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A STRATEGIC SUPPLY CHAIN SIMULATION MODEL

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ABSTRACT

In this paper, we describe a simulation game designed to quantify the benefits of an enterprise resource planning system coupled with the balanced scorecard framework in an extended enterprise. We present three scenarios of the same enterprise: a base case scenario with a non-integrated legacy system, a scenario with an integrated, enterprise resource planning system, and a scenario with an enterprise resource planning system using the balanced scorecard framework. Results from this game support our research and teaching activities on the benefits of systems integration, data and process standardization, visibility across the business enterprise, improved decision support functionality, and operationalizing strategy.

1 INTRODUCTION

Over the last decade, many business organizations have implemented enterprise resource planning (ERP) systems. ERPs provide many benefits over the legacy systems that they have replaced. Our discussions with business professionals involved in ERP implementations along with a growing body of academic research (Mabert, Soni, and Venkataramanan 2000; McAfee 2000; Ettlie 2000) suggest four main benefits: better systems *integration*, *standardization* of data and processes, end user *visibility* across the business enterprise, and improved decision support *functionality*. Integration, standardization, and functionality are an inherent part of the ERP implementation and the system itself. On the other hand, visibility relies on the interaction of end users with the ERP system. In fact, McAfee (2000) defines visibility broadly to include the end user's job performance capabilities and level of technical sophistication. Thus, visibility is a derived benefit and is by no means guaranteed by the ERP implementation itself. Rather, the ERP system creates an environment in which visibility is likely to improve.

Organizations in the post-ERP implementation stage are seeking ways to leverage their ERP systems at the highest levels. One such approach, reflected in an initiative by the major ERP vendor SAP called *Strategic Enterprise Management* (SAP 2000), uses the *Balanced Scorecard Framework* (BSF) (Kaplan and Norton 1996). The BSF guides management decision making by providing a “balanced” set of lagging and leading indicators. These indicators measure resources that drive value for learning and development, internal processes, customers, and financials. The operation to strategy logic is that investment in learning and development promotes continuous improvement in internal processes, which continuously improves the customer experience, thus providing satisfied customers, which drive revenues. By providing data from these processes throughout the value chain, the ERP provides the conduit through which an organization *operationalizes strategy*. We view this as a fifth benefit yet to be realized by organizations with completed ERP implementations. Of course, this benefit is also very dependent on the end-user, namely, management. Thus, it is not guaranteed by the presence of BSF or ERP, even in combination.

In this paper, we describe an enterprise simulation game designed to quantify the potential benefits of ERP and the BSF. The simulation model used in the game contains the main elements of a business enterprise in the telecommunications industry including production, procurement, customer service, field service, new product development, human resources, and finance and accounting. The specific application (see Section 2) provides a case study setting (i.e., a concrete business setting) that we use in the classroom. However, the model's structure transcends the particular industry. As such, results derived from the game in teaching and research apply more broadly than the telecommunications industry.

We consider three scenarios of the enterprise. A base model considers the organization pre-ERP implementation (Section 3). The next model represents the improved organization after an ERP implementation (Section 4). This model directly incorporates the benefits inherent in the ERP implementation, i.e., integration, standardization, and, functionality. Visibility is not incorporated into the simulation model. Rather, it becomes apparent as participants interact with the simulation model during the game. Section 5 describes the post-ERP model combined with BSF designed to facilitate strategy operationalization. Again, much of the benefits of operationalizing strategy are not incorporated into the model but become apparent based on participant performance during the game. Collectively, the three scenarios provide a way to quantify the benefits of ERP and BSF.

The final section of the paper provides a summary of our results and a discussion of future research.

2 SYSTEM OVERVIEW

This section briefly describes the environment within which the firm operates, its basic processes, and the supplier network to which it belongs. The model simulates the extended supply chain of a residential, wireless telecommunications firm. The regional market in which the firm operates is mature and highly competitive, with multiple competitors and relatively low customer switching costs. The firm focuses primarily on customer service and network maintenance. The firm's supply chain includes suppliers of the switching and handset technologies, parts inventory, the technical staff to install and maintain the technology, the call center staff, and the customer base they serve. The model emulates the information that senior executives in this firm would use to make strategic decisions over a 7-year period.

3 BASE MODEL: PRE-ERP

This section introduces the methodology used to develop the simulation model, provides an overview of the model, and describes how the model performs before the implementation of an ERP system.

3.1 Methodology

Following the logic of the resource-based view of the firm, the model simulates the main resources in the wireless telco supply chain, the accumulation dynamics for each resource, and the set of policies that interrelate the dynamics of the different resources. The model was developed with system dynamics, a simulation methodology that focuses on these specific attributes of systems (i.e., resources, policies, and interrelationships (Forrester 1961)). The model is currently implemented in the ithink Simulation Package (Richmond and Peterson 1996).

3.2 Model Overview

We developed the model structure with experts in wireless telecommunications, enterprise systems, and the balanced scorecard, including senior managers in a wireless telco, academics, and strategy consultants. The model was validated using expert knowledge and data from two firms in the industry. The model parameters were then scaled to protect the confidentiality of the two firms.

This section briefly describes the major structural elements of the model and how they interrelate. The model encompasses external and internal components of the supply chain, as denoted by boxes in Figure 1. External components include the suppliers of parts for the switching equipment and the customers. Internal components include human resources, technology, service-supporting information technology, and financial capital.

3.2.1 External Components

In the Supply Chain component, the firm orders enough materials to satisfy current demand for a specified time. The supplier receives orders from the firm, and delivers the materials after a lead time, which is a function of the variance in customer demand. Stable demand creates stable lead times, while fluctuating demand causes the lead time to fluctuate. Materials arrive into the warehouse. On the other end of the supply chain, in the Customer Satisfaction component, the firm provides services to customers for a fee. The customer chooses to continue with the firm, if satisfied with the service provided for the price paid. Satisfaction is measured relative to both the competitive offering in the marketplace and the customer's disposable income dedicated to telephone services. Satisfaction is measured as a utility function of the price paid for a perceived level of call quality, customer service, and functionality. Each of these satisfiers is determined endogenously, as explained in the following section. Demand for wireless services is assumed to fluctuate over the seven-year simulation period, with the customer's average disposable income for telco services following a ten-year cycle in the economy. In the Customer Base component, relative Customer Satisfaction affects movement of customers between the firm and the competition.

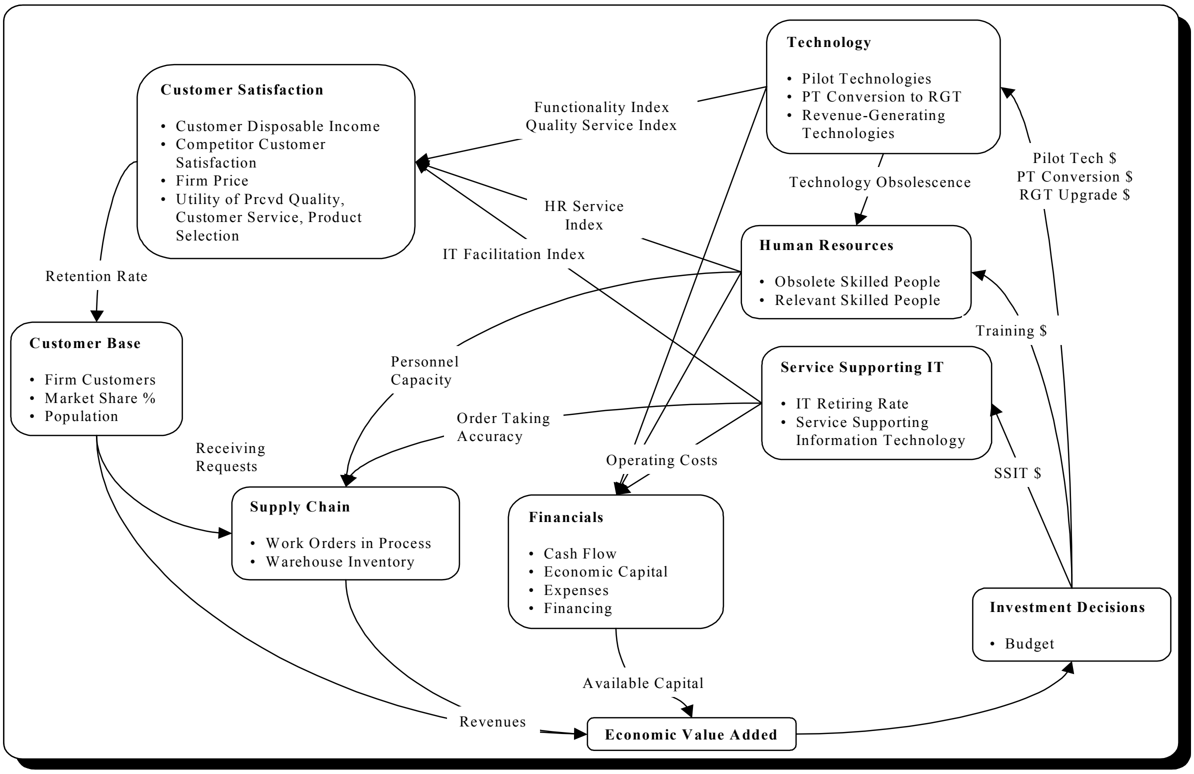

Figure 1: Model Structural Overview

3.2.2 Internal Components

Following the logic of the internal value chain, in the Supply Chain component, warehouse inventory receives the supplier materials, which the technicians deplete by filling work orders in process. In the Technology component, the technicians install materials in the switching system, adding to the revenue-generating technology. The firm also invests in pilot technologies, and converts the successful pilots into revenue-generating technologies. In the Supply Chain component, the call center employees receive work orders from customers and pass them on through the information system to the technicians. The accuracy and number of handoffs in the system affect the accuracy of the technician's installation. The Human Resources component describes the dynamic of human resource skills as employees are hired or fired, and as they are trained or their skills are obsoleted by changing technologies. The Service Supporting Information Technology component depicts the dynamics of the information systems that support the call centers. The Financials component calculates the financial statements based on the status and flow of resources in the firm. The Investment Decisions component translates the participant's periodic capital allocation decisions on a continuous basis.

3.3 Model Performance

In the pre-ERP scenario, participants are given traditional, best of class information from independent information systems about the firm's resources. These strategic-level performance indicators focus on financials and operations. Financial indicators include economic value added (EVA) and the components of EVA, as well as capital invested, debt to equity ratio, and current budgetary allocations. Operational indicators include average monthly orders, inventory, number of employees, and market share. To emulate independent systems, the simulation lags the information and provides it in financial and operational terms, using best-in-class standards.

4 POST-ERP MODEL

The second scenario provides the participant with the same firm, after the implementation of an ERP system. The model emulates an ERP by providing the following benefits, which were derived from the experience of experts on the team that had implemented various ERP systems. The benefits are explained by component.

In the Supply Chain component, customer support representatives (CSR) have access to a complete array of information, and many decisions, such as credit checks, are made automatically. This reduces the number of CSRs with which the customer interfaces, which also reduces administrative costs. Automating much of the decisionmaking process greatly reduces the number of handoffs between parts of the system, significantly decreasing errors due to insufficient and incorrect dataentry at multiple points in the value chain. This same logic applies to the relationship with suppliers. By connecting suppliers to the firm's ERP, the data is transmitted accurately in real-time, allowing suppliers to deliver quicker and more accurately. A key customer satisfier, the expected delivery date, is affected by the ERP's integration with the Logistics and Human Resources sections, allowing precise, real-time calculation of the estimated delivery time. This integration greatly reduces delivery time uncertainty increasing customer satisfaction.

In the Human Resources component, the ERP tracks the relevant skills of thousands of employees, more efficiently identifying those employees requiring training and scheduling their availability for specific courses.

In the Service Support IT component, the ERP decreases the retirement rate of whole IT systems but increases the rate of updating systems.

In the Technology component, engineering change orders slow down the adoption rate of new technologies. The ERP facilitates rapid maintenance of engineering specifications allowing the firm to improve the speed with which they convert successful pilot technologies to revenue-generating technologies.

With the ERP system, the participant is given integrated, real-time, standardized information about the firm's financial and operational resources.

5 POST-ERP WITH BSF

As described in the introduction, the BSF provides decision makers with leading and lagging indicators. Leading indicators should help decision makers understand future performance. For example, customer satisfaction is a leading indicator of revenues, and improved internal processes are a leading indicator of the ability to continue to satisfy customers. Lagging indicators document how well the strategy worked. By providing a more "balanced" view of the firm, the BSF proposes to help decision makers more accurately understand where to make investments throughout the value chain and when to provide sustainable growth.

Participants in this scenario are given timely, integrated, standardized data from the four sectors of the balanced scorecard (see Section 1). Financial data includes EVA, the EVA components, and Debt to Equity ratio. Customer data includes overall Customer Satisfaction (CS), the CS component measures, and customer net turnover. Internal process data includes percent on-time orders, order accuracy, index of the adoption of new technology, and the service quality index. Learning and development data includes the ratio of employees with relevant skills to obsolete skills, the rate of skill obsolescence, the rate of training, and investment in pilot technologies.

6 CONCLUSION

The simulation game we describe in this paper is designed to quantify five major benefits of ERP and BSF: integration, standardization, visibility, functionality, and strategy operationalization. These factors are difficult to quantify in practice due to lack of good data, difficulty in designing an experiment to eliminate confounding of other factors, and the high cost of experimenting on the real system. Our game is being used in our classes on enterprise systems and supply chain management in the form of a case study to demonstrate the benefits of ERP and BSF.

In order to construct the simulation model, we have had to conduct some research on the benefits of ERP at the process level. An empirical study by Cotteleer (2000) suggests benefits from ERP systems will be most evident at the process level. At higher levels of the enterprise (e.g., plant or division levels), it is more difficult to measure benefits empirically due to the presence of confounding factors. This makes simulation an ideal tool to quantify the benefits at higher levels of an organization, because a simulation can describe processes extremely well and can be used to design experiments that control for other factors.

The game is also being used in a research study to test various hypotheses about the impact of ERP data in a balanced scorecard format on strategic decision making. This research explains how data affects the strategic sensemaking process, provides constructs for measuring these effects, and develops an experiment to test the constructs with the simulation game (Ritchie-Dunham 2000). This framework proposes that the timeliness, integration, and standardization of data (benefits of the ERP) will have less impact on strategic sensemaking than will the method for selecting which data is reviewed, such as in the BSF.

Finally, we envision that the simulation game could be used in consulting to assess the benefits of ERP and BSF prior to implementing these systems.

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