AN ANALYTICAL PERFORMANCE MANAGEMENT FRAMEWORK ENABILING ENTERPRISE STRATEGY MANAGEMENT

by

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ABSTRACT

AN ANALYTICAL PERFORMANCE MANAGEMENT FRAMEWORK ENABILING ENTERPRISE STRATEGY MANAGEMENT

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Performance management has gained noticeable interest from both researchers and executive in the past two decades. Financial measures are no longer a primary emphasis for researchers and executives. One of the most popular performance management methodologies is the Balanced Scorecard. The Balanced Scorecard framework facilitates translating strategy into objectives and initiatives across four perspectives. These perspectives are financial, customer, internal processes, and learning and growth. The second component of the balanced scorecard is strategy maps. Strategy maps outline the cause and effect between the four perspectives, and illustrate the value creation process through transforming leading indicators (operational measures) into lagging indicators (financial measures).

This research extends the balanced scorecard framework by introducing Stochastic

Timed Strategy Maps (STSM). STSM quantifies the strategic value creation process by quantifying the cause and effect relationship on strategy maps. We introduce three dimensions for the cause effect relationships. These dimensions are quantity, time phase, and uncertainty. The three dimensions quantify the cause effect relationship between the BSC objectives. Monte Carlo simulation is utilized to simulate the quantified scorecard and establish a future view of the financial performance of the enterprise. STSM along with balanced scorecard simulation allow translating various operational measures into expected time-phased financial performance.

A simulated case study using data generated as part of the research is analyzed. The case study is used to demonstrate the theoretical feasibility of the framework. In addition, the case study is used to communicate and illustrate the application of the proposed framework in comparison with other methodologies as used in the literature and industry. Simulation results demonstrated that the proposed framework provides a better evaluation mechanism than traditional tradeoff-based approaches. Simulation results also showed the importance of focusing on process improvements as it allows improving both the expected output performance and the variability of the expected values. The research suggests that adopting the proposed analytical framework will provide additional insight and value into strategic planning and execution processes.

Keywords; Balanced Scorecard, Strategy Maps, Simulation, Multi Objective Analysis, Performance Management, Strategy Management.

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CHAPTER 1

INTRODUCTION

1.1. Importance of Performance Management

Performance measurement and management has received a great deal of attention from both researchers and practitioners in the recent decade. We summarize the importance of performance management systems into the following categories:

1.1.1. Drive Actions

Metrics drive organizational actions for two reasons. First, monitored measures get high visibility within an organization and the organization strives to achieve high performance with respect to these measures. Such an organizational behavior is positive in terms of achieving strong performance of visible measures. However, this behavior is toxic in terms of its negative impact on other important metrics that are ignored within performance measurement systems. It is always emphasized that metrics should be aligned with strategy (Kaplan and Norton, 1992; Kaplan and Norton, 2000). The second aspect of metrics driving organizational actions is by identifying areas where actions need to be changed. Ivancevich et. al. (1997) illustrates an incidence where call center operators had a poor performance of answering customer calls. Management measured the number of phone rings before a customer call was answered. This measure was made available to the call center representatives. After making this metric available within the organization, it has improved because representatives started paying attention to improving this measure. A proper performance measure in this case has identified a shortfall in the process, and has helped driving positive action.

1.1.2. A framework to drive decision making

Measures also provide a basis to evaluate alternatives and identify decision criteria. Researchers arrive to different conclusions based on the performance criteria they choose to apply. The scheduling process illustrates a perfect example for this point. Scheduling is a low-level activity within the context of supply chain management. Research in scheduling shows how different policies should be adopted according to the measure of interest. For example, shortest processing time policy appears to be the policy of choice when considering time in system or waiting time measures. However, an earliest due date policy is more favorable when considering order lateness as the measure of interest (Chan et. al. 2003). Even though the scheduling problem is not our focus point in this research, it shows the vitality of a proper performance measurement based on both operational and tactical direction. Job waiting time is directly related to strategic measures such as inventory turns and cycle time reduction. On the other hand, order lateness is directly related to customer service measures, which is of equal strategic importance.

An ideal performance management system would drive an enterprise performance by defining relevant performance metrics at multiple levels of the organization hierarchy. Such a performance measurement system would ensure effectiveness within the organization (doing the right thing). The proper implementation of process (at a high level) and algorithms (at a granular level) would assure organizational efficiency (doing it right).

1.1.3. Provides close loop control

Feed back is an integral part of any process. An effective enterprise performance system would allow proper monitoring of business process. Performance monitoring is vital as it provide feedback that enables:

1. Compare actual progress to planned or budgeted values.

2. Facilitates benchmarking against industry best practices.
3. Identifies poor performance and suggest or prompt corrective action.
4. Identifies improvements and suggest or prompt improvement opportunity.
5. Complexity of Performance Management

Since no single measure can be used to assess performance, the problem becomes more complex. The trade off between different performance aspects is very difficult to quantify. The need for multiple measures rises from the following conflict:

1. Quantification of intangibles: There is no straight forward mean to quantify and assess the impact of intangibles on the over all performance.
2. Short term versus long term impact: Although some metrics are quantifiable, there impact is observed over different period of times over the time horizon. For example, spending on research and development is a quantified measure. Taken at face value, R&D spending has a negative short term impact on bottom line measures such as earning per share, or net profit. However, when R&D spending creates unique products and services, it would result in increased product sales at later reporting periods in the time horizon.

Metric relationships are complex. For example, the trade off between customer service level and inventory turns is known, but the amount of trade off is not easily quantified. Therefore, decision makers would monitor both measures in their decision making process.

Akkermans and Oorschot (2005) research discovered a counter-intuitive insight. Goals in their study were not conflicting and mutually exclusive, however goals are “mutually reinforcing”. We hypothesis that one category of goal conflict is time-phased conflict. Other measures will remain conflicting in nature, and their conflict is not time-phased. For example, the trade-off between inventory levels and order fill rate is not a pure time-phase conflict.

1.2. Problem Statement

The research problem can be stated as to develop a performance management framework that enhances strategy management through:

1. Improved trade-off analysis between different performance metrics.
2. Identifying short term and long term performance of the enterprise.
3. Modeling cause-effect relationships between various performance metrics.
4. Addressing time lag effects and uncertainty in the cause – effect relationships between performance metrics.

1.3. Dissertation Outline

This chapter included a brief background of the problem, and demonstrated its relevancy. Chapter 2 includes the literature review. The research gap and the need for the framework is demonstrated. Next, we introduce the research methodology in Chapter 3. Chapter 3 describes the research methodology as well as illustrating the proposed framework. In chapter 4 we introduce the details of a simulated case study we use in this research. The results of using the simulated case study are detailed in Chapter 5. Finally, Chapter 6 includes discussions and conclusion based on the proposed framework and research results.

CHAPTER 2

LITERATURE REVIEW

2.1. Characteristics of Performance Management Frameworks

Traditional performance management systems focused on measuring and monitoring financial measures. This seems to be logical, considering that the purpose of the enterprise is to increase shareholders value. Therefore, making decisions based on their financial impact seems logical. In his widely famous and successful book (The Goal), Goldratt and Cox (1992) state that the goal of an enterprise is to “make money now and in the future”. Although focusing on financial measures seems justified, recent performance management research rejects managing performance by focusing solely on financial and monitory measures.

Most of the research in the performance management arena is influenced by denouncing traditional accounting as the primary framework for performance management. Traditional financial oriented measurement systems were not often satisfactory as they are short term biased and do not address operational excellence and intangible assets (Kaplan 1983, Kaplan and Norton (1992). These deficiencies prompted researchers and practitioners to seek other frameworks for performance management. The following concepts has emerged with researchers shifting away from traditional costing systems.

Balanced Performance: The concept of balanced performance management systems specifies that there should be balance between monitored metrics within a performance management system. The most dominant work in the area of balanced performance management system is the Balanced Score Card by Kaplan and Norton (1992). The balanced scorecard focuses on measuring a balanced set of metrics, one of these sets is financial measures. The balanced scorecard framework is detailed in further section.

Aligned with organization strategy: A performance management system should reflect an organization strategy. Metrics are usually driven by the enterprise mission, vision, and strategy (Neely and Adams, 1996; Bititci and Suwignjo, 2000; Abu-Suleiman et. al. 2003). Kaplan and Norton (1992, 1996, 2000) emphasize that performance measurement should communicate and deploy an organization strategy.

Dynamic: A performance management system should be able to adapt to changes in various aspects including strategy, competitive landscape, customer behavior and other factors (Bititci and Turner (2000), Youngblood and Collins (2002), and Wagner (2004)).

2.2. The Balanced Score Card Framework

Introduced by Kaplan and Norton (1992), the balanced score card has been widely used in industry. Since no single measure can assess the performance, managers need to observe a balanced view of both operational and financial measures. Kaplan and Norton (1992) make the analogy between the balanced scorecard and a pilot cockpit. Both tools give the users (the pilot and the manager) complex information at a glance. Personal experience and interaction with managers in the industry indicates wide adoption of the balance scorecard approach in multiple companies across different industries.

Kaplan and Norton (1992) propose four basic perspectives that managers should monitor (Figure 2-1):

Financial perspective: The financial perspective attempts to answer the question, “How do we look to shareholders”.

Customer perspective: The customer perspective attempts to answer the question, “How do customers see us”

Internal perspective: The internal perspective attempts to answer the question, “What must we excel at”.

Innovation and Learning: The innovation and learning perspective attempts to answer the question, “Can we continue to improve and create value”

Having these four perspectives in mind, managers can translate strategies into specific measures that can monitor the overall impact of the strategy on the enterprise. The four perspectives also help in avoiding focusing on short term and financial results. If an enterprise execution was short term biased, the BSC will show week performance in other perspectives such as internal processes and/ or learning and growth perspective.

Some researchers modified the four perspectives to fit within a specific context. Brewer and Speh (2000) mapped Kaplan’s balanced scorecard dimensions into SCM specific measures. They replaced the Business Process perspective with SCM goals (e.g. waste reduction, flexible response), and the innovation and perspective with SCM process improvement (product/ process innovation, partnership management, information flows). Other dimensions such as people and sustainability (Lohman et. al. 2004) and safety, morale and quality (Bond 1999) were introduced as supply chain specific dimensions into the BSC. Maltz et al. (2003) used five dimensions in their version of the balanced score card. The five dimensions are: financial, market, process, people, and future.

Kaplan and Norton (1992) outline the following advantages of following the balanced scorecard approach:

1. Provide a comprehensive picture of the enterprise’s performance at a glance. A single report includes multiple measures that are tied to desired core competencies such as cycle time, return on investment and customer satisfaction.

2. The balanced score card protects from local optimization. Since managers can view all important aspects of the business, the tendency of improving one area at the expense of the other is minimized. Balancing the objective promotes positive improvement in processes, e.g. improving set up times by reducing process set up rather than increasing batch size. The balanced score card provides insight whether an improvement is based on actual process improvement or by reducing the performance of other processes.

3. Helps avoiding information overload by keeping only measures that are tied to strategy.

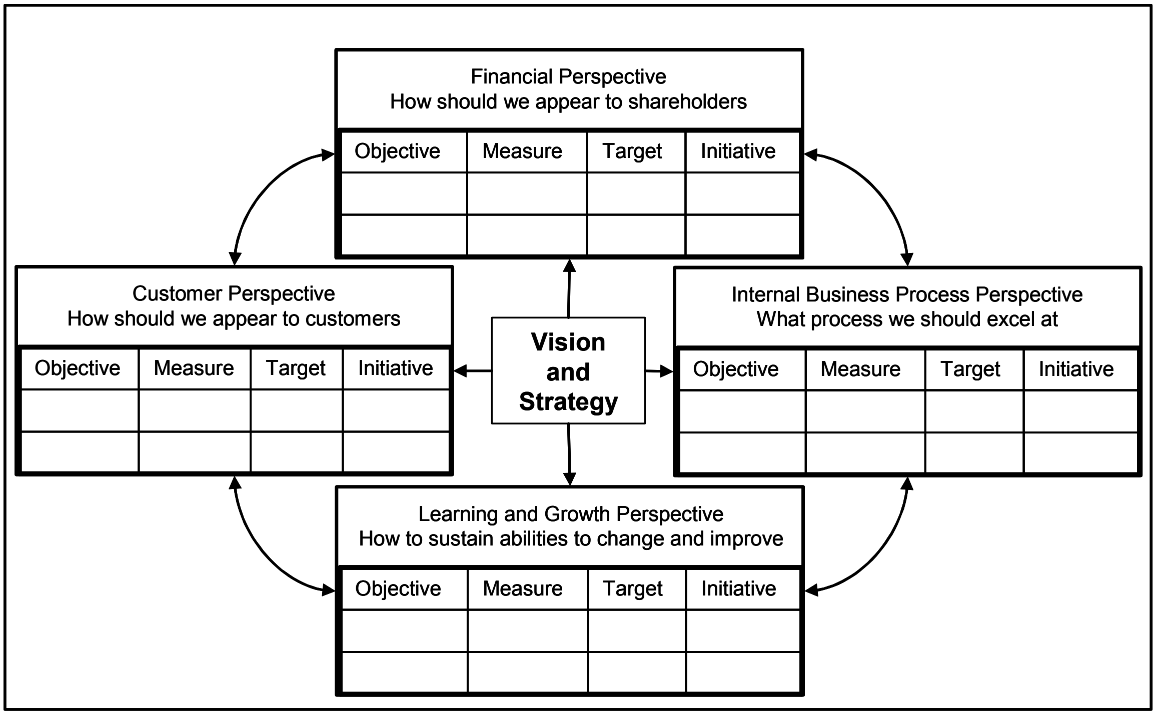


Figure 2-1 The Balance Scorecard (Adopted from Kaplan and Norton 1996)

Within the balanced scorecard approach, Kaplan and Norton introduced the concept of leading indicators and lagging indicators (Kaplan and Norton, 1992, 1996; Niven, 2005). Leading indicators are performance metrics that will help predict the lagging indicators (e.g.

financial outcome) in the future. On the other hand, lagging indicators are the results realized from leading indicators. For example, an improvement in the Customer Perspective of the balanced scorecard is expected to result in improved financial results. In this case, a customer satisfaction measure is a leading indicator and the financial measure is the lagging indicator. The distinction between leading and lagging indicators is helpful in realizing trade offs between short term and long results. However, current practice and research does not provide the tools to quantify the trade off or to model the lag time between leading and lagging indicators.

Figure 2-1 earlier, shows how a balanced scorecard is structured. At the center of the balanced scorecard is the enterprise vision and strategy. Each perspective includes the following components:

1. Objectives: Niven (2005) describes objectives as the link between measures and strategy. They describe what aspects and activities must be performed well in order to execute strategy. Therefore, objectives are more detailed than the vision and mission statements, however, they are more abstract than specific measures and key performance indicators (KPI)
2. Measures: Measures are the means to assess the execution of objectives.
3. Targets: Targets are numerical values that represent the effectiveness of achieving the specified objective.
4. Initiatives: Initiatives are strategic level programs that are introduced to achieve the target objectives within the specified perspective.

The following example explains these major balanced scorecard elements. The example is summarized from Niven (2005). The objective is to increase customer loyalty. The measure is customer loyalty rating as measured by quarterly surveys. The target value of this measure is

75%. And finally the initiative to achieve this measure is customer service training.

Niven (2005) also illustrated how the balance scorecard can be used to rationalize strategic initiatives. After initiative alternatives are identified, a score for each of these initiatives is determined, and initiatives with the best scores are implemented.

2.3. Strategy Maps and the Balanced Scorecard

After the success of the Balanced Score card approach, Kaplan and Norton introduced the concept of strategy maps (2000). The purpose of strategy maps (Figure 2-2) is to communicate strategy through the organization as well as illustrating how each element on the balanced score card will result in achieving the overall organization strategy. Strategy maps provide qualitative means to model cause and effect relationship between various metrics. In addition, strategy maps help managers to understand and use the concept of leading and lagging indicators. Kaplan and Norton (2000, 2004) describe strategy maps as a strategy description tool.

Although strategy maps have been proven in industry to help communicate and describe the strategy, it does not provide the means to quantify the cause and effect relationship between various BSC elements. Strategy maps illustrate the relationship between leading and lagging indicators, however, they do not quantify impact, time, or uncertainty of these relationships.

In addition, Kaplan and Norton (2000) distinguish between two basic strategy types. At the top of the strategy maps, the financial perspective is grouped under two strategies. The first is revenue growth strategy. Revenue growth strategy attempts to improve shareholders value by growing revenues, i.e. growing the top line. The second strategy is productivity strategy. The productivity strategy contributes to the shareholders value by reducing cost and increasing efficiencies. The goal of the productivity strategy is to improve the bottom line. Strategy maps helps managers and executives to identify how each score card elements contributes to each of the two strategies.

Strategy Maps are used now as an integral part of the Balanced Scorecard implementation methodology (Kaplan and Norton, 2005; Niven 2005). Niven (2005) stated that the Balanced Scorecard as framework serves as a performance measurement system, strategic planning tool and a communication tool.

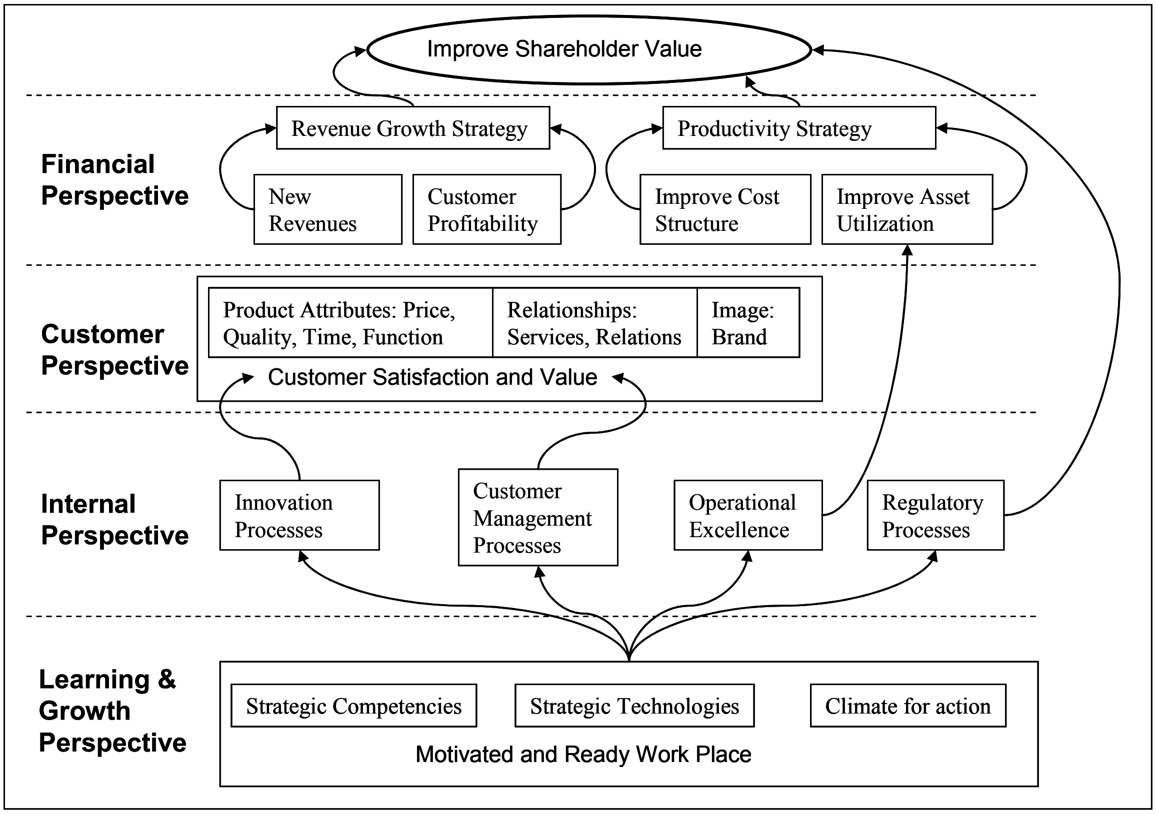


Figure 2-2 Strategy Maps - Kaplan and Norton (2000)

2.4. Review of BSC Criticism

The balanced scorecard methodology has received wide attention from both researchers and practitioners. The balanced scorecard is used at most Fortune 500 and 64% of U.S. companies use some form of the balanced scorecard framework as a performance measurement and strategy management tool (Gumbus, 2005). With such popularity, researchers and practitioners reached mixed results about the value and usefulness of BSC implementations.

Marr and Schiuma (2003) analyzed relevant performance management research and found the Balance Score Card a dominant approach in the literature. They also point the lack of a cohesive body of knowledge in this area.

Lawrie and Cobbold (2004) classified 3 milestones in the balanced score card evolution. First, is the general framework, second includes choosing measures that relate to strategy and strategy map as a visual representation of cause and effect. Third is limited to author's contribution being destination statement and adding the "activity" and "outcome" perspectives.

Nørreklit (2003) suggested that the balanced scorecard is a result of persuasive rhetoric and not a convincing theory. Akkermans and Oorschot (2005) were not as extreme, but suggested that good timing and marketing contributed to the success of the balanced scorecard. Another criticism of the BSC is that it is a top down approach only (Kanji, 2000 and Malina and Selto, 2001). Therefore, it is not a participative approach, and the approach might fail to detect existing interaction between different process metrics (Kanji, 2000). Lohman et al. (2004) find in the corporate setting they studied, that the BSC did not provide an opportunity to develop, communicate and implement strategy. In addition, the balanced scorecard approach was criticized because it provides a conceptual frame work only. Although powerful and widely used in the industry, lack of implementation methodology results in deviating of the merit of the concept itself. The lack of formal methodology and subjective measures often lead to focusing on short term financial measures (Kanji, 2000; Malina and Selto, 2001). Hoque (2003) praised the BSC framework and suggested it adds employee satisfaction into TQM, therefore it's a natural evolution for companies adopting TQM.

2.5. Quantification of the Balanced Scorecard

This section reviews various research efforts to add more analytical depth into the balanced scorecard. In reviewing relevant literature, we first review general approaches to calculate various scores on the BSC. Next, we review more complex analytical models that researchers used to reach a quantitative performance measurement system. We categorize these efforts in three categories:

1. Analytical Models to identify relative importance of performance measures.
2. Analytical Models to assess and measure tradeoffs between various performance measures.
3. Analytical Models to measure or discover relationships between various performance measures.

2.5.1. General approach in quantifying scorecards

The balanced scorecard provides the basis of identifying critical metrics and how they are related to strategy. However the Balanced Score Card lacks measuring trade-offs between various metrics on the balanced scorecard (Collins and Youngblood, 2003). The most common approach in the literature and industry is to normalize various components in the balanced scorecard by assigning weights to each perspective (Lohman et. al. 2004; Niven 2004, Kaplan and Norton, 2004; Malina and Selto, 2001). Ittner et. al. (2003) found in an empirical research that weighting system is biased towards financial and easily measurable metrics defeating the merit of balance scorecard. The generic form of normalized scores follows Equation 1:

$$S = \sum_{i=1}^{n} W_i S_i \quad \text{Equation 1}$$

Where;

S: Total Score of the Balanced Scorecard.

n: Number of performance measures in the balance scorecard.

W_i: Relative weight of performance measure i

S_i: Score of performance measure i.

i: The identifier of a performance measure

There main approach of calculating the value of each scorecard element (S_i) is to divide actual value by target value. This approach is widely uses in the literature and industry (Lohman et. al. 2004; Niven 2004, Kaplan and Norton, 2004). Other researchers (Collins and Youngblood, 2003) established feasible ranges for scorecard elements. The score of each element is based on the actual value of the performance measure relative to the feasible range of the performance measure.

The following sections will review research efforts to add additional quantification into the general balanced scorecard approach. First we review efforts to analytically determine different weights between performance measures. In equation 1, determining the value of various weights W_i is the focus of these efforts. Next, we review various efforts to calculate a total score (S) using more quantitative approaches with relaxed assumptions. Last, we review analytical methods to measure the interaction and relationship between various performance measures.

2.5.2. Measuring Relative Importance of performance measures

The dominant approach to assign relative weights between various performance measures is subjective managerial judgment. Decision makers estimate the relative importance of each performance measure (Lohman et. al., 2004; Niven 2004, Kaplan and Norton, 2004; Malina and Selto, 2001; Ittner et. al., 2003). The general guidelines is that the relative importance between various BSC perspectives should be almost equal (Collins and Youngblood, 2003; Niven 2004). Kaplan and Norton (2001 b) suggest that the financial perspective should be assigned less than 22% weight because it is not important for future growth as the other perspectives. Ittner et. al. (2003) found in a field study that the importance of financial measures is usually given more importance in companies that use the balance scorecard. Ittner et. al. (2003) found that monitory based measures are easier to measure and manage, and managers tend to assign higher importance on them.

The second approach used by researchers is field surveys. DeBusk et. al (2003) analyzed survey response data and estimated relative performance based on these survey results. Using common industry weights eliminates any inherent bias by managers within the enterprise. On the other hand, using weights based on general industry trends ignores any specific circumstances for an enterprise. For example an enterprise that tries to gain competitive advantage through customer satisfaction should use higher weights for customer satisfaction metrics.

Analytical hierarchy process (AHP) has been used widely among researchers to identify relative weights between performance measures (Yurdakul, 2003; Chou and Liang 2001; Sohn et. al. (2003); Bititci et. al.; 2001). Fundamentally, AHP is still based on managerial judgment. However, it provides structure and focus to the managerial judgment. Managers would provide input to simpler pair wise comparison of performance measures rather than attempting to provide an actual ratio for weighing relative importance of metrics.

This review of research efforts in identifying relative importance suggests a common weakness. The weights depend highly on how managers and teams creating scorecards perceive the importance of these measures. AHP provides a better structure to help managers decide the weight of BSC elements.

2.5.3. Analytical models to aggregate multiple objectives

As discussed earlier, simple weighted average is dominant in research and industry.

Additive Multi-Attribute utility theory was used by Youngblood and Collins (2003) and by Stewart and Mohamed (2001). The mathematical model for multi-attribute utility theory is shown in Equation 2:

$$U(S) = \sum_{i=1}^{n} W_i U(S(i)) \quad \text{Equation 2}$$

Where;

U(S): Utility of total Score of the Balanced Scorecard.

n: Number of performance measures in the balance scorecard.

W_i: Relative weight of performance measure i

S_i: Score of performance measure i.

U(S(i)): Utility of score of performance measure i

Table 2.1 illustrates the utility based balanced scorecard as implemented by Youngblood and Collins (2003). Additive multi-attribute utility theory assumes independent utility of different measures. The utility of any metric is only a function of its value. This assumption may need to be relaxed. The effect of a specific performance measure depends on the overall state of the system. In Table 2.1, inventory carrying cost and inventory on hand are dependent measures. If inventory on hand is high, then inventory carrying cost would have a higher effect on the total utility of the balanced scorecard. On the other hand, if the value of inventory on hand is low, then inventory carrying cost would not have a great impact on the total utility of the balanced scorecard. However, additive multi attribute utility theory does not distinguish between the two situations. Therefore, we propose that exploring relaxing the dependence condition is research worthy.

Table 2.1 Utility Based Scorecard (Adopted from Youngblood and Collins, 2003)

Financial Perspective				Category Weight = 25%		
Metric	***Value***	***Min***	***Max***	***Score***	***Weight***	***Wt. Score***
Cost Per Operation	0.86	0.05	1.00	0.15	20%	0.03
Cost Per Transaction	0.06	0.03	0.50	0.94	30%	0.28
Inventory Carrying Cost	2.40	1.00	5.00	0.65	35%	0.23
Inventory On hand	301	20	300	0.00	15%	0.00
						Total 0.54
Customer Perspective				Category Weight = 25%		
Customer Complaint Rate	0.12	0.00	0.15	0.20	35%	0.07
Perfect Order	0.99	0.90	1.00	0.90	15%	0.14
Repeat Customer	79%	1%	80%	0.99	30%	0.30
Inventory Accuracy	96%	80%	100%	0.80	20%	0.16
						Total 0.66
Learning and Growth Perspective				Category Weight = 25%		
Absenteeism	1.5%	1%	15%	0.96	20%	0.19
Associate Retention	80%	25%	85%	0.92	30%	0.28
Supplier Partnership	89	1	100	0.89	40%	0.36
Training hrs per person	41	0	50	0.45	10%	0.05
						Total 0.66
Internal Business Perspective				Category Weight = 25%		
Shipping rate	22	1	50	0.43	20%	0.09
Asset utilization	80%	70%	100%	0.33	30%	0.10
Fill Rate	95%	75%	100%	0.80	40%	0.32
On-time Delivery	66%	50%	100%	0.32	10%	0.03
						Total 0.54
						Total score for all categories = 65%

2.5.4. Analytical models for quantifying performance measures relationships

Lebas (1995) emphasized the role of causality in performance management and illustrated how activity based costing (ABC) is used for that. Lebas suggested that a powerful performance management system should reflect cause and effect relationships.

Banker et. al (2004) used Data Envelopment Analysis to measure tradeoffs between different balanced score card metrics in the telecommunication industry. They also found trade-offs might not exist between different metrics in a balanced scorecard. They concluded that measures that require trade-off with financial measures should be included in the balanced scorecard.

Dangayach and Deshmukh (2004) explored the relationship between manufacturing competency and business performance management. The relationship was established empirically through analysis of survey data. Different manufacturing aspects (e.g. competitive priorities, advanced technology and integrated computer systems) were combined into a single competence index. The manufacturing competence index was reached by using logarithmic conversion introduced by Cleveland et. al. (1989). The manufacturing competing index is calculated in Equation 3 as:

$$C_j = \sum_i WiLogK_i \quad \text{Equation 3}$$

where;

C_j: Manufacturing Competence index for enterprise j

i: strategic manufacturing issue

K_i: inverse rank of strategic manufacturing issue

W_i: weight of strategic manufacturing issue.

Akkermans and Oorschot (2005) used a system dynamics approach to model causality between various components of the balanced scorecard. Their causal loop model yielded an interesting observation in contrast to intuition. They observed that measures assumed to be conflicting are not contradictory but mutually reinforcing. They applied this approach at an insurance company. Figure 2-3 shows a summarized casual loop for insurance case processing. The purpose of Figure 2-3 is to demonstrate the concept of mutually reinforcing measures introduced by Akkermans and Oorschot (2005). Employee training (a component of the learning and growth BSC perspective) and employee productivity (a component of the financial BSC perspective) are not mutually exclusive. Managerial intuition leads to view the two measure as independent, and a trade-off in one is required to improve the other. However, the casual map below shows that employee training results, through improving various measures, results in improving employee productivity. The immediate impact of employee training is reducing employee productivity, because their time is spent on training not case processing. On the other hand, employee training improves employee retention by increasing morale and increasing employee efficiency. With higher employee retention, increase tenure results in increased employee experience. Next, as employee experience increases, they become more efficient which reduces case processing rate. Reducing cause processing rate is a positive impact. Finally, reduced case processing rate results in increasing employee productivity. The delayed impact is shown in Figure 2-3 as a dotted line, and it is not a part of the initial casual loop.

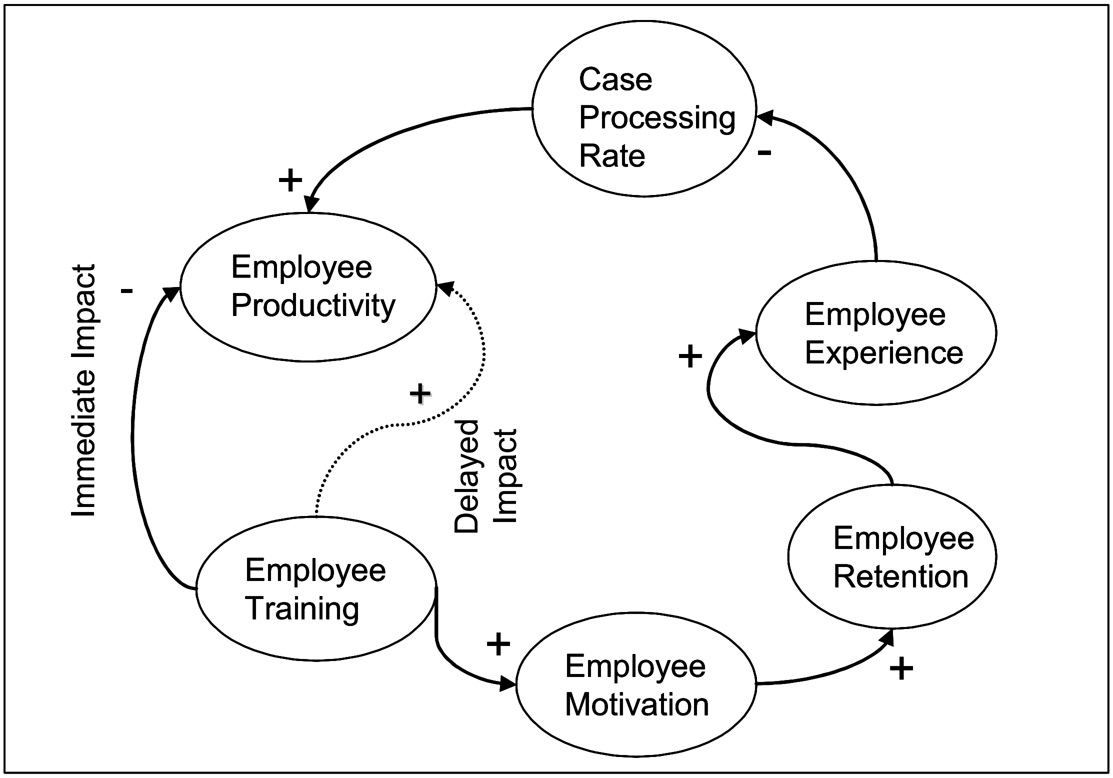


Figure 2-3 Casual Loop - Akkermans and Oorschot (2005)

The second step of their approach is quantitative simulation modeling that can be used in evaluating alternatives. Casual loops and cognitive maps were also used by Suwignjo and

Bititci (2000) as means to describe causality between different metrics in a performance management framework. Efforts to quantify the relationship between various BSC elements can be categorized in as follows:

Data Driven: Historical data or survey responses are analyzed to find statistical correlation between various performance measures.

Hypothesis driven: Business processes are analyzed and cause effect relationships are structured based on the common understanding of business processes. Kaplan and Norton (2000) and Navin (2005) emphasize that the balanced scorecard and strategy maps form a hypothesis of how various perspectives contribute to the overall financial performance through cause and effect.

Ittner and Larker (2003) focused on the value of identifying and validating casual loops. Their research indicates that companies who validate casual loops during strategy planning enjoy better ROI. Ittner and Larker (2003) identify the following shortfalls if casual loops are not verified:

1. Use of inappropriate measures. Without understanding true performance drivers, managers and decision makers tend to use measures that are not relevant to the overall strategy. Using inappropriate measure would have a very negative impact as the overall organization would attempt to optimize performance metrics that will not result in realizing the intended strategy.
2. Assuming inaccurate relative weights of performance measures.
3. Setting wrong targets. Without understanding relationships between various performance measures, managers would use their intuition to set targets. Often more than not, these targets do not result in achieving the intended strategy.

The topic of measures relationships was also studied as means to identify balanced scorecard elements. Banker et. al (2004) and Collin and Youngblood (2003) analyzed correlations between balance scorecard measures and attempted to identify existence of trade offs. Banker et. al (2004) used Data Envelopment Analysis while Collin and Youngblood (2003) determined correlation coefficients between measures. The two efforts propose that measures without trade offs should not be used together on the balanced scorecard.

2.6. Multi-Objective Decision Analysis

Clemens (1996) specifies that structuring values and objectives is the first step of structuring decision analysis problems. The purpose of this section is to review means to structure and model objective functions. From a BSC and performance management perspective, structuring values and objectives are the most relevant aspect of decision analysis. Once the balanced scorecard is structured and formulated, it provides an objective function for decision makers. Considering the BSC sample in Table 2.1, the total score provides the direction, and maximizing the total score becomes the objective for decision makers. The balanced scorecard and performance management systems in general, are concerned with modeling values and objectives of multiple performance measures. Therefore, multi objective analysis is the focus of this section.

The purpose of decision analysis is to maximize the preference of the collective set of decision variables (Keeney, 1982; Keeney and Raiffa, 1976). Considering a decision analysis problem of with multiple attributes ($x_1, x_2, .., x_n$), the objective is to maximize the preference of the collective values of ($x_1, x_2, .., x_n$). Keeney (1982) and Keeney and Raiffa (1976) establish the difference between value and utility is that utilities are determined based on risk tolerance of the decision maker. Without considering risk tolerance, the objective of a decision analysis problem is mathematically modeled in Equation 4, where $x_1, x_2, .., x_n$ are the decision problem attributes.

$\max v(x_1, x_2, .., x_n)$ Equation 4

where;

v: is the total value of the decision

x: decision problem attribute

The utility of the collective values of decision attributes depends on decision maker's risk tolerance. For a single attribute, the objective would be to maximize the utility of the attribute u(v(x)) (Keeney, 1982). Figure 2-4 illustrates different utilities according to risk attitude. A risk neutral decision maker would have a linear utility of decision attribute. The convexity or concavity of the utility function represents risk attitude.

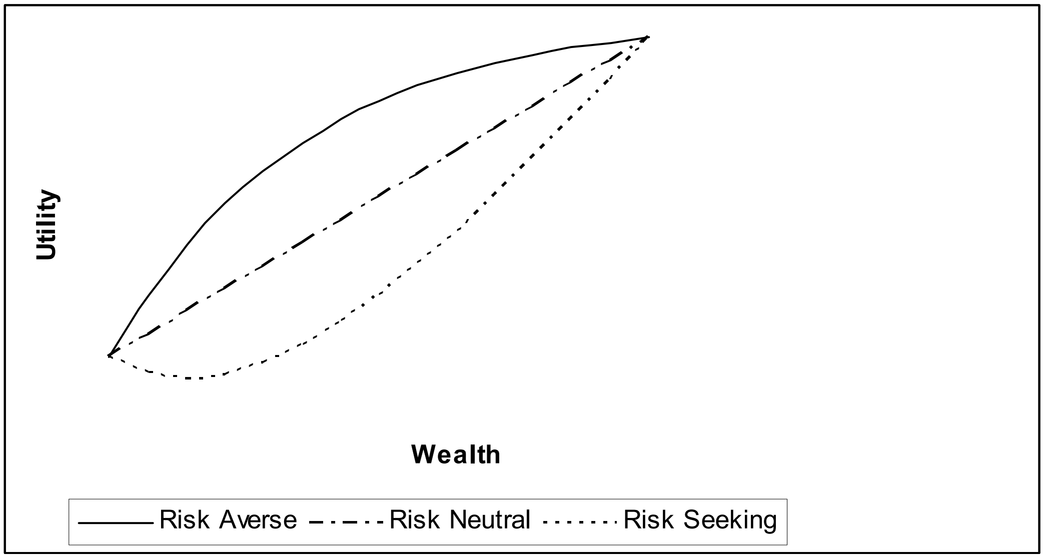


Figure 2-4 Utility and Risk attitude

Multi attribute utility theory is concerned with maximizing the utility of the collective values of decision attributes, as shown in Equation 5.

$\max u(x_1, x_2, .., x_n)$ Equation 5

where;

u: the utility of the decision

x: decision problem attribute

Equation 5 can be simplified according to how decision attributes are related. The following conditions of attribute independence are used to mathematically simplify the Equation 5.

Preferential independence: An attribute x_1 is said to be preferentially independent of attribute x_2 if preferences for specific outcomes of x_1 do not depend on values of x_2 (Clemens, 1996).

Utility independence: The utility independence condition is stronger the preferential independence. The difference between utility independence and preferential independence is considering uncertainty. An attribute x_1 is said to be utility independent of x_2 if preferences for uncertain choices involving x_1 are independent on the values of x_2 (Clemens, 1996).

Additive independence: Additive independence is a special case with a stronger assumption than utility independence. If the collective utility of attributes x_1 and x_2 is identified only by the utility of x_1 and x_2, then the additive independence condition holds. In other words, the collective utility does not depend on the interaction between variables x_1 and x_2.

Equation 5 can be reduced to Equation 6, if the utility independence condition holds (Keeney, 1982; Keeney and Raiffa, 1976).

$$u(x_1, x_2, ..., x_n) = f(u_1(x_1), u_2(x_2), ..., u_n(x_n)) \quad \text{Equation 6}$$

For a two attribute decision problem, Keeney and Raiffa (1976) define the multi-linear representation of Equation 6 as follows

$$u(x_1, x_2) = k_1 u_1(x_1) + k_2 u_2(x_2) + k_{12} u_1(x_1) u_2(x_2) \quad \text{Equation 7}$$

Keeney and Raiffa (1976) define the multiplicative form of multi attribute utility theory in Equation 8. The multiplicative form defined in Equation 8 is equivalent to the multi-linear form in Equation 7.

$$u(x_1, x_2, \ldots, x_n) = \frac{\prod_{i=1}^{n}[kk_i u(x_i) + 1] - 1}{k} \quad \text{Equation 8}$$

Next, if the additive independence condition holds, then utility can be represented in the additive form in Equation 9 (Keeney and Raiffa, 1976; Clemens 1982). The difference between the multi-linear form and the additive form is dropping the last term in Equation 7. Since the collective utility does not depend on the interaction between attributes, the last term of the equation is dropped.

$$u(x_1, x_2, \ldots, x_n) = \sum_{i=1}^{n} k_i u(x_i) \quad \text{Equation 9}$$

2.7. Research Gap

The review of the literature suggests the following areas of improvement within the BSC framework.

Quantifying the time phase between various strategy maps and balanced scorecard elements. While some researchers (Banker et. al., 2004; and Youngblood and Collin 2003) suggested only conflicting measures should be used on the balanced scorecard, Akkermans and Oorschot (2005) concluded that measures seemingly mutually exclusive are mutually reinforcing. The lack of measuring time-phased impact between measures contributes to the vagueness. A framework that handles different type of trade-offs is required. Modeling and analyzing time-phased trade offs is a research worthy direction. For example, order fill rate and inventory levels are conflicting at the same time. A trade-off is required in one to improve the other. On the other hand, the trade off between R&D spending and cost effectiveness is a trade off between time phases. One improves the financial perspective now, while the other improves it in the future.

As discussed earlier, assigning weights to the balanced scorecard is highly influenced by managerial judgment. The Balanced Score Card perspectives are viewed as independent elements. Targets and scores of each perspective do not depend on the collective nature of the system. Using multi attribute utility theory provides better alternative (than simple normalization) to reach to a single score. However, MAUT as used by Youngblood and Collins (2003) and by Stewart and Mohamed (2001) assumed independent utilities and used the additive form of multi-attribute utility theory. Relaxing the independence assumption is an interesting research opportunity. Keeny (1975) found that some MAUT attributes have dependent utility. These attributes included retained earnings, formal training and compensation plan.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Proposed Characteristics of a New Strategy Management Framework

This goal of this dissertation is to propose and demonstrate a quantitative performance management framework that facilitates strategy management. This section demonstrates the required characteristics of such a framework. The required characteristics are:

1. Extend strategy maps with the ability to model three dimensions of the cause-effect relationship. These dimensions are:
    a. Quantity: Strategy Maps as proposed by Kaplan and Norton identify the cause and effect relationships between various objects. This relationship is qualitative and not quantitative. For example, both high employee satisfaction and employee training improve process efficiencies. However, a traditional strategy map does not distinguish between the impacts of the two factors.
    b. Time Lag: As described in the literature review, the BSC identifies the financial perspective measures as lagging indicators, while other indicators are leading indicators. We propose to model the time needed to realize the cause effect between the relationships.
    c. Uncertainty: The cause-effect relationship between BSC components is not deterministic. It is uncertain that new product development efforts will lead to new products. Furthermore, new products are not certain to attract customers and create financial value for the enterprise.

2. Improve current trade-off analysis techniques. Current methodologies assume different objectives in the balanced scorecard are independent.

To illustrate this need, consider the two different scenarios, scenario 1 and scenario 2 in Table 3.1 and Table 3.2 respectively. Scenario 1 represents a situation where an enterprise has performed 50% in all of the four BSC perspectives. While Scenario 2 represents shorter time bias. Shorter term indicators (financial and customer perspectives) have a score of 100%, while longer term indicators (internal processes and learning and growth) have a score of zero. The two scenarios are evaluated according to the weighted average approach. The weighted average approach concludes that the two scenarios have the same utility, and therefore there is no preference between them. The weighted average approach fails to provide preference between the two scenarios because it assumes no interaction between the two scenarios. The example provides an extreme representation, but is used to illustrate the need to relax the independence condition in the weighted average approach.

Table 3.1 BSC Scenario 1

Perspective	***Score***	***Weight***
Financial	50%	0.25
Customer	50%	0.25
Internal Processes	50%	0.25
Learning and Growth	50%	0.25
Total Score		***50%***

Table 3.2 BSC Scenario 2

Perspective	***Score***	***Weight***
Financial	100%	0.25
Customer	100%	0.25
Internal Processes	0%	0.25
Learning and Growth	0%	0.25
Total Score		***50%***

In addition consider an opposite situation to scenario 2, where financial score is zero and growth and learning is 100%. The cause – effect relationships between the four perspectives represent the value creation process in the enterprise. The poor financial performance does not allow creating value out of learning and growth excellence. In such a situation, excellence in the learning and growth does not have a great impact on the enterprise, while financial performance is the most important perspective in such situations. Static weights, used in weighted average and additive MAUT techniques do not allow proper evaluation of trade-offs. A multi objective analysis technique that allows for dynamic weights and relaxes the independence condition between BSC objectives is needed. Multiplicative multi attribute utility theory is a suitable candidate for such analysis.

3. The framework should allow analyzing short and long term performance of the enterprise. Remember that one of the basic objectives of the BSC is to minimize short term bias in performance measurement. The analysis is important as it will provide decision makers with a future view of the enterprise. The future view provides a feedback mechanism to perform any changes in the enterprise strategy based on both

short and long term performance.

4. Integrate the strategic planning process with execution. Execution provides fact based data to validate the hypothesis of the BSC. Integrating strategy with execution also facilitates closed loop strategic planning processes.

3.2. Research Tools

The previous section identified the requirements for a quantitative performance management framework. In this section, we illustrate the tools and techniques used to achieve such characteristics. These tools are:

1. Timed Stochastic Strategy Maps (TSSM): We introduce TSSM to allow modeling quantity, time lag and uncertainty in cause-effect relationships.
2. Balanced Scorecard Simulation: We propose simulation as an analysis tool. TSSM provide a quantitative casual model that can be simulated to provide an output for future performance. Simulation output also allows analyzing the effect of various BSC components.
3. Analytical Performance Management (APM) methodology: We propose APM as a methodology to integrate strategic planning processes with execution processes. The purpose is to introduce and follow a formal methodology that allows deploying strategy, and utilize enterprise execution as the feedback for strategic planning processes.

The previous two sections outlined the performance management system requirements as well as proposed tools to achieve these requirements. Table 3.3 summarizes these requirements and the proposed tool to achieve each requirement respectively. The rest of this chapter is used to describe these tools.

Table 3.3 Summary of Requirements and Tools

Requirement	Tool
Model 3 dimensions of the casual relationship	Stochastic Timed Strategy Maps
Predict Future Performance	Balanced Scorecard Simulation
Improve Trade Off Analysis	Numerical Analysis of BSC Simulation Output
Integrate Strategy with Execution	Analytical Performance Management (APM) Methodology

3.3. Stochastic Timed Strategy Maps (STSM)

In this research we propose to extend strategy maps by enhancing casual modeling. Strategy maps outline how BSC objectives are related and how they affect the enterprise strategy of maximizing shareholder value. We propose extending strategy maps by modeling the following three dimensions:

1. Quantity
2. Time Lag
3. Uncertainty

We introduce a simple example to guide through introducing Stochastic Timed Strategy Maps (STSM) as well as other tools we introduce in this research. Figure 3-1 shows a simplified strategy map with one objective per perspective. The strategy map starts at the bottom with training people. Training results in improved people skills and is translated to better research and development (from the learning and growth perspective). The improved R&D efforts results in improving the organization product through improved innovation (patents, innovative features, better quality, etc.). Last, with customers enjoying better products, increased sales improves net income. The strategy map details the cause and effect relationship between the various BSC perspectives.

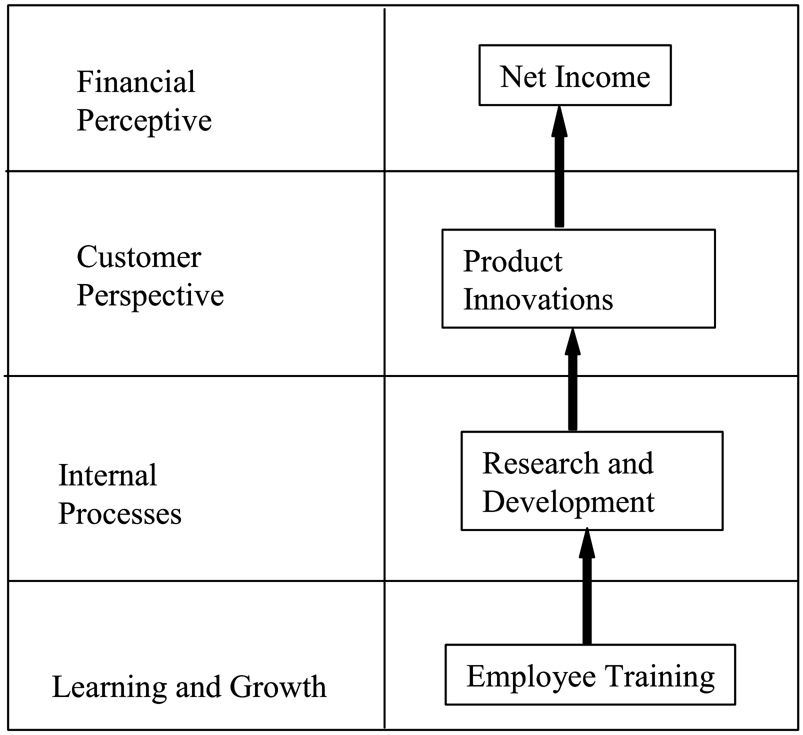
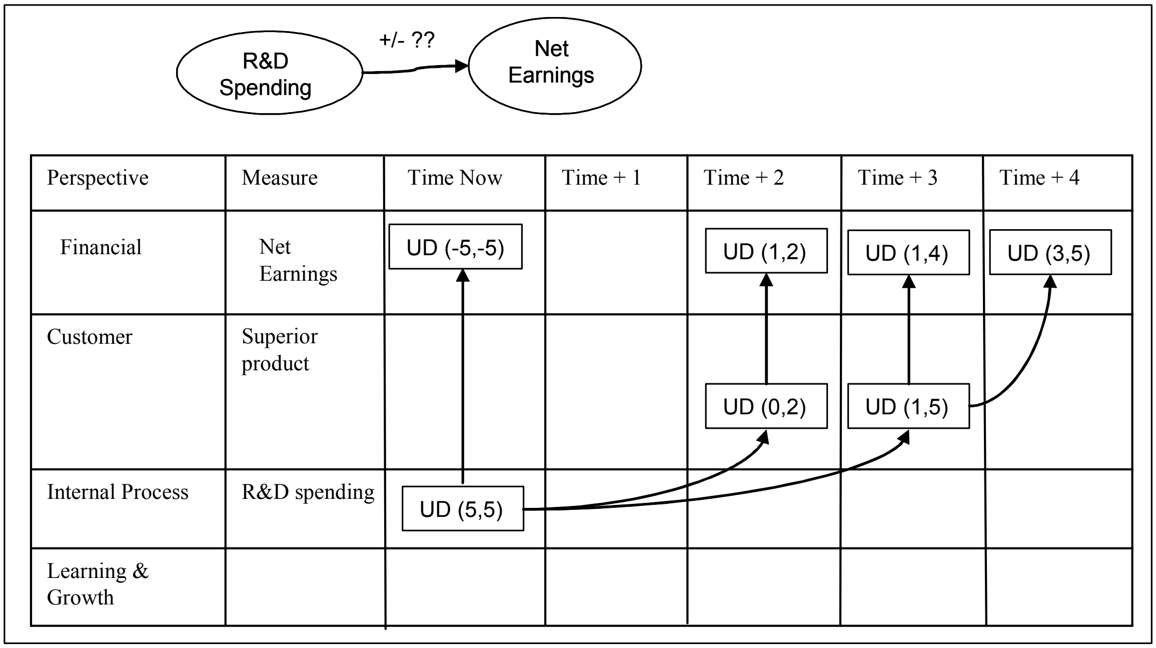


Figure 3-1 Strategy Map for Simple Example

A traditional strategy map (as in Figure 3-1) outlines the qualitative aspect of the relationship. However, the relationship is not quantified. Figure 3-2 illustrate how Stochastic Times Strategy Maps (STSM) are used to model the three dimensions of the relationship. Research and development illustrates the need to model the three aspects of casual relationship for two reasons. First, the outcome of research and development is not certain. Investigating a specific technology or a new approach does not always yield new better products and services. In addition, the outcome of research and development activities is not instantaneous.

This example is oversimplified and is used only to facilitate communicating the methodology and tools of this research. Multiple values are assumed (such as simulation results) without being calculated or estimated. A more comprehensive example is used in the next chapter.



Perspective	Measure	Time Now	Time + 1	Time + 2	Time + 3	Time + 4
Financial	Net Earnings	UD (-5,-5)		UD (1,2)	UD (1,4)	UD (3,5)
Customer	Superior product			UD (0,2)	UD (1,5)	
Internal Process	R&D spending	UD (5,5)				
Learning & Growth						

Figure 3-2 STSM Dimensions

Figure 3-2 illustrates an example of modeling the casual relationship between R&D and net income using Stochastic Timed Strategy Maps (STMS). The effect of investing in Research and development is modeled over five time period. A time horizon of five time periods is used. The effect of each objective of the balanced scorecard is identified by a quantity, time phase, and uncertainty. Initially, R&D spending results in reducing net earnings in the first period by five units. Next, R&D spending would result in new or superior product over two time periods (Time +2 and Time +3) . The amount of improvement is uncertain. Therefore it is modeled as a uniform distribution. For example, at time (Time +3) superior product would improve somewhere between one and five units. Note that the effect of R&D on period (Now +2) is a uniform distribution between 0 and 2. A zero effect designates that R&D spending may not result in improved products in two time periods.

The next step in the casual model illustrates the effect of improved customer perspective (measured by superior product) on the financial perspective (measured by net income). The improved product is expected to result in improving net income. Again, a traditional strategy map would illustrate the qualitative aspect of the relationship. STSM quantifies the casual relationship. For example, improving product superiority at time (Time + 3) affects net income over two time periods. Net income improves instantaneously somewhere between one and four units. Net income also improves in the future period (time now + 4) somewhere between three and five units. The example in Figure 3-2 illustrates how STSM models the three aspects of the relationship, and allows additional insight into predicting future performance.

The addition of the time dimension facilitates a different type of tradeoff analysis. Without modeling the time dimension, a tradeoff between net income and R&D appears to be required. Decision makers would use target values for net income, along with static weights of a traditional scorecard to decide on target values for R&D spending. On the other hand, the STSM model facilitates tradeoff based on expected net income over the time horizon. This model confirms the concept of mutually re-enforcing objectives as introduced by Akkermans and Oorschot (2005). Although R&D spending results in decreasing the financial score at time zero, it results in improving the financial score in the future, at time now + 2 until now + 4. Therefore the R&D spending and net income are not conflicting measures, rather they are mutually reinforcing. The tradeoff can be now analyzed as time – phase conflict and not goal conflict.

Table 3.4 Time –Phase Conflict

	Time 0	Time 1	Time 2	Time 3	Time 4	Time 5
Alternative A	0	0	0	0	0	0
Alternative B	-5	0	0	UD(1,2)	UD (1,4)	UD(3,5)

Time-phased conflict is illustrated in Table 3.4. For the strategy map in Figure 3-2, we will assume that a decision maker have two alternatives. The first alternative is not to invest in R&D. We will assume that this alternative does not have any impact on the current and future periods. The second alternative is to invest in R&D and realize an uncertain increase in net income as outlined Table 3.4. UD (x, y) designates a uniform distribution with a lower limit x and an upper limit y. The decision maker now has alternate criteria to choose from either alternatives, A or B. A discounted cash flow approach can be used to identify preference of alternative A over B or vise versa. It is noteworthy to mention that alternative A assumes that not investing in R&D will not have any effect on net income in the future. Kaplan (1986) challenged this assumption and stated that status quo does not mean static performance. In an ever changing competitive advantage, competitors always attempt to improve themselves. Also, customers do not have the same requirements all the time. Therefore, declining to invest in R&D will probably have a negative effect, and alternative A of "Do Nothing" should possibly have a negative net income effect in future periods. The negative impact of the "Do Nothing" alternative is modeled in the formal experiment conducted in this research.

3.4. Balanced Scorecard Simulation

The second tool we propose in this research is Balanced Scorecard simulation. Stochastic Timed Strategy Maps (STSM) provide detailed hypothesis of the casual relationship between BSC objectives. The quantified casual relationship can be used to simulate the BSC. Simulation output provides a prediction of the future financial performance of the enterprise. The future financial performance facilitates addressing tradeoffs as time-phased tradeoffs. In addition, simulation results can predict the variability in future performance. STSM allow modeling uncertainty as a dimension of the cause – effect relationship, and therefore can be simulated. Statistical analysis of the simulation output can identify a range of expected future outcomes. Traditional BSC implementations focus on absolute values of target performance. The absolute value does not account for uncertainty, and can be misleading. Actual performance is usually different from target performance. Multiple factors contribute to the variance, some of which are outside the control of the enterprise. Therefore, a range of target performance may be more suitable that a single value for target performance. If actual performance lies within the range of target performance, then the enterprise performance is in line with expectations. Balanced Scorecard simulation facilitates constructing ranges for target performance.

3.5. Numerical Analysis of BSC Simulation Output

We use simulation as a tool to analyze Stochastic Timed Strategy Maps (STSM) and estimate future performance. Simulation will create an expected value for each of BSC objectives over the simulated timed horizon. We use an example to facilitate illustrating the tools used for analyzing simulation output. Consider the example we used to introduce STSM in Figure 3-2. Table 3.5 shows a hypothetical output of BSC simulation

Table 3.5 Simulation Output of STSM Example

Time	**Net Income**
0	UD(-5,-5)
1	0
2	0
3	UD(1,2)
4	UD(1,4)
5	UD(3,5)

The example above is simplified to illustrate the concept of simulation output analysis. After simulating the BSC, we use numerical analysis to analyze simulation results. We use discounted cash flow analysis, regression analysis, and confidence intervals to gain more insight into the simulation results. These tools are explained in the next subsections.

3.5.1. Discounted Cash Flow (DCF) Analysis

The first tool we use to analyze simulation output is discounted cash flow. DCF provides a single value to evaluate alternatives. For the values in Table 3.5, we can calculate the net present value (NPV) for the expected net income in future time periods. Since the example is simplified, the expected net income can be identified analytically without having to run a simulation experiment. For each time period, the expected net income is the average of the lower and upper bound of the uniform distribution. The average net income is shown in Table 3.6.

Table 3.6 Expected Net Income for STSM Example

Time	**Net Income**	**Expected Net Income**
0	UD(-5,-5)	-5
1	0	0
2	0	0
3	UD(1,2)	1.5
4	UD(1,4)	2.5
5	UD(3,5)	4

After identifying the expected value of net income in future period, we can calculate net present value to create a single measure for the enterprise performance, or in this case evaluate a specific alternative. NPV can be calculated using Equation 10.

$$NPV = \frac{\sum_{i=0}^{n} C_i}{(1+r)^i} \text{ Equation 10}$$

Where;

NPV: Net Present Value

i: Time Period (e.g. year)

C_i: Cash Flow at time i

r: Discount rate

For this example, C_i represents the net income at time period i. We assume a discount rate r of 10%, by using NPV formula, NPV is:

NPV = 0.29 units

The value 0.29 can serve as single unit of measurement of performance. DCF can reduce the multi-attribute decision analysis problem into a single attribute decision analysis problem.

A more complex DCF analysis can be performed by adjusting future net income values using a utility function. In Table 3.6 we used an average of the uniform distributed to calculate the expected net income. Another approach that we can use is calculating expected utility for net income rather than expected net income. Using expected utility is a better measure of total performance because it does account for the risk seeking nature of the organization. In our example, the future net income for year 5 is a uniform distribution between 3 and 5. The expected net income was 4. However the expected utility of UD (3,5) may not be 4. Depending on the utility function of the organization, the expected utility may be higher or lower than 4. In the simplified example, the expected utility can be calculated as:

$$EU = \int_{i=x}^{y} p(i)U(i)di \text{ Equation 11}$$

Where;

x: The lowest limit of the uniform distribution

y: The highest limit of the uniform distribution

u(i): utility of net come instance i as identified by the utility function.

P(i): The probability of random variable i.

EU: Expected Utility

The expected utility can be calculated analytically because the simple example provided a statistical distribution for net income. In a simulation experiment, the utility of net income is calculated, and the expected utility will be calculated as an average on net income utility over the number of simulation repetitions. For illustration purposes, we will continue with our previous example and assume the expected utility as in Table 3.7. The expected utilities are artificially generated to illustrate the usage of expected utility.

Table 3.7 Expected Utility for STSM Example

Time	**Net Income**	**Expected Net Income**	**Expected Utility**
0	UD(-5,-5)	-5	-5
1	0	0	0
2	0	0	0
3	UD(1,2)	1.5	2
4	UD(1,4)	2.5	3
5	UD(3,5)	4	4.5

After identifying expected utility for future periods, we can now calculate a single measure of performance by applying DCF. Using the same equation of net present value, NPV for expected utility is calculated to be 1.22 units. A summary of the two approaches is presented in Table 3.8. It is worth reiterating that example provided in this section is simplified and is intended to illustrate how DCF and utility function are used to analyze simulation output.

Table 3.8 Expected Utility and Expected Net Income Summary

Time	**Net Income**	**Expected Net Income**	**Expected Utility**
0	UD(-5,-5)	-5	-5
1	0	0	0
2	0	0	0
3	UD(1,2)	1.5	2
4	UD(1,4)	2.5	3
5	UD(3,5)	4	4.5
NPV (discount rate 10%)		0.29	1.22

3.5.2. Regression Analysis to Facilitate Multi-Objective Analysis

The balanced scorecard enables a balanced view of performance metrics within the enterprise. From a decision making perspective, a decision maker will require a decision criteria to evaluate different alternatives and progress over time. The literature review identified how researchers and practitioners analyzed different BSC measures. The simplest approach was the weighted average approach. Others used more complex approaches such as multi attribute utility theory, and specifically additive multi attribute utility theory. We also demonstrated the motivation to relax a common assumption in the literature, specifically utility independence between multiple BSC objectives. Equation 12 restates the basic form of multi attribute analysis, and Equation 13 restates the multiplicative form of MAUT. The two equations were discussed in detail in the literature review.

$$u(x_1, x_2, ..., x_n) = f(u_1(x_1), u_2(x_2), ..., u_n(x_n)) \quad \text{Equation 12}$$

$$u(x_1, x_2) = k_1 u_1(x_1) + k_2 u_2(x_2) + k_{12} u_1(x_1) u_2(x_2) \quad \text{Equation 13}$$

DCF analysis provides a single measure of reference for performance. In the previous section, we used NPV as the single measure. Other DCF analysis measures can be used such as NPV, future value (FV), internal rate of return (IRR) or others. The important outcome is the ability to identify a single performance output or decision criteria. In this research we use NPV to represent the utility of the BSC. Therefore;

$$NPV(EU) \equiv u(x_1, x_2, ..x_n)$$

In the early stages of this research, we planned on using simulation output to reduce Equation 12 to Equation 13, the multiplicative form of MAUT. However, the multiplicative form of MAUT does assume utility independence. The multiplicative form of MAUT is suited in cases where the utility function is built from the individual utilities of decision attributes. Since we use DCF to estimate the utility of overall solution, the utility independence assumption is not needed. Keeney (1973) identified curve fitting as suitable technique to create the utility function when utility independence condition does not hold. Simulation and DCF analysis can be used to generate multiple utility points, which can be used to create an empirical function of utility. Specifically, we use regression analysis to create an empirical utility function. The empirical utility function is created by simulating multiple values for each BSC objective. The following steps identify how to create the empirical utility function

1. Construct a simulation model for the enterprise BSC
2. Create a set of experiments representing scenarios or decision alternatives. Each experiment will have values for x_1, x_2,…x_n.

3. Simulate each experiment, and identify the utility of net income for each simulation repetition.
4. Calculate the utility of experiment variables, x_1, x_2,...x_n as the average each simulation repetition utility.
5. Use statistical regression to create the empirical utility function.

3.5.3. Confidence Interval analysis of Simulation Output

The traditional implementation of balanced scorecard does not address uncertainty. STSM provides the framework and the synthesis to analyze uncertainty within the BSC. We consider again the example we discussed earlier in this chapter (Figure 3-2). The simplified example shows the statistical distribution of the expected output for each BSC perspective. We illustrated earlier one benefit of simulating uncertainty. Using expected utility facilitates risk management by increasing or decreasing the utility of net income according to the degree of risk aversion.

The second benefit of simulating uncertainty is to identify the expected range of future performance. Using simulation output, we can construct confidence intervals for the expected range of each BSC metric. For each metric, the range represents the enterprise capability relative to that metric. As we discussed earlier, traditional BSC implementation set an absolute value for goals and targets. We suggest that goals and targets should be set according confidence intervals. We reconsider the sample example in this chapter. The example shows that the future net income for time periods 3, 4, and 5 is UD (1,2), UD (1,4) and UD (3,5) respectively. A 95% confidence interval is calculated and illustrated in Figure 3-3.

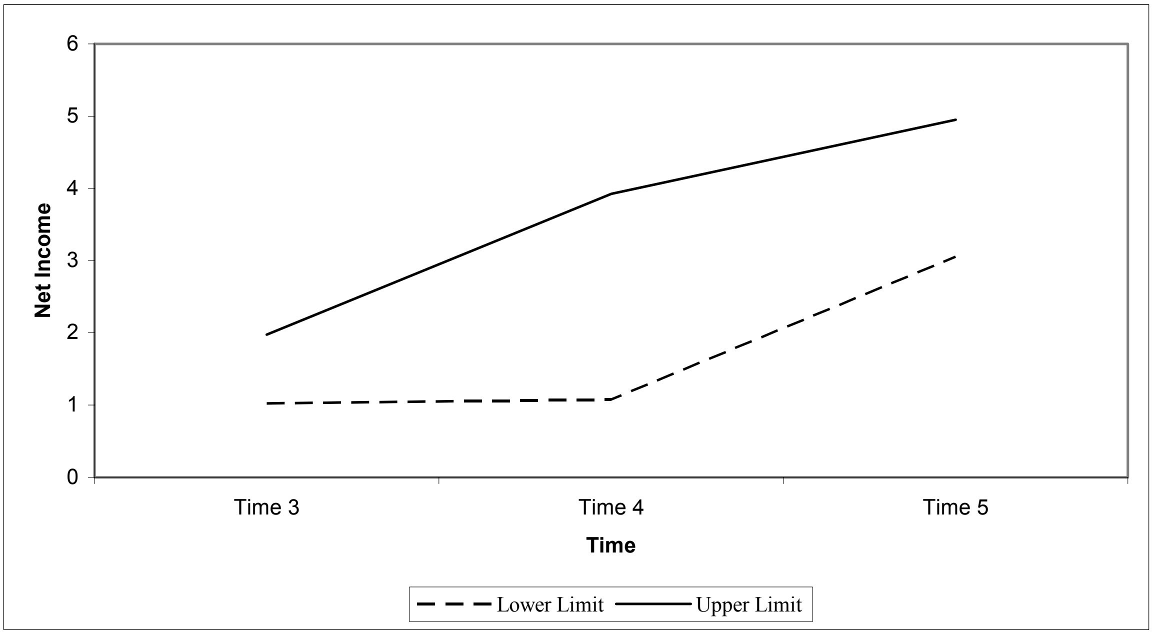


Figure 3-3 Performance Range for STSM example

The area between the upper and lower limits of the confidence interval represents the expected net income in future periods and therefore the enterprise capability with regards to net income. The performance target should not be set with lower accuracy than the confidence interval. The exact value of future performance is beyond management control. If the confidence interval range is wider than acceptable, then management should seek reducing the inherent variability in its environment. Reducing variability starts with addressing root cause, which is the uncertainty on the cause effect links of STSM.

3.6. Analytical Performance Management (APM) Methodology

The third tool we propose in this research is a methodology to integrate strategic planning with execution. Earlier, we outlined STSM and BSC simulation as analytical tools for modeling and analysis of performance models. Stochastic Timed Strategy Maps (STSM) is a tool to model performance, while BSC simulation facilitates analyzing these models. In this section, we introduce and outlined the steps to integrate strategy and execution, as well as STSM and

BSC simulation. The methodology consists of the following steps:

1. Identify Strategic Metrics, Initiatives and Objectives

This step involves analyzing the organization environment. The output of this step is a list of objectives, metrics to measure these objectives, and initiatives to improve these metrics. The first step of implementing the framework is similar to Kaplan and Norton BSC methodology. However, the results of next steps contribute to refining this step as part of the feedback process.

2. Structure Stochastic Timed Strategy Maps (STSM)

The second step is to structure STSM. After identifying the BSC elements in step 1, values of cause effect relationships are identified. This may be the most critical step in the research methodology. All subsequent analysis and decision making depends on the quality of relationship values.

The values of the three dimensions of STSM relationships can be estimated through process and data analysis. The value of the uncertainty dimension can be increased as a safety margin when the cause-effect relationship is not easily defined. In addition, the iterative nature of the methodology allows updating the values of the relationship dimension, and therefore improves the quality of the estimations.

There is another benefit for quantifying the cause-effect relationship between BSC metrics. As we illustrated in the literature review, using the wrong performance measures is one of the most common mistakes when implementing balanced scorecard. Performance measures are not important by themselves. They are important because the serve as a measure to the organization goals. In the simple STSM example, the first objective was improving employee training. The reason for this objective is the intent to improve R&D process. One measure of employee training could be training hours. The exercise of estimating the effect of training hours on R&D process improvement may reveal that training hours is not the best measure. The best measure may be specific certifications or specific technology training.

3. Simulate STSM and Analyze Simulation Results.

The third step is to conduct BSC simulation. This step includes creating a simulation model for the STSM. Using Monte Carlo simulation, STSM is simulated and the future performance is analyzed. Simulation output analysis is discussed earlier and includes predicting future performance, constructing ranges of expected performance and constructing an empirical multi attribute utility function for BSC measures.

4. Evaluate Execution of Strategy

This step starts dealing with actual execution. The earlier steps were part of a top down approach. The first three steps result in the plan to execute the strategy. They identify objectives, measures and trade-off analysis between metrics.

The fourth step in the methodology is to analyze actual performance. This step depends on the existence business intelligence applications that facilitate data collection, data warehousing and data analysis. Business intelligence applications are becoming increasingly important and are implemented widely in the industry. Probert and O’Regan (2003) analyze and describe using Business Intelligence systems to facilitate measuring enterprise performance. Using business intelligence systems, data regarding actual performance is collected and analyzed. Actual data enables comparing actual performance to projected performance. The gap between actual performance and planned performance can be attributed to two reasons. The underlying assumptions of BSC simulation may not be accurate. The second reason is poor execution of the enterprise strategy.

5. Refine STSM and BSC Based on Actual Execution

The results of actual execution are used to update the top down direction of this methodology. Execution feed back includes the following

1. Identifying new objectives
2. Identifying new measures for these objectives
3. Changing the estimates of STSM cause effect dimension
4. Revealing new relationships between BSC elements

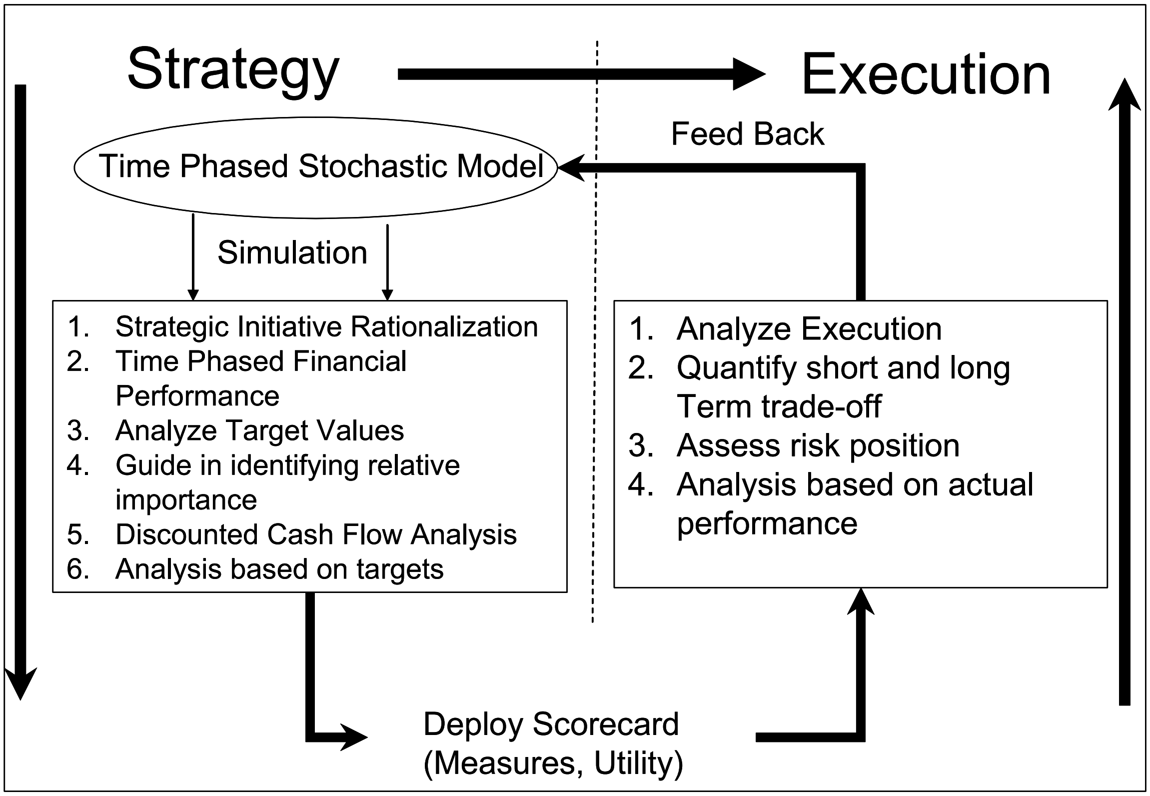


Figure 3-4 Analytical Perfomance Management Framework

CHAPTER 4

CASE STUDY SIMULATION MODEL

4.1. Introduction

In this research, we use a simulated case study to illustrate the analytical performance management framework. Creating the simulated case study includes the following tasks:

1. Create and structure Stochastic Timed Strategy Maps (STSM)
2. Create a simulation model for STSM
3. Verify and validate simulation Model
4. Identify different scenarios and run the simulation model
5. Analyze simulation results and refine APM

This chapter describes the details of constructing the case study and implementing the simulation model. Simulation data and results are discussed in the next chapter.

4.2. Case Study Model and Data Creation

The first step to create and analyze a case study is to create a case study model. We distinguish between case study model and case study data. The distinction serves better communication and enhanced readability through out the dissertation document.

4.2.1. Case Study Model Definition

The case study model is the qualitative data describing the enterprise model. Model data includes the following elements:

1. Balanced Scorecard Perspectives
2. Objectives in each perspective (e.g. New Product Revenue, Employee Training)

3. Measure of each objective (e.g. Number of training hours)

4.2.2. Case Study Data Definition

Case study data is the actual numbers representing a value or a set of values for each model element. Therefore, case Study data includes target and actual value for each performance measure. The quantified cause and effect relationship between balanced scorecard objectives are also part of case study data. Case study date also include the discount rate used discounted cash flow analysis, utility function and other numerical values.

4.2.3. Case Study Model Description

This section includes the description of case study model. The case study model is constructed using four balanced scorecard perspectives; each perspective contains a set of objectives. The strategy map used for this case study is shown in Figure 4-1. The strategy map is adopted from the generic strategy map introduced by Kaplan and Norton (2001). The same strategy map was used by Abu-Suleiman and Priest (2006). The strategy map used in this research contains the following perspectives and objectives:

1. Financial Perspective: The financial perspective contains the following objectives:
    a) Existing Product Revenue
    b) New Product Revenue
    c) Cost Effectiveness
2. Customer Perspective: The customer perspective contains these objectives:
    a) Brand
    b) Time to Market
    c) Customer Satisfaction
    d) Product Quality

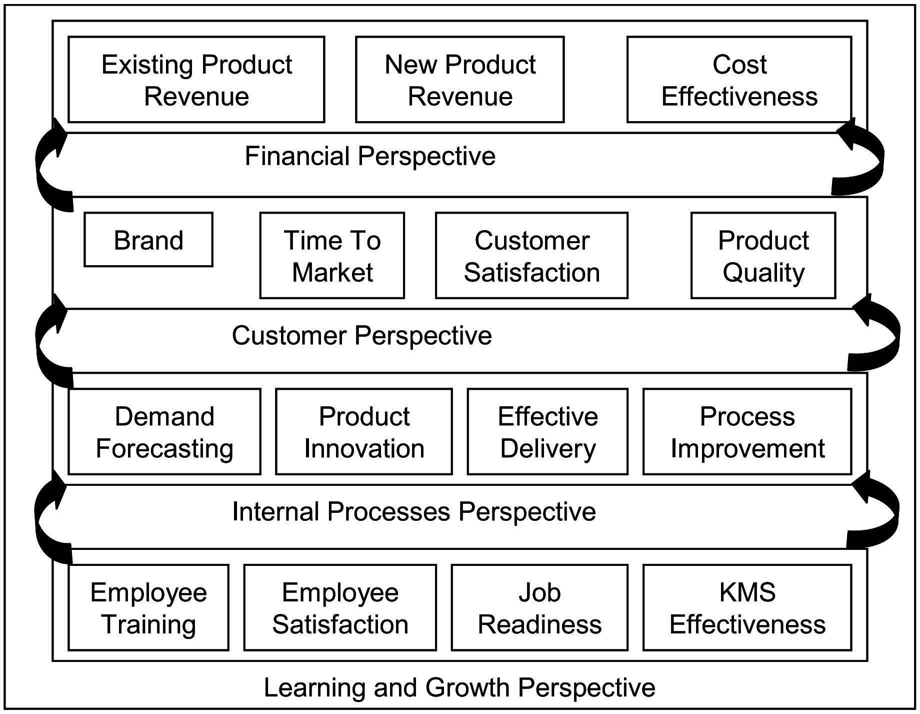


Figure 4-1 Case Study Model - Strategy Map

3. Internal Process Perspective: The internal process perspective contains the following objectives:
    a) Demand Forecasting
    b) Product Innovation
    c) Effective Delivery
    d) Process Improvement
4. Learning and Growth Perspective: The learning and growth perspective includes the following objectives:
    a) Employee Training
    b) Employee Satisfaction
    c) Job Readiness
    d) Knowledge Management Systems (KMS) effectiveness.

The objectives are summarized in Table 4.1. Each objective is abbreviated by notation that is used in the simulation model. Notations are constructed using a letter that corresponds to the perspective and a number corresponding to the objective number within the perspective. For example, Brand is notated as C1 (first objective in customer perspective).

Table 4.1 Strategy Map Objectives and Notation

Objective	Notation
Net Income	N1
Existing Product Revenue	F1
New Product Revenue	F2
Cost Effectiveness	F3
Brand	C1
Time To Market	C2
Customer Satisfaction	C3
Product Quality	C4
Demand Forecasting	I1
Product Innovation	I2
Effective Delivery	I3
Process Improvement	I4
Employee Training	P1
Employee Satisfaction	P2
Job Readiness	P3
KMS Effectiveness	P4

Each objective within the balanced scorecard is linked with a cause and effect model to other objectives. For example, employee training causes improved product innovation. Next, product innovation results in improved brand and faster time to market. Faster time to market results in improving new product revenue. Also, improved brand results in improving both existing product revenues and new product revenue.

4.2.4. Case Study Data Description

The next step after creating the case study model is to create the data for the case study. The simulation model is parameterized to enable changing data values as needed. Data for the case study is created for multiple scenarios. The following elements and relationships were made when generating the data:

1. Each objective is measured using a normalized score between 0 and 1. Since data is generated by this research, an absolute measure is not necessary and may be misleading. A normalized and relative measure for the objective maintains a more realistic nature of the case study.

Normalized scores are set between the values of 0 and 1. Where a score of zero represents the worst possible score and a score of 1 represents the best possible score. Normalizing scores between 0 and 1 is common technique in the literature. This technique was used by Youngblood and Collins (2003), and by Stewart and Mohammed (2002). A normalized score is a simple mean to communicate performance as it abstracts the actual values of individual metrics into a global measure of fitness for the specific metric.

2. The three financial perspective measures can be aggregated in a single financial measure. In this research, we assume that a net income score can be estimated by averaging the three objectives in the financial perspective. Net income is calculated according to Equation 14:

$$N1 = \frac{\sum_{i=1}^{n} F_i}{n} \quad \text{Equation 14}$$

Where;

N1: Net Income

n: number of measures in the financial perspective

F_i: The value of objective i of the financial perspective

3. The quantity dimension of the cause and effect relationship is proportional to value of the cause score. For any two objectives O_1 and O_2, the effect of O_1 on O_2 is proportional to the value of O_1. For the simulation model, we create a matrix that represents the impact of across the strategy map objective.

Table 4.2 Cause and Effect Sample - Quantity Dimension

	F1	F2	F3
C1	0.15	0.15	0.15
C2	0.15	0.15	0.15
C3	0.15	0.15	0.15
C4	0.15	0.15	0.15

Table 4.2 illustrates a sample matrix of the quantity dimension of the cause-effect relationship. The matrix contains the relationship between the customer perspective and the financial perspective. For example, objective C1 impacts objective F1 by 15% of its value. Therefore, if the normalized value of C1 was 1 (i.e. 100%), then the effect of C1 on F1 is an improvement of 15%. Not that the figure 15% represents only the quantity dimension of the cause and effect relationship. The time phase and uncertainty dimensions are needed to identify the complete relationship between C1 (brand) and F1 (Existing Product Revenue).

The quantity dimension of the cause effect relationship is notated as $Q_{i,j}$, which is read as the quantity effect of objective i on objective j.

4. There us a negative impact for continuing with status quo.

Kaplan (1986) identified that maintaining status quo means current performance will not be maintained without continuing to improve processes. Customers are going to be more demanding or change there preferences. Also, competition is going to catch up or introduce new products. For example, personal computer speeds improved and will to continue to improve over time. A company that needs to compete based on PC speed will need to continue improving its product according to new market conditions. These conditions are typically driven by consumer expectations and by improved competition capabilities. A PC speed that results in a normalized score of 1 may result in 0.85 score in the future. Alternatively, to maintain a normalized score of 1, an 20% improvement in PC speed is required. The previous numbers are used as examples, but illustrate that performance will suffer overtime by maintaining status quo. The same applies on the strategy map we use for this research (Figure 4-1). We use employee training as a driver for product innovation. The concept is that increasing employee training will result in more product innovations. Product innovation will no remain at the same level if employees are not continuously trained. New technologies and concepts evolve all the time, therefore employee knowledge is likely to be outdated without continues training. Once employee knowledge is outdated, we can not expect the same knowledge of product innovation.

For this case study we assume there is a negative impact for “doing nothing”. The do nothing impact is notated as DN_i, read as the do nothing impact on objective i.

5. The effect of a cause is realized over one time period only. For any two objectives O_1 and O_2, the effect of O_1 on O_2 is realized at one time period only (e.g. after 1 time period, 2 time periods, etc). For the simulation model, we create a matrix that

represents the time phase relationship across the strategy map objective.

Table 4.3 Cause and Effect Sample – Time-Phase Dimension

	F1	F2	F3
C1	-1	-1	-1
C2	-1	-1	-1
C3	-1	-1	-1
C4	-1	-1	-1

Table 4.3 illustrates a sample matrix of the time-phase dimension of the cause-effect relationship. The matrix contains the time phase of the impact between the customer perspective and the financial perspective. The first cell (C1-F1) of the matrix is read as “Objective F1 is affected by the value of objective C1 at the previous time period (current time period -1). Alternatively, the first cell can be read as “Objective C1 affects object F1 in the next time period (current time period +1).

The time-phase dimension of the cause-effect relationship is notated as $TP_{i.j}$, read as the time required to realize the impact of objective i on objective j.

6. The uncertainty dimension of the cause-effect relationship is modeled as a uniform distribution. Uncertainty is modeled as a ratio of the quantity dimension of the cause-effect relationship. The uncertainty dimension is identified as ratio of the quantity dimension. For the simulation model, we create a matrix that represents the uncertainty dimension of the cause-effect relationship across the strategy map objective. The uniform distribution of the cause-effect relationship is identified by the quantity and uncertainty dimensions of the cause effect

relationship.

Table 4.4 Cause and Effect Sample – Uncertainty Dimension

	F1	F2	F3
C1	50%	50%	50%
C2	50%	50%	50%
C3	50%	50%	50%
C4	50%	50%	50%

Table 4.4 illustrates a sample matrix of the time-phase dimension of the cause-effect relationship. The matrix contains uncertainty ratio of the cause-effect relationship between the customer perspective and the financial perspective. For example the first cell (C1-F1) shows that the width of the uniform distribution is 50% of the quantity of the cause-effect between objective C1 and F1. The uncertainty dimension of the cause-effect relationship is notated as $U_{i,j}$, read as the uncertainty in the effect of objective i on objective j. After identifying the quantity and uncertainty dimensions, we identify the relationship between two objectives as $UD_{i,j}(x_{i,j}, y_{i,j})$ where;

$UD_{i,j}$: the uniform distribution for the effect of objective i on objective j

$x_{i,j}$: the minimum effect for objective i on objective j

$y_{i,j}$: the maximum effect for objective i on objective j

The lower and upper bounds of the uniform distribution are calculated according to Equations 15 and 16 respectively.

$x_{i,j} = Q_{i,j} - (Q_{i,j})(U_{i,j})/2$ Equation 15

and

$y_{i,j} = Q_{i,j} + (Q_{i,j})(U_{i,j})/2$ Equation 16

The previous description identifies four variables affecting the value of an objective j. These factors are: $O_{j,t-1}$, $Q_{i,j}$, DN_j, $TP_{i,j}$, and $U_{i,j}$. If objective j is affected by objective i only, then the value of objective j at any time t ($O_{j,t}$) is calculated in Equation 17:

$O_{j,t} = (O_{j,t-1}) * (DN_j) + (O_{i,TP_{i,j}}) * (Q_{i,j}) * (UD(x_{i,j}, y_{i,j})$ Equation 17

Where;

$O_{j,t-1}$: The normalized score of objective j at the previous time period (t=t-1)

$Q_{i,j}$: The ratio effect of objective i on objective j

DN_j: The do nothing impact for objective j

$TP_{i,j}$: The time-phase required to realize the effect of objective i on objective j

$x_{i,j}$: The lower bound of the uniform distribution, calculated according to Equation 15

$y_{i,j}$: The upper bound of the uniform distribution, calculated according to Equation 16

$UD(x_{i,j}, y_{i,j})$: A random value from the uniform distribution with lower bound $x_{i,j}$ and upper bound $y_{i,j}$

7. There is a utility of net income that is S shaped. The utility of net income is identified in Equation 18.

$u(N1) = \frac{N1^{0.5}}{N1^{0.5} + (1 - N1)^{0.5}}$ Equation 18

Where;

u(N1): utility of objective N1, i.e. utility of Net Income

N1: Net Income

The above utility function is an S-shaped function. This function indicates that a decision maker is risk averse at lower values of net income, and risk seeking at high values of net income. Figure 4-2 illustrates the utility of x over values between 0 and 1 for the utility function we use in this research. The utility function is used to adjust net income values over the simulated time horizon.

The following represents a summary of the simulation model inputs:

1. A matrix representing the quantity dimension of the casual relationship ($Q_{i,j}$)
2. A matrix representing the time-phase dimension of the casual relationship ($TP_{i,j}$)
3. A matrix representing the uncertainty dimension of the casual relationship ($U_{i,j}$)
4. A vector representing the "Do nothing" impact for each objective (DN_i)
5. A utility function representing the risk position (Equation 18)
6. The discount rate used perform discounted cash flow analysis (r)
7. The normalized scores required to represent the initial condition.

The above are the different inputs that are fed to the simulation program. The simulation program uses these inputs and the logic described earlier. The output of the simulation model is the normalized score of each objective at each time period ($O_{j,t}$).

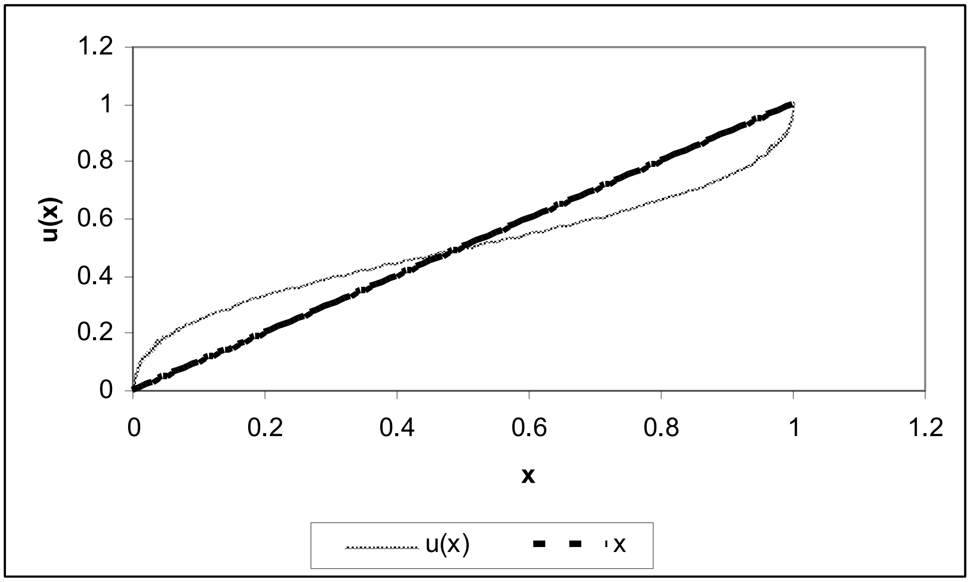


Figure 4-2 Utility Function

4.3. Simulation Model Implementation

The previous sections described the generation of case study model, data and relationships between model elements. This section describes transforming the case study model into a simulation model. The simulation model is implemented in Excel 2003. Excel 2003 was used to conduct Monte Carlo simulation experiments by many researchers. Gedam and Beaudet (2000) used Excel and Excel Marcos to simulation reliability block diagram (RBD) by modeling their system in Excel spreadsheets. Juan and Vila (2002) used VBA and Excel to conduct Monte Carlo simulation of system reliability.

4.3.1. Appropriateness of using Microsoft Excel for Monte Carlo Simulation

Extending Microsoft Excel with VBA (Visual Basic for Applications) macros offers sufficient flexibility for simulating the case study. The critical aspect of using Microsoft Excel for Monte Carlo simulation purposes is the quality of its random number generator. The statistical analysis capabilities of Microsoft Excel were generally criticized by researchers (McCullough and Wilson, 2004; Knusel, 2002). The literature also showed that many imperfections in Microsoft Excel were improved in Excel 2003 (Keeling and Pavur, 2004; McCullough and Wilson, 2004). Random numbers generated by Excel 2003 was described as pseudo random numbers in the literature (Seila, 2004; Keeling and Pavur, 2004). In this research we are interested sampling random numbers from uniform distribution. The following two issues about Excel uniform random sampling were identified in the literature.

1. The two tails of the random distribution get sampled with lower frequency than the rest of the distribution.
2. Specific observations seem to be sampled with higher frequency than the rest of the uniform distribution range.

Seila (2004) and Keeling and Pavur (2004) suggested to take caution when using Microsoft Excel in simulation experiments. We conducted a test to identify the appropriateness of using Microsoft Excel random number generation for this research. The specific requirement for this research is to generate random number between 0 and 1. This random number is used to sample a value of the uncertainty dimension ($U_{i,j}$). We created a list of 60,000 random numbers using *rnd()* function in a VBA macro. The resulting random numbers are transformed to random integers between 0 and 100. This was achieved by multiplying the resulting random number by 100 and rounding the result to the nearest integer. The range of random number was generated through using the following Excel VBA macro:

```
For i = 1 To 60000
Range("D" & 1 + i).Select
ActiveCell.Formula = Rnd()
Range("e" & 1 + i).Select
ActiveCell.Formula = Int(Round((Range("d" & 1 + i).Value), 2) * 100)
Next
```

The above code generates two columns in an excel spreadsheet. The first column contains the observation of random number sampling, and the second column contains its transformation into a random number between 0 and 100. The minimum random value was (7.86781311035156E-06), and the maximum random value was (0.999988555908203). This confirms that Excel did not generate values outside of designed range. The next step in our test

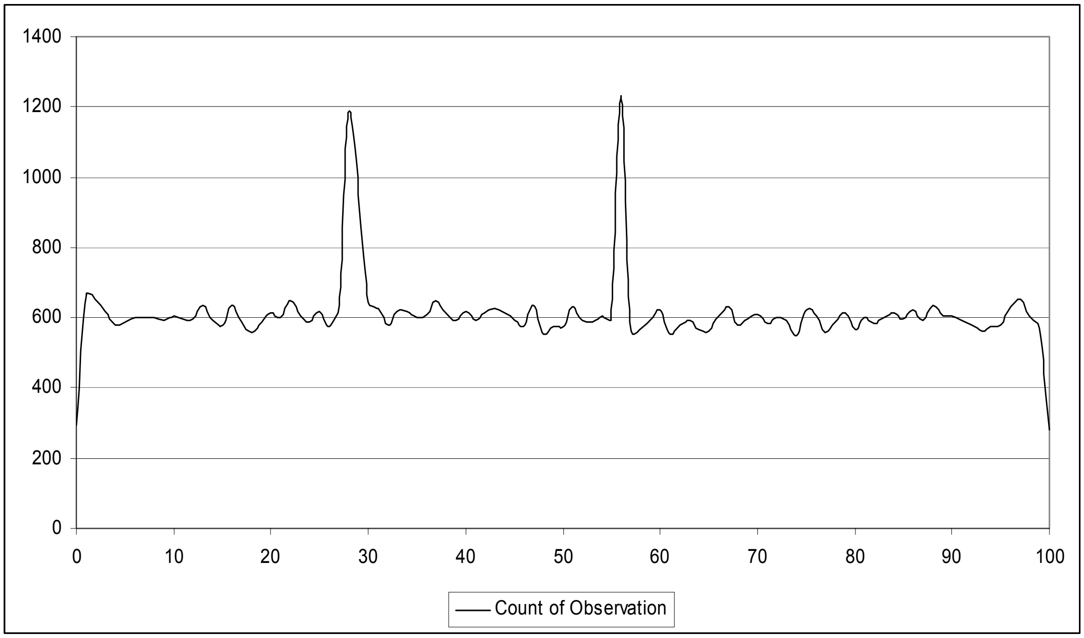


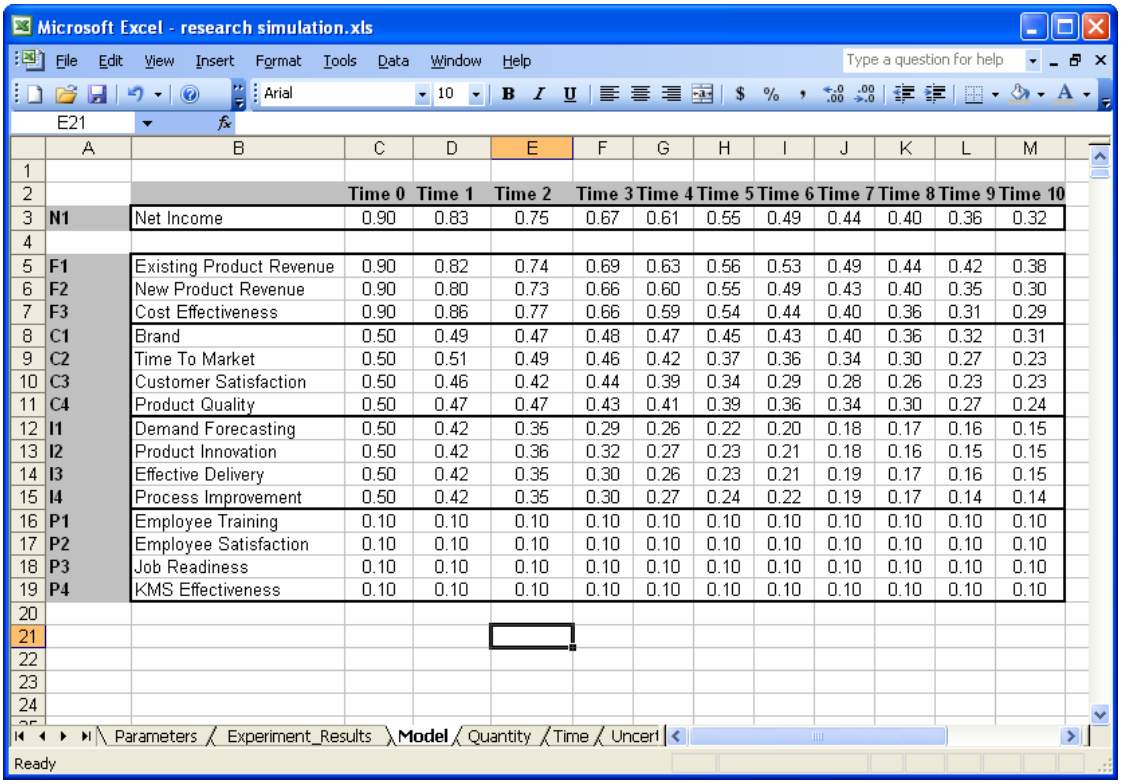
Figure 4-3 Excel Random Number Test

was to observer the frequency of random numbers. Figure 4-3 shows the frequency of sampling numbers between 0 and 100. Theoretically, the frequency of each integer between 0 and 100 should be 600 (60,000 repetitions divided by 100 observations). The test confirms previous research findings regarding Excel random number generator. The same two issues are concluded from our test. The tails of the uniform distribution were sample with less frequency than the rest of the uniform distribution range. In addition, integers 28 and 56 were sampled 1200 times, twice the expected frequency of 600. The rest of the generated observations seem to follow the uniform distribution.

In this research, we accept the quality of the random numbers generated by Microsoft Excel. The assumption of accepting the pseudo random number is also widely accepted in the literature. In addition, the error in random number generation is substantially lower than errors in assuming uniform distribution. Therefore, random numbers generated by Excel are deemed satisfactory for this case study.

4.3.2. Excel Simulation Model Description

In this subsection, we describe the details of the Excel simulation Model. The simulation model is designed to simulate the relationship between the strategy maps objectives over 10 future time periods. The initial time period notated as "Time 0" represents the current time. The rest of the time periods are notated as "Time 1", "Time 2", until "Time 10". The core of the simulation model is a sheet within the Excel application that contains the normalized value of



		Time 0	Time 1	Time 2	Time 3	Time 4	Time 5	Time 6	Time 7	Time 8	Time 9	Time 10
N1	Net Income	0.90	0.83	0.75	0.67	0.61	0.55	0.49	0.44	0.40	0.36	0.32
F1	Existing Product Revenue	0.90	0.82	0.74	0.69	0.63	0.56	0.53	0.49	0.44	0.42	0.38
F2	New Product Revenue	0.90	0.80	0.73	0.66	0.60	0.55	0.49	0.43	0.40	0.35	0.30
F3	Cost Effectiveness	0.90	0.86	0.77	0.66	0.59	0.54	0.44	0.40	0.36	0.31	0.29
C1	Brand	0.50	0.49	0.47	0.48	0.47	0.45	0.43	0.40	0.36	0.32	0.31
C2	Time To Market	0.50	0.51	0.49	0.46	0.42	0.37	0.36	0.34	0.30	0.27	0.23
C3	Customer Satisfaction	0.50	0.46	0.42	0.44	0.39	0.34	0.29	0.28	0.26	0.23	0.23
C4	Product Quality	0.50	0.47	0.47	0.43	0.41	0.39	0.36	0.34	0.30	0.27	0.24
I1	Demand Forecasting	0.50	0.42	0.35	0.29	0.26	0.22	0.20	0.18	0.17	0.16	0.15
I2	Product Innovation	0.50	0.42	0.36	0.32	0.27	0.23	0.21	0.18	0.16	0.15	0.15
I3	Effective Delivery	0.50	0.42	0.35	0.30	0.26	0.23	0.21	0.19	0.17	0.16	0.15
I4	Process Improvement	0.50	0.42	0.35	0.30	0.27	0.24	0.22	0.19	0.17	0.14	0.14
P1	Employee Training	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
P2	Employee Satisfaction	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
P3	Job Readiness	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
P4	KMS Effectiveness	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Figure 4-4 Spreadsheet Simulation Model

each objective from time periods 0 until 10 (Figure 4-4).

4.3.3. Initial Simulation Experiment

The first step of conducting simulation experimentation is to conduct an initial simulation experiment. The purpose of the initial simulation experiment is:

1. Verify and validate the simulation model
2. Facilitate conducting statistical tests to determine the number of simulation repetitions for each simulation scenario.

The simulation VBA program is designed to simulate more than one scenario. A simulation scenario represents a situation or an alternative. A simulation scenario is defined by the following parameters:

1. Initial Conditions: The initial conditions are the normalized score values for each objective.
2. Cause-Effect relations dimensions: The cause effect dimensions are the set of variable $Q_{i,j}$, $TP_{i,j}$, and $U_{i,j}$
3. Model specific parameters:
    a. The "do nothing effect" DN_j
    b. The discount rate for cash flow analysis
4. The number of simulation repetitions: The number of simulation repetition is determined after conducting the initial simulation experiment.

The normalized scores at time period ("Time 0") are fed as inputs to the simulation model. The VBA macro creates the formula for each cell for subsequent time periods ("Time 1" until "Time 10"). Each cell represents the normalized score for objective j at time t ($O_{j,t}$). The value of the normalized score ($O_{j,t}$) is calculated as identified earlier in Equation 17. The value of variables $Q_{i,j}$, DN_j, $TP_{i,j}$, and $U_{i,j}$ are entered in other sheets within the spread sheet application. The details of Excel simulation including input sheets and VBA code are explained in detail in Appendix A.

The following example illustrates how the value of cell "D15" (in Figure 4-4) is calculated. Cell "D15" represents the normalized score of the objective Process improvement at time period "Time 1" ($O_{I4,1}$). The value of $O_{I4,1}$ depends on the following parameters:

1. The normalized score of Process Improvement at time 0 ($O_{I4,0}$). The value of $O_{I4,0}$ according to the model is 0.50.
2. The "Do Nothing" impact for Process Improvement (DN_{I4}). Its value is 0.8.
3. All objectives that have a cause relationship with Process Improvement. In this example, all objectives from the Learning and Growth perspective affect Process Improvement. Therefore the following parameters affect $O_{I4,1}$: $Q_{i,I4}$, $TP_{i,I4}$, $U_{i,I4}$, where i is P1, P2, P3, P4 (the objectives in Learning and Growth perspective). Table 4.5 includes the values for each of these variables as identified in the simulation model. The table includes the casual effect in rows, and the dimensions of the casual relationship in columns.

Table 4.5 Dimensions of casual relationship affecting Process Improvement

	Q	TP	U
P_1, I_4	0.05	-1	2
P_2, I_4	0.05	-1	2
P_3, I_4	0.05	-1	2
P_4, I_4	0.05	-1	2

The VBA code performs the logic to identify the value of each parameter from the respective sheets. After identifying the values for each of the parameters, the normalized score of Process Improvement can be calculated. Process Improvement score for time period 1 is calculated in cell "D15". The VBA macro identified the formula for cell "D15" as:

$$D15 = C15*0.8 + C16*0.022 + C17*0.034 + C18*0.031 + C19*0.092 \quad \text{Equation 19}$$

The first term of the equation represents the "Do Nothing" effect $(O_{j,t-1})*(DN_j)$. The rest of the terms represent the effect of each of the four learning and growth objectives. The second term of this equation "C16*0.022" represents the effect of employee training on process improvement. This term identified in two parts. First, the time phase between employee training is identified ($TP_{P1,I4}$). The value of $TP_{P1,I4}$ is -1, meaning $O_{P1,T0}$ is the normalized score affecting process improvement. Therefore cell "C16" is used. The second part is to identify a sample of a random distribution identifying the relationship between P1, and I4. The uniform distribution is identified from the parameters $Q_{i,I4}$, $U_{i,I4}$. The values for these variables are 0.05 and 2 respectively. Therefore the uniform distribution can be represented as UD(0, 0.1). For the first term, the sample from the uniform distribution was 0.022. It is worth noting that the casual effect relationship between the four Learning and growth objectives and Process Improvement have the same parameters (Table 4.5). These parameters are Q = 0.05, TP = -1 and U =2. Therefore the rest of the terms in Equation 19 are identified similarly. The first part of each term refers to normalized scores of Employee Satisfaction, Job Readiness and KMS Effectiveness. Therefore these terms reference cells "C16", "C17" and "C19" respectively. Also, the second part of each of the remaining three terms represents a sample from a uniform distribution of UD(0,0.1). The sample for the second, third and fourth term of the equation were 0.034, 0.031 and 0.092 respectively.

The above discussions described the basic building block of the simulation model. That basic block is how the value of a normalized score of Objective j at Time t is estimated. The VBA code uses the same logic to identify a formula for each cell in the sheet over the simulated time horizon. After the value of the normalized score for each objective is identified, net income (N_1) for each time period (Time 1 to Time 10) is calculated. As described earlier, net income score is calculated as the average of financial objectives (F_1, F_2, F_3) scores. Net Income represents the core output of a simulation repetition result. In the model sheet, the values of N1 scores for the 10 simulated time periods are identified in cells “C1” to “M1”.

4.3.4. Excel Simulation Output Description

After each set of Net Income score ($O_{N1,1}, O_{N1,2},..O_{N1,10}$) is identified, the VBA macro copies that set into another sheet within the Excel application. The VBA macro also estimates the utility of the net income at each time period. Net income scores and their utilities are saved in a sheet name (Run_Results). Each row in this sheet represents the result of a simulation repetition within that simulation scenario. In addition, net present value (NPV) of net income utility is identified as part each repetition analysis. Table 4.6 shows the result for one simulation repetition.

Table 4.6 Results of Simulation Repetition

Time Period	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	NPV
Net Income(N1)	0.90	0.83	0.75	0.69	0.65	0.59	0.51	0.45	0.42	0.38	0.34	
Utility of N1	0.69	0.63	0.60	0.57	0.55	0.51	0.47	0.46	0.44	0.42	0.69	4.22

In this experiment, the number of simulation repetitions is 50. The identification of the number of repetitions is explained in the next section. The following statistics are collected for each simulation scenario:

1. Minimum utility of Net Income for each time period.
2. Maximum utility of Net Income each time period.
3. Average utility of Net Income each time period.
4. Standard deviation of utility of Net Income each time period.

The VBA macro calculates the above outputs based on the individual results of simulation repetitions. For this experiment, the collected results are presented in Table 4.7.

Table 4.7 Simulation Scenario Results (Net Income)

Time	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	NPV
Avg.	0.678	0.629	0.594	0.560	0.533	0.507	0.483	0.462	0.442	0.424	4.19
Min.	0.644	0.599	0.571	0.540	0.512	0.482	0.455	0.434	0.420	0.400	NA
Max.	0.709	0.657	0.621	0.579	0.553	0.529	0.506	0.489	0.466	0.440	NA
Stdev.	0.014	0.013	0.012	0.011	0.010	0.010	0.010	0.010	0.010	0.009	0.062

4.3.5. Determining the Number of Simulation Repetitions

The number of simulation repetitions is an important parameter in simulation experiments. The variability of simulation output is reduced by running more simulation repetitions. The variability of output is reduced by increasing the number of repetitions up to a certain level. After that, the variability of simulation output is attributed to the uncertainty modeled within the simulation system. Therefore, increasing the number of repetitions after that limit will only cause longer simulation runs, without improving the accuracy or variation of point estimates.

We followed the following steps to identify the number of simulation runs

1. Identify 10 scenarios to be simulated with different simulation repetitions. The difference in each scenario is the initial conditions. These initial conditions are the

normalized scores of each objective. Table 4.8 shows the initial conditions for each of the 10 scenarios.

Table 4.8 Initial Conditions for determining Number of Simulation Repetitions

Obj.	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	Scen. 6	Scen. 7	Scen. 8	Scen. 9	Scen. 10
F1	0.8	0.5	0.3	0.76	0.47	0.25	0.51	0.69	0.76	0.52
F2	0.8	0.5	0.2	0.7	0.46	0.59	0.47	0.53	0.56	0.6
F3	0.8	0.5	0.3	0	0.65	0.32	0.55	0.03	0.67	0.85
C1	0.8	0.5	0.8	0.73	0.72	0.83	0.83	0.03	0.44	0.01
C2	0.8	0.5	0.8	0.32	0.96	0.6	0.22	0.39	0.94	0.85
C3	0.8	0.5	0.8	0.3	0.3	0.2	0.04	0.84	0.85	0.68
C4	0.8	0.5	0.8	0.31	0.1	0.85	0.81	0.74	0.35	0.93
I1	0.8	0.5	0.2	0.01	0.09	0.01	0.77	0.97	0.37	0.43
I2	0.8	0.5	0.4	0.72	0.5	0.24	0.32	0.03	0.89	0.01
I3	0.8	0.5	0.5	0.14	0.6	0.3	0.42	0.33	0.51	0.33
I4	0.8	0.5	0.2	0.64	0.53	0.75	0.57	0.12	0.38	0.96
P1	0.8	0.5	0.7	0.06	0.57	0.09	0.36	0.97	0.02	0.19
P2	0.8	0.5	0.3	0.95	0.18	0.55	0.41	0.14	0.44	0.95
P3	0.8	0.5	0.4	0.81	0.93	0.45	0.92	0.42	0.06	0.91
P4	0.8	0.5	0.6	0.2	0.94	0.46	0.34	0.53	0.31	0.54

2. Simulate the above 10 scenarios for using different number of simulation repetitions. We used a range from 2 to 100 simulation repetitions.
3. For each set of simulation repetitions, record the average net present value (NPV), and the standard deviation for NPV.
4. Graph the output of mean NPV and standard deviation of NPV.
5. Visually identify the number of repetitions after which the point estimate and variance (standard deviation) is stabilized.

We followed the above steps to graphically identify the point at which point estimate (NPV) and variation (standard deviation) stabilize. Figure 4-5 shows the estimate of net present value, while Figure 4-6 shows the estimate for standard deviation. The variation in both NPV and standard deviation stabilizes after around 20 simulation repetitions. Since simulation time is not a constraint, we decided to use 50 repetitions for each simulation run.

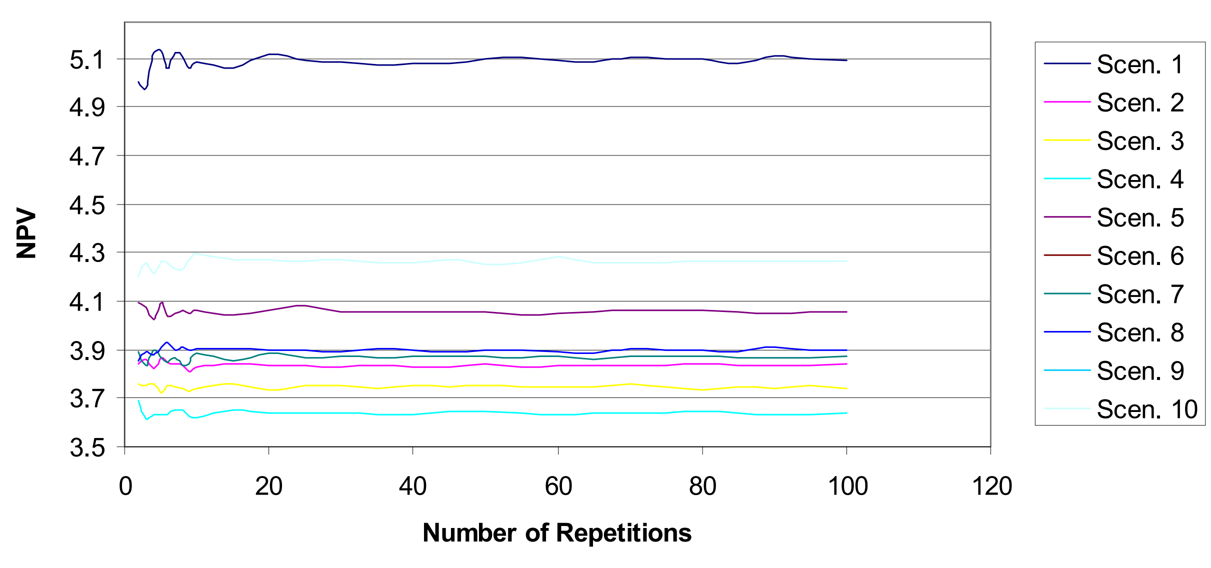


Figure 4-5 NPV vs. Number of Repetitions

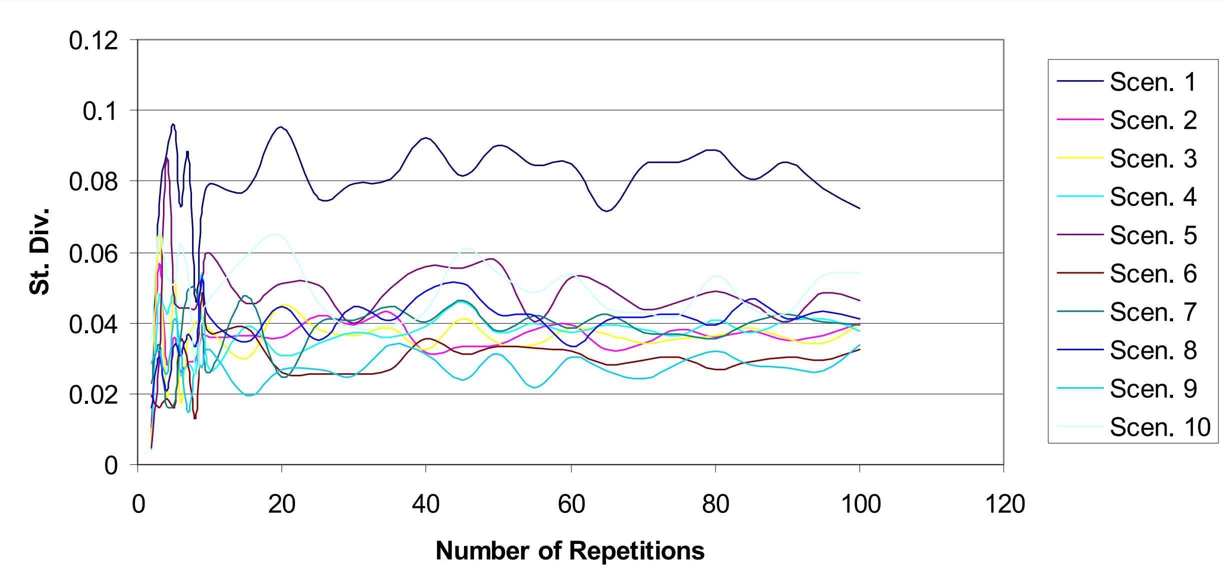


Figure 4-6 Standard Deviation vs. Number of Repetitions

4.3.6. *Statistical Analysis of Simulation Results*

The simulation results are used to estimate future net income and in comparing the output of multiple scenarios. In addition, the simulation results are used to identify the range of expected net income at each time period. In this research, we use 50 repetitions for each simulation scenario. According to the central limit theorem, net income is normally distributed at each time period. If the number of repetitions for each scenario was under 30, a t distribution is appropriate.

Table 4.9 Scenario Results with Confidence Intervals

Time	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	NPV
Avg.	0.678	0.629	0.594	0.560	0.533	0.507	0.483	0.462	0.442	0.424	4.19
Min.	0.644	0.599	0.571	0.540	0.512	0.482	0.455	0.434	0.420	0.400	NA
Max.	0.709	0.657	0.621	0.579	0.553	0.529	0.506	0.489	0.466	0.440	NA
Stdev.	0.014	0.013	0.012	0.011	0.010	0.010	0.010	0.010	0.010	0.009	0.062
U.C.I.	0.705	0.654	0.618	0.582	0.553	0.527	0.503	0.482	0.462	0.442	0.705
L.C.I	0.651	0.604	0.570	0.538	0.513	0.487	0.463	0.442	0.422	0.406	0.651

For each time period we construct a 95% confidence interval for net income. The confidence interval is constructed according to Equation 20.

$L = m \pm z(\sigma)$ Equation 20

Where;

L: limit of confidence interval

m: the mean of sample (average net income)

z: the normalized score of normal distribution for the confidence interval of interest

σ: The standard deviation of the sample (standard deviation of net income)

For a 95% confidence interval, the corresponding value of z is 1.96.

We construct a confidence interval using the simulation scenario results identified earlier in Table 4.7. We add the upper and lower confidence interval limits according to Equation 20. The confidence interval limits are presented in Table 4.9. The upper limit of the confidence interval is denoted as U.C.I, and the lower limit is L.C.I.

The confidence interval provides additional insights into the enterprise operations. The confidence interval allows working with expected ranges instead of rigid absolute figures. This is essential especially when dealing with target values. Figure 4-7 illustrates the confidence interval for the simulated scenario. Confidence interval analysis is very insightful, especially when target values fall within confidence interval limits. In such a case, falling short of target values is a natural income of enterprise processes, not a sign of underachieved performance. Confidence intervals also allow decision makers to identify whether they need to improve the uncertainty in the STSM by undertaking process improvement initiatives such as TQM or six sigma.

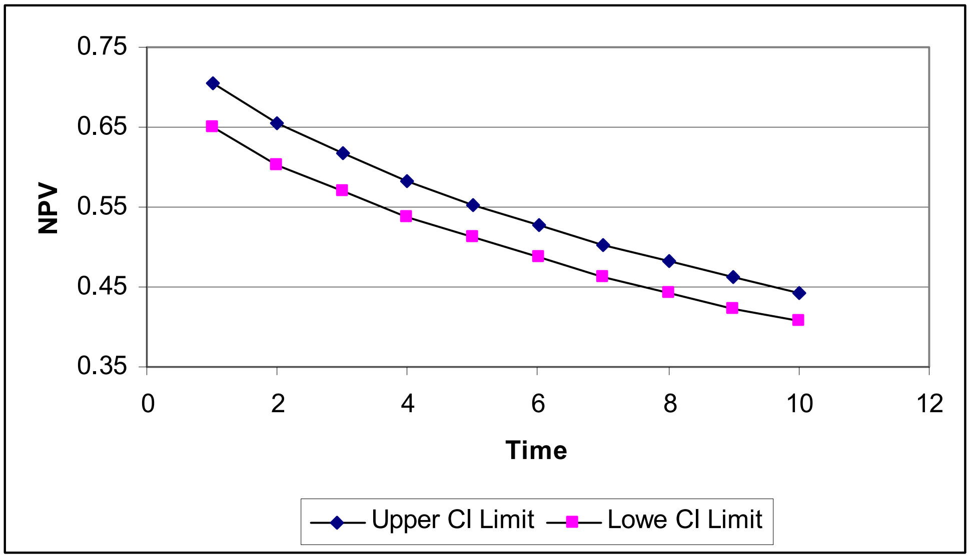


Figure 4-7 Confidence Interval Limits of Simulated Scenario

CHAPTER 5

FRAMEWORK APPLICATIONS

5.1. Introduction

In previous Chapters, we introduced the proposed framework, its components and details. We also illustrated the details of the case study and its simulation in chapter 4. Chapter 4 included the simulation with preliminarily data points that are intended to illustrate the case study, and the specifics of the simulation model. In this Chapter, we continue with the case study and the simulation model, with the purpose of illustrating the usage of the proposed methodology.

In this Chapter, we use the case study structure, and the simulation model to illustrate the following applications:

1. Illustrate using the framework for initiative rationalization and alternative evaluation.
2. Setting performance targets and identifying actual vs. target analysis.
3. Conducting trade off analysis between multiple BSC objectives.
4. Identifying trade-offs between short and long term performance.

We use the case study explained in chapter 4 to demonstrate the above concepts. The case study consists of a strategy map with different objectives in each perspective. The case study model data is static. However, data is changed according to the intended analysis purpose.

The purpose of this chapter is to demonstrate different applications of our proposed framework. The conclusions reached via applying the framework and the methodology are not as relevant. The conclusions will need to be validated by collecting and analyzing real data.

5.2. Strategy Evaluation and Initiative Rationalization

A strategy provides the means to achieve the enterprise vision. The balanced scorecard framework (including strategy maps) allows us to describe and communicate the strategy. Our proposed methodology extends the framework by enabling strategy evaluation. We evaluate the strategy by simulating the STSM and estimating the future financial performance of the enterprise. Strategy evaluation enables two critical management aspects. First, it provides quantitative means to assess the strategy and its impact. Second, it provides the ability to compare multiple alternatives and facilitates decision making between multiple alternatives.

We illustrate this application by simulating the strategy map introduced earlier in Chapter 4. In the next two sections, we use different initial conditions to illustrate how to use the proposed framework to enable decision making.

5.2.1. Strategy Evaluation

In this section, we illustrate how simulation of STSM add additional perspective and provide more detailed insight into the enterprise strategy. The set of initial conditions for the simulation is provided in Table 5.1. We use the same normalized score for each the BSC objectives. The normalized score of each objective in all perspectives is 60%.

The second component of inputs into STSM is the three dimensions of relationships between various strategy maps objectives. For the quantity dimension, we use 15% as the impact between each leading and lagging perspective. For example, each of the growth and learning perspective objective affect the internal process perspective by 15% (on average). We also use the same time phase between each of the leading and lagging indicators. A time phase of one time period used to identify the time phase dimension of the relationship between leading and lagging indicators objectives. Finally we use a value of 1 for the uncertainty dimension between the objectives leading and lagging perspectives. Table 5.2 through Table 5.4 show the values we use for the quantity dimension ($Q_{i,j}$). Table 5.5 through Table 5.7 show the values we use for the time phase dimension ($T_{i,j}$). Finally Table 5.8 through 5.10 show the values we use for the uncertainty dimension ($U_{i,j}$).

Table 5.1 Strategy Evaluation - Initial Normalized Scores

Perspective	**Metric**	**Normalized Score**
Financial	Existing Product Revenue	0.60
	New Product Revenue	0.60
	Cost Effectiveness	0.60
Customer	Brand	0.60
	Time To Market	0.60
	Customer Satisfaction	0.60
	Product Quality	0.60
Internal Processes	Demand Forecasting	0.60
	Product Innovation	0.60
	Effective Delivery	0.60
	Process Improvement	0.60
Growth and Learning	Employee Training	0.60
	Employee Satisfaction	0.60
	Job Readiness	0.60
	KMS Effectiveness	0.60

Table 5.2 Quantity Dimension ($Q_{i,j}$)- Customer to Financial

	F1	F2	F3
C1	0.15	0.15	0.15
C2	0.15	0.15	0.15
C3	0.15	0.15	0.15
C4	0.15	0.15	0.15

Table 5.3 Quantity Dimension ($Q_{i,j}$)- Internal Processes to Customer

	C1	C2	C3	C4
I1	0.15	0.15	0.15	0.15
I2	0.15	0.15	0.15	0.15
I3	0.15	0.15	0.15	0.15
I4	0.15	0.15	0.15	0.15

Table 5.4 Quantity Dimension ($Q_{i,j}$)- Learning and Growth to Internal Processes

	I1	I2	I3	I4
P1	0.15	0.15	0.15	0.15
P2	0.15	0.15	0.15	0.15
P3	0.15	0.15	0.15	0.15
P4	0.15	0.15	0.15	0.15

Table 5.5 Time Phase Dimension ($T_{i,j}$) - C to F

	F1	F2	F3
C1	-1	-1	-1
C2	-1	-1	-1
C3	-1	-1	-1
C4	-1	-1	-1

Table 5.6 Time Phase Dimension ($T_{i,j}$)- I to C

	C1	C2	C3	C4
I1	-1	-1	-1	-1
I2	-1	-1	-1	-1
I3	-1	-1	-1	-1
I4	-1	-1	-1	-1

Table 5.7 Time Phase Dimension ($T_{i,j}$) - P to I

	I1	I2	I3	I4
P1	-1	-1	-1	-1
P2	-1	-1	-1	-1
P3	-1	-1	-1	-1
P4	-1	-1	-1	-1

Table 5.8 Uncertainty Dimension ($U_{i,j}$) - C to F

	F1	F2	F3
C1	1	1	1
C2	1	1	1
C3	1	1	1
C4	1	1	1

Table 5.9 Uncertainty Dimension ($U_{i,j}$) – I to C

	C1	C2	C3	C4
I1	1	1	1	1
I2	1	1	1	1
I3	1	1	1	1
I4	1	1	1	1

Table 5.10 Uncertainty Dimension ($U_{i,j}$) - P to I

	I1	I2	I3	I4
P1	1	1	1	1
P2	1	1	1	1
P3	1	1	1	1
P4	1	1	1	1

After identifying the STSM in the tables above, the strategy can be evaluated by means of Monte Carlo Simulation. The first step in conducting the simulation is to identify the expected net present value (NPV) for future periods. Table 5.11 shows the results of simulating this strategy map. The average net income, along with minimum, maximum and standard deviation are estimated after running the simulation. In addition, the net present value (NPV) is estimated for the simulated time horizon. Managers and decision makers have better means to evaluate the strategy. The strategy is expected to result in a net present value (NPV) of 4.24 over the future 10 time periods.

Table 5.11 Strategy Evaluation Results

Time	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	NPV
Average	0.553	0.549	0.550	0.546	0.548	0.550	0.549	0.550	0.551	0.550	4.24
Min	0.509	0.518	0.508	0.488	0.488	0.510	0.501	0.508	0.498	0.505	N/A
Max	0.581	0.595	0.605	0.587	0.590	0.604	0.586	0.601	0.588	0.584	N/A
STD	0.016	0.019	0.018	0.021	0.026	0.023	0.019	0.023	0.019	0.018	.076

In addition to the analysis of mean values, we can perform variance and uncertainty analysis. STSM enables such uncertainty analysis. Uncertainty is implicitly addressed in the net present value analysis since NPV is calculated as the net present value of the utility of net income rather than the NPV of net income. For any period, there is a different net income output for each simulation repetition, and using utility of net income for each repetition allows to capture and consider the preference for each repetition output.

The second level of analyzing uncertainty is by creating confidence intervals for net income as explained earlier in section 4.3.6. Figure 5-1 illustrate the confidence interval for net income over the simulated time horizon. The confidence interval allows managers to better predict and manage the uncertainty of net income. The simulation results for this example show that average net income for the simulated time horizon is around 0.55 units. However, the statistical analysis shows that net income can be any where between the upper and lower level of the confidence interval. This is specifically important if a net income value of 0.53 units is not acceptable. The simulation allows management to understand that such output is a possibility, and allows them to react accordingly.

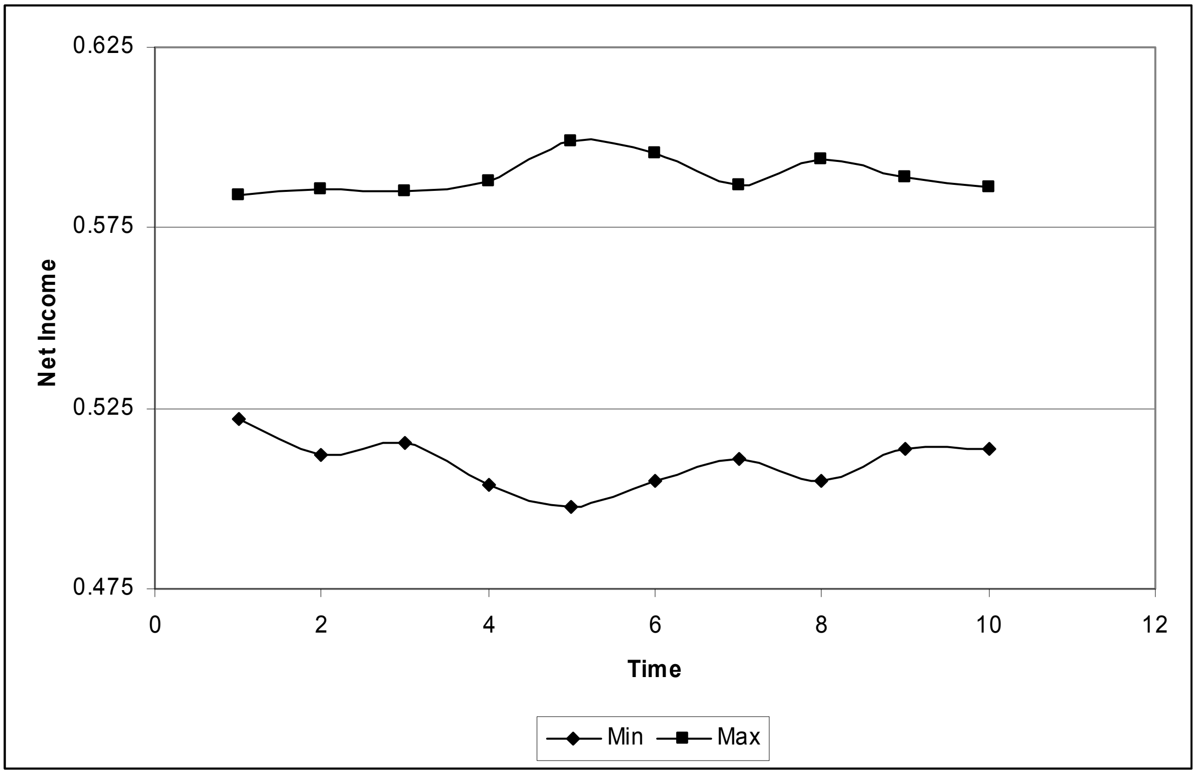


Figure 5-1 Strategy Evaluation: Net Income Confidence Interval

5.2.2. Initiative Rationalization

The balanced scorecard framework is used as strategic management tool. Its usage include communicating strategy, identifying measures to measure the strategy, and creating and evaluating alternate initiative to execute the strategy. Niven (2005) illustrated how alternative initiatives are identified. The exercise of identifying alternatives could be very complex. Niven

(2005) then explains how the balanced scorecard can be used to evaluate different candidate initiatives and choose effective ones. We do not intend to modify or suggest different means to identify different alternatives, however, we use our framework to provide an alternative approach to evaluate and rationalize such initiatives. We provide an example to show the difference between the two approaches for rationalizing strategic initiatives. A similar illustration was published by Abu-Suleiman and Priest (2006) as part of this research outcome.

We illustrated initiative rationalization by considering a new initiative "Initiative B" in comparison with base case illustrated earlier in section 5.2.1. We will consider the base case as "Initiative A". "Initiative B" represents a initiative that targets improving the learning and growth perspective. Table 5.12 illustrate the different initial conditions "normalized score" between the two initiative. Note that normalized score for the learning and growth objective are higher for "Initiative B". Since improving these objectives requires investments in these initiatives, the normalized score for the financial objectives is lower for "Initiative B".

We analyze the two imitatives using traditional approach based, used by Norton and Kaplan (2003) and Niven (2005). The traditional approach relies on using a weighted average for each alternative and compare the total score for each alternative. To enable this analysis, we assume the weight of each perspective, and the weight of objectives within each perspective. We assume a similar weight across perspectives and with each perspective. This assumption is realistic as it is often used in the literature and in industry. After assigning the weights, the score of each perspective is calculated, then a total score is calculated.

Table 5.12 Initiative Rationalization Application

Perspective	Metric	Initiative A	Initiative B
Financial	Existing Product Revenue	0.60	0.4
	New Product Revenue	0.60	0.7
	Cost Effectiveness	0.60	0.2
Customer	Brand	0.60	0.5
	Time To Market	0.60	0.5
	Customer Satisfaction	0.60	0.5
	Product Quality	0.60	0.5
Internal Processes	Demand Forecasting	0.60	0.5
	Product Innovation	0.60	0.5
	Effective Delivery	0.60	0.5
	Process Improvement	0.60	0.5
Growth and Learning	Employee Training	0.60	0.9
	Employee Satisfaction	0.60	0.7
	Job Readiness	0.60	0.6
	KMS Effectiveness	0.60	0.7

Table 5.13 Traditional Initiative Rationalization

Perspective	Objective	Objective Weight	Initiative A	Initiative B
Financial	Existing Product Revenue	0.33	0.60	0.40
	New Product Revenue	0.33	0.60	0.70
	Cost Effectiveness	0.33	0.60	0.20
Score		0.25	0.60	0.43
Customer	Brand	0.25	0.60	0.50
	Time To Market	0.25	0.60	0.50
	Customer Satisfaction	0.25	0.60	0.50
	Product Quality	0.25	0.60	0.50
Score		0.25	0.60	0.50
Internal Processes	Demand Forecasting	0.25	0.60	0.50
	Product Innovation	0.25	0.60	0.50
	Effective Delivery	0.25	0.60	0.50
	Process Improvement	0.25	0.60	0.50
Score		0.25	0.60	0.50
Growth and Learning	Employee Training	0.25	0.60	0.90
	Employee Satisfaction	0.25	0.60	0.70
	Job Readiness	0.25	0.60	0.60
	KMS Effectiveness	0.25	0.60	0.70
Score		0.25	0.60	0.73
Total Score			***0.60***	***0.54***

The above analysis shows a total score of 60% for “Initiative A”. This is expected as the input values for each objective is a score of 60%. On the other hand, the total score for “Initiative B” is 54%. The conclusion from this analysis is that “Initiative A” is more effective, and decision maker would choose "Initiative A".

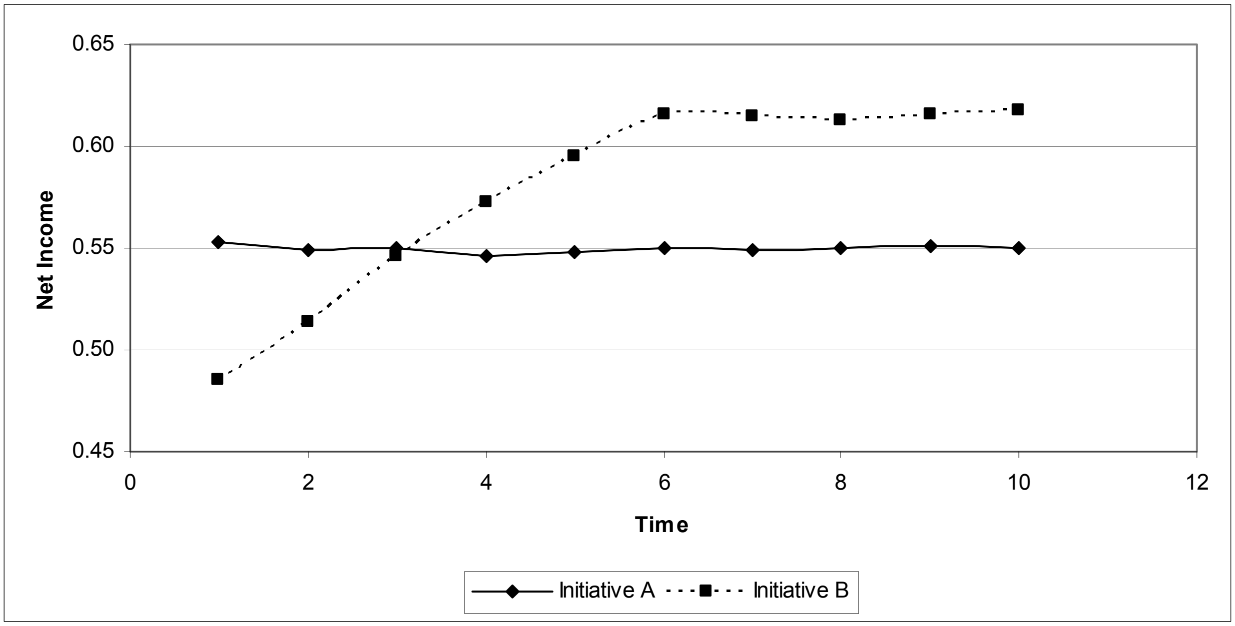


Figure 5-2 Initiative Rationalization - Simulation Results

The alternative analysis we propose in this research is based on using simulation results. We simulate the two initiatives based to estimate the future performance for each of the two initiatives. We use the same relationships between the BSC objectives as shown earlier in Table 5.2 through Table 5.10. Figure 5-2 shows the net income for each of the two initiatives. The simulation output shows that Initiative "A" performs better than Initiative "B" in the initial period of the simulated time horizon. Initiative "B" starts to perform better than "Initiative A" after the third time period. We use NPV as the evaluation criteria between the two initiatives. Table 5.14 shows the average and standard deviation of net present value for each initiative.

Table 5.14 Initiative Rationalization - NPV results

	"Initiative A"	"Initiative B"
Average NPV	4.24	4.42
Standard Deviation of NPV	0.076	0.110

Although “Initiative B” has a higher average NPV, a statistical z-test does not prove “Initiative B” to be better than initiative A at 95%. Therefore, we conclude that the two alternatives are statistically the same. Statistically, the two initiatives are different at 65% confidence. The above statistical analysis motivates us to analyze the differences between the two initiatives in further detail. Figure 5-2 showed the difference in mean value of net income between “Initiative A” and “Initiative B”. We construct confidence intervals of net income for the two alternatives to facilitate better analysis. Figure 5-3 shows the confidence interval of net income for the two initiatives. The graph has the same legend for upper and lower limits of the confidence interval for each initiative. The analysis shows that although the average net income for “Initiative B” is higher than “Initiative A” after time period 3, the difference is not statistically significant. We reach the conclusion that the two initiatives are statistically equivalent by noticing that the two confidence intervals overlap. There is only one time period at

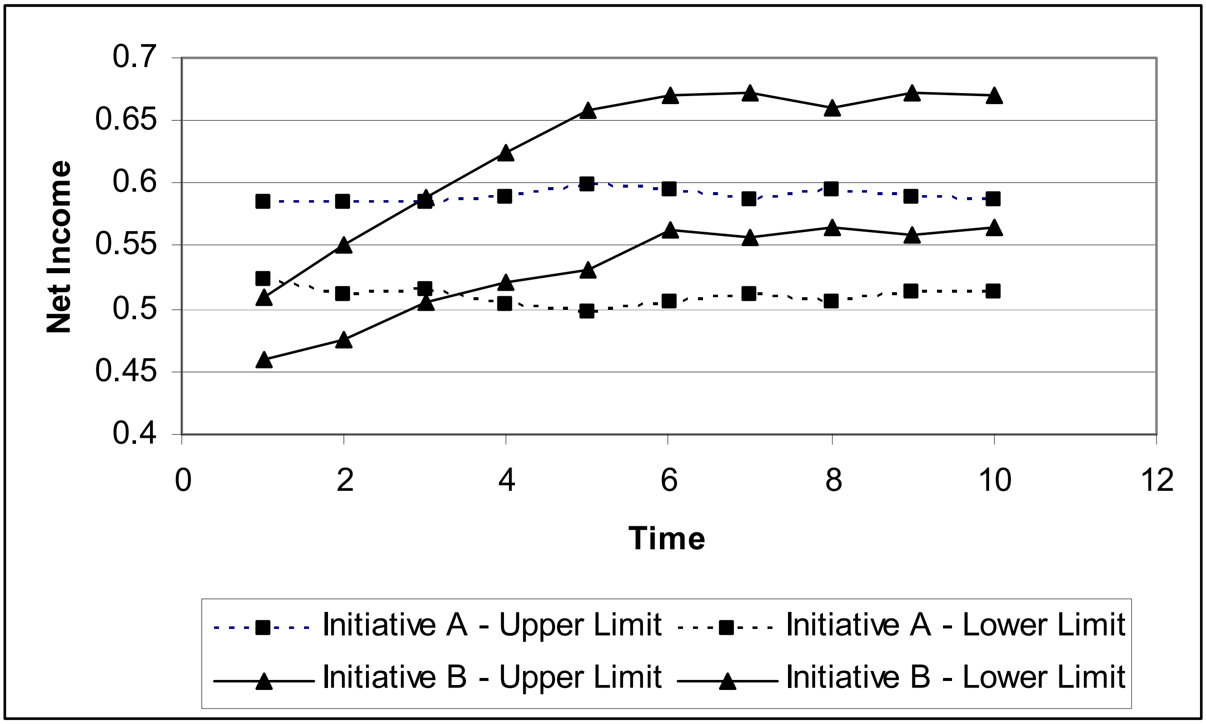


Figure 5-3 Confidence Intervals for Initiative Rationalization Analsys

which the net income for “Initiative A” is different than “Initiative B”. That is at time period 1 where “Initiative A” is statistically better than “Initiative B”.

The above analysis yields that “Initiative A” is not different from “Initiative B”. This conclusion is different from the conclusion identified by following the traditional weighted average approach for initiative rationalization.

5.3. Target Setting

Each perspective in the balanced scorecard is always associated with objectives, metrics, and targets. Objectives state the aspects or direction the enterprise should perform well. Metrics are the indicators or the measures organization use to monitor and evaluate the progress and execution of each objective. Finally, targets are the numerical values that the enterprise desire to reach for each target. In our research, we used objectives as an abstract of measures. The BSC, strategy maps, and simulations were conducted by using normalized scores of each objective. We mainly abstracted measures to objectives because we generated research data, and attempted to maintain a more realistic model.

Since we use normalized scores to abstract measures, target setting is translated to a desired normalized score for each objective. The normalized score is calculated as the ratio of actual metric value to the target metric value. For example, the normalized score for objective O_j is calculated as:

$$O_j = \frac{A_j}{T_j} \text{ Equation 21}$$

Where;

O_j: the normalized score for objective j

A_j: The actual value of metric j

T_j: The target value of metric j

In addition to metric targets, we propose establishing targets for the relationships between various objectives. Strategy maps and our proposed extension STSM suggest that the lagging indicators depend on their leading indictors and the dimensions of the relationships as proposed in STSM. The next two sub-sections illustrated the usage of our proposed framework in target setting.

5.3.1. Objective Target Setting

In this section we refer to the traditional balanced scorecard target setting as "Objective Target Setting". Targets are set for two main reasons:

1. Identify the desired level of excellence for a specific metric and therefore objective.
2. Targets are often used as means to manage people, set up individual goals, and link compensation to performance. Employees are compensated based on the value of actual metric compared to the target metric.

We suggest that objective target setting is suitable for the first purpose. However, we suggest that actual performance is based on multiple variables, one of which is employees execution. As discussed in the previous section, actual performance is expected to fall within a range. This range is controlled by the uncertainty of cause effect relationships between different objectives. The variability of the cause effect relationship between multiple objectives suggest that actual metrics are not completely controlled by employees.

We propose using the proposed framework for target setting by continuing with the same example used in section 5.2. One reason to set performance targets is to identify tradeoffs between different objectives. Such an application is similar to the example illustrated earlier in section 5.2.2, the initiative rationalization example. Target setting is also used to identify acceptable levels of performance that will yield desired future financial performance. We will consider the example in section 5.2.1. The strategy was evaluated in that section and the and the expected net present value was 4.42. We assume that the minimum desired net present value is 5.0. Targets can be set accordingly so that a 5.0 NPV can be achieved. We analyze improving the net present value from 4.42 to 5.0 by increasing the normalized score for the learning and growth perspective and customer perspective from 60% to 80%. Then, we run the simulation model to analyze the impact of these changes. Table 5.15 shows the results for this simulation. Simulation results suggest that increasing the target values for the customer and learning & growth perspectives allow to achieve the desired NPV of 5.0.

Table 5.15 Objective Target Setting Simulation Output

Time	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	NPV
Average	0.59	0.62	0.64	0.66	0.66	0.67	0.67	0.67	0.68	0.67	5.01
Min	0.54	0.57	0.58	0.58	0.59	0.59	0.59	0.61	0.60	0.61	N/A
Max	0.63	0.68	0.72	0.81	0.76	0.82	0.80	0.79	0.81	0.75	N/A
STD	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.151

It is important to emphasize the difference between traditional target setting and our proposed target setting. Traditional target setting is usually based on environment analysis tools such as SWOT analysis and industry benchmarking. The extension of strategy maps into STSM allow assessing the impact of target values. The proposed framework allow to establish targets that will result in achieving desired long term financial performance.

5.3.2. Process Targets

In addition to objective targets, we propose that an enterprise should establish and monitor process targets. In previous sections, we demonstrated that there is a range of expected financial performance, which depends on the parameters of the cause effect relationship between the BSC objective. In this section, we take a process oriented view of the strategy map. The strategy maps can be view as a value creation process. Figure 5-4 illustrates the value creation process for a vertical section of the strategy map we used in this research. The process starts by transforming training into innovation, next innovation is transformed into a superior product and brand name. At last, the improvement in the customer perspective results in revenues. Therefore, the value creation process converts employee training into revenues.

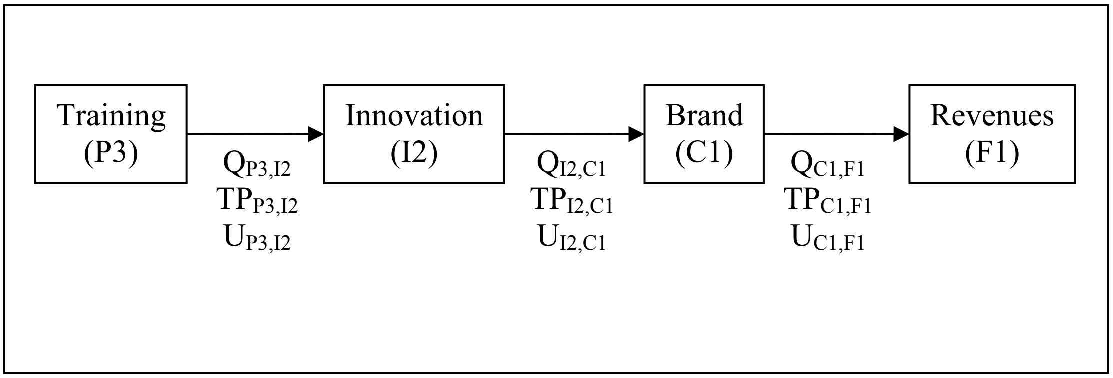


Figure 5-4 Value Creation Process

The process oriented view allows us to recognize that revenues are the end product of the process. The goal of improving the end product will be achieved by improving the process. Revenues by themselves are outputs and not control variables. The distinction between process orientation and goal orientation becomes clearer when considering other perspectives. Revenues as an objective, can be measured without ambiguity. However, it is more difficult to identify metrics for the innovation objective or the training objective. For example, training hours can be used as the metric for employee training. In fact, many organizations require their employees to complete certain amount of training hours in specific time interval or review cycle. For example, an organization might set a target that 15% of employee time should be spent on training. Unfortunately, once this target is identified, it becomes a goal from individual point of view.

Once achieving the target training time becomes a goal, the ultimate goal of transforming training into innovation disappears.

The uncertainty aspect of the cause effect relationship demonstrates the need for process oriented targets. We continue with the simulation experiment for strategy evaluation in section 5.2.1. The simulation output showed that the normalized score of average net income (N1) is 0.55. The statistical analysis shows that expected net income could occur anywhere within the established confidence interval. The inherent uncertainty in the cause effect relationship randomizes the actual output of the value creation process. Lets consider that the target score for net income is 55%, and that a value of 52.5% for net income score is not acceptable. The simulation results show that both these results are valid outputs. In fact even if the targets of BSC objectives are met, the actual net income may not be acceptable.

A process oriented view will establish targets for the value creation process parameters. We propose that establishing targets for the cause effect parameters is more effective than establishing targets for objectives themselves. In the strategy evaluation example, establishing a target that minimized the uncertainty in the cause effect relationship will result in reducing the randomness in the process output, i.e. net income (N1). Previously the value of $U_{i,j}$ was set at 1 for the relationship between all objectives. The enterprise can establish targets for reducing the uncertainty in the cause effect relationships between all objectives.

In this application, we assume a target for all $U_{i,j}$ values of 0.5 as compared to 1.0 as used earlier in the strategy evaluation application. After identifying the target values for the uncertainty dimension, we simulate the STSM to analyze the effect of these targets. We use the same initial conditions as in section 5.2.1. However we change the uncertainty dimension. Therefore we replace Tables 5.8 through Table 5.10 by Table 5.16 through Table 5.18 as idenintified below.

Table 5.16 Target Values for ($U_{i,j}$) - C to F

	F1	F2	F3
C1	0.5	0.5	0.5
C2	0.5	0.5	0.5
C3	0.5	0.5	0.5
C4	0.5	0.5	0.5

Table 5.17 Target Values for ($U_{i,j}$) – I to C

	C1	C2	C3	C4
I1	0.5	0.5	0.5	0.5
I2	0.5	0.5	0.5	0.5
I3	0.5	0.5	0.5	0.5
I4	0.5	0.5	0.5	0.5

Table 5.18 Target Values for ($U_{i,j}$) - P to I

	I1	I2	I3	I4
P1	0.5	0.5	0.5	0.5
P2	0.5	0.5	0.5	0.5
P3	0.5	0.5	0.5	0.5
P4	0.5	0.5	0.5	0.5

The results of simulating the above scenario are outlined in Table 5.19. The net present value for the simulated scenario is 4.25 (compared to 4.24), and the standard deviation is 0.037 (compared to 0.076). In addition, the average net income remains around 0.55 as expected. However the standard deviation for the net income (and NPV) was reduced.

Table 5.19 Simulation Output for Process Targets

Time	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	NPV
Average	0.552	0.550	0.550	0.548	0.549	0.550	0.550	0.550	0.551	0.550	4.25
Min	0.529	0.534	0.529	0.518	0.519	0.530	0.526	0.528	0.523	0.527	N/A
Max	0.565	0.572	0.576	0.568	0.569	0.576	0.568	0.574	0.569	0.567	N/A
STD	0.008	0.009	0.009	0.011	0.013	0.011	0.010	0.011	0.010	0.009	0.037

We also analyze the simulation output to establish confidence intervals for the net income at each time period. Figure 5-3 shows the confidence interval for net income across the simulated scenario. The mean of the confidence interval is same as it was before reducing the variability in the cause effect relationship, however, the variability is reduced. The enterprise can statistically ascertain that the normalized score for net income (N1) will be over 55.25%.

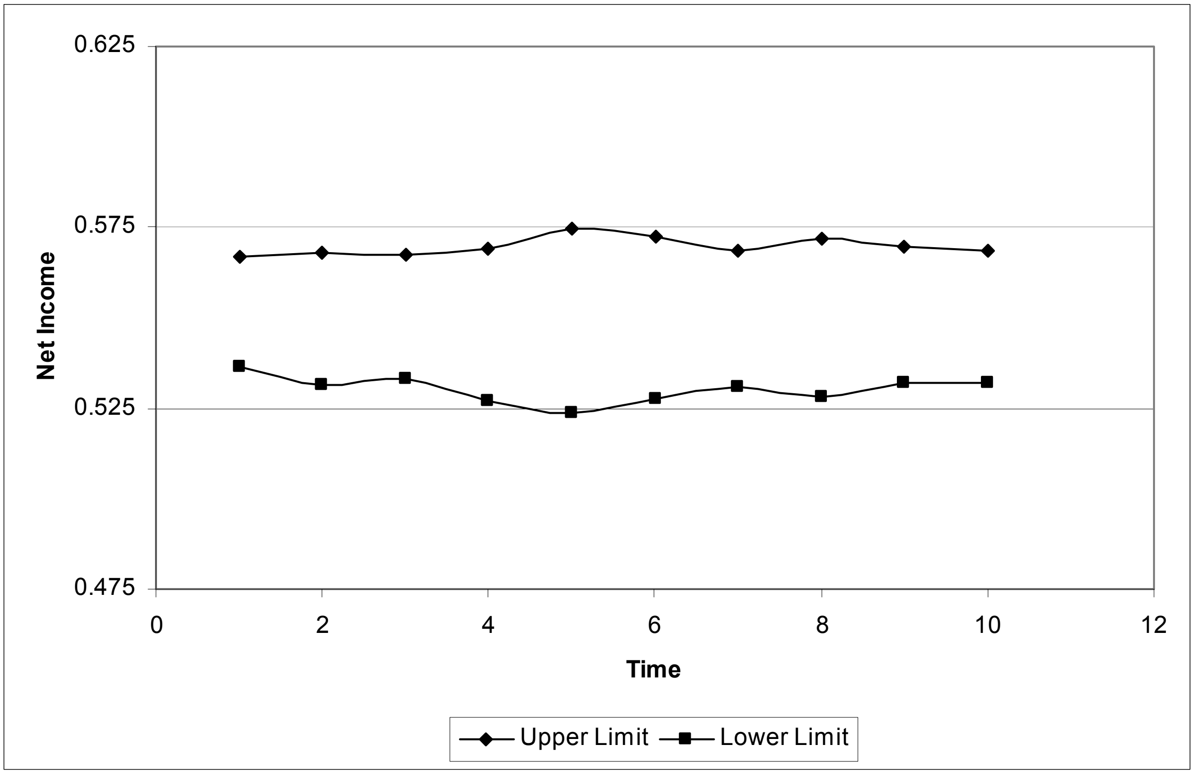


Figure 5-5 Confidence Interval for Net Income / Reduced Variability

5.4. Trade-off Analysis between BSC Objectives

The balanced scorecard provides the strategic direction in terms of which objective and metrics are important to the enterprise strategy. After structuring the balanced scorecard and assigning weights to each metric, the resulting BSC serves as an objective function for the enterprise. Managers and decision makers will attempt to optimize the total score according to the BSC structure. We identified earlier the limitations and of using static weights for to identify relative performance for the balanced scorecard metrics. We also propose an alternative approach for structuring the balanced scorecard and we follow a decision analysis approach to identify the BSC trade-offs.

We utilize the concept of Stochastic Timed Strategy Maps (STSM) as the tool to model interactions between various BSC objectives. STSM enables simulating the enterprise strategy and creating a single output for any set of objective scores. The single output is the net present value (NPV) for the simulated scenario. Therefore, we model the normalized scores of each BSC objective as inputs, and net present value as an output. The purpose of this analysis is to identify a relationship between net present value and the normalized score of each of the BSC objectives. We achieve this relationship by simulating multiple initial conditions, and analyzing the output (NPV) of these initial conditions (inputs). The output and inputs are then fed into a regression model that hypothesis NPV as a function of BSC objectives.

The following experiment was conducted to estimate a regression model for experiment variables and experiment response. The response is net present value (NPV) and the variables are the different BSC perspectives. We used four levels of normalized score for each of the four BSC perspectives. Based on these levels, a full factorial design was used to identify the parameters for each experiment. Table 5.20 illustrates the normalized scores used at each level for each perspective. Based on these levels, the full experiment design consisted of 256 experiments. A full experiment design was chosen because simulation execution time is not a major constraint. A list containing the details of each of the 256 experiments is presented in Appendix B. Minitab release 14 (Carver, 2003 and Ryan et. al., 2005) was used to generate the data points for the full factorial experiment design and to analyze experminet result data.

Table 5.20 Experiment Design for Regression Model

	Level 1	Level 2	Level 3	Level 4
Financial	0.3	0.5	0.7	0.9
Customer	0.3	0.5	0.7	0.9
Internal Processes	0.3	0.5	0.7	0.9
Learning and Growth	0.3	0.5	0.7	0.9

After identifying the list of experiments, they were fed to the simulation model. The simulation of each experiment produced a single output, which is net present value. Table 5.21 illustrate a sample output for 5 experiments. A full list of the experiment output is presented in Appendix C.

Table 5.21 Sample Experiment Output

	Financial	Customer	Internal Process	Learning and Growth	NPV
1	0.3	0.5	0.9	0.9	5.311
2	0.9	0.7	0.9	0.9	5.653
3	0.7	0.3	0.3	0.9	4.837
4	0.9	0.9	0.3	0.7	4.505
5	0.5	0.7	0.9	0.3	3.726

The 256 data points were entered in Minitab. The regression feature of Minitab was used to create a regression model between the four perspectives and NPV. The resulting regression equation is shown in Eqauation 22.

$$\mathrm{NPV} = 1.02\,\mathrm{F} + 1.09\,\mathrm{C} + 1.48\,\mathrm{I} + 3.48\,\mathrm{L} \quad \text{Equation 22.}$$

The above regression model has an r^2 value of 0.995, indicating high and acceptable appropriateness of the model. The detailed output of Minitab is shown in Appendix D for reference.

The above model illustrate an alternate evaluation criteria for balanced scorecard analysis. The coefficients of the regression model above can be normalized and used as weights for the balanced score card. Table 5.22 shows the weights of each perspective reached by normalizing the regression model above. The weights are definitely influenced by the experiment setup, mainly the parameters used for each of the cause effect dimensions of the STSM. However, the approach shows an alternate approach to assign weights to the balanced scorecard.

Table 5.22 Assigning BSC weights based on simulation results

Perspective	**Weight**
Financial	14.4%
Internal Processes	15.4%
Customer	20.9%
Learning and Growth	49.2%

CHAPTER 6

DISCUSSIONS AND CONCLUSIONS

6.1. Introduction

The previous chapters outlined the literature background, research problem, and the tools introduced in this research to address the research problem. We also demonstrated the usage of the proposed framework by using a simulated case study.

6.2. Identifying The Dimensions of Cause Effect Relationship

In this research, we proposed quantifying the cause effect relationship between BSC objectives using three dimensions. These dimensions are: quantity, time-phase and uncertainty. We also demonstrated the usage of the framework using a model and model data generated as part of this research tasks. The concept of quantifying the cause effect relationship is new, and was demonstrated in this research by generating data that is based on reasonable assumption. In this section, we discuss identifying the values of the three dimensions. We also discuss the practicality and feasibility of identifying the values of the cause effect relationship.

6.2.1. Procedures to quantify cause effect dimension

As mentioned earlier, we assumed reasonable values to quantify the cause effect relationship in this research. The exercise of identifying the cause effect relationships in real-world scenario would be complex, as multiple consideration would be required. The values of the cause effect relationships can be identified by analyzing existing internal and external data. Process analysis, and managerial judgment can also guide identifying the values of STSM cause effect dimensions.

By design, strategy maps hypothesize a cause effect relationship between multiple objectives. The analysis of internal and external data can provide guidance into quantifying the cause effect relationship. Ittner et. al. (2003) suggested that cause-effect relationships should be validated to achieve a successful performance management implementation. The additional step of data and process analysis adds complexity to the proposed framework. However, this level is complexity was suggested by previous researchers such as Ittner et. al. (2003), who emphasized the importance of analyzing data and processes to realize desired value from performance management system implementation.

6.2.2. Validity of Assumptions

The validity of the conclusions reached by following the proposed methodology depends on input assumptions. These input assumptions are the values of the STSM dimensions. In this section we discuss this risk. The following considerations are used to mitigate the risk of using inaccurate estimates.

1. The exercise of identifying the values of the cause-effect relationship facilitates and stimulates further analysis of the hypothesized cause-effect relationship. This analysis may reveal other important factors that should be considered in the strategy map. The analysis may also suggest that such relationship does not exist. We suggest that this exercise may result in a better qualitative strategy map, due to the additional data and process analysis.
2. The uncertainty dimension can be relaxed to address any concerns about the accuracy of the quantity and time-phase dimension values. For example, we consider the objective of employee training resulting in improving product innovation. Data may not exist to support quantifying the cause effect relationship, and the only available option was a human judgment of 20% within a year. Since the confidence in this estimate is not high,

we can increase the uncertainty dimension of cause effect relationship. Therefore we build the STSM with 5 – 50%, i.e. improving employee training will improve product innovation somewhere between 5 to 50%. Increasing the uncertainty dimension will cause simulation results to be inconclusive. When the variability is high, the resulting confidence intervals will be wider, and different options will be statistically indifferent. Increasing the uncertainty dimension, may impede the ability to reach conclusions, however, it allows avoiding making wrong conclusions.

3. The iterative nature of the proposed framework allows refining the values of STSM dimensions. As time progresses, the hypothesized values of the STSM dimensions are tested and adjusted respectively. As the time progresses, the feedback from actual values will allow refining the STSM. Davenport (2006) illustrated how data analysis can improve competitiveness by allowing enterprises to adjust their performance based on data analysis.

6.3. Process Orientation vs Results Orientation

In the previous chapter, simulation results showed that actual performance measures will vary according to the inherent variability modeled in the uncertainty dimension of the STSM. The variability shows that achieving targets does not depend on execution, but on the variability of the system itself. The results also showed that decisions and conclusions should not be made based on the absolute value of measures. Variability should be considered when making any decisions. For example, if the value of a specific metric is improving over time (e.g. last three months), a conclusion that the process is improving may not be statistically accurate. Statistical analysis should be used to identify whether the difference between any two values is significant.

The use of metrics and targets in employee compensation adds another level of complexity. Employee performance appraisal should include measurable and attainable measures. Individual measures are cascaded from top level balanced scorecard. These measures are intended to measure the performance of the BSC objective. A dilemma would rise from this situation. If individual measure capture the system variability, then employees will not be able to control their destiny. On the other hand, measures can be tailored so that the outcome is under individual's control. In this case, there is a risk of measuring metrics that do not contribute into the strategic direction. The cause effect relationship between such metrics and other objectives on the strategy map may not exist.

Figure 6-1 illustrates an hybrid approach combining both process-orientation and results orientation. During strategic planning process, the planning process follows a top down approach. Management formulate the strategy by focusing on identifying the objective that will allow achieving the ultimate goal of increasing shareholders value. The strategy is modeled using stochastic timed strategy maps (STSM). Strategy formulation and tradeoff analysis can be achieved by simulating the balanced scorecard as illustrated in the previous chapter. Once the strategy is implemented, actual performance is a result of executing the transformation processes. The transformation processes are the processes that turn human capital (learning and growth perspective) into business process excellence (internal process perspective), and so forth with the other perspectives. Management attention and focus during execution should be directed towards improving the efficiency of transforming the balanced scorecard objective across the strategy map.

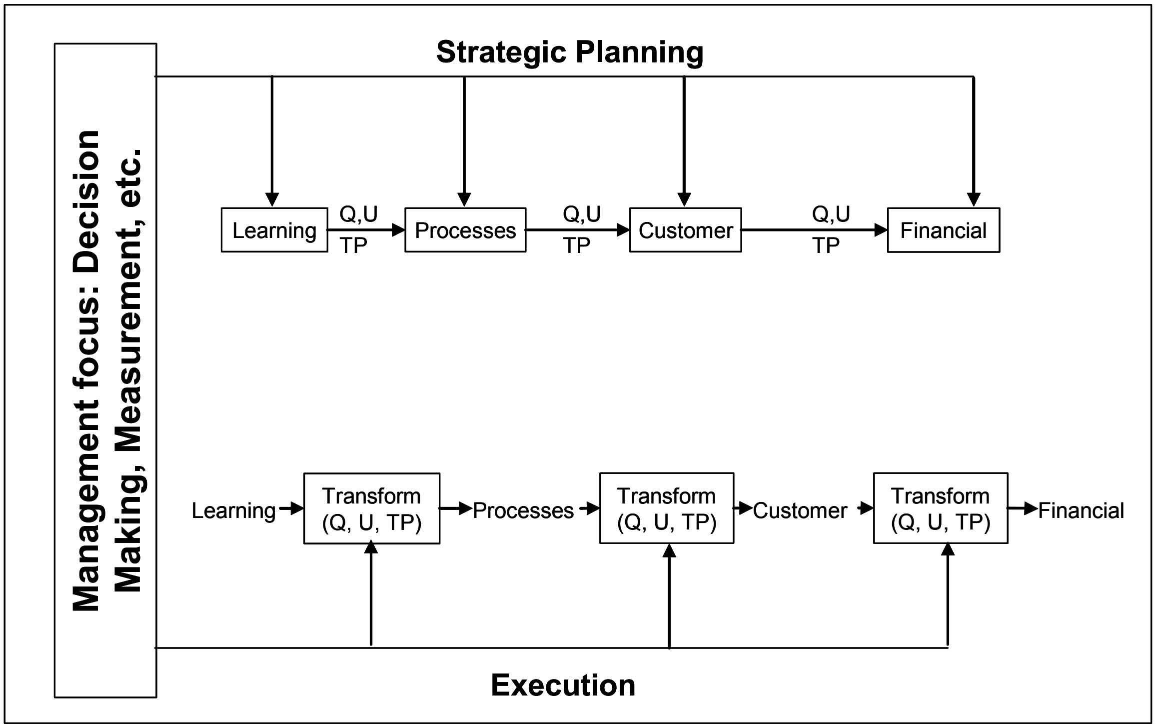


Figure 6-1 Combining Results Orientation and Processes Orientation

6.4. Research Contribution

In this research we identified some limitations in the literature, and introduced new approaches and techniques to address them. The limitations in the balanced scorecard literature and industry are:

1. The cause effect relationships on strategy maps are qualitative.
2. There is room to improve multi-objective decision analysis.
3. The current literature and practical BSC implementations does not address uncertainty.

The contribution of this research can be analyzed from multiple angles: tools, frameworks and solutions.

From a tool perspective, we introduced two tools in this research. The first tool is Stochastic Timed Strategy Maps (STSM). Stochastic Timed Strategy Maps allow quantifying the cause effect relationship with three dimensions; quantity, time-phase and uncertainty. STSM allow analytical formulation strategy. In addition, STSM formulation will facilitate building strategy maps by marinating the focus on cause effect relationship. The additional analysis required to identify the cause-effect dimensions should help refining and improving the strategy map, balanced scorecard and associated objectives.

The second tool is balanced scorecard simulation. BSC simulation allows utilizing STSM to estimate future financial performance. Future financial performance can be used as alternate evaluation criteria, which provides different results than traditional BSC trade-off analysis. In addition, BSC simulation allows analyzing and understanding the effect of uncertainty as modeled in STSM.

This research also contributed into trade-off analysis within the performance management body of knowledge. First, the research provided a methodology to bridge the gap between financial and operational performance measures. The research provided the methodology to transform non-financial measures into predicted future financial measures. The research shows that trade-offs between measures can be transformed into time-phase trade-offs. The analytical tools facilitate short and long term tradeoff analysis, which showed different and potentially better decisions when compared with decisions made under traditional tradeoff analysis.

6.5. Future Research

This research has provided a new performance management framework. The framework is still in early stages, and at this point is mainly a theoretical one. Future research building on this framework can take either a theoretical or practical flavor. Practical future research would focus on validating the framework. Theoretical future research would focus on relaxing the assumptions assumed in this research. We find the following research direction intriguing, and believe they would enhance the proposed framework.

1. Industry application of the proposed performance management system. Perhaps this the most intriguing future research direction. Real world implementation will add practical validation into the theoretical application. In addition, we expect some unknown factors to arise in a real know implementation. Such factors will help refine the proposed framework.
2. This research has assumed one decision maker, as we focused on the top level balanced scorecard. Once the balanced scorecard is cascaded through the enterprise, multiple decision makers will be involved. The use of game theory may be appropriate. Morton (1983) and Michael et. al. (2006) illustrate that game theory is the generalization of decision analysis with more than one player. The consideration of multiple players (decision makers) adds another level of trade-off and adds to the complexity of the decision analysis problem.
3. Extending the framework to non-profit organizations. The framework relies on the ability to transform multiple objectives into a single time phased financial measure. Non profit organizations have other objectives, which may not be transformed into a single objective. Additional mathematical formulation will be needed to provide trade-off analysis for non profit organizations.
4. Expanding the framework by combining processes improvement methodologies such as six sigma and TQM may add to the value of this framework. In this research, we laid some foundation into this research direction by identifying the importance of process improvement, and by pointing that variability should be

expected in the end results. If such variability exceeds targets or desired consistency levels, then process improvement efforts are required.

APPENDIX A

EXCEL VBA MACRO

1. Simulate Module

The Simulate module is designed to calculate the values for each objective at a specific time period. The Visual Basic for Applications (VBA) code is detailed below.

```
Sub Simulate()



' Macro1 Macro
' Macro recorded 1/7/2006 by amr
'
'***********************************
' Constants
'************************************
' Rows for different measures
  N1row = 3
  F1row = 5
  F2row = 6
  F3row = 7
  C1row = 8
  C2row = 9
  C3row = 10
  C4row = 11
  I1row = 12
  I2row = 13
  I3row = 14
  I4row = 15
  P1row = 16
  P2row = 17
  P3row = 18
  P4row = 19

' Columns for time period
T0 = "C"
T1 = "D"
T2 = "E"
T3 = "F"
T4 = "G"
T5 = "H"
T6 = "I"
T7 = "J"
T8 = "K"
T9 = "L"
T10 = "M"
' Effect between Metrics
I1P1 = "L17"
I1P2 = "L18"
I1P3 = "L19"
I1P4 = "L20"

I2P1 = "M17"
```

```
I2P2 = "M18"
I2P3 = "M19"
I2P4 = "M20"

I3P1 = "N17"
I3P2 = "N18"
I3P3 = "N19"
I3P4 = "N20"

I4P1 = "O17"
I4P2 = "O18"
I4P3 = "O19"
I4P4 = "O20"


C1I1 = "H13"
C1I2 = "H14"
C1I3 = "H15"
C1I4 = "H16"

C2I1 = "I13"
C2I2 = "I14"
C2I3 = "I15"
C2I4 = "I16"

C3I1 = "J13"
C3I2 = "J14"
C3I3 = "J15"
C3I4 = "J16"

C4I1 = "K13"
C4I2 = "K14"
C4I3 = "K15"
C4I4 = "K16"


F1C1 = "E9"
F1C2 = "E10"
F1C3 = "E11"
F1C4 = "E12"

F2C1 = "F9"
F2C2 = "F10"
F2C3 = "F11"
F2C4 = "F12"

F3C1 = "G9"
F3C2 = "G10"
F3C3 = "G11"
F3C4 = "G12"

'***************************************************************
'Do NonthingImpact
'***************************************************************
  F1_Do_Nothing = 5
  F2_Do_Nothing = 6
```

```
  F3_Do_Nothing = 7
  C1_Do_Nothing = 8
  C2_Do_Nothing = 9
  C3_Do_Nothing = 10
  C4_Do_Nothing = 11
  I1_Do_Nothing = 12
  I2_Do_Nothing = 13
  I3_Do_Nothing = 14
  I4_Do_Nothing = 15
  P1_do_nothing = 16
  P2_do_nothing = 17
  P3_do_nothing = 18
  P4_Do_Nothing = 19



  Sheets("Model").Select
'**********************************************************************************************************
'Internal Process Perspective Calculations
'**********************************************************************************************************
  cell = T1 & I1row
  Range(cell).Select
  For i = 1 To 10
    ActiveCell.FormulaR1C1 = cell_formula(4, I1P1, I1P2, I1P3, I1P4, I1_Do_Nothing)
    ActiveCell.Offset(0, 1).Select
  Next i

  cell = T1 & I2row
  Range(cell).Select
  For i = 1 To 10
      ActiveCell.FormulaR1C1 = cell_formula(3, I2P1, I2P2, I2P3, I2P4, I2_Do_Nothing)
      ActiveCell.Offset(0, 1).Select
  Next i

  cell = T1 & I3row
  Range(cell).Select
  For i = 1 To 10
      ActiveCell.FormulaR1C1 = cell_formula(2, I3P1, I3P2, I3P3, I3P4, I3_Do_Nothing)
      ActiveCell.Offset(0, 1).Select
  Next i

  cell = T1 & I4row
  Range(cell).Select
  For i = 1 To 10
      ActiveCell.FormulaR1C1 = cell_formula(1, I4P1, I4P2, I4P3, I4P4, I4_Do_Nothing)
      ActiveCell.Offset(0, 1).Select
  Next i
'**********************************************************************************************************
'Customer Perspective Calculations
'**********************************************************************************************************
  cell = T1 & C1row
  Range(cell).Select
  For i = 1 To 10
    ActiveCell.FormulaR1C1 = cell_formula(4, C1I1, C1I2, C1I3, C1I4, C1_Do_Nothing)
    ActiveCell.Offset(0, 1).Select
  Next i
```

```
  cell = T1 & C2row
  Range(cell).Select
  For i = 1 To 10
      ActiveCell.FormulaR1C1 = cell_formula(3, C2I1, C2I2, C2I3, C2I4, C2_Do_Nothing)
      ActiveCell.Offset(0, 1).Select
  Next i

  cell = T1 & C3row
  Range(cell).Select
  For i = 1 To 10
      ActiveCell.FormulaR1C1 = cell_formula(2, C3I1, C3I2, C3I3, C3I4, C3_Do_Nothing)
      ActiveCell.Offset(0, 1).Select
  Next i

  cell = T1 & C4row
  Range(cell).Select
  For i = 1 To 10
      ActiveCell.FormulaR1C1 = cell_formula(1, C4I1, C4I2, C4I3, C4I4, C4_Do_Nothing)
      ActiveCell.Offset(0, 1).Select
  Next i
'**************************************************************************************************
'Financial Perspective Calculations
'**************************************************************************************************
  cell = T1 & F1row
  Range(cell).Select
  For i = 1 To 10
    ActiveCell.FormulaR1C1 = cell_formula(4, F1C1, F1C2, F1C3, F1C4, F1_Do_Nothing)
    ActiveCell.Offset(0, 1).Select
  Next i

  cell = T1 & F2row
  Range(cell).Select
  For i = 1 To 10
    ActiveCell.FormulaR1C1 = cell_formula(4, F2C1, F2C2, F2C3, F2C4, F2_Do_Nothing)
    ActiveCell.Offset(0, 1).Select
  Next i

 cell = T1 & F3row
  Range(cell).Select
  For i = 1 To 10
    ActiveCell.FormulaR1C1 = cell_formula(4, F3C1, F3C2, F3C3, F3C4, F3_Do_Nothing)
    ActiveCell.Offset(0, 1).Select
  Next i


End Sub
  Function cell_value(cell) As Double
  cell_value = Range(cell).Formula
  End Function
  Function random_range(A, B) As Double
  random_range = (A - A * B / 2) + Rnd() * A * B
  End Function

  Function random_effect(effect) As Double
  A = cell_value("Quantity!" & effect)
```

```
  B = cell_value("Uncertainity!" & effect)
  random_effect = random_range(A, B)
  End Function

  Function timed_effect(A, effect) As String
  If IsNull(effect) = True Then GoTo end1
  timed_lag = "R[" & A & "]C[" & cell_value("Time!" & effect) & "]"
  If IsNumeric(ActiveCell.Offset(A, cell_value("Time!" & effect)).Value) = True Then
  timed_effect = timed_lag & "*" & random_effect(effect)
  Else
  timed_effect = 0
  End If
end1:   End Function
  Function Do_No_Impact(Metric) As Double
  Do_No_Impact = Range("Do_Nothing!C" & Metric).Formula
  End Function

  Function cell_formula(A, effect1, effect2, effect3, effect4, Do_Nothing)
  cell_formula = _
     "= RC[-1] *" & Do_No_Impact(Do_Nothing) & "  + " _
   & timed_effect(A, effect1) & " +" _
   & timed_effect(A + 1, effect2) & " +" _
   & timed_effect(A + 2, effect3) & " +" _
   & timed_effect(A + 3, effect4)

  End Function
```

2. Run Experiment Module

The “Run Experiment” module is designed to manage simulation repetitions within each simulation experiment. The VBA code for “Run Experiment” module is detailed below.

```
Sub Run_Experiment()
'
' Macro2 Macro
' Macro recorded 1/8/2006 by amr
'

'
   Application.Visible = False
   Application.Interactive = False
   Range("Parameters!C29:Parameters!E50").Formula = Null
   Range("Parameters!S29:Parameters!T50").Formula = Null
   Sheets("Experiment_Results").Select
   Cells.Clear
   Range("C5").Select
For Scen = 1 To Range("Parameters!C4").Value

   Range("Parameters!C" & Scen + 28).Formula = "Scenario " & Scen
   Range("Parameters!D" & Scen + 28).Formula = Time$
   Sheets("Model").Select
   Range("C5").Select
   ActiveCell.FormulaR1C1 = "=Parameters!R[-1]C[" & Scen + 4 & "]"
```

```
        Range("C5").Select
        Selection.Copy
        Range("C6:C19").Select
        Selection.PasteSpecial Paste:=xlPasteFormulas, Operation:=xlNone, _
        SkipBlanks:=False, Transpose:=False
        Application.CutCopyMode = False

        Range("Run_Results!C5:M30000").Formula = Null   ' Clear previous net income
        Range("Run_Results!O6:X30000").Formula = Null   ' Clear previous


        For i = 1 To Range("Parameters!C3").Value

        Call Simulate
        Sheets("Model").Select
        Range("C3:M3").Select
        Selection.Copy
        Sheets("Run_Results").Select
        Range("C" & 4 + i).Select
        Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
          :=False, Transpose:=False
        Range("Y" & 4 + i).Formula = "=NPV(" & Range("Parameters!C5").Value & ",Run_Results!O"
& 4 + i & ":X" & 4 + i & ")"
        Next i
        Range("O5:X" & 4 + Range("Parameters!C3").Value).Select
        Application.CutCopyMode = False
        Selection.FillDown

      '   Fill scenario results
        Sheets("Experiment_Results").Select
        STARTCELL = "C" & 3 + (Scen - 1) * 8
        Range(STARTCELL).Select
        ActiveCell.Formula = "Scenario " & Scen
        ActiveCell.Offset(2, -1).Select
        ActiveCell.FormulaR1C1 = "Time"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "Average"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "Min"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "Max"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.FormulaR1C1 = "STD"
        Range(STARTCELL).Select
        ActiveCell.Offset(2, 0).Select
        ActiveCell.Formula = "=Run_Results!D4"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.Formula = "=AVERAGE(Run_Results!O5:O" & 4 + Range("Parameters!C3").Value
& ")"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.Formula = "=MIN(Run_Results!O5:O" & 4 + Range("Parameters!C3").Value & ")"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.Formula = "=MAX(Run_Results!O5:O" & 4 + Range("Parameters!C3").Value & ")"
        ActiveCell.Offset(1, 0).Select
        ActiveCell.Formula = "=STDEV(Run_Results!O5:O" & 4 + Range("Parameters!C3").Value &
")"
```

```
Range("C" & (3 + (Scen - 1) * 8) + 2 & ":L" & (3 + (Scen - 1) * 8) + 6).FillRight

Range(STARTCELL).Select
Selection.Font.Bold = True
Range("B" & (3 + (Scen - 1) * 8) + 2 & ":L" & (3 + (Scen - 1) * 8) + 6).Select
Selection.Borders(xlDiagonalDown).LineStyle = xlNone
Selection.Borders(xlDiagonalUp).LineStyle = xlNone
With Selection.Borders(xlEdgeLeft)
    .LineStyle = xlContinuous
    .Weight = xlThick
    .ColorIndex = xlAutomatic
End With
With Selection.Borders(xlEdgeTop)
    .LineStyle = xlContinuous
    .Weight = xlThick
    .ColorIndex = xlAutomatic
End With
With Selection.Borders(xlEdgeBottom)
    .LineStyle = xlContinuous
    .Weight = xlThick
    .ColorIndex = xlAutomatic
End With
With Selection.Borders(xlEdgeRight)
    .LineStyle = xlContinuous
    .Weight = xlThick
    .ColorIndex = xlAutomatic
End With
With Selection.Borders(xlInsideVertical)
    .LineStyle = xlContinuous
    .Weight = xlThin
    .ColorIndex = xlAutomatic
End With
With Selection.Borders(xlInsideHorizontal)
    .LineStyle = xlContinuous
    .Weight = xlThin
    .ColorIndex = xlAutomatic
End With
Selection.Copy
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False

Range("B" & (3 + (Scen - 1) * 8) + 2 & ":L" & (3 + (Scen - 1) * 8) + 2).Select
Selection.Borders(xlDiagonalDown).LineStyle = xlNone
Selection.Borders(xlDiagonalUp).LineStyle = xlNone
With Selection.Borders(xlEdgeLeft)
    .LineStyle = xlContinuous
    .Weight = xlThick
    .ColorIndex = xlAutomatic
End With
With Selection.Borders(xlEdgeTop)
    .LineStyle = xlContinuous
    .Weight = xlThick
    .ColorIndex = xlAutomatic
End With
With Selection.Borders(xlEdgeBottom)
    .LineStyle = xlContinuous
```

```
        .Weight = xlMedium
        .ColorIndex = xlAutomatic
    End With
    With Selection.Borders(xlEdgeRight)
        .LineStyle = xlContinuous
        .Weight = xlThick
        .ColorIndex = xlAutomatic
    End With
    Selection.Borders(xlInsideVertical).LineStyle = xlNone
    With Selection.Interior
        .ColorIndex = 15
        .Pattern = xlSolid
    End With


    Range("Parameters!E" & Scen + 28).Formula = Time$

    Range("Run_Results!Y" & 5 + Range("Parameters!C3").Value).Formula = _
        "=Average(Y4:Y" & 4 + Range("Parameters!C3").Value & ")"

    Range("Run_Results!Y" & 6 + Range("Parameters!C3").Value).Formula = _
        "=Stdev(Y4:Y" & 4 + Range("Parameters!C3").Value & ")"

    Range("Parameters!S" & Scen + 28).Formula = Range("Run_Results!Y" & 5 +
Range("Parameters!C3").Value).Value
    Range("Parameters!T" & Scen + 28).Formula = Range("Run_Results!Y" & 6 +
Range("Parameters!C3").Value).Value

Next Scen


    Sheets("Experiment_Results").Select
    Range("C5").Select
    Application.Visible = True
    Application.Interactive = True

End Sub
```

3. STAT Analysis Module

The “STAT Analysis” module is used in the first phase of building the simulation model. The module was used to generate multiple experiments with different simulation repetitions. The module helps to identify the number of required simulation repetitions.

```
Sub Stat_Analysis()
'
' Macro3 Macro
' Macro recorded 1/14/2006 by amr
'

'
```

```
    Application.Visible = False
    Application.Interactive = False
For STAT = 2 To Range("sheet1!G25").Value
    Range("Parameters!C3").Formula = Range("sheet1!S" & STAT).Value
    Call Run_Experiment
    Sheets("Parameters").Select
    Range("S29:T38").Select
    Selection.Copy
    Sheets("Sheet1").Select
    Range("F" & 2 * STAT + 26).Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=True
    Range("E" & 2 * STAT + 26).Select
    Application.CutCopyMode = False
    ActiveCell.FormulaR1C1 = "NPV"
    Range("E" & 2 * STAT + 27).Select
    ActiveCell.FormulaR1C1 = "STDEV"
    Range("D" & 2 * STAT + 26).Select
    ActiveCell.FormulaR1C1 = Range("sheet1!S" & STAT).Value
    Range("D" & 3 * STAT + 26).Select
    ActiveWorkbook.Save
    ActiveWorkbook.SaveCopyAs   ("E:\Personal\research\SIM_RUNS\SIMRUN_"   &   STAT   &
".XLS")

Next STAT

    Application.Visible = True
    Application.Interactive = True
End Sub
```

APPENDIX B

DETAILS OF FACTORIAL ANALYSIS DESIGN

This Appendix include the list of values for each experiment of the full experiment design. For each experiment, the level used for each of the experiment objectives is shown below.

Experiment	F1	F2	F3	C1	C2	C3	C4	I1	I2	I3	I4	L1	L2	L3	L4
1	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
2	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
3	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
4	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
6	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
7	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
8	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
10	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
11	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
12	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
13	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
14	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
15	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
16	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
17	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
18	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
19	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
20	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
21	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
22	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
23	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
24	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
25	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
26	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
27	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
28	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
29	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
30	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
31	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
32	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
33	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
34	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
35	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
36	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
37	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7

38	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
39	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
40	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
41	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
42	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
43	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
44	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
45	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
46	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
47	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
48	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
49	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
50	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
51	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
52	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
53	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
54	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
55	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
56	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
57	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
58	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
59	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
60	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
61	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
62	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
63	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
64	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
65	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
66	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
67	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
68	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
69	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
70	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
71	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
72	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
73	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
74	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
75	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
76	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
77	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
78	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
79	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
80	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
81	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

82	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
83	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
84	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
85	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
86	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
87	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
88	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
90	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
91	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
92	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
93	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
94	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
95	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
96	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
97	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
98	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
99	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
100	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
101	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
102	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
103	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
104	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
105	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
106	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
107	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
108	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
109	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
110	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
111	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
112	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
113	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
114	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
115	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
116	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
117	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
118	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
119	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
120	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
121	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
122	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
123	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
124	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
125	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7

126	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
127	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
128	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
129	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
130	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
131	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
132	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
133	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
134	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
135	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
136	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
137	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
138	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
139	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
140	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
141	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
142	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
143	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
144	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
145	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
146	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
147	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
148	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
149	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
150	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
151	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
152	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
153	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
154	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
155	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
156	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
157	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
158	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
159	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
160	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
161	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
162	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
163	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
164	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
165	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
166	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
167	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
168	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
169	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3

170	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
171	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
172	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
173	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
174	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
175	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
176	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
177	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
178	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
179	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
180	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
181	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
182	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
183	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
184	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
185	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
186	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
187	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
188	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
189	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
190	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
191	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
192	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
193	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
194	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
195	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
196	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
197	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
198	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
199	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
200	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
201	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
202	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
203	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
204	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
205	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
206	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
207	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
208	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
209	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
210	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
211	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
212	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
213	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

214	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
215	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
216	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
217	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
218	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
219	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5
220	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
221	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
222	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
223	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
224	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
225	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
226	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
227	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
228	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3
229	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
230	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
231	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
232	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
233	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
234	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
235	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
236	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7
237	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
238	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9
239	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
240	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
241	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
242	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
243	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
244	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
245	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
246	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
247	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
248	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
249	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
250	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3
251	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
252	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.9	0.9	0.9	0.9
253	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9
254	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7
255	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
256	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

APPENDIX C

RESULTS OF EXPERIMENT FOR TRADE OFF ANALYSIS

The following table includes the results of each experiment used for trade off analysis.

StdOrder	RunOrder	PtType	Blocks	F	C	I	L	NPV
29	1	1	1	0.3	0.5	0.9	0.9	5.31128
175	2	1	1	0.9	0.7	0.9	0.9	5.65342
204	3	1	1	0.7	0.3	0.3	0.9	4.83698
7	4	1	1	0.9	0.9	0.3	0.7	4.50509
210	5	1	1	0.5	0.7	0.9	0.3	3.72643
152	6	1	1	0.9	0.5	0.9	0.3	3.78251
202	7	1	1	0.3	0.7	0.5	0.3	3.36609
49	8	1	1	0.3	0.5	0.9	0.7	4.61413
24	9	1	1	0.3	0.3	0.3	0.7	4.08217
125	10	1	1	0.3	0.5	0.3	0.3	3.13783
159	11	1	1	0.5	0.5	0.3	0.7	4.22569
182	12	1	1	0.5	0.3	0.5	0.7	4.29612
165	13	1	1	0.7	0.5	0.7	0.5	4.06734
92	14	1	1	0.3	0.7	0.3	0.5	3.72743
109	15	1	1	0.5	0.7	0.9	0.5	4.23190
142	16	1	1	0.7	0.3	0.3	0.5	3.70173
9	17	1	1	0.9	0.5	0.7	0.7	4.65328
145	18	1	1	0.3	0.5	0.9	0.3	3.58316
162	19	1	1	0.3	0.3	0.5	0.3	3.21248
25	20	1	1	0.9	0.5	0.9	0.7	4.82604
43	21	1	1	0.5	0.5	0.9	0.5	4.15186
96	22	1	1	0.9	0.7	0.7	0.9	5.41588
59	23	1	1	0.7	0.3	0.3	0.7	4.21268
124	24	1	1	0.5	0.9	0.7	0.9	5.36635
215	25	1	1	0.3	0.7	0.7	0.5	4.01603
214	26	1	1	0.3	0.5	0.3	0.9	4.79012
53	27	1	1	0.9	0.7	0.9	0.3	3.87495
86	28	1	1	0.5	0.3	0.9	0.9	5.28371
2	29	1	1	0.9	0.3	0.3	0.7	4.27337
34	30	1	1	0.9	0.5	0.9	0.5	4.29199
20	31	1	1	0.7	0.3	0.9	0.3	3.63105
6	32	1	1	0.5	0.9	0.5	0.7	4.52471
243	33	1	1	0.9	0.3	0.7	0.5	4.05892
97	34	1	1	0.5	0.5	0.7	0.5	4.00662
118	35	1	1	0.9	0.3	0.9	0.3	3.69929
3	36	1	1	0.3	0.5	0.3	0.5	3.64957
19	37	1	1	0.3	0.9	0.9	0.7	4.78304
141	38	1	1	0.5	0.9	0.9	0.5	4.31805
169	39	1	1	0.7	0.5	0.5	0.7	4.43425
248	40	1	1	0.5	0.3	0.3	0.3	3.12138
61	41	1	1	0.9	0.5	0.3	0.7	4.34789
240	42	1	1	0.7	0.3	0.7	0.3	3.48520
163	43	1	1	0.9	0.3	0.7	0.9	5.23707
114	44	1	1	0.5	0.5	0.3	0.3	3.20278
146	45	1	1	0.9	0.3	0.3	0.5	3.76716
234	46	1	1	0.7	0.9	0.5	0.5	4.07714
50	47	1	1	0.7	0.3	0.9	0.7	4.66752
249	48	1	1	0.5	0.7	0.9	0.9	5.47398
15	49	1	1	0.9	0.9	0.9	0.3	3.97757
205	50	1	1	0.9	0.7	0.7	0.5	4.22016

132	51	1	1	0.7	0.7	0.7	0.7	4.66527
186	52	1	1	0.5	0.9	0.9	0.9	5.59582
84	53	1	1	0.7	0.9	0.5	0.3	3.56809
174	54	1	1	0.5	0.7	0.5	0.3	3.42759
203	55	1	1	0.7	0.9	0.3	0.3	3.41986
32	56	1	1	0.9	0.5	0.7	0.9	5.32511
238	57	1	1	0.5	0.7	0.7	0.7	4.59828
63	58	1	1	0.3	0.5	0.7	0.9	5.12901
224	59	1	1	0.9	0.5	0.3	0.3	3.32965
107	60	1	1	0.3	0.9	0.3	0.9	4.94724
95	61	1	1	0.3	0.3	0.5	0.5	3.72073
219	62	1	1	0.7	0.7	0.7	0.5	4.14428
103	63	1	1	0.3	0.5	0.7	0.7	4.45964
164	64	1	1	0.7	0.7	0.5	0.9	5.16884
31	65	1	1	0.5	0.3	0.5	0.9	4.93071
131	66	1	1	0.3	0.5	0.7	0.5	3.94649
252	67	1	1	0.3	0.7	0.9	0.9	5.40903
52	68	1	1	0.7	0.9	0.9	0.3	3.88459
156	69	1	1	0.9	0.7	0.3	0.7	4.42358
21	70	1	1	0.5	0.7	0.7	0.3	3.57193
108	71	1	1	0.7	0.9	0.5	0.7	4.59004
78	72	1	1	0.9	0.9	0.7	0.5	4.31102
172	73	1	1	0.7	0.7	0.3	0.3	3.34374
254	74	1	1	0.3	0.9	0.5	0.3	3.43972
247	75	1	1	0.7	0.7	0.9	0.7	4.83522
5	76	1	1	0.3	0.5	0.5	0.9	4.95299
110	77	1	1	0.3	0.9	0.5	0.7	4.46555
149	78	1	1	0.9	0.7	0.5	0.9	5.23575
79	79	1	1	0.3	0.9	0.7	0.5	4.09349
236	80	1	1	0.9	0.9	0.9	0.5	4.49383
127	81	1	1	0.9	0.9	0.3	0.3	3.48772
171	82	1	1	0.7	0.7	0.9	0.9	5.56714
176	83	1	1	0.7	0.9	0.7	0.9	5.44122
193	84	1	1	0.9	0.9	0.5	0.3	3.64012
211	85	1	1	0.5	0.7	0.5	0.7	4.44414
140	86	1	1	0.7	0.7	0.3	0.5	3.85336
64	87	1	1	0.7	0.9	0.7	0.5	4.22493
14	88	1	1	0.7	0.7	0.9	0.5	4.30429
40	89	1	1	0.9	0.9	0.9	0.7	5.04236
111	90	1	1	0.3	0.3	0.9	0.3	3.50485
197	91	1	1	0.7	0.5	0.5	0.5	3.92417
242	92	1	1	0.9	0.9	0.7	0.3	3.80159
150	93	1	1	0.9	0.5	0.7	0.3	3.62783
73	94	1	1	0.3	0.9	0.5	0.5	3.95089
71	95	1	1	0.7	0.9	0.9	0.7	4.93922
72	96	1	1	0.7	0.9	0.7	0.3	3.72401
216	97	1	1	0.3	0.5	0.5	0.7	4.30798
119	98	1	1	0.9	0.9	0.3	0.5	3.99833
13	99	1	1	0.3	0.7	0.7	0.7	4.53671
223	100	1	1	0.3	0.7	0.5	0.7	4.38675
170	101	1	1	0.3	0.3	0.9	0.7	4.53516
194	102	1	1	0.5	0.7	0.9	0.7	4.76763
48	103	1	1	0.5	0.3	0.3	0.7	4.14749

228	104	1	1	0.9	0.3	0.5	0.5	3.90844
89	105	1	1	0.5	0.5	0.3	0.9	4.85104
33	106	1	1	0.5	0.9	0.7	0.3	3.65108
128	107	1	1	0.5	0.9	0.7	0.7	4.68181
218	108	1	1	0.3	0.9	0.7	0.3	3.58903
166	109	1	1	0.5	0.7	0.5	0.5	3.93477
104	110	1	1	0.3	0.7	0.9	0.7	4.69863
39	111	1	1	0.9	0.5	0.5	0.7	4.49944
55	112	1	1	0.7	0.7	0.3	0.9	4.99007
37	113	1	1	0.9	0.7	0.7	0.7	4.74281
51	114	1	1	0.3	0.7	0.5	0.9	5.03303
105	115	1	1	0.5	0.7	0.7	0.5	4.08177
200	116	1	1	0.5	0.5	0.9	0.9	5.38433
136	117	1	1	0.9	0.3	0.7	0.7	4.56824
81	118	1	1	0.5	0.5	0.3	0.5	3.71705
220	119	1	1	0.5	0.9	0.9	0.3	3.80501
158	120	1	1	0.9	0.3	0.3	0.9	4.90474
56	121	1	1	0.5	0.7	0.3	0.9	4.93382
1	122	1	1	0.3	0.3	0.5	0.7	4.23197
74	123	1	1	0.5	0.9	0.3	0.7	4.36814
38	124	1	1	0.7	0.5	0.7	0.7	4.58531
100	125	1	1	0.5	0.3	0.9	0.7	4.59326
208	126	1	1	0.7	0.9	0.7	0.7	4.75731
42	127	1	1	0.3	0.7	0.5	0.5	3.87314
77	128	1	1	0.9	0.3	0.5	0.7	4.42266
75	129	1	1	0.9	0.9	0.5	0.5	4.14925
93	130	1	1	0.3	0.3	0.9	0.5	4.01126
187	131	1	1	0.3	0.3	0.9	0.9	5.22116
185	132	1	1	0.7	0.9	0.3	0.9	5.07617
126	133	1	1	0.9	0.3	0.9	0.7	4.73094
181	134	1	1	0.3	0.3	0.3	0.5	3.57493
88	135	1	1	0.3	0.9	0.3	0.7	4.31608
209	136	1	1	0.7	0.7	0.7	0.3	3.63668
45	137	1	1	0.5	0.5	0.5	0.5	3.86414
148	138	1	1	0.3	0.9	0.3	0.5	3.80544
179	139	1	1	0.5	0.3	0.5	0.5	3.78314
190	140	1	1	0.7	0.3	0.7	0.9	5.18183
22	141	1	1	0.9	0.5	0.7	0.5	4.13760
35	142	1	1	0.5	0.3	0.9	0.5	4.07354
106	143	1	1	0.3	0.5	0.9	0.5	4.08485
213	144	1	1	0.9	0.9	0.7	0.7	4.83849
143	145	1	1	0.5	0.5	0.7	0.9	5.18778
151	146	1	1	0.9	0.7	0.9	0.7	4.92835
173	147	1	1	0.3	0.7	0.9	0.3	3.65979
137	148	1	1	0.9	0.5	0.3	0.5	3.84163
54	149	1	1	0.9	0.7	0.7	0.3	3.71228
23	150	1	1	0.5	0.5	0.7	0.3	3.49761
62	151	1	1	0.5	0.9	0.7	0.5	4.15969
101	152	1	1	0.7	0.5	0.7	0.9	5.25574
184	153	1	1	0.5	0.3	0.3	0.5	3.64003
245	154	1	1	0.3	0.3	0.7	0.7	4.38528
123	155	1	1	0.7	0.9	0.9	0.9	5.67919
155	156	1	1	0.5	0.3	0.5	0.3	3.27667

28	157	1	1	0.7	0.5	0.9	0.3	3.71277
198	158	1	1	0.7	0.5	0.7	0.3	3.56139
65	159	1	1	0.3	0.9	0.5	0.9	5.11159
192	160	1	1	0.7	0.5	0.3	0.9	4.91055
206	161	1	1	0.3	0.7	0.7	0.3	3.51023
102	162	1	1	0.5	0.3	0.7	0.7	4.44267
30	163	1	1	0.7	0.3	0.7	0.5	3.99006
115	164	1	1	0.3	0.9	0.9	0.3	3.73354
47	165	1	1	0.9	0.5	0.5	0.3	3.48053
229	166	1	1	0.7	0.7	0.7	0.9	5.35445
11	167	1	1	0.3	0.7	0.3	0.7	4.23254
138	168	1	1	0.5	0.3	0.7	0.5	3.92871
232	169	1	1	0.5	0.9	0.5	0.3	3.50211
121	170	1	1	0.9	0.5	0.5	0.9	5.15099
41	171	1	1	0.7	0.7	0.5	0.3	3.49132
256	172	1	1	0.3	0.9	0.7	0.7	4.61826
82	173	1	1	0.5	0.9	0.5	0.9	5.18141
17	174	1	1	0.7	0.7	0.3	0.7	4.36087
235	175	1	1	0.7	0.5	0.9	0.5	4.21792
18	176	1	1	0.5	0.5	0.7	0.7	4.51748
144	177	1	1	0.5	0.9	0.9	0.7	4.85792
189	178	1	1	0.3	0.7	0.3	0.9	4.86845
147	179	1	1	0.3	0.7	0.9	0.5	4.16481
57	180	1	1	0.9	0.3	0.7	0.3	3.54845
58	181	1	1	0.5	0.9	0.3	0.3	3.35619
90	182	1	1	0.3	0.5	0.5	0.3	3.28584
139	183	1	1	0.3	0.3	0.7	0.5	3.86640
46	184	1	1	0.3	0.9	0.9	0.9	5.51378
133	185	1	1	0.7	0.5	0.3	0.5	3.77581
68	186	1	1	0.7	0.9	0.3	0.7	4.43974
199	187	1	1	0.9	0.9	0.5	0.7	4.66747
8	188	1	1	0.7	0.9	0.9	0.5	4.39213
12	189	1	1	0.9	0.7	0.3	0.3	3.40853
255	190	1	1	0.7	0.3	0.3	0.3	3.18438
98	191	1	1	0.5	0.7	0.3	0.5	3.79545
154	192	1	1	0.5	0.5	0.9	0.7	4.67712
4	193	1	1	0.9	0.7	0.9	0.5	4.38236
196	194	1	1	0.5	0.3	0.7	0.9	5.10858
168	195	1	1	0.5	0.3	0.9	0.3	3.57013
16	196	1	1	0.3	0.5	0.3	0.7	4.16036
244	197	1	1	0.3	0.9	0.9	0.5	4.24403
225	198	1	1	0.9	0.9	0.7	0.9	5.53269
253	199	1	1	0.7	0.3	0.9	0.5	4.14046
66	200	1	1	0.9	0.7	0.3	0.9	5.06792
188	201	1	1	0.9	0.3	0.5	0.3	3.40119
120	202	1	1	0.3	0.3	0.7	0.9	5.04064
85	203	1	1	0.7	0.5	0.3	0.3	3.26495
94	204	1	1	0.9	0.7	0.5	0.7	4.57382
157	205	1	1	0.3	0.3	0.3	0.3	3.05616
241	206	1	1	0.9	0.7	0.5	0.5	4.06842
70	207	1	1	0.3	0.7	0.3	0.3	3.21789
161	208	1	1	0.5	0.7	0.5	0.9	5.09383
135	209	1	1	0.7	0.7	0.5	0.7	4.50465

60	210	1	1	0.9	0.9	0.3	0.9	5.13762
112	211	1	1	0.5	0.9	0.3	0.9	5.00984
83	212	1	1	0.5	0.5	0.5	0.7	4.36841
177	213	1	1	0.3	0.9	0.3	0.3	3.29471
231	214	1	1	0.3	0.3	0.7	0.3	3.35920
230	215	1	1	0.5	0.5	0.5	0.9	5.01239
160	216	1	1	0.9	0.5	0.9	0.9	5.53430
44	217	1	1	0.7	0.3	0.9	0.9	5.36426
246	218	1	1	0.5	0.5	0.9	0.3	3.64424
130	219	1	1	0.9	0.3	0.9	0.5	4.20436
251	220	1	1	0.9	0.3	0.3	0.3	3.25001
201	221	1	1	0.5	0.7	0.7	0.9	5.27038
195	222	1	1	0.7	0.5	0.5	0.9	5.07572
26	223	1	1	0.9	0.5	0.3	0.9	4.97793
226	224	1	1	0.3	0.5	0.5	0.5	3.80152
233	225	1	1	0.7	0.9	0.3	0.5	3.93084
69	226	1	1	0.5	0.7	0.3	0.3	3.27965
221	227	1	1	0.7	0.5	0.5	0.3	3.41515
80	228	1	1	0.7	0.7	0.9	0.3	3.79530
227	229	1	1	0.3	0.3	0.5	0.9	4.87454
183	230	1	1	0.3	0.3	0.3	0.9	4.70152
207	231	1	1	0.7	0.3	0.5	0.7	4.35629
99	232	1	1	0.5	0.5	0.5	0.3	3.35305
250	233	1	1	0.7	0.9	0.5	0.9	5.24841
10	234	1	1	0.9	0.9	0.9	0.9	5.79230
222	235	1	1	0.3	0.5	0.7	0.3	3.43492
167	236	1	1	0.7	0.5	0.9	0.7	4.74982
116	237	1	1	0.9	0.7	0.5	0.3	3.55818
67	238	1	1	0.5	0.3	0.3	0.9	4.77035
129	239	1	1	0.3	0.7	0.7	0.9	5.20158
87	240	1	1	0.7	0.5	0.3	0.7	4.28580
134	241	1	1	0.7	0.3	0.7	0.7	4.50742
76	242	1	1	0.7	0.3	0.5	0.5	3.85165
217	243	1	1	0.5	0.3	0.7	0.3	3.42373
117	244	1	1	0.9	0.7	0.3	0.5	3.92188
153	245	1	1	0.9	0.5	0.5	0.5	3.98722
27	246	1	1	0.7	0.5	0.9	0.9	5.44801
91	247	1	1	0.9	0.9	0.5	0.9	5.32278
113	248	1	1	0.7	0.3	0.5	0.9	5.00014
180	249	1	1	0.9	0.3	0.9	0.9	5.43098
191	250	1	1	0.7	0.3	0.5	0.3	3.33829
178	251	1	1	0.5	0.9	0.3	0.5	3.86704
239	252	1	1	0.9	0.3	0.5	0.9	5.06323
212	253	1	1	0.3	0.9	0.7	0.9	5.29824
36	254	1	1	0.5	0.7	0.3	0.7	4.30395
237	255	1	1	0.7	0.7	0.5	0.5	4.00305
122	256	1	1	0.5	0.9	0.5	0.5	4.00941

APPENDIX D

MINITAB OUTPUT

The follwing is the output of the regression feature from MINITAB release 14.

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The regression equation is
NPV = 1.69 + 0.339 F + 0.413 C + 0.801 I + 2.80 L


Predictor     Coef  SE Coef       T      P  VIF
Constant   1.69357  0.01627  104.09  0.000
F          0.33866  0.01333   25.41  0.000  1.0
C          0.41283  0.01333   30.97  0.000  1.0
I          0.80122  0.01333   60.11  0.000  1.0
L          2.79962  0.01333  210.04  0.000  1.0


S = 0.0476868   R-Sq = 99.5%   R-Sq(adj) = 99.5%

PRESS = 0.594783   R-Sq(pred) = 99.47%


Analysis of Variance

Source           DF       SS      MS         F      P
Regression        4  112.192  28.048  12333.99  0.000
Residual Error  251    0.571   0.002
Total           255  112.762


No replicates.
Cannot do pure error test.


Source  DF   Seq SS
F        1    1.468
C        1    2.182
I        1    8.217
L        1  100.325


Obs      F      NPV      Fit   SE Fit  Residual  St Resid
  1  0.300  5.31128  5.24234  0.00766   0.06894      1.46
  2  0.900  5.65342  5.52810  0.00766   0.12532      2.66R
  3  0.700  4.83698  4.81451  0.00766   0.02248      0.48
  4  0.900  4.50509  4.57001  0.00766  -0.06493     -1.38
  5  0.500  3.72643  3.71287  0.00666   0.01356      0.29
  6  0.900  3.78251  3.76576  0.00766   0.01674      0.36
  7  0.300  3.36609  3.32465  0.00666   0.04144      0.88
  8  0.300  4.61413  4.68242  0.00666  -0.06829     -1.45
  9  0.300  4.08217  4.11912  0.00766  -0.03695     -0.78
 10  0.300  3.13783  3.08184  0.00766   0.05599      1.19
 11  0.500  4.22569  4.26942  0.00550  -0.04372     -0.92
 12  0.500  4.29612  4.34710  0.00550  -0.05098     -1.08
 13  0.700  4.06734  4.09771  0.00400  -0.03037     -0.64
 14  0.300  3.72743  3.72433  0.00666   0.00310      0.07
 15  0.500  4.23190  4.27279  0.00550  -0.04089     -0.86
 16  0.700  3.70173  3.69466  0.00666   0.00707      0.15
 17  0.900  4.65328  4.72537  0.00550  -0.07209     -1.52
 18  0.300  3.58316  3.56257  0.00766   0.02059      0.44
 19  0.300  3.21248  3.15951  0.00766   0.05297      1.13
 20  0.900  4.82604  4.88561  0.00666  -0.05957     -1.26
 21  0.500  4.15186  4.19023  0.00550  -0.03837     -0.81
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22  0.900  5.41588  5.36786  0.00666   0.04802      1.02
23  0.700  4.21268  4.25458  0.00666  -0.04190     -0.89
24  0.500  5.36635  5.31496  0.00666   0.05139      1.09
25  0.300  4.01603  4.04482  0.00550  -0.02879     -0.61
26  0.300  4.79012  4.76161  0.00766   0.02851      0.61
27  0.900  3.87495  3.84833  0.00766   0.02662      0.57
28  0.500  5.28371  5.22751  0.00766   0.05620      1.19
29  0.900  4.27337  4.32231  0.00766  -0.04894     -1.04
30  0.900  4.29199  4.32569  0.00666  -0.03370     -0.71
31  0.700  3.63105  3.61547  0.00766   0.01559      0.33
32  0.500  4.52471  4.59479  0.00550  -0.07009     -1.48
33  0.900  4.05892  4.08288  0.00666  -0.02396     -0.51
34  0.500  4.00662  4.02998  0.00400  -0.02336     -0.49
35  0.900  3.69929  3.68320  0.00853   0.01609      0.34
36  0.300  3.64957  3.64176  0.00666   0.00781      0.17
37  0.300  4.78304  4.84755  0.00766  -0.06451     -1.37
38  0.500  4.31805  4.35536  0.00666  -0.03731     -0.79
39  0.700  4.43425  4.49739  0.00400  -0.06314     -1.33
40  0.500  3.12138  3.06700  0.00766   0.05438      1.16
41  0.900  4.34789  4.40488  0.00666  -0.05699     -1.21
42  0.700  3.48520  3.45522  0.00666   0.02998      0.63
43  0.900  5.23707  5.20273  0.00766   0.03434      0.73
44  0.500  3.20278  3.14957  0.00666   0.05321      1.13
45  0.900  3.76716  3.76239  0.00766   0.00477      0.10
46  0.700  4.07714  4.10260  0.00550  -0.02546     -0.54
47  0.700  4.66752  4.73532  0.00666  -0.06779     -1.44
48  0.500  5.47398  5.39264  0.00666   0.08134      1.72
49  0.900  3.97757  3.93090  0.00853   0.04667      0.99
50  0.900  4.22016  4.24801  0.00550  -0.02785     -0.59
51  0.700  4.66527  4.74020  0.00400  -0.07493     -1.58
52  0.500  5.59582  5.47521  0.00766   0.12061      2.56R
53  0.700  3.56809  3.54268  0.00666   0.02542      0.54
54  0.500  3.42759  3.39238  0.00550   0.03521      0.74
55  0.700  3.41986  3.38243  0.00766   0.03743      0.80
56  0.900  5.32511  5.28529  0.00666   0.03981      0.84
57  0.500  4.59828  4.67247  0.00400  -0.07419     -1.56
58  0.300  5.12901  5.08210  0.00666   0.04691      0.99
59  0.900  3.32965  3.28503  0.00766   0.04462      0.95
60  0.300  4.94724  4.92674  0.00853   0.02050      0.44
61  0.300  3.72073  3.71944  0.00666   0.00130      0.03
62  0.700  4.14428  4.18028  0.00400  -0.03599     -0.76
63  0.300  4.45964  4.52217  0.00550  -0.06253     -1.32
64  0.700  5.16884  5.13988  0.00550   0.02895      0.61
65  0.500  4.93071  4.90702  0.00666   0.02369      0.50
66  0.300  3.94649  3.96225  0.00550  -0.01576     -0.33
67  0.300  5.40903  5.32491  0.00766   0.08412      1.79
68  0.700  3.88459  3.86317  0.00766   0.02142      0.46
69  0.900  4.42358  4.48745  0.00666  -0.06387     -1.35
70  0.500  3.57193  3.55262  0.00550   0.01931      0.41
71  0.700  4.59004  4.66253  0.00550  -0.07249     -1.53
72  0.900  4.31102  4.33058  0.00666  -0.01956     -0.41
73  0.700  3.34374  3.29987  0.00666   0.04388      0.93
74  0.300  3.43972  3.40721  0.00766   0.03251      0.69
75  0.700  4.83522  4.90045  0.00550  -0.06523     -1.38
76  0.300  4.95299  4.92185  0.00666   0.03113      0.66
77  0.300  4.46555  4.52706  0.00666  -0.06151     -1.30
78  0.900  5.23575  5.20762  0.00666   0.02813      0.60
79  0.300  4.09349  4.12738  0.00666  -0.03389     -0.72
80  0.900  4.49383  4.49082  0.00766   0.00301      0.06
81  0.900  3.48772  3.45016  0.00853   0.03755      0.80
82  0.700  5.56714  5.46037  0.00666   0.10677      2.26R
83  0.700  5.44122  5.38269  0.00666   0.05852      1.24
84  0.900  3.64012  3.61041  0.00766   0.02971      0.63
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 85  0.500  4.44414  4.51223  0.00400  -0.06809     -1.43
 86  0.700  3.85336  3.85979  0.00550  -0.00643     -0.14
 87  0.700  4.22493  4.26285  0.00550  -0.03791     -0.80
 88  0.700  4.30429  4.34052  0.00550  -0.03623     -0.76
 89  0.900  5.04236  5.05075  0.00766  -0.00839     -0.18
 90  0.300  3.50485  3.48000  0.00853   0.02485      0.53
 91  0.700  3.92417  3.93747  0.00400  -0.01330     -0.28
 92  0.900  3.80159  3.77065  0.00766   0.03094      0.66
 93  0.900  3.62783  3.60552  0.00666   0.02231      0.47
 94  0.300  3.95089  3.96714  0.00666  -0.01625     -0.34
 95  0.700  4.93922  4.98301  0.00666  -0.04379     -0.93
 96  0.700  3.72401  3.70292  0.00666   0.02109      0.45
 97  0.300  4.30798  4.36193  0.00550  -0.05395     -1.14
 98  0.900  3.99833  4.01009  0.00766  -0.01175     -0.25
 99  0.300  4.53671  4.60474  0.00550  -0.06803     -1.44
100  0.300  4.38675  4.44450  0.00550  -0.05775     -1.22
101  0.300  4.53516  4.59985  0.00766  -0.06469     -1.37
102  0.500  4.76763  4.83272  0.00550  -0.06509     -1.37
103  0.500  4.14749  4.18685  0.00666  -0.03936     -0.83
104  0.900  3.90844  3.92263  0.00666  -0.01420     -0.30
105  0.500  4.85104  4.82934  0.00666   0.02170      0.46
106  0.500  3.65108  3.63519  0.00666   0.01589      0.34
107  0.500  4.68181  4.75504  0.00550  -0.07323     -1.55
108  0.300  3.58903  3.56746  0.00766   0.02157      0.46
109  0.500  3.93477  3.95230  0.00400  -0.01753     -0.37
110  0.300  4.69863  4.76499  0.00666  -0.06636     -1.41
111  0.900  4.49944  4.56512  0.00550  -0.06568     -1.39
112  0.700  4.99007  4.97964  0.00666   0.01043      0.22
113  0.900  4.74281  4.80793  0.00550  -0.06513     -1.37
114  0.300  5.03303  5.00442  0.00666   0.02861      0.61
115  0.500  4.08177  4.11255  0.00400  -0.03077     -0.65
116  0.500  5.38433  5.31007  0.00666   0.07426      1.57
117  0.900  4.56824  4.64280  0.00666  -0.07456     -1.58
118  0.500  3.71705  3.70949  0.00550   0.00756      0.16
119  0.500  3.80501  3.79543  0.00766   0.00957      0.20
120  0.900  4.90474  4.88224  0.00853   0.02250      0.48
121  0.500  4.93382  4.91191  0.00666   0.02191      0.46
122  0.300  4.23197  4.27936  0.00666  -0.04740     -1.00
123  0.500  4.36814  4.43455  0.00666  -0.06641     -1.41
124  0.700  4.58531  4.65764  0.00400  -0.07232     -1.52
125  0.500  4.59326  4.66758  0.00666  -0.07433     -1.57
126  0.700  4.75731  4.82277  0.00550  -0.06546     -1.38
127  0.300  3.87314  3.88457  0.00550  -0.01144     -0.24
128  0.900  4.42266  4.48256  0.00666  -0.05990     -1.27
129  0.900  4.14925  4.17033  0.00666  -0.02108     -0.45
130  0.300  4.01126  4.03993  0.00766  -0.02867     -0.61
131  0.300  5.22116  5.15978  0.00853   0.06139      1.31
132  0.700  5.07617  5.06221  0.00766   0.01397      0.30
133  0.900  4.73094  4.80305  0.00766  -0.07211     -1.53
134  0.300  3.57493  3.55919  0.00766   0.01574      0.33
135  0.300  4.31608  4.36682  0.00766  -0.05074     -1.08
136  0.700  3.63668  3.62035  0.00550   0.01633      0.34
137  0.500  3.86414  3.86974  0.00400  -0.00560     -0.12
138  0.300  3.80544  3.80689  0.00766  -0.00145     -0.03
139  0.500  3.78314  3.78717  0.00550  -0.00403     -0.09
140  0.700  5.18183  5.13500  0.00666   0.04684      0.99
141  0.900  4.13760  4.16544  0.00550  -0.02784     -0.59
142  0.500  4.07354  4.10766  0.00666  -0.03412     -0.72
143  0.300  4.08485  4.12249  0.00666  -0.03765     -0.80
144  0.900  4.83849  4.89050  0.00666  -0.05201     -1.10
145  0.500  5.18778  5.14983  0.00550   0.03795      0.80
146  0.900  4.92835  4.96818  0.00666  -0.03983     -0.84
147  0.300  3.65979  3.64514  0.00766   0.01466      0.31
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148  0.900  3.84163  3.84496  0.00666  -0.00332     -0.07
149  0.900  3.71228  3.68809  0.00666   0.02419      0.51
150  0.500  3.49761  3.47006  0.00550   0.02755      0.58
151  0.500  4.15969  4.19511  0.00550  -0.03542     -0.75
152  0.700  5.25574  5.21756  0.00550   0.03818      0.81
153  0.500  3.64003  3.62693  0.00666   0.01310      0.28
154  0.300  4.38528  4.43961  0.00666  -0.05433     -1.15
155  0.700  5.67919  5.54294  0.00766   0.13625      2.89R
156  0.500  3.27667  3.22725  0.00666   0.04943      1.05
157  0.700  3.71277  3.69803  0.00666   0.01474      0.31
158  0.700  3.56139  3.53779  0.00550   0.02361      0.50
159  0.300  5.11159  5.08699  0.00766   0.02460      0.52
160  0.700  4.91055  4.89707  0.00666   0.01347      0.29
161  0.300  3.51023  3.48489  0.00666   0.02533      0.54
162  0.500  4.44267  4.50734  0.00550  -0.06467     -1.37
163  0.700  3.99006  4.01515  0.00550  -0.02509     -0.53
164  0.300  3.73354  3.72770  0.00853   0.00584      0.12
165  0.900  3.48053  3.44528  0.00666   0.03525      0.75
166  0.700  5.35445  5.30013  0.00550   0.05432      1.15
167  0.300  4.23254  4.28425  0.00666  -0.05171     -1.10
168  0.500  3.92871  3.94741  0.00550  -0.01871     -0.39
169  0.500  3.50211  3.47495  0.00666   0.02717      0.58
170  0.900  5.15099  5.12505  0.00666   0.02594      0.55
171  0.700  3.49132  3.46011  0.00550   0.03121      0.66
172  0.300  4.61826  4.68731  0.00666  -0.06905     -1.46
173  0.500  5.18141  5.15472  0.00666   0.02669      0.57
174  0.700  4.36087  4.41971  0.00550  -0.05884     -1.24
175  0.700  4.21792  4.25796  0.00550  -0.04004     -0.85
176  0.500  4.51748  4.58991  0.00400  -0.07242     -1.52
177  0.500  4.85792  4.91528  0.00666  -0.05737     -1.21
178  0.300  4.86845  4.84418  0.00766   0.02427      0.52
179  0.300  4.16481  4.20506  0.00666  -0.04025     -0.85
180  0.900  3.54845  3.52295  0.00766   0.02550      0.54
181  0.500  3.35619  3.31470  0.00766   0.04148      0.88
182  0.300  3.28584  3.24208  0.00666   0.04376      0.93
183  0.300  3.86640  3.87968  0.00666  -0.01328     -0.28
184  0.300  5.51378  5.40748  0.00853   0.10631      2.27R
185  0.700  3.77581  3.77722  0.00550  -0.00141     -0.03
186  0.700  4.43974  4.50228  0.00666  -0.06254     -1.32
187  0.900  4.66747  4.73026  0.00666  -0.06279     -1.33
188  0.700  4.39213  4.42309  0.00666  -0.03096     -0.66
189  0.900  3.40853  3.36760  0.00766   0.04093      0.87
190  0.700  3.18438  3.13473  0.00766   0.04964      1.05
191  0.500  3.79545  3.79206  0.00550   0.00339      0.07
192  0.500  4.67712  4.75015  0.00550  -0.07303     -1.54
193  0.900  4.38236  4.40825  0.00666  -0.02590     -0.55
194  0.500  5.10858  5.06726  0.00666   0.04132      0.88
195  0.500  3.57013  3.54773  0.00766   0.02240      0.48
196  0.300  4.16036  4.20169  0.00666  -0.04133     -0.88
197  0.300  4.24403  4.28763  0.00766  -0.04360     -0.93
198  0.900  5.53269  5.45043  0.00766   0.08226      1.75
199  0.700  4.14046  4.17539  0.00666  -0.03493     -0.74
200  0.900  5.06792  5.04737  0.00766   0.02055      0.44
201  0.900  3.40119  3.36271  0.00766   0.03848      0.82
202  0.300  5.04064  4.99953  0.00766   0.04111      0.87
203  0.700  3.26495  3.21730  0.00666   0.04765      1.01
204  0.900  4.57382  4.64769  0.00550  -0.07387     -1.56
205  0.300  3.05616  2.99927  0.00853   0.05689      1.21
206  0.900  4.06842  4.08777  0.00550  -0.01934     -0.41
207  0.300  3.21789  3.16440  0.00766   0.05348      1.14
208  0.500  5.09383  5.07215  0.00550   0.02168      0.46
209  0.700  4.50465  4.57996  0.00400  -0.07531     -1.58
210  0.900  5.13762  5.12994  0.00853   0.00769      0.16
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211  0.500  5.00984  4.99447  0.00766   0.01537      0.33
212  0.500  4.36841  4.42966  0.00400  -0.06126     -1.29
213  0.300  3.29471  3.24697  0.00853   0.04774      1.02
214  0.300  3.35920  3.31976  0.00766   0.03944      0.84
215  0.500  5.01239  4.98959  0.00550   0.02281      0.48
216  0.900  5.53430  5.44554  0.00766   0.08876      1.89
217  0.700  5.36426  5.29524  0.00766   0.06902      1.47
218  0.500  3.64424  3.63030  0.00666   0.01394      0.30
219  0.900  4.20436  4.24312  0.00766  -0.03876     -0.82
220  0.900  3.25001  3.20246  0.00853   0.04755      1.01
221  0.500  5.27038  5.23240  0.00550   0.03799      0.80
222  0.700  5.07572  5.05732  0.00550   0.01840      0.39
223  0.900  4.97793  4.96480  0.00766   0.01313      0.28
224  0.300  3.80152  3.80201  0.00550  -0.00049     -0.01
225  0.700  3.93084  3.94236  0.00666  -0.01152     -0.24
226  0.500  3.27965  3.23213  0.00666   0.04751      1.01
227  0.700  3.41515  3.37754  0.00550   0.03761      0.79
228  0.700  3.79530  3.78060  0.00666   0.01470      0.31
229  0.300  4.87454  4.83929  0.00766   0.03525      0.75
230  0.300  4.70152  4.67904  0.00853   0.02247      0.48
231  0.700  4.35629  4.41483  0.00550  -0.05853     -1.24
232  0.500  3.35305  3.30981  0.00550   0.04323      0.91
233  0.700  5.24841  5.22245  0.00666   0.02596      0.55
234  0.900  5.79230  5.61067  0.00853   0.18163      3.87R
235  0.300  3.43492  3.40233  0.00666   0.03260      0.69
236  0.700  4.74982  4.81788  0.00550  -0.06806     -1.44
237  0.900  3.55818  3.52784  0.00666   0.03034      0.64
238  0.500  4.77035  4.74678  0.00766   0.02357      0.50
239  0.300  5.20158  5.16467  0.00666   0.03692      0.78
240  0.700  4.28580  4.33715  0.00550  -0.05135     -1.08
241  0.700  4.50742  4.57507  0.00550  -0.06765     -1.43
242  0.700  3.85165  3.85490  0.00550  -0.00325     -0.07
243  0.500  3.42373  3.38749  0.00666   0.03624      0.77
244  0.900  3.92188  3.92752  0.00666  -0.00564     -0.12
245  0.900  3.98722  4.00520  0.00550  -0.01798     -0.38
246  0.700  5.44801  5.37781  0.00666   0.07020      1.49
247  0.900  5.32278  5.29018  0.00766   0.03260      0.69
248  0.700  5.00014  4.97475  0.00666   0.02539      0.54
249  0.900  5.43098  5.36297  0.00853   0.06801      1.45
250  0.700  3.33829  3.29498  0.00666   0.04332      0.92
251  0.500  3.86704  3.87463  0.00666  -0.00758     -0.16
252  0.900  5.06323  5.04248  0.00766   0.02075      0.44
253  0.300  5.29824  5.24723  0.00766   0.05101      1.08
254  0.500  4.30395  4.35198  0.00550  -0.04803     -1.01
255  0.700  4.00305  4.02003  0.00400  -0.01699     -0.36
256  0.500  4.00941  4.03487  0.00550  -0.02546     -0.54

R denotes an observation with a large standardized residual.


Durbin-Watson statistic = 1.85699


Lack of fit test
Possible interaction in variable I  (P-Value = 0.001 )


Possible curvature in variable L  (P-Value = 0.000 )
Possible interaction in variable L  (P-Value = 0.000 )

Possible lack of fit at outer X-values (P-Value = 0.009)
Overall lack of fit test is significant at P = 0.000
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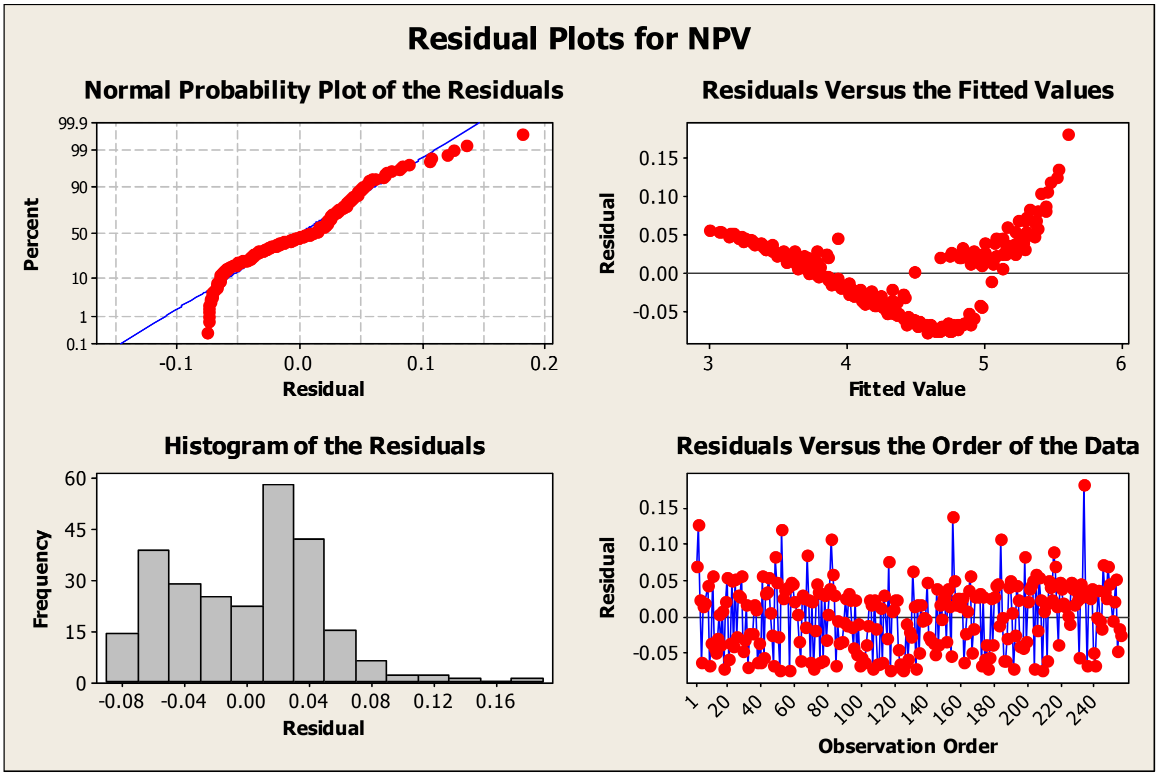
Residual Plots for NPV



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