AN ENTERPRISE SIMULATION APPROACH TO THE DEVELOPMENT OF A DYNAMIC BALANCED SCORECARD

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Abstract. The balanced scorecard seeks to provide managers with a comprehensive set of measures of performance of the organization. However, almost only big organizations could successfully implement scorecards and numerous failures have been reported. We argue that the causes of failure are fundamentally the inevitable subjectivity inherent in the methodology and the lack of a reliable tool to guide the implementation process. We recently proposed a hybrid approach using discrete event simulation and system dynamics to total enterprise simulation modeling. In this paper we explore the merits of using the enterprise simulation model to support management in developing the balanced scorecard.

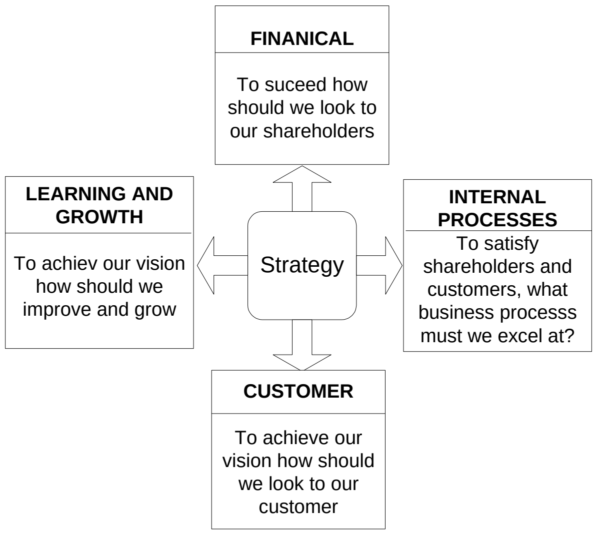
Introduction

The tendency toward integrated systems in businesses and the system approach perspectives have changed the way businesses are being managed during the current decades. To cope with this tendency, we have recently started the development of an entire enterprise simulation model using a hybrid approach of the discrete event simulation and system dynamics methodologies (Rabelo et al., 2003). The enterprise simulation model basically covers the strategic, tactical, and operational levels of decision-making in a single simulation of multiple models at different levels and resolutions. The complete enterprise simulation model is still an ongoing research at the University of Central Florida (Orlando FL, USA). One of the promising uses of the model that we have suggested is the support of management in the balanced scorecard implementation process. In fact, we propose that the enterprise simulation be the underlying structure of the scorecard. In this paper we demonstrate with a simple case study the hybrid enterprise simulation model and then highlight its significance in developing balanced scorecards.

The Balanced Scorecard

Kaplan and Norton developed the balanced scorecard in the early 1990s while investigating the development of a better and more comprehensive system of measures of performance (Kaplan and Norton, 1996). The methodology seeks to provide managers with a comprehensive range of internal and external measures and metrics describing the company's performance. Specifically, the balanced scorecard (BSC) links performance measures in four key perspectives of the organization: financial perspective, customer perspective, internal business process, and learning and growth. BSC is supposed to integrate all activities in the enterprise toward the achievement of the overall mission. It aligns the efforts across all units of the enterprise as represented by these four perspectives with the strategic mission of the enterprise, as depicted by Exhibit 1 below.

Exhibit 1. BSC Translates Mision to a Set of Metrics



The theory behind BSC is very sound and matches the characteristics of the business environment today. It has been successfully implement in all kinds of organizations around the world (Gumbus and Lyons, 2002, Solano et al., 2003). As mentioned, BSC was a response for the need that arose at the early 1990s for new performance measurement systems, which were required to be integrated, balanced, strategic, improvement-oriented and dynamic (Bititci et al., 1999). However, the BSC is not a dynamic tool. It gives a snapshot of the performance of the organization as reflected by the set of measures given the settings and the operating circumstances of the organization at the time of measuring the performance. It, however, offered a comprehensive approach to assessing the performance that helps coordinating the business functions. It represents a shift from the shareholder-value perspective, which is of limited scope, towards a stakeholder-value perspective (Krause and Mertins 1999).

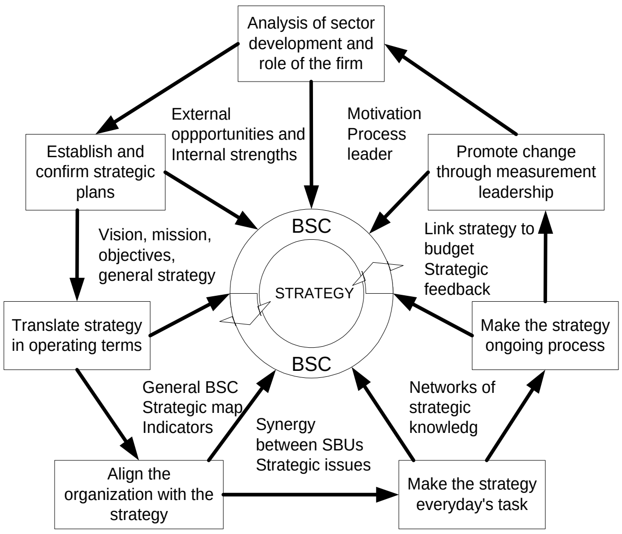
Traditionally, companies measure performance with financial-based metrics using legacy financial accounting systems. With these systems, only past financial performance is measured, with no hints to plans for future actions. Besides, financial measures can't capture the enterprise's intangible assets. The intangible assets of a company account for at least 75% of the company's market value (Kaplan and Norton, 2004). In the information-age environment these assets are more important for achieving the competitive advantages.

The BSC expands the set of business objectives beyond summary financial measures and complements them with measures of the drivers of future performance. Using BSC puts emphasis on having financial and nonfinancial measures as parts of the information system for the employees at all levels of the enterprise. It also requires senior executives to understand the drivers of the long term financial success. Kaplan and Norton assume that each company should develop a strategic BSC, and based on that each business unit would develop its BSC, and so would each employee. All must be linked and integrated. They stress that unless coordinated and integrated, the implementation of the corporate strategy will fail. Achieving this level of coordination is necessary for the success in implementing the corporate strategy itself. Studies shows that 70% to 90% of companies fail to realize success from their strategies (Niven 2002, Kaplan and Norton, 2004).

Kaplan and Norton (Kaplan 1996) also emphasize that BSC be based on a series of cause-and-effect relationships derived from the corporate strategy and they define its function as to translate an organization's mission and strategy into a comprehensive set of measures that provide the framework for a strategic measurement and management system.

The BSC implementation process. BSC is proposed as a strategic management tool that helps achieve enterprise-wide coordination. At the same time, coordinated efforts of all enterprise units are assumed prior to the development of the BSC. The process of implementing the BSC is shown in Exhibit 2. It shows casual guidelines and recommendations. Each organization implements them in its own way. Following these guidelines, the management needs to define a set of measures for each of the four perspectives and the target values for these measures. Then, for each measure on the BSC, management must identify the strategic initiatives needed to achieve the target. Actions and plans that define and provide the required resources for these strategic initiatives must be aligned around the strategic themes of the organization. The whole process must be viewed as an integrated bundle of investments instead of as stand alone projects (Kaplan and Norton, 2004).

Exhibit 2. Process for Developing BSC (Kaplan and Norton, 2001)



Other researchers have formulated their own procedures. Vardangalos and Pantelis (2000) have summarized a procedure to develop BSC as follows:

- Conduct initial interviews in an executive workshop to understand the expectations and objectives of the company's strategy.
- Assess opportunities and scope of BSC by identifying the critical success factors and how the organization approaches business.
- Draft BSC based on evaluating the critical success factors and analysis of the process model, and selected metrics.
- Finalize BSC in an executive workshop by reviewing the proposed metrics.
- Provide BSC implementation support.
- Facilitate goal setting in executive workshops.
- Assist management in methods for deploying performance improvement goals at all levels of the organization.

Baltimore Workforce Investment Board (2003) has also formulated its own version of the process as follows:

- Identify measures that describe how organization adds value, reflecting the customer's point of view.
- Identify the financial and market goals necessary to achieve that customer value.
- Identify core business processes and internal procedures necessary to creating value.
- Identify the organizational and system capabilities that enable the organization to achieve its goals and how they can be improved through learning and innovation

Similar to Kaplan and Norton's framework, these suggested procedures, as well as those suggested by others (e.g. Niven, 2002, Gumbus and Lyons, 2002, Solano et al., 2003) are casual and rely on the human experiences, skills and judgment. In fact they are all different versions of the Kaplan and Norton process. The tools that Kaplan and Norton had in mind and used when they proposed the BSC were the interviews and the interactive workshops with executives and other personnel (Kaplan and Norton, 2001).

Success and failure of the BSC. BSC enjoyed wide popularity. About 50% of the Fortune 1000 companies in the US and about 40% in Europe have attempted a version of BSC (Ittner et al., 2003). However, failures have reported for many reasons. Schneiderman (1999) considered it the single most important management tool. But he observed that the vast majority of the BSCs fail over time to meet the expectations, and he described the reasons for that as follows:

1. Incorrectly identifying non-financial variables as primary drivers of future stakeholder satisfaction.
2. Missing quantitative linkages between non-financial and financial results
3. Improvement goals are negotiated and metrics are poorly defined
4. No deployment system to break high-level goals down to the sub-process level

All these reasons imply that the failure of BSC is due to the human factor. Individuals in charge of developing BSC depend on their judgment and experience in comprehending the organization system, communicating to other individuals and units, selecting the metrics, establishing the relationships among them, and interpreting what the measures imply. There are no specific tools or techniques that support this process against human subjectivity. Being biased and subjective are inevitable human characteristics that affect the reliability of the balanced scorecards. Without a supporting tool this cannot guarantee reliable outcomes.

Ittner et al. (2003) investigated the subjectivity impact on the development of BSC for a rewarding and bonus plan in a financial services firm. The way they developed the scorecard plan allowed superiors to reduce the ‘‘balance’’ in bonus awards by placing most of the weight on financial measures, to incorporate factors other than the scorecard measures in performance evaluations, to change evaluation criteria from quarter to quarter, to ignore measures that were predictive of future financial performance, and to weight measures that were not predictive of desired results. This puts doubts on the explanation of the firm's measurements practices. The high level of subjectivity in the balanced scorecard plan led many branch managers in the firm to complain about favoritism in bonus awards and uncertainty in the criteria being used to determine rewards. The system ultimately was abandoned in favor of a formulaic bonus plan based solely on revenues.

Such a situation is not unexpected in other kinds of firms. We believe that this is the main reason for the failures of any BSC implementation program. This is particularly significant given that BSC is a strategic management tool, which would put lower level managers under pressure. It can be said that BSC can enhance and add to the success to of a successful organization, but it might not create success.

On the other hand, success stories such as those in (Kaplan, 1993), (Gumbus and Lynos, 2002), (Gumbus and Johnson, 2003), and (Solano et al., 2003) can be as follows. Gumbus and Johnson (2003) described developing a BSC in an aluminum production company with 50 years of experience in business. The management of the company made an extensive set of surveys at all levels and phases to collect data about each of the four perspectives of the BSC. The management gave more attention to the learning and growth perspective as it believed that employees were the cornerstone in the company's success. For the financial perspective, the management devised an Excel tool to compare and analyze the cost data per each customer and used this tool to identify the worst 50 cases to focus on them on the monthly management reviews. The management hired a consultant to assist in conducting customer surveys in particular. Based on their surveys they identified the goals and the influential factors to be considered in the BSC measurement system. A version of the strategy map (Kaplan and Norton, 2004) was tailored in support of the company's focus on the employees' (learning and growth) perspective. That is, the BSC was not really balanced but biased toward a certain perspective. Yet it served the management's concern.

Ten years before that, Kaplan (1993) reported the implementation of the BSC at a large, very diversified company that produced more than 300 products in 21 divisions worldwide. The company conducted a comprehensive data collection program in all divisions and departments within the guidelines set by the top management. Managers of the various levels were required to pick the measures of performance and related parameters that they would consider to represent their processes and performances the best. Mangers were required to focus on outcome measures rather than the time, cost, and quality measures that used to be considered. Outcome measures encouraged mangers to understand their industry better and to realize real improvements. These measures were then related to the higher level metrics and eventually to the top financial metrics of the company. The implementation process was planned to avoid focusing on the short term financial performance at divisions. The management believed that when asking for financial performance from each department, it would get a bad performance from one and a good performance from another such that they would add up to an average that might be misleading about the overall performance. The management allowed divisions to devise their own strategies to focus on their operations. By reporting performance on these operations, the top management would assess the execution of the overall strategic plan. The process in total was successful and the key success factor was the commitment of the employees at all levels to follow the top management guidelines and directions.

These two stories as well as others show that an enterprise that has an effective management communication system and the ability to coordinate the effort of its employees effectively, can successfully develop and use a BSC. What we conclude is that, in developing a BSC there is no guard against subjectivity, bias, or inability to follow a holistic view of the system except the experiences and skills of the personnel involved in implementing the BSC.

Strategy maps. Kaplan and Norton proposed strategy maps as a tool to enhance the effectiveness of the BSC implementation process. The strategy map is a graphic representation tool that is used to provide a visual representation of organizations' critical objectives and the relationships among the key performance measures. In addition to helping in understanding the interrelationships among various system parameters, a strategy map can help establish a guiding framework to align the objectives of the various business units with the strategic objectives. Kaplan and Norton recommend identifying the cause-and-effect relationships among the measures of performance and the strategy map as the tool to visualize these relationships (Kaplan and Norton, 2001, Solano et al., 2003, Kaplan and Norton, 2004).

Kaplan and Norton (2001) define the role of the strategy maps in developing the BSC as to make the organization' strategy's hypotheses explicit. The measures of performance are made embedded in a chain of cause-and-effect relationships that connect the desired outcomes from the strategy with the drivers that will lead to the strategic outcomes. In this sense, the strategy map is an approach by Kaplan and Norton to improve the reliability of their BSC implementation process. They employ the maps to provide "the visual framework for integrating the organization's objectives in the four perspectives of a BSC" (Kaplan and Norton, 2004). The map is also divided into four sections for each of the four BSC perspectives, and in each section the objectives of the organization are listed. Arrows representing the interrelationships among objectives in all sections are drawn to represent the cause-and-effect relationships. This is a smart approach and is easier as a graphical representation, to understand than having objectives and their interactions listed on tables or in minds of the BSC development teams. They dedicated their recent book *Strategy Maps: Converting intangible assets into tangible outcome* (Kaplan 2004) to this part of their BSC theory. In that book they reported how the maps motivated employees to discuss their roles and locations in their organization's strategy, and in their expression, this "made strategy everyone's job", which is an expression they coined in their earlier books.

However the strategy map is no more than a visual representation of the metrics and objectives and their associated business units' interrelationships, and it does not quantify these relationships or provide a description of their natures. People can describe structure and local behavior of a system well but they fail to predict global behavior, especially if feedback loops of different lengths and complexities are part of the system (Jarke et al., 1997), which is the case in all business organizations (Forrester, 1965, Sterman, 2000).

Hybrid Enterprise Simulation Model

In a recent paper (Rabelo et al., 2003), we proposed a hybrid approach to manufacturing enterprise simulation modeling that combines discrete event simulation and system dynamics approaches. The enterprise simulation model basically covers the strategic, tactical, and operational levels of decision-making in a single simulation of multiple models at different levels and resolutions. We propose using the enterprise simulation model to develop the BSC. The simulation model can guard the process against subjectivity and emphasize the dynamic characteristic in the scorecard. A description of the hybrid enterprise simulation model and its potentials as the needed mechanism for developing dynamic BSCs are presented in a later section. An introduction to System Dynamics, which is the basis of the simulation model, is presented next.

System Dynamics simulation. System Dynamics (SD) is a system thinking approach that offers a well-elaborated methodology for continuous deterministic simulation. Its origins lie among the elements of traditional management, feedback control theory, and computer simulation principles. The feedback control theory provides both a structure for the model building and a way for selecting the proper information for decision-making. When considering feedback information, only the study of the whole system as a feedback system will lead to correct results about its behavior. Based on that SD takes an integrative perspective in modeling systems (Forrester 1965, Mandal et al., 1998, Reid and Koljonen ,1999, Bradl 2003).

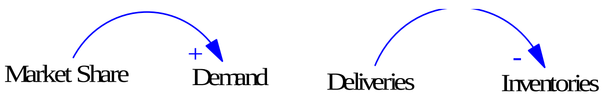
SD was developed with the work of Jay Forrester of MIT during the 1950s (Forrester, 1965). It was initially known as industrial dynamics and first applied in 1958 to a production-inventory control situation. Since then it has found its way into many diverse and interdisciplinary systems including industrial, social, economic, political, and environmental systems. It was later renamed as System Dynamics. Forrester defined SD as the application of feedback concepts to social systems and he considered it an approach to corporate policy design (Forrester, 1968).

The methodology uses causal loop diagrams to represent the dynamic hypotheses about the behavior of the system, and feedback loops to represent the structure of the system. The main diagramming components are the stocks (or levels) that are used to represent the system state variables, and the flows (or rates) that are used to represent the actions or activities that affect the levels of the system state. A SD consists of a number of interacting feedback loops. A feedback loop consists of an alternating set of levels and rates. Integral and other simple mathematical equations are then added to the diagrams to model the relationships among system parameters. Computer simulation is then used to solve these equations such that deterministic simulation experiments are conducted.

SD recognizes, in particular, the roles of the feedback information and the cause-and-effect relationships in creating the dynamic behaviors of the systems. In that way, SD goes further beyond the strategy maps of Kaplan and Norton. Not only does it depict the causal interrelationships between all system components, but it also recognizes the nature of these relationships and describes in a quantified approach how these components interact. A major advantages that SD offers based on that is the ability to trace the causes of system behavior to its roots, anywhere in the system, such that a better understanding is possible and the right correction or adjustment actions can be taken.

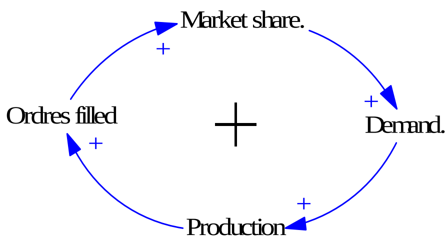
The creation of a SD model requires the identification of the causal relationships that form the system's feedback loops. Feedback loops can be either negative or positive based on the direction of influence a parameter has on another. A negative loop is a series of causal relationships that tend to force behavior towards a certain goal. In contrast, a positive loop is self-reinforcing; it amplifies disturbances in the system to create higher variations in behavior. Exhibit 3 depicts the types of causal relationships and an example of a positive feedback loop.

Exhibit 3. Positive and negative causal relationships and feedback loop diagrams in SD



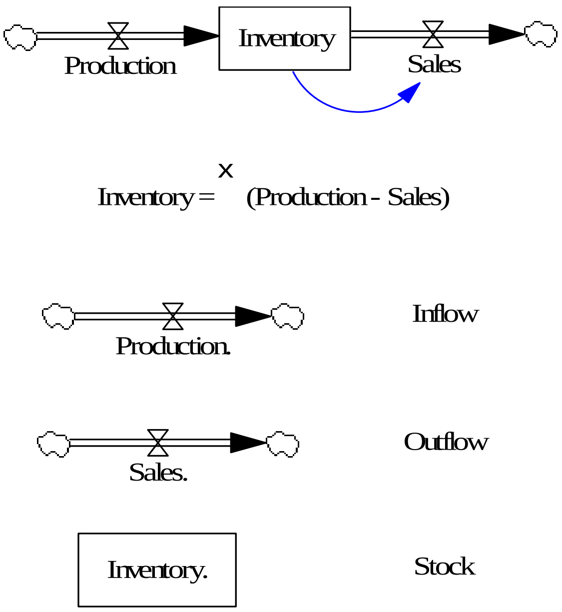
Link polarity is positive. If Market share increases then Demand increases

Link polarity is negative. If Deliveries increase then Inventory decrease



From the causal loops, we develop the stocks and flows diagram of the system structure. Stocks are accumulations of information or materials that characterize the state of the system. Stocks are represented by rectangles. They generate the information upon which decisions and actions are based. They also create delays by accumulating the differences between the inflow and outflow of a process. Inflows and outflows are represented by the flows. Flows are added to or subtracted from stocks. Flows are represented graphically as valves going in or out of stocks. This graphical description of the system can be mapped into a mathematical description of the relationships among system variables. Exhibit 4 depicts the stocks and flows and how they are represented in a stocks and flows diagram.

Exhibit 4. Stocks and flows structure of SD models



Using SD for BSC. The structure of the SD model implicitly include an advanced form of the strategy maps. Besides, the nature of the modeling approach offers the comprehensive, holistic view of the organization system that is required in the development of the BSC. Beyond that, SD does not only offer a measurement system but it is also a modeling tool to analyze and understand the behavior of the organization system and how success or failure of the organization depends on its structure, the interaction between its components and the managerial policies in effect. SD is widely applied in managerial applications. In fact Forrester introduced system dynamics in his book Industrial Dynamics (Forrester, 1965) as a method of systems analysis for management. Bradl (2003) strongly recommended it for management applications, arguing that undesirable consequences of management's decision are often discovered after it is too late to take the proper actions and there are no methodologies that can resolve this problem. For this regard SD offers managers the methodology to recognize the causality relationships and foresee the consequences so that actions – not reactions – can be made. In the same way believe that a SD-based model of the enterprise will help managers understand in a well defined way the causes behind the performances of the different divisions of the enterprise as reflected by the outputs of the model which constitute the BSC contents.

SD also offers the ability to model qualitative system parameters. Bradl (2003) proposed two SD models for the human resource training function in an enterprise. Since training happens overtime and gains from it are gradual instead of discrete, SD was the right choice. The levels of proficiency of trainees were classified in qualitative terms (excellent, good, moderate, poor) and these could be incorporated into a SD model. He also proposed building a SD model to simulate the balance sheet of the corporation. The items of the balance sheets were modeled as stocks in the SD model whereas the drivers of these items were modeled as flows. The benefits of that were helping managers to interpret the items based on the cause-and-effect relationships embodied in the model so that they could locate where they were to act. In addition, future estimates of the situation were generated as outputs of the simulation model. Bradl also suggested, as future work, to connect SD with the BSC to enhance the management process.

Solano et al. (2003) has gone an extra step after Bradl and combined SD with the BSC but not with the intent to model BSC. He used BSC to get a systemic quality program integrated in the company's strategy and developed a SD model for the company that was focused on the parameters used in the BSC development. The objective was to estimate the performance of the system in the future after the systemic quality program is implemented. What is interesting in that work was classifying the stocks and output values of the SD model into four classes to correspond to the four perspectives of the BSC. We consider that an unintentional modeling of the BSC using SD. However Solano used a partial model of the enterprise system that had a specific objective and did not reflect the overall performance of the enterprise.

Describing the hybrid enterprise simulation model. The hybrid enterprise simulation model that we proposed (Rabelo et al., 2003] aimed at building a complete simulation model of the enterprises system. The model consists of a SD model for the entire enterprise system and a number of discrete event simulation (DES) models for selected units of the enterprise, especially in the operational and tactical levels of decision making. The DES will be interacting with the overall SD model in an integrative approach. Where should DES models be used depends on the projected use of the model and the required level of details in the analysis. The ultimate objective of developing such a hybrid model is to be able to develop reliable integrated decision-making and performance analysis model to address the interactions and interdependencies within the integrated enterprise systems. The hybrid SD-DES simulation model of the enterprise system is still in development. The model is designed to include the following elements (assuming a manufacturing enterprise):

1. The internal supply chain of the enterprise
2. Strategic decision related activities: mainly resources allocation and financing functions.
3. External market and economy indicators
4. Suppliers as external aggregate indicators: supplier reliability, capacity, quality, etc.
5. Customers as external aggregate indicators: customer satisfaction level, loyalty, etc.
6. DES models for production units and other internal business units as analysis requires

The planned use of the hybrid simulation model is for policy design and control. Management can use the model to test proposed policies before they are implemented, and project the impact of theses policies into the future. Testing using the model is conducted on a holistic level reflecting the impact of the new policies in the various divisions, business units, and decision making levels. The impact of any local decision or work method can be reflected on the other enterprise units such that all personnel can locate themselves in the overall enterprise system and smooth their performance based on the results of the model. Theses results are to be reported in a BSC form. There will be no BSC implementation as it automatically will results upon running the simulation model.

An illustrative example. The section presents an example for the hybrid SD-DES enterprise simulation model. We assume a semiconductor enterprise that has two production plants; a FAB plant and a Sealer Process plant. The objective of the experiment is to test the strategic management policy in allocating reinvestment resources to each of the two plants. The corporate strategy in this firm is to re-invest 55% of its earnings before interest and taxes The allocation can follow one of three different policies that are considered:

1. Proportional to Average Return. Reinvestment amount allocated to a plant is based on the proportional size of its average return.
2. Proportional to Revenues. The re-investment amount allocated to a plant is based on the proportional size of its revenues (with respect to the total revenues of the corporation).
3. Proportional to Earnings. Re-investment amount allocated to a plant is based on the proportional size of its earnings before taxes.

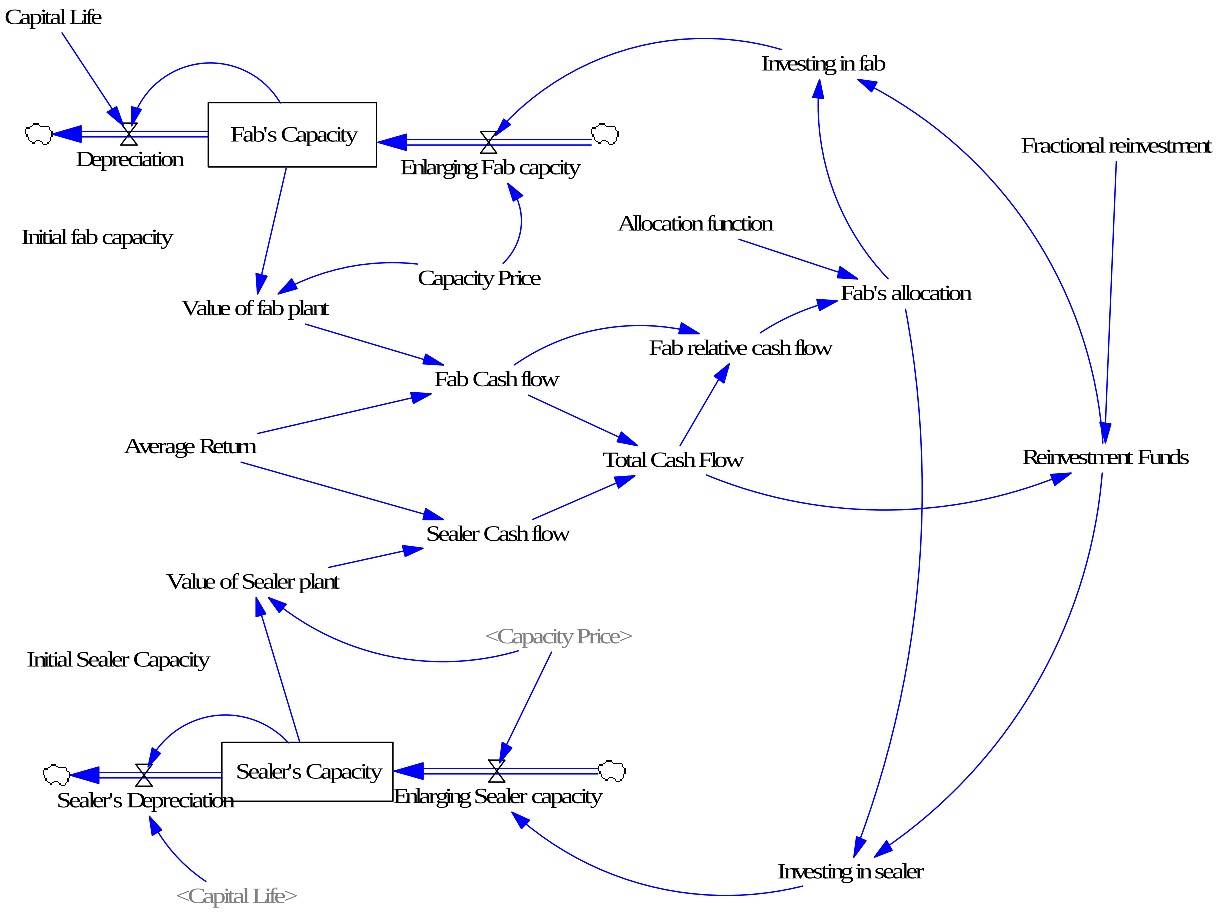
The scenario for implementing the hybrid model calls for these decisions and all relevant information at the strategic level of the firm to be modeled using SD, while the operations at the plants be modeled using DES. DES is successfully used for modeling production systems at any required levels of details. SD on the other hand is preferred for overall views and not recommended for detailed analyses. This is the fundamental concept in combining the two methodologies in this SD-DES simulation model.

The model starts by allocating financial resources for each of the two plants according to one of the allocation rules. The reinvestment decisions at the plant level, such as increasing capacity or improving existing facilities, are evaluated in the DES models. Feedback in terms of productivity, utilization, and other measures of performance are sent to the SD model, which will react appropriately to adjust the reinvestment decisions based on the feedback information and the allocation rules in consideration. The cycle of exchanging data between models continues while observing the performance of the enterprise in the model output, over a period of 10 years. Each of the three policies was tested in a separate experiment.

A SD model of the enterprise system and two DES models for the two plants were developed. Exhibit 5 shows the SD enterprise model in which the two plants are shown as two capacity stocks. Each of these stocks is a complete DES model. DES models are not shown. Communication between the SD model and the DES has been manual. Currently, we are developing a methodology for the interaction between models so that models can interact and exchange data automatically. The methodology receives outputs from all models and formats them to be read by other models and then sends signals indicating the readiness of the data. We are considering the use of the open database connectivity tools for communication between models. Formatting data includes matching them to the input format of the simulation software in use and performing the aggregation and disaggregation processes to prepare data for the different levels of decision making involved. Data requirements at the strategic level, for instance, are different from that on the operational level. Details are not required at the top levels, and therefore operational data must be aggregated to fit the uses at the higher tactical and strategic levels. Disaggregation is needed for the opposite direction of communications. In addition to that the communication approach accounts for the differences in planning frequencies between the higher and lower management levels by sending signals of data readiness such that data is sent to the demanding model at the appropriate times.

The results of the experiments of testing the three allocation policies, in the semiconductor enterprise are shown in Exhibit 6.

Exhibit 5. SD model of the two-plant enterprise system for re-investment allocation policy analysis

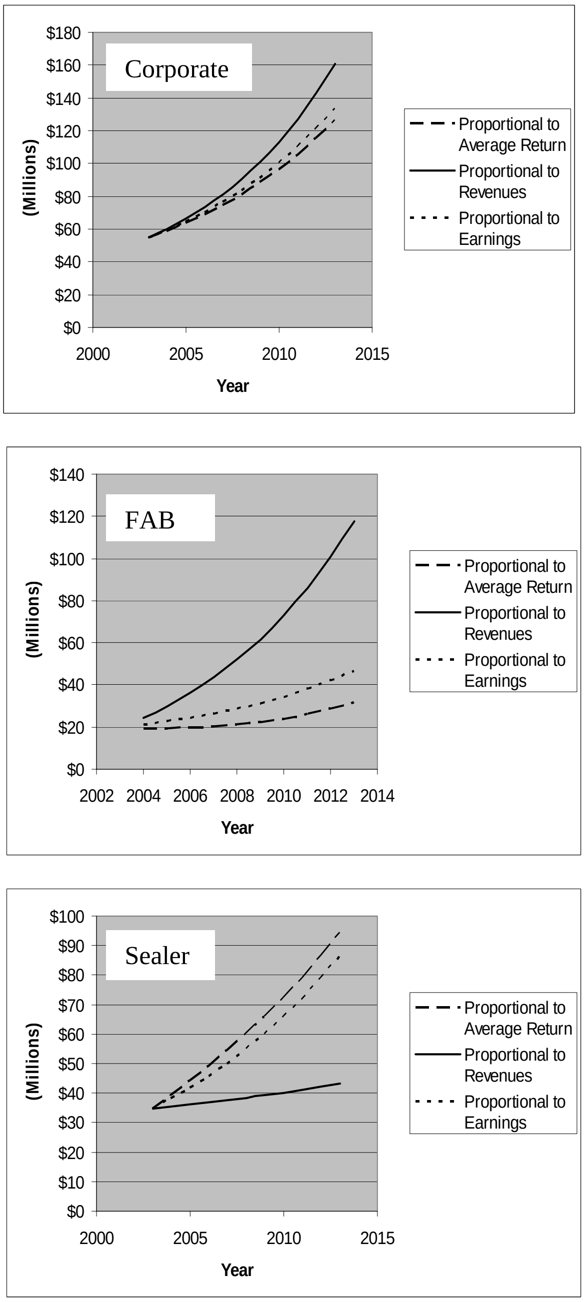


The first chart in Exhibit 6 shows the growth at the corporate level of the enterprise. As shown all the reinvestment policies tested in by the model are favorable at the corporate level, with the second set of policies being slightly better that the others. Top management of the firm should be satisfied with any of these polices. The second chart in Exhibit 6 shows the growth of the FAB plant and it is obvious that the same best policy at the corporate level is the right choice for this plant. The other two policies cause very much lower growth rates. However the chart of the Sealer Process plant shows that this same preferred policy is the worst for that plant's growth and either of the other two policies should be used. Over the 10-year period, the Sealer plant's performance will decline compared to the FAB plant. At the same time the top management is reading good overall performance measures and rates of growth for the enterprise. This situation takes place because of connecting the allocation policies to the performance of the plants. As the FAB plant growth faster than the Sealer plant, more money will be allocated the FAB and less the Sealer.

At a certain point in time, the management will start considering reengineering the Sealer plant in order to improve its growth and performance. This can call for conducting a market survey to test the causes of the declining of plant, in addition to analyzing its capabilities, which may point to the need for a major investment in that plant. However if management had the projected impact of their reinvestment policies, then it would have changed that policy with one that is optimized for all levels of management and all business units, not only for the corporate level. The hybrid enterprise simulation model offers this opportunity to test strategic policies with respect to various enterprise system components and management levels.

BSC based on the hybrid simulation model. This situation described in the previous section supports the need for a comprehensive performance measurement system that is not only based on the financial measures. This is basis of the development of the BSC. We propose to use the BSC as the format for the ultimate output of the hybrid simulation model. model.

Exhibit 6. Growth rate with each of the reinvestment policies: Coprporate, FAB, Sealer



Stocks (system state variables) of the SD part of the hybrid enterprise model will be used as the measures included in the BSC. Flows and other auxiliary variables can also be used. The DES models are practically sub-models into the overall SD part, to enhance the resolution of enterprise model especially at the operational management levels. They are aggregated in the SD part as stocks and flows. For instance the Fab's Capacity stock in Exhibit 5 is the aggregation of the capacity of the FAB plant. Details are found in the FAB DES model and include equipment and personnel.

The SD stocks and flows will be arranged as a BSC in a dashboard-like format. The process of developing the simulation model will, implicitly, be the BSC development process. Selecting the set of measures for the scorecard will be made from the set of simulation results. This makes preparing the BSC highly flexible as the simulation model is comprehensive and all parameters that impact the system behavior and performance are already included in it. For instance, the capacity of the plants, value of each plant, and the net cash flow of each them can be used as measures of performance on the BSC. These parameters are already included in the simulation as shown in Exhibit 5. It should be noted that the shown SD model in Exhibit 5 is simplified for the purpose of demonstrating the concept of the hybrid model.

The BSC can also be used according to Kaplan and Norton's theory. That is by developing BSCs at the various management levels. The contribution of the enterprise simulation model is the quantification of the BSC development process using a reliable technique as simulation, which can be validated and verified as an acceptable model of the real system. The process then is guarded against subjectivity and the loss of the holistic point of view.

Another advantage of using the hybrid model to develop BSC is the ability to project the performance of the enterprise system into future. Traditionally a BSC gives a snapshot of the performance of the enterprise at a certain point of time given certain work settings. Thus a BSC based on the hybrid model does not only reflect the current or past performances but it shows the future trends due to the taken management and work policies. In other words, the BSC that is built based on the hybrid simulation model is a dynamic performance measurement system that is automatically updated with any changes in the settings in the simulation model, which adds the dimensions of robustness and efficiency to the BSC theory and implementation process.

Conclusion and Future Work

In this paper we discussed the potentials of using the hybrid system dynamics-discrete event simulation enterprise simulation model in developing dynamic balance scorecards. We showed that the current balanced scorecard theory is missing a robust, quantitative tool that guides the scorecard development process and safeguards against human subjectivity or inadequate comprehensiveness. The hybrid enterprise simulation model has very promising potentials to be this missing tool. We demonstrated the concept of the hybrid simulation model and discussed its suitability and merits to be used for developing balanced scorecards that have the added characteristic of being dynamic and robust.

Currently, we are continuing the building of the hybrid enterprise simulation model for a manufacturing enterprise. Once completed and validated, the balanced scorecard will serve as a dashboard on top of the simulation model.

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