

The Use of System Dynamics in Management

Reasons and Applications

Peter Bradl

FORWISS – Bavarian Research Center for Knowledge-based Systems

Information Systems Research Group

Aeusserer Laufer Platz 13-15

D-90403 Nuernberg

Germany

Tel.: +49 911 5302-265

Fax: +49 911 536634

E-Mail: bradl@forwiss.de

Abstract:

This paper discusses the benefits of SD in management. The first part raises questions why SD is not used widely and, based on underlying feedback structures in management decisions, gives arguments why it should be more present – like spreadsheet software. The second part exemplarily describes two specific areas of application that may be relevant for most corporations, namely Knowledge Management and derivation of the balance sheet. We will focus on specific problems in these fields as well as typical questions and approaches how to answer them by introducing SD. User interfaces will briefly be discussed as well as input control using rule bases. The paper concludes with an outlook and critical evaluation.

Keywords: System Dynamics, Knowledge Management, Corporate Planning, Balance Sheet

1 System Dynamics (SD) in Management

1.1 Status Quo

„[System Dynamics] is an approach that should help to solve important problems on top management level” [Fo61]. This statement was made some 40 years ago. Although an increasing number of books showing the various applications of SD were published within the last few years [e.g. Co96; Fo99; Ka98; MC00; St00], SD is still not very present in management. However, direct comparison to the Balanced Scorecard (which was and is promoted strongly by the inventor and many other consulting firms) shows that SD is more difficult to understand intuitively. This assumption is backed by the fact that only few publications deal with SD in management explicitly. In management literature several alternative approaches to planning were introduced during the last decade (e.g. Total Quality Management, Business Process Reengineering [see MC00, 4-5]). They mainly addressed a certain field or operational area. Except the Balanced Scorecard, only few individual techniques linked management aspects [Ma99, 166]. Organizational theory itself hardly allows the use of figures, however, figures carry and represent the type of information managers are familiar with. Since planning strategies change over time [Ma99, 158] they require a method that takes this into account as well.

Such a methodology, that builds on the aspects mentioned above and supports the use of quantitative data, is available and in use in a small but increasing number of companies – System Dynamics.

1.2 Why should SD be enforced in Management?

Corporate or strategic planning covers activities and procedures that are ‘daily business’ for managers, however, the expression has been heard much more often in recent years. This is the case for general publications as well as research reports. (Using *yahoo.com* or *google.com* with the phrase ‘strategic planning’ returns more than a million hits.) Additionally, an increasing number of (freelance) consultants offer support for the process of strategic planning, promising their clients an increase in sales and profits [seeSt02]). No matter whether or not these promises are kept, it seems obvious that successful management of a company requires different tools and methodologies than some years ago. Since half-life of knowledge decreases, timely access to necessary information becomes increasingly more important in order

to have required information (regarding the own area of business) available at all times. In addition, the abundance of data raises different questions. It's not the availability of information rather than the question where to find and how to discover causalities and dependencies. A (time consuming) task that is difficult for one person to cope with – particularly if no methodology or system is available to support this process.

Additionally, it becomes increasingly difficult for managers to identify dependencies between decisions they make and how consequences in turn may affect even a total different department within the firm for example. This means to acknowledge that feedbacks are part of all systems (department, company, market) we belong to and implies that our own actions will probably affect us later probably in a way we did not intend. This is worsened by the fact that results may be recognized with a substantial delay. So when finally the unwanted effect is noticed it will be far too late to reconsider the original decision as it was probably made numerous years ago.

Generally, dependencies and delays may be relatively easy to follow – ex post. Cases can be found in the recent past in investment banking where whole teams left a bank to be hired by competitors [So02]. Besides the unforeseen vacancy in a (critical) position this constellation is threatening since the former employees take their knowledge about the old firm (and its strategy) to the new employer – and nobody in the old firm wants that to happen. Various examples show that decisions – especially at management level – cause side effects that may be realized too late to correct or at least adapt the action. Very often only measures to relieve the symptoms are left. A goal would be to be able to foresee such side effects and to act rather than react. Simulations with SD support this.

1.3 Benefits of the Modeling Procedure

Experienced modellers can easily design Stock Flow Diagrams (SFD) 'on the fly'. However, this is not the case with every user of SD. As an intermediate stage towards SFD so-called Causal Loop Diagrams (CLD) which allow identifying interactions and relationships between actions and, e.g., their effect concerning different departments, are commonly used. Amongst others, Richardson describes some serious problems that might occur when transforming CLD into SFD [Ri86]. However, even if CLD is not used as a base for SFD, the application of the latter is still beneficial, especially on management level, since they may function as a type of communi-

cation tool. A main problem in decision-making processes (even on the corporate level) is the fact that participants have a different understanding on a subject and use different terminologies (e.g. sales may be interpreted as sales quantity or revenue). The use of CLD by applying modeling techniques as described e.g. in [GP99] or [MC00] within a group aid team members to use terms within their realm during the design process. Finally, when discussing dependencies, different interpretations become obvious. So modelling (especially CLD) helps to gain a common understanding of relevant terms. (Alternatively, a derivation of CLD from SFD is possible and useful.)

1.4 Models and Simulation

As a result of the usually high number of feedback and delays regarding management processes it is almost impossible to describe them at their transitional stage using mathematical equations and, should it be manageable to find equations, it is very unlikely that they can be solved – at least not by a manager who needs quick support for her decisions. SD allows to ‘develop’ and ‘model the problem’ while aiming to answer a certain question.

A ‘correct’ model (SFD or CLD) *represents* reality (e.g. members within a project team, project teams in a profit centre) and allows ‘playing’ within a safe environment [Me82]. Assuming that the models are valid (structure and parameters) simulations that show results of decisions made today on the future development of the firm will be run and analyzed. Simulation in SD can focus on quantitative figures (number of engineers required to finish a project in time) as well as qualitative issues (effects of increase in wage on motivation).

1.5 Manageability of Software

Another reason that might still be responsible for the under representation of SD at management level is the fact that originally the software (in the beginning DYNAMO) could neither be used on standard PCs should they have been available nor the GUI was particularly user orientated. Actually, the proper use of a computer to develop and run SD models required deep knowledge in programming [Jo90]. These requirements neglected the manager who deals with corporate issues.

Computers and software that are available today use GUI, and simplify the modeling process. Knowledge about integral and differential equations is not necessary any-

more but still useful if the manager wants to analyze the structure or an observed behaviour in detail. Additionally, today's software includes alerts that inform users about wrong or contradictory input and prevents 'mistakes before they occur' – debugging is not necessary anymore. Databases and warehouses (fed by ERP systems) contain information about almost every transaction that took place in the past. This information is extremely helpful for validation of models and brings confidence to the user. Eventually, SD models are as simple to handle as spreadsheets.

In the following, two different fields of management are considered to show the importance of SD. After a short introductory sample a number of questions are raised and the possible use of SD is examined. The first example additionally covers issues how to handle and customize existing models to ensure proper use. At present, we are developing reference models for management planning, which is based on relevant key performance indicators and datasets transferred from a data warehouse to support a whole strategic planning procedure.

2 Applying SD for Knowledge Management

2.1 Introduction

This section exemplarily describes an area in management which will strongly benefit from the use of SD and deals with questions about qualification and training for employees. Assumption and restrictions will be introduced before presenting the model and its structure. An excursion about an appropriate user interface will end this subsection. Details about this model can be found in [Br03]

Example:

A software firm faces declining orders and management decides to decruit 30 software engineers. This process requires a careful check which employees are the least valuable ones – in terms of productivity as well as know-how. Although management only want to lay off these 'less skilled' employees this action functions like a signal for the colleagues that additional people might get fired. This causes the valuable and highly qualified developer to look for an alternative employer – a goal that is usually not too difficult to reach for this group. Finally, the CEO may face a much smaller number of employees than intended to fulfil orders – missing the efficient working power. The reason for this outcome, however, lies in the past when the decision to lay off engineers was made.

Even this simple example shows how complex the effects and interactions are and it will be extremely difficult if not impossible to find an answer or to design a 'model' by using spreadsheet software. SD models on the other hand allow simulating these dynamic systems and can provide the answer whether or not the effects mentioned above will occur (or at least at what probability) and how intense they are and which final results must be expected.

2.2 Human Resources and Knowledge Management

A main reason for the use of SD in human resource management is that training or coaching occurs over time – this is exactly what the continuous time simulation in SD does. Effects of training are attained gradually instead of discrete, which makes it more difficult to model and simulate these processes in an environment that is based on equations.

In traditional companies like knitting firms or printing shops knowledge of people is mainly tied to machines and other equipment while in 'modern business' this relationship – if valid at all – is much more loose (as the example shows). In order to increase productivity and efficiency investment into hardware becomes less important. In addition, all sort of consulting and software companies are currently doing business with an asset called 'knowledge' and 'experience'. So they have to invest into people that hold the right qualification in order to match clients' needs – these may change faster and probably more drastic from one assignment to another than within one traditional corporation. In order to survive, management needs to assure that at least 'state of the art knowledge' is available at any point in time. Human resource management becomes a factor with enormous costs that has to be dealt carefully within the corporate planning process to ensure that the right people (holding the right qualification) are ready when needed and can be assigned onto the incoming jobs.

Since half-life of knowledge decreased strongly within the past few years (in computer science it equals three to four years [EF00]) training and coaching becomes more and more important. Employees that are participating in training – either as trainer or as participant – are withdrawn from their daily work which might cause a shortage in workforce planned. Training not only has to be done under consideration of requirements for today's business but also and especially with a focus on needs for future assignments. So management not only has to have expectations about future needs but also has to connect the tasks of training and coaching with the allocation process as integral part of the corporate planning process.

2.3 Issues within Knowledge Management

Based on two reasons we currently focus on a software company. First, software firms strongly depend on manpower and knowledge – as a resource – linked to the employees. So the strategic task and major point of interest is 'ensuring knowledge' by qualifying staff. The hiring process itself and the transition of newly hired employees to experienced workers have already been covered in several models [see MC00; St00]. Second, if we choose a company, e.g., in the field of engine building we will have to consider the production sector. This would drastically increase complexity of the whole model but rarely add benefit in the sector of interest – training and knowledge management. The absence of big investments in machines – com-

pared to, e.g., printing companies – reduces complexity of the model without strong effects on the results concerning the main issue. Furthermore, these types of firms are usually more dependent on their employees as assets since (as said earlier) they hold the knowledge that represents the main product of the company. Especially in this business it is important that an employer is somehow attractive for an employee for example through high salary or nonmonetary compensation. These costs have to be covered by profit from daily business that is only possible if the employees that are in charge of the company can be assigned to the incoming projects. The task for management is to assure that knowledge is available when and where it is needed. This can be attained through correct allocation as well as training.

The model will cover hiring and firing as well as the allocation problem and related questions that yield to training needs. An example will illustrate possible trigger for a new training process:

A department of about 100 software engineers is currently responsible for a product that will be replaced. The new platform will be programmed in a different computer language. Management wants to know how to do the training. Among other things, the following issues are important:

- 1. Which particular qualification will be needed and at which level?*
- 2. What time is the latest to start training?*
- 3. Who has to be trained first and how many engineers can be trained simultaneously without any harm for daily business?*
- 4. Which minimum workforce is necessary to guarantee support and maintenance of the 'old' technology? (Deficiencies in this will affect the reputation of the company with its clients that in turn might result in change of their willingness to buy the new product.)*

Goal is to find a solution with minimum effect on daily business and minimum costs.

In order to use SFD we have to find a way to make knowledge measurable. This requires a thorough definition and description of the qualifications and a corresponding classification. Finally, a scale has to be found that allows for ranking the different levels that people might hold.

Types of Qualification

We distinguish between three main types of qualification: *Programming* (Cobol, ABAP¹, C++ and Java which are representatives for any type or pattern of sub qualifications that might be of interest.), *Business Administration* and *Social Skills*.

¹ ABAP is trademark of SAP AG

(Whether it is necessary to formulate sub qualifications for the latter skills (like the four languages in programming) depends on the question(s) that should be answered with the model and simulation runs.)

Levels of Qualification

The classification described above does not distinguish between different peculiarities. Hence, we categorize the types of qualification into five different classes that allows assigning the right person to the right task.

Null Poor Average Good Expert

Distribution of Qualifications

When new employees are assigned to the department (either external or from another division) their profile of qualification (type and level) is recorded. Several distributions are calculated initially which are the base for the allocation of staff or the determination of training needs. Based on the (distribution of the) initial qualification of a programmer it is possible for him to reach a higher level as well as to receive a 'downgrade' which means to gain and accumulate knowledge or to lose it. How this will be done can be seen in the following section.

Gaining Knowledge

This describes the case that the cumulative knowledge in a particular type of qualification that is available within the company is raised from a lower into a higher level. Two alternative ways exist; *Experience* and *Training*

Reduction of 'Valuable Knowledge'

This is that knowledge as a whole 'loses value' for the company either because it is not available or because it cannot be billed or it is not on-hand any longer. Reasons for this are *Loss* or *Defective Knowledge*.

Specifics in Training

When talking about training activities and the required time, several correlations or dependencies exist. We consider the need to train two persons in Java (goal: average) that both currently hold the level 'Null'. One of the two is Cobol_Expert while the other is C⁺⁺_Good. It is obvious that there is no need to explain basics in object oriented programming to the one who knows C⁺⁺ well. Hence, the training measures will be very different for the two.

2.4 Planning with ,Knowledge'

Allocation and Training

As mentioned before, management and planning are mainly about getting the 'right' people assigned to the 'right' jobs. Accordingly, the distribution of knowledge (of all employees) has to be evaluated steadily. Future needs must be determined in advance (by using incoming orders or target figures) and consequences for the actions in personnel development must be derived. Special focus is required for projects in which revenue is generated with 'outdated' knowledge because employees that are only valuable for projects that rely on this particular qualification may be hard to assign on upcoming jobs that require 'new' qualifications. This becomes even more crucial if a person does not hold more than one qualification at an appropriate level.

Miscellaneous Parameters

Besides the measurable qualification of a person (e.g. social skills or Java) other issues exist that are of importance. One factor is experience in general, which means that a newly hired programmer cannot know the structure of the firm as well as his colleague who is employed by the firm for several years now. Additionally, if a project is the follow up of another one a software engineer who was part of the former project team holds specific knowledge, e.g., about the client or problems in the past that lead to the current design which is used as starting point for the new project. These differences are hard to put into a structure of knowledge and particularly into different levels. In the model these differences between new and 'experienced' employees are handled in a way that these rookies – even software specialists – are less efficient than their colleagues and must orient themselves in the beginning. So their output is lowered by a factor that can be set and is chosen as 80 percent.

2.5 Costs for 'Knowledge '

Within the model the asset 'knowledge' is necessary to fulfill engagements or any sort of clients' requests. Orders in general are received by the sales department and are an 'external parameter' within the model. These figures are usually provided several months in advance. Attention has to be paid to personnel costs. These are mainly the payment for project members like salaries that have to be paid – regardless whether these people are currently working in a project, are in training or not assigned to a project at all. These issues are considered under the following catego-

ries: *Hiring, Induction period, Difference in wages* (Experienced workers or beginners), and *Abrogation*.

Other effects are that there are lower costs for training of rookies since it is assumed that the new employees have the right qualification – that is why they were hired. Discussions regarding training and costs lead to decisions about the type of education. On the job or fulltime; internal or external; team-by-team or only a certain percentage of the team at once? Revenue that might be lost due to reduced manpower while employees are in training is an important factor when talking about training costs.

2.6 Software

At our institute we use Powersim² as the environment for SD modelling. The main and sub-models consist of stocks for each qualification as well as each level within the qualifications and employees in training. The main purpose of the sub-models is to allow calculation of knowledge distribution (as mentioned above). Besides, they are connected to the ‘main model’ in which financial issues are the focus. The use of arrays keeps the main model simple in its structure, which backs acceptance in management.

As mentioned before, distribution of knowledge is calculated almost continuously. Hence, it is extremely important that all data related to an employee is available and updated permanently. An advantage of Powersim here is that it supports connection to databases or Excel and allows to get data from these sources as well as writing results of simulation runs back into them. If it is necessary to enter data into the model directly, the manager can use the personalized ‘portals’. They allow customized simulation adapted to different members of management by providing access to different simulation parameters. This enhanced handling supports the use and finally acceptance of the existing model.

2.7 Stock Flow Diagram

The following screenshots show the structure of the sub-model that solely deals with knowledge. The rectangular symbols represent the stocks that ‘hold’ the qualification (Null-Poor-Average-Good-Expert). Qualification is withdrawn from the stocks in the center (Qualification Level in figure 1) whenever it is not available there. Reasons for

² Powersim is trademark of Powersim Corporation

		NULL	Poor	Average	Well	Expert
Programming	Cobol	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
	ABAP	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
	C++	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Java	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Business Administration		<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Social Skills		<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 2: Interface for data entry

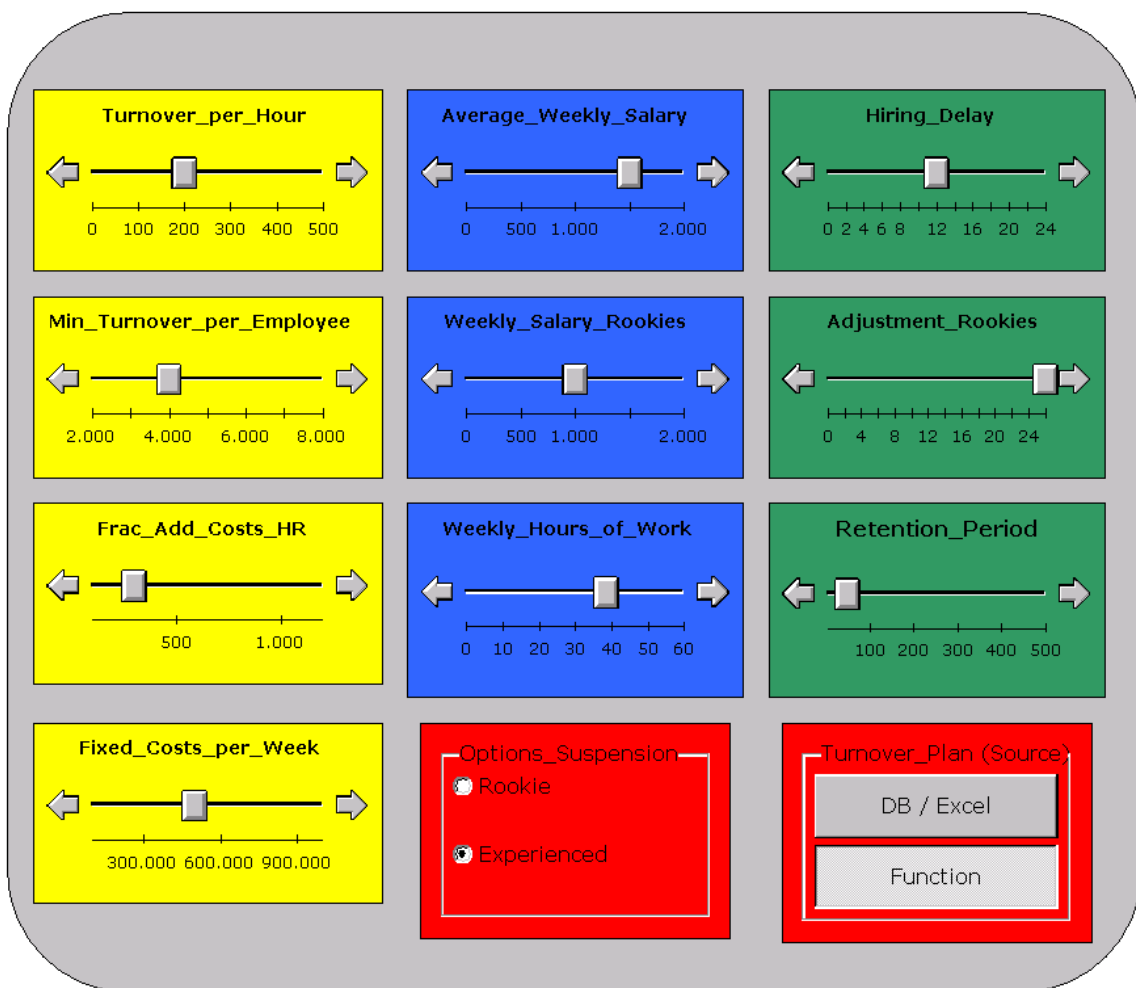


Figure 3: Control board for simulations

Both parties that will operate the system (data typist and manager) will be supported by an error detection system as well as a rule base. The first ensures that e.g. no entry is forgotten (a level has to be entered for each qualification) the latter checks plausibility. For example if a manager starts simulation with a combination of very low wages and a short hiring delay the system must create an alert that asks if the operator is aware of that contradiction.

2.9 Scenarios

A previous version of the model which is currently under validation was used for several scenarios. Within one particular simulation run emphasis was put on the question which training approach should be preferred – full time (absence from daily work) or on the job. Assumptions were made about correlation between knowledge (as effect of training) and efficiency as well as the dependency of wages and efficiency. The scenarios showed that the example company will gain higher profits when training is performed on the job. It is clear that untrained employees perform not as well as others but they still cover workload and ensure that the company is able to complete orders in time.

3 Modelling a Balance Sheet

Besides the area of knowledge management based on the qualification of employees and job requirements, we attempt to apply SD to a more general field on the corporate level – modelling a balance sheet. Within the past two years we designed a tool that allows to simulate possible future developments of a balance sheet based on predictions and assumptions like exchange rates, sales etc. This prototype is based on a spreadsheet software and enhanced by Visual Basic and Java add-ons. Additionally, we had to implement a separate database for intermediary results when running simulations over time. All in all it served its purpose and we are still not in the position to do flexible simulation runs. So far we do not know about any other appropriate tool that supports simulations for balance sheets, however, we are confident to handle this by using SD.

In this section we try to show the relevance of simulations of balance sheets and why SD is an appropriate underlying method.

3.1 Balance Sheet – Requirements

Big corporations are required to publish information and figures for a given period. The frequency of publication depends on various rules and regulations. While national laws may only ask for an annual account, corporations that are quoted at the stock exchange face additional requirements. Quarterly reports are demanded in many countries like the United States and Germany. Although U. K. (London Stock Exchange) does not ask for publications every three months, the commission of the EU already plans to enjoin on corporations to publish the balance on a quarterly base [NT03].

National guidelines determine how a balance sheet has to be derived. The main difference is in the assumptions about how certain positions have to be valued. International companies (which are listed at the NYSE) may face the problem of different requirements for the balance sheet – depending on their country of origin where they have to present their statement. Besides national accounting standards like US-GAAP (United States Generally Accepted Accounting Principles) there exists the IAS (International Accounting Standard) which is gaining widespread use and recognition throughout the world. Based on this development and the fact that it is possible to

transform the balance sheets from one regulation into another we focus on US-GAAP in our work.

Table 1 shows a basic balance sheet designed by applying the requirements of US-GAAP.

Assets	Liabilities and Stockholders' Equity
<p>Current assets</p> <ul style="list-style-type: none"> Cash and equivalents Marketable securities Accounts receivable and notes Inventories Deferred income tax asset Prepaid expenses <p>Fixed assets</p> <ul style="list-style-type: none"> Property, plant and equipment <ul style="list-style-type: none"> Land and land improvements Buildings Machinery and equipment Intangible assets Long term investments Other assets 	<p>Current liabilities</p> <ul style="list-style-type: none"> Short term borrowings Current portion of long term debt Accounts payable and notes Income taxes Other accrued liabilities <p>Non-current liabilities</p> <ul style="list-style-type: none"> Long-term debt (less current portion) Deferred income taxes Postretirement benefits other than pension Other liabilities <p>Stockholders' equity</p> <ul style="list-style-type: none"> Preferred stock Common stock Additional paid-in capital Retained earnings

Table 1: Balance sheet according to US-GAAP (exemplarily)

3.2 Balance Sheet – Frequency of Publication

Today, balance sheets can be derived easily. Since the majority of corporations use information technology, namely PCs, ERP-Systems and databases, a balance statement can be created almost by instantaneously. The result is a snapshot and exactly shows the situation of the company – at that very moment. Whenever this balance sheet is compared to one that was created one or two periods ago, the growth of the company may be evaluated. However, this ex-post consideration is not

sufficient to formulate a reliable outlook, although, these balance sheets increasingly call attention of analysts and shareholders.

So far it is not possible to make a forecast for the financial statement based on simulations. So, the significance of the balance sheet is in doubt because it only shows the performance at a given time compared to another aggregation that is 3, 6 or 12 months old. Hence, it would be helpful to find out how the performance of the corporation will be in the nearer future based on the figures which are presented. The need for a means that allows for the prediction of the trend of a balance sheet is backed by the fact that the big crashes at the NYSE in 2002 could not be foreseen by analysing the balance sheets that had been presented. If there had been a chance to recognize bad performance ahead of time, much of the losses could have been prevented.

3.3 Balance Sheet and SD

Why should SD be a good methodology for transforming this table into a model? As mentioned earlier, the balance sheet is a snapshot of the figures that describe the well doing of a corporation at a specific moment – a frozen picture. Having in mind that SD consists of stocks which contain their value when the simulation run is stopped, drives to use SD as an approach to address simulation and forecast when dealing balance sheets. Consequentially, all the terms in the table relate to figures that will be presented as stocks in the later model.

Additionally, a model that represents a balance sheet will always be a good means for understanding relationships. So a side effect is, that an SFD backs the understanding of the relationships between the individual positions that are presented.

3.4 Model structure

As said before the balance sheet only contains factors that are ‘available’ at a certain time – like stocks and it is straight forward to model an SFD right away. There is no need for the (commonly used) intermediary CLD. All the positions that change the values of the positions in the balance sheet have to be flows. Based on the balance sheet in table 1 modelling of ‘current assets’ will be described in the following.

It can clearly be seen that the sub model consists of 6 stocks, which represent the positions in the balance sheet. The inflows and outflows are not connected to stocks but sources and drains. This implies that, e.g., there would be no limit from the market to grant credit. Of course, there is a limitation, however, the availability is a matter

of the current standing of the corporation or the expectations about the future but usually not caused by a shortage in the supply (e.g. for money) from the market.

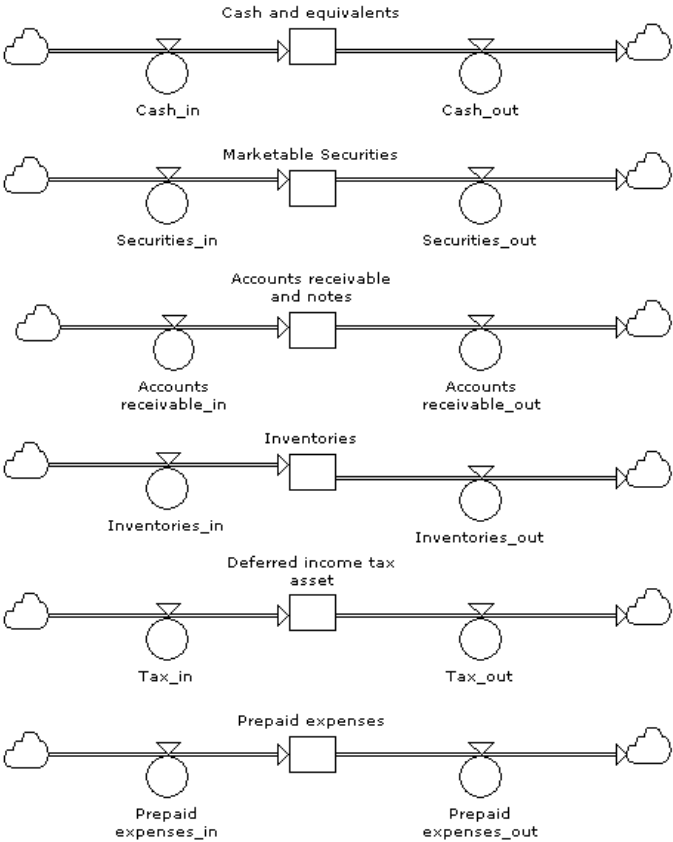


Figure 4: SFD sub model for current assets

Figure 5 and figure 6 display the positions that determine the composition of the in-flows and outflows for 'cash and equivalence'. The values of the auxiliaries (e.g. for profit) are derived from the profit and loss statement, which can be modelled as an SFD as well.

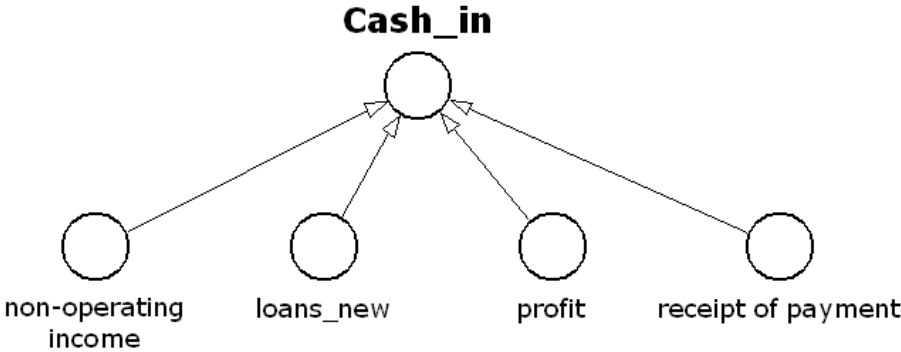


Figure 5: Composition of cash_in

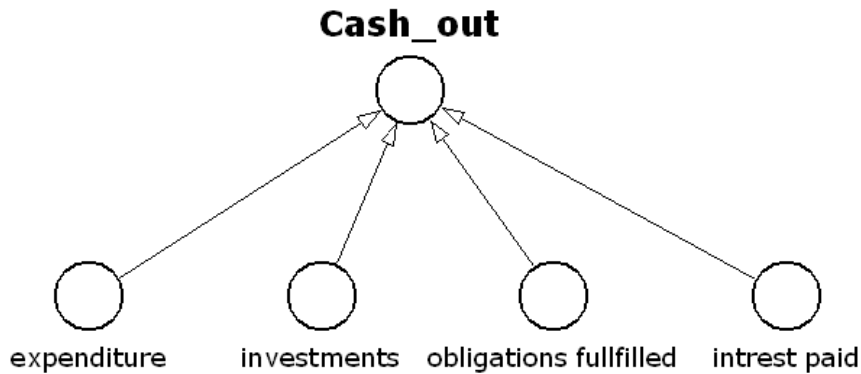


Figure 6: Composition of cash_out

The calculation for the other flows is equivalent. The dependencies can be found in publications about accountancy rules or the regulations e.g. US-GAAP (see [Co01], [DAEF00]).

Although, it is possible to model 'each position' that sums in the profit and loss account or balance sheet, we decided not to do so. The additional benefit of such detailed models compared to more general ones is questionable since many positions are relatively independent and can be delivered by a database directly.

3.5 Validation

A very convenient side effect when using SD in corporations is that validation of designed models is quite easy since many firms have been collecting data of their transactions and activities for several years now. This is a major advantage of SD in management compared to applications that may lack sufficient data. Actually, the database enables to validate the model and run simulations about past periods – of which real data are available. The results of the simulation runs will be compared to the recorded data of the corresponding date. So the goal is to tune the model in a way that the results of simulation runs with figures from, e.g., the year 2000 match with the real outcome of that period – delivering the balance sheet that fits the one which was actually published.

Currently we access the data warehouse of a consulting firm which is specialized in data mining issues. Here we benefit from their experience about detection of correlations and get access to abundant datasets which are independent from a particular corporation. This strongly backs our goal to provide reference models for different industries.

3.6 Results

Modelling balance sheets with SD is useful and doesn't require deep knowledge about SD itself. The planning process as well as controlling are supported. An example for this is that the achievement for key performance indicators (KPI) can be double checked. Simulation runs for single departments have to be analysed and computed into KPIs. As a next step all the KPIs are combined together and 'become part of the balance sheet'. Applying the balance sheet to calculate the KPIs 'backwards' will enable a double-check. A further aspect is that simulation in SD allows to consider soft factors. If management wants to know how a decline in image affects positions on the balance sheet, a relationship between image (or customer satisfaction etc.) and sales will be formulated and included into the model. The following simulation run shows a possible outcome. Finally, cascading models allows to simulate consolidated accounts.

4 Conclusion and Outlook

As shown before (and well known by 'system thinkers'), dependencies in complex systems cannot be recognized intuitively. It is obvious that (the structure of) planning that is exclusively based on spreadsheets – if possible at all – is hard to follow. Actually, it might not make a lot of sense since dynamic behaviour cannot be considered appropriately. Hence, a method must be used to cover complexity and deal with feedback. System Dynamics does this – and more. Even the simulation of only three types of scenarios – best, worst, and most realistic case – for one variable will help to make plans in advance. Thus managers will be prepared what to do if the anticipated scenario arises in reality. The 'low' software and hardware requirements nowadays allow the use of SD almost everywhere and should help to bring SD into management. Some important points:

1. A variety of profound models for human resources allocation issues is available today. However, the use of SD for knowledge management is still not under intensive research. The linkage of HR planning – as part of Corporate Planning – with SD to databases and warehouses is new so far.
2. The benefits of using SD for modelling balance sheet are substantial, however, tricks that allow to colour a balance sheet in order to have a good standing on the market will always be a problem. But if the simulation runs generated totally dif-

ferent results than the finally presented balance sheet it has to be clarified – one of the two outcomes has to be incorrect.

3. The connectivity of SD software to databases not only allows the use of real data for simulation runs – but also enables to write results back into, e.g., info cubes. The information stored there can then directly be applied in the process of detailed planning.
4. The fact that SD software nowadays strongly supports the technique of ‘cascaded models’ makes it predestined as a tool for managers. The control of access to different levels in simulation runs is as important as the fact that people only see the ‘layer’ of the model that is relevant for them.
5. Interestingly, the acceptance of SD as a methodology seems to correlate with the professional qualification of managers. A more thorough knowledge in technical issues (e.g. a degree in engineering) seems to provide a ‘better’ background for working with SD models – independent from the particular field where it is applied.
6. Future work, which was presented at conferences and published in articles deals with connecting SD with BSC. This ought to be taken as proof that SD is a methodology that is utilisable in today’s business.

Although, SD is not commonly used at management level today the paragraphs above show that there are various challenges for managers – at each level – for which they don’t have the appropriate tool at their fingertips. This is mainly caused by misinterpretations regarding the complexity of the problem that should be solved as well as false estimation about the difficulty of SD as a tool. In the long run companies cannot afford to leave a powerful methodology.

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