; Davenport, 2006).

Analytics can be defined as the use of business analytics, business intelligence, data analytics, big data analytics and analytical skills (Davenport and Harris, 2007). Several surveys have shown the importance of analytics for the future (e.g. Accenture, 2013; McKinsey, 2011); surveys within management accounting too have shown that it will become increasingly important for management ac-
countants to have analytical skills in future (ACCA, 2009; CIMA, 2008) as well as knowledge of quantitative tools (CIMA, 2009; Collier et al., 2007). Even though the concept of ‘big data’ or ‘big-data analytics’ is often applied in a marketing context, it is also applicable to performance management (Eckerson, 2011, Giles, 2012 in The Economist).

In a 2008 interview with Paul Sharman, the President of the American IMA (Institute of Management Accountants), Kaplan pointed out too that ‘Management accounting analytics are no longer constrained by limited or complex access to companies’ databases. But to excel at analytics, management accountants will require extensive training in modeling, multivariate statistics, and econometrics.’ The tendency is also seen in the field of New Public Management, i.e. the use of accounting techniques within the public sector (see e.g. IBM, 2011; SAS Institute White paper, 2011).

An exhaustive search of published literature on management accounting/control and (business) analytics by the authors, across a number of library databases (e.g. ABI/INFORM Global, Business Source Complete) and on the internet (e.g. Google, Business Source Complete and Social Science Research Network), yielded only a handful of papers discussing the convergence of business analytics and management accounting (e.g. in Nielsen et al., 2010; Silvi et al., 2013).

Over the last few years, surveys have shown increased interest in using the BSC as a holistic planning tool (Otley, 2003; De Geuser et al., 2009; Wiersma, 2009) with a feed-forward as well as a feedback model, often called the ‘Closed-Loop Management System’ (Kaplan & Norton, 2008).

Inspired by these tendencies we formulated the following research question: ‘How can a company use a system dynamics approach to accomplish the development of its analytical PMS (Performance Management System) in order to increase the insight of organizational learning?’ The structure of this research process is inspired by Brinberg and McGrath’s (1985) Validity Network Schema (VNS) in which research contains relations between domains, levels, stages and paths.

As Sterman eloquently puts it, ‘Change is accelerating, and as the complexity of the systems in which we live grows, so do the unanticipated side-effects of human actions, further increasing complexity. Many scholars call for the development of systems thinking to improve our ability to manage wisely. But how do people learn in and about complex dynamic systems? Learning is a feedback process in which our decisions alter the real world. We receive information feedback about the world and revise the decisions we make and the mental models that motivate those decisions’ (J. D. Sterman, 1994, Article first published online: 26 December 2006).

In stage one, we seek to combine data and information from the company (substantive domain) with the methodological domain (the clausal loop diagrams
techniques from system dynamics) in order to identify a number of causal mechanisms and relations.

‘Effective methods for learning in and about complex dynamic systems must include (1) tools to elicit participant knowledge, articulate and reframe perceptions and create maps of the feedback structure of a problem from those perceptions; (2) simulation tools and management flight simulators to assess the dynamics of those maps and test new policies; and (3) methods to improve scientific reasoning skills, strengthen group process and overcome defensive routines for individuals and teams’ (J. D. Sterman, 1994, see reference above).

The outcome is a specific theory of the company based on system dynamics definitions and assumptions. Sections 2 and 3 describe this stage. The next step is to form a number of differential equations in the Vensim™ software to enable us to quantify and simulate a number of scenarios in system dynamics. The outcome is shown in section 4.

2. Integration of the Balanced Scorecard with system dynamics

Since 1992 (Kaplan and Norton, 1992) the Balanced Scorecard (BSC) has evolved through different developments and versions. A huge number of survey and case studies have been conducted (e.g. Malina and Selto, 2001). In Denmark, the BSC model is also a popular framework for performance management (Nielsen and Sørensen, 2004; Sandalgaard and Bukh, 2008). The idea of such a ‘holistic framework’ for a management control system is not new, however (see e.g. Anthony, 1965; Flaholtz, 1979; Lyneis, 1980).

Despite its popularity and appealing simplicity at a conceptual level, the BSC concept has also been the subject of criticism. Criticism and discussion of the BSC can be referred to as a ‘methodology disagreement’ or – more specifically – a disagreement about how to estimate time-lags (e.g. between different perspectives) and the causes and effects of KPIs (key performance indicators). Several attempts have been made to see whether (traditional) statistical significance might be established (Malina et al., 2007) based on Sims-Granger type causality (Granger, 1969). However, others have argued that the classical statistical view and assumptions on cause and effect are mistaken or not applicable here, and that alternative interpretations should be used (Bukh and Malmi, 2005; Wallenburg and Weber, 2006; Kaplan, 2012). Or, as Meadows (1980) puts it, ‘The non-linear feedback structure of system dynamics models makes standard econometric techniques either inapplicable or extremely difficult to use’ (for an example see Sterman et al., 1997 in combination with TQM). This may be caused by the fact that deep, ‘nature-given’ causal relations are almost impossible to encounter in socio-economic systems (Senge and Forrester, 1980). Instead, the concept of mental models as discussed within system dynamics (Forrester, 1958; Warren, 2004; Senge, 1990) seems much more appropriate for BSC modeling in quantitative terms.
System dynamics thinking was first introduced by Forrester in 1958 as an example of a macroeconomic problem of production distribution. Applications have now expanded to environmental change, politics, economic behavior, medicine and other fields (Lane, 1992; Vennix, 1999; Warren, 2008). The main idea is that ‘you can’t just do one thing’ without thinking that ‘everything is connected to everything else’, which is also at the center of analytical performance management.

Inspired by Kaplan and Norton (2007) and Sterman (2000), Figure 1 shows steps and points of resemblances for SDM (System Dynamic Modeling) and a BSC.

![Figure 1: The Balanced Scorecard stage model and steps in system dynamics](image)

A number of studies have been conducted using system dynamics for performance management/measurement based on different assumptions (Akkermans and Oorschot, 2005; Nielsen and Nielsen, 2008; Capelo and Dias, 2009; Salterio, 2012).

3. Case study
The subject for our case study is a service department within an international company. In the autumn of 2009 the company began to design and work with the Balanced Scorecard concept with a view to optimizing strategy execution throughout the organization. Consultants from the Palladium Group were used as sparring partners in the implementation and the Balanced Scorecard Group within the company was given the primary responsibility for implementation.

The formulation of the strategy was the first step and had already been conducted for the department. When we started our study, the department worked with the setup of a strategy map and strategic objectives (or what Spreckbacher et al. (2003) call a type I BSC).

The first two steps in Figure 1 are the qualitative issues, i.e. the formulation of the problem in formal terms and the formulation of a dynamic hypothesis (Sterman, 2000).
3.1. Formulation of the modeling problem

The formulation of the problem is seen as the most important step (Forrester, 1991; Sterman, 2000; Warren, 2008). Here, reference modes, selection of key variables, the time over which the model should be used, and the settings for the dynamic problem formulation are set out. The primary tasks for the team were the formulation of the problem, mapping the interaction between the KPIs in the support department in order to bring its efficiency to the top-of-world class as seen from the department’s view and as expressed in the strategy.

The department had already defined and established a large number of key variables and various efficiency measures, some of which were filtered out as part of the iterative modeling process in order to achieve a more focused initial situation. In partnership with the department staff we identified and selected three key variables as the main drivers supporting the purpose of this study. These were ‘user recommendation of the department’, which is a measure of whether users are satisfied with the service supplied; ‘workload’, i.e. a measurement for the number of cases (work assignments) that are not solved in the time allowed; and ‘perceived competence fit’ which measures whether employees possess the necessary skills to solve the daily tasks set by other parts of the organization.

3.2 Formulation of the dynamic hypotheses and the causal loop diagrams

When the purpose of the model was identified and characterized over an appropriate time horizon a ‘theory’ was developed (also called the dynamic hypothesis) to account for the problematic behavior of the model.

Finally, the Causal Loop Diagram (CLD) had to be developed. This is based on the model boundary chart (not shown here) and illustrates the interactions between the identified key variables. The CLD diagram is shown in Figure 2 and is the result of the discussion with the department.

The CLD is identified through eight interacting feedback loops (where + and – indicate the type of change-based causal reaction (‘correlation’) to be expected), which together exemplify the model’s dynamic nature. The loops are either referred to as »R« or »B«, referring to self-reinforcing loops (Reinforcing) and balanced loops (Balancing)².

3.3 The quantitative structure of the System Dynamics Model

We used the qualitative model as a skeleton for a System Dynamics Model (SDM) for the BSC. We used the department team as sparring partners and gave them what Richardson and Andersen (1995) refer to as a gatekeeper role, providing valuable information and learning. A final finesse of the closed-loop causal reasoning described above is that it relates almost directly to the SDM tradition as it has been implemented for example in the VENSIM™ software we used for our project. Below, we show only a single CLS example from the process perspective (the incoming case subsystem) and value prospective (the efficiency subsystem) based on stocks and flows.
3.3.1 Process perspective

The service department categorizes cases in three groups, with special focus given to incidents representing something out of the ordinary. Figure 3 shows the number of incoming cases and, as can be seen, unusual incidents are recorded separately whereas the other two types of cases are recorded together. Trends in the number of incoming cases are obtained through two stocks where the initial value is the number of cases recorded in 2009. These stocks are multiplied by an estimated growth rate for each of the five years of the simulation time. The annual growth rate used in the model is estimated by the department team and is an expression of the mental image rather than the result of estimated forecast. As the final step, the numbers of the three case types are added together to form a single variable.
It is important to realize that this perspective consists of both a capacity and a productivity module (not shown here). It is based on learning-curve theory (see e.g., Hirsch, 2002, chapter 5), in which experience is linked with productivity. We have used the model provided by Sterman (2000, p. 507) for our calculations of productivity.

3.4. Value-add perspective

The department does not get a specific financial payment for the service it provides to other departments; it is instead measured on the change created by the department in the net sales for the company group as a whole. Because the two all-important goals are effectiveness and efficiency, the SDM is designed to focus on and support these goals. The efficiency target focuses on the department’s ability to keep costs down, while the effectiveness target is geared to the level of service provided.

As the department has a supporting role, the actual costs of the department have to be compared to planned costs to give a true and fair view of the development over time. Efficiency is measured as the service department’s total costs relative to the total net sales for the whole company, whereas value-add is measured as the company’s total net sales minus the total costs of the department.

The efficiency subsystem is shown in Figure 4.
The fixed costs are set to be constant throughout the simulation period because changes occur primarily in variable costs. The variable costs are accounted for predominantly by labor expenses. The model includes an annual wage increase for employees of 3%. We have set a specific time-span for the growth rates (and the setting for the simulation) as being from the start of 2010 to the end of 2014.

4. Validation, experiments and results

Validation of System Dynamics Models has two major aspects: structure validation and behavior validation (Barlas 1996; Sterman, 2000; Warren, 2008). Structure validation aims to demonstrate that the model’s internal structure (set of relationships) is an adequate description of the real system with respect to the problems of interest. Behavior validation aims to check whether the output behavior of the model adequately describes real dynamic behavior. The structural validation of the service department’s model was carried out by a range of logic tests, extreme-condition, sensitivity and boundary tests, which will not be discussed here. We simply state that the model was found to be structurally reliable and also expressed behavioral validity.

Numerous simulation experiments in Vensim™ (Eberlein and Peterson, 1992) were carried out on the model in order to find answers to the problems formulated at the beginning of this paper, and to predict a few possible outcomes based on finding relevant KPIs that strongly affect the company’s strategy execution (De Geus, 1992; Simon, 1990). For the purposes of this study we will only change two input variables within the Learning and Growth Perspective to see the changes in six KPIs from different perspectives as outcome variables. The scenarios are:

- **Base**: simulation of the current model with original parameters.
- **Base1**: simulation of an increase in ‘multiplier for employees’ satisfaction’ of 20%.
- **Base2**: simulation of an increase in ‘multiplier for perceived competence fit’ of 20%.
In the short term, if the company wants to improve the result (meaning improvement in user recommendation and cost efficiency), the choice is either an increase in employee satisfaction (Base1) or an increase in employees’ competence (Base2). Optimization by a mix of the scenarios might also be possible, but will not be done here. The chosen KPIs are all so-called »lagging« KPIs in the BSC setup, meaning that they accumulate information from other KPIs within the same perspective for passing information to new KPIs and perspectives (Kaplan and Norton, 1996).

Figure 5 illustrates how the two KPIs increase over the timescale for the simulation. Note that perceived employee satisfaction does not rise immediately as employees’ perception of satisfaction is not detected immediately. The model explicitly illustrates these delays, which is one of the great advantages of using SDM for BSC. Therefore, if the department launched an initiative on employee satisfaction (e.g. job rotation), System Dynamics Modeling would make it possible to understand the dynamic mechanisms and then the delayed impact on user satisfaction would not come unexpectedly. The model outcome clearly shows that the full effect of the increase in employee satisfaction in the department can only be read in user satisfaction after about 2.5 years, meaning that the financial result comes even later. Besides, the identification of delays in the KPIs in the model also contributes to an understanding of the side-effects, i.e. an increase in perceived competence fit. Depending on the construction of the model’s dashboard it is possible to illustrate that an increase in employee satisfaction also positively affects several other KPIs.
Figure 6 shows the simulation output for two KPIs from the process perspective. Both capacity utilization and changes in number of ideas implemented change markedly when the company is able to increase the satisfaction of the employees by 20% (Base1). For capacity utilization this implies that the company is able to come up with free capacity that may be used for other things (e.g. insourcing). At the same time innovation is initiated through an increase in the number of ideas implemented. Also note that «free capacity» and «number of new ideas implemented» (i.e. innovation) change at different points in time in the simulation, i.e. they are both delayed, but at different rates (see Figure 6). We also see that satisfaction is a much better idea than better competences (compare Base2 and Base1). As a result of the multiplier effect the KPI quickly rises to a high level.

Figure 7: KPI lag-indicators from a Value-Added Perspective

Two KPIs from the value-added perspective are shown in Figure 7. The graph for user recommendation shows that the effect of employee satisfaction (Base 1) comes rather late, almost three years after the initiative was brought in. The (cost) efficiency graph further shows that additional efficiency results from an increase in employees’ satisfaction with 20% Base1) rather than from an increase in competence fit (Base2). User recommendation indicates the effectiveness of the department as this KPI measures the demand for its services. Note that the development of the two KPIs is offset as the delays are included in the model.
5. Conclusion

This paper used the Brinberg and McGrath (1985) research setup in combination with the idea of ‘analytics’ to document the possibilities of designing and using the SDM approach for the Balanced Scorecard model. To further focus our model we also used two other themes that are often discussed in relation to system dynamics: the Double-Loop Learning (Senge, 1990; Sterman, 2000) and Bounded Rationality (Simon, 1957, 1991). The double-loop learning concept has been used in the model development phase, where the iterative feedback structure has contributed to changes in the pre-conceived mental sub-models of the people in the service department, and has increased the understanding of the department’s dynamic structure and mental behavior. The use of bounded rationality has helped us simplify the choice variables by focusing on only three input KPIs in the design stage, as described earlier (user recommendation of the department, workload and competence fit). The principles of system dynamics provide a rigorous approach to strategy that is grounded in solid evidence from the situation concerned (Warren, 2005) and can be used for many decision problems in management accounting.

The paper also shows that the SDM approach can overcome some of the inherent limitations of using only unidirectional cause-effect relationships and statistical methods (e.g. multiple regressions) and the static structure over time, meaning using feed-forward and feedback for testing different strategy scenarios. Compared to earlier research (e.g. Akkermans and Oorschot, 2005), this paper has included some financial KPIs and thereby emphasized the value of the learning outcome from the project modeling project.

Given the huge amount of ‘big data’ available both from internal but also from external databases (e.g. Orbit or Bloomberg) today, researchers in the field of management accounting will be able to construct and test different types of more generic cost management models (in the same way as within finance), but practical managers will also have the potential to quickly assess their strategic options and opportunities and to design their first version of a dynamic BSC.

Therefore, great opportunities exist now for designers of management accounting programs to develop the right skills for CFO and controllers to be able to handle these challenges in future, by combining ‘business analytics’ with management accounting and control as also noted by Kaplan.3
Reference
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Notes
1. The authors would like to thank two anonymous reviewers for their comments and suggestions. The authors are also grateful to the company in our case study for allowing us to use their materials and other documentation and for their support and comments on this research.

2. It should be noted that the above model consists of far more loops than the eight loops shown in figure 2. The eight loops shown here are considered to be of primary importance for the dynamics of the model.

3. This challenge has already been taken up by CIMA (the Chartered Institute of Management Accountants) in UK (see e.g.: http://www.cimaglobal.com/Events-and-cpd-courses/Events/Mastercourses/Strategic-Management/Business-analytics/).