2013

A Real Option Dynamic Decision (rodd) Framework For Operational Innovations

Wilawan Onkham
University of Central Florida

STARS Citation

Onkham, Wilawan, "A Real Option Dynamic Decision (rodd) Framework For Operational Innovations" (2013). *Electronic Theses and Dissertations, 2004-2019*. 2873.
https://stars.library.ucf.edu/etd/2873

A REAL OPTION DYNAMIC DECISION (RODD) FRAMEWORK FOR OPERATIONAL INNOVATIONS

by

WILAWAN ONKHAM
B.S. Chiang Mai University, 2002
M.A. Old Dominion University, 2007
M.E.M. Old Dominion University, 2010

A document submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the Department of Industrial Engineering and Management Systems
in the College of Engineering and Computer Science
at the University of Central Florida
Orlando, Florida

Fall Term
2013

Major Professor: Luis C. Rabelo

ABSTRACT

Changing the business operations and adopting new operational innovations, have become key features for a business solution approach. However, there are challenges for developing innovative operations due to a lack of the proper decision analysis tools, lack of understanding the impacts transition will have on operational models, and the time limits of the innovation life cycle. The cases of business failure in operational innovation (i.e. Eastman Kodak Company and Borders Group Inc.,) support the need for an investment decision framework.

This research aims to develop a Real Option Dynamic Decision (RODD) framework for decision making, to support decision makers for operational innovation investments. This development will help the business/organization to recognize the need for change in operations, and quickly respond to market threats and customer needs. The RODD framework is developed by integrating a strategic investment method (Real Options Analysis), management transition evaluation (Matrix of Change), competitiveness evaluation (Lotka-Volterra), and dynamic behavior modeling (System Dynamics Modeling) to analyze the feasibility of the transformation, and to assess return on investment of new operation schemes.

Two case studies are used: United Parcel Service of America, Inc., and Firefighting Operations to validate the RODD framework. The results show that the benefits of this decision-making framework are (1) to provide increased flexibility, improved predictions, and more information to decision makers; (2) to assess the value alternative option with regards to uncertainty and competitiveness; (3) to reduce complexity; and (4) to gain a new understanding of operational innovations.

I dedicate this work to my beloved parents.

ACKNOWLEDGMENTS

I am grateful to my family members and friends for their support and love during these years. I am thankful to Mr. Sitthran Uparisatjakul for inspiration, advice, and sympathy during the most difficult times.

I would like to express my greatest gratitude to my advisor Dr. Luis Rabelo for his continued guidance and direction throughout my research. My special thanks to him and Dr. Albert Jones, Supervisory Operations Research Analyst-Systems Integration Division Office, National Institute of Standards and Technology, for their valuable technical advice and introducing me to the interesting area of the smart firefighting operation. I would also like to thank my committee, Dr. Thomas O'Neal, Dr. Jennifer Pazour, and Dr. Huyla Yazici for their valuable comments and suggestions in the preparation of this work.

I am very grateful to Mr. Bruce Gunning, Senior Industrial Engineering Manager at United Parcel Service of America, Inc.; Fire Chief Howard Goldberg, Battalion Chief for the Orange County Fire Rescue, Florida; Fire Chief Adam K. Thiel, Fire Chief for the City of Alexandria, Virginia; Lieutenant Colonel Eliot Evans, Deputy Commander, 166th Mission Support Group, Delaware Air National Guard; and Michael Ferrante, Lead Systems Engineer with the Department of Defense/Reserve Sheriff's Captain Orange County, Florida for their expertise and feedback on this research.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS/ABBREVIATIONS

CAD	Computer-Aided Dispatch
CPS	Cyber-Physical System
DCF	Discounted Cash Flow
IC	Incident Commander
NPV	Net Present Value
R&D	Research and Development
ROA	Real Options Analysis
RODD	Real Option Dynamic Decision
ROI	Return on Investment

CHAPTER ONE: INTRODUCTION

1.1 General Introduction

Currently, organizations recognize that innovation is the most important factor to improve business performance. Innovation has become the foundation of long-term competitive advantages and business performance sustainability. Changes in advanced technology and customers' behavior, and the recent economic recession drive the need for developing new, innovative, business operations. The main goals of creating and implementing innovation are to increase revenue, improve business performance, expand new markets, enhance market competitive advantages, and create future market value. A higher innovation level can indicate business success (Amit & Zott, 2012; Boutellier et al., 2010; Hamel, 2006).

Innovations are the basis of economic growth (Boutellier et al., 2010; Godin, 2008; Ruttan, 1959). They are described variously as: the use of inventions (Ruttan, 1959; Schön, 1967); use of accumulative knowledge to generate new products or services, new processes, new organizational structure and new markets (Freeman, 1982); new way of doing activities through commercialization of technologies (Sullivan, 1990); new things to increase business success and sustainability (Betz, 2001); invention of new technology and development through marketing-based new technology and the components of novelty that increase profit (Narvekar & Jain, 2006); and substance for economic dynamics, social processes, organizational operations and structures (Peschl & Fundneider, 2012).

Innovations are categorized within seven categories: product, process, market development, new sources, new organizational structures, business model, and operation. First, product innovation generates new products or improves the quality of existing products in order to increase sales and market competitive advantages. Second, process innovation is a new task or activity to produce products or services in order to decrease cost and increase productivity. The consequences are changes in production and the operating structure of a business. Third, new market development focuses on new customers. It is related to new strategies or new marketing attractiveness. The fourth type of innovation is the new sources of development suppliers. Fifth, new organizational structure focuses on the development of management and its structure which relate to process innovation. Although these types of innovation have different characteristics, they are related to each other. For instance, when business develops and commercializes product innovations, process innovations have to change accordingly to meet any new requirements (Boutellier et al., 2010; Godin, 2008).

Sixth, operational innovation is a new paradigm of business model that has shifted to a new organizational structure and management by reinventing and restructuring business activities, relationship with customers and suppliers, and stakeholders' roles. (Amit & Zott, 2012; Boutellier et al., 2010; Chesbrough, 2010; Comes & Berniker, 2008; McGrath, 2011; Osterwalder & Pigneur, 2010; Zott & Amit, 2002).

Finally, operational innovation is defined as *"the development and deployment of new ways of doing work such as filling orders, developing products, providing customer service, and activity that an enterprise performs"* (Hammer, 2004). The advantages of operational innovation are lower direct cost, better use of assets, faster cycle time, enhanced accuracy, higher customization or precision, higher added value, and simplified processes (Hammer, 2004, 2005).

Market pressure and customers' needs have encouraged reinventing existing business operations. For example, electronic-reading devices provide more flexibility and product accessibility by allowing users to read and download product information anywhere, anytime, 24/7. Exponential growth of e-devices has influenced customers' behavior and their preferences on media products (Amit & Zott, 2012). These product innovations force businesses to develop the new business operations and sale distribution networks.

The best examples of businesses that benefitted from implementing operational innovations successfully are Walmart (cross-docking), Progressive Insurance (immediate response to auto claims handling), Toyota (Toyota production system), Schneider National (requests for proposals (RFPs) and acquired new business (ABN) system), and Shell (single workforce for all aspects of an order fulfillment) (Azadegan, 2011; Hammer, 2004, 2005).

Successful implementation does not always lead to successful businesses. In fact, many businesses heavily invest in operational innovation development, but fail to do so in a timely manner. Kodak Company and Borders Group Inc., for example, both implemented new digital technologies too late. Kodak invested in digital camera technology and digital photography, but its response was too late. Its stock fell from $15.32 in June, 2008, to 22 cents in June, 2012, or approximately 98 percent. The company failed to understand the digital markets and lacked the holistic viewpoint of changes in a business operation and core products. Kodak Company did not anticipate the change in customers' preferences. Although Kodak invested more than $2 billion in R&D to innovate the digital imaging technology and business operating system, the company had failed in both traditional photo printing and new digital imaging markets. It is clear that Kodak lacked a systematic perspective considering important factors of its business such as changes in business operations, customers' behavior, lack of leadership, and lack of situation awareness

(Anthony, 2012; L. Baker, Porter, Bishopric, & Change, 2012; Gilbert & Bower, 2002; Sandler, 2010).

Borders Group Inc. was the second largest U.S. bookstore chain, and it went bankrupt in February 2011. The stock went down 54.90 percent (02/2009-2/2011), and the final stock price before bankruptcy was 23 cents. The company initially failed to follow the example of its main competitors Amazon.com and Barnes and Nobles, who were offering online shopping. By the time Borders offered similar online services, it was too late. The company was unable to understand the holistic viewpoint of its existing core business and rapid changes in an advanced technology market. The company still heavily invested in CD and DVD products although music and movies shifted toward digital files. In 2008, it launched Borders.com website, and invented its own electronic reading device, “Kobo,” and e-book store in 2010. Again, it was too late to compete with Amazon.com and Barnes and Nobles (Austen, 2011; Border Group, Inc., 2012; Kary & Sandler, 2012) who already had successful offerings on the market.

The results from Kodak and Borders Group show that there are various factors that influence the successful implementation of operational innovations. They include uncertainty, competitive threats and responses, organizational transformation, strategy, and most importantly, timing. There are several problems related to the strategic investment of operational innovation including a lack of understanding existing and new business operations, and a lack of systematic perspective in decision makers.

Any strategic investment must be aligned with business’s strategies. The Boston Consulting Group Matrix, Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, and Balance Scorecard are the example techniques to evaluate strategies implementations

(Kaplan & Norton, 2000). Businesses tend to capitalize to satisfy customers' needs, and to increase competitive advantages, value-added, and revenue stream aligning with business's objectives or strategies. Alkaraan & Northcott, (2007) propose the pre-decision control mechanism framework based on the strategic management approach, which takes both quantitative and qualitative aspects into consideration. These frameworks uses a traditional financial method as an assessment, and addresses organizational strategy, operational objectives, formal decision processes, authorized responsibility level, and managerial awareness.

The traditional financial valuation methods, for instance the Discounted Cash Flow (DCF) method, Decision Tree Analysis, Ad-hoc Scoring model and Basic Metric (Rate of Return, Payback Period, Breakeven, etc.), have been effectively used for strategic investment in numerous projects both in public and private sectors. However, over the past 20 years, researchers have found that these traditional valuation methods have 5 major limitations (H. K. Baker, Dutta, & Saadi, 2011; Carr, Kolehmainen, & Mitchell, 2010; Kodukula & Papudesu, 2006; Kong & Kwok, 2007; Nagar, 2011; Trigeorgis, 1993a).

First, they cannot provide the flexibility in decision making or easily change the decisions due to unexpected situations in the future. Second, they assume a predetermined, deterministic, linear, cash-flow stream and specific objective. Third, these methods do not adequately take into account the effects of market dynamics, risk, or uncertainty. Fourth, they do not provide enough information regarding the stability of competitive pressures or the flexibility of keeping investment options open. Finally, they do not consider the value of contingent decisions, because the value of cash flow is predetermined. In reality, the future value of a project may be higher than expected NPV. As a result, there is a need for a comprehensive framework that considers statistical generation, logic of replication, and measureable value to enhance the effectiveness of decision-making method (Bucherer, Eisert, & Gassmann, 2012).

Any decisions related to operational innovation, must take into account business environment and its features such as including high risk, uncertainty, complexity, the impact of a competitor, short life cycles of technology. The cash flow should be viewed as both non-linear and probabilistic. As a result, those traditional financial methods are not entirely applicable to support decision makers for operational innovation strategic investment.

1.2 Problem Statement

Implementing operational innovation increases profits, business operational efficiency and effectiveness, and customer satisfaction. The results from business cases and literature reviews show that the most significant factors impacting these benefits include uncertainty, competitive threats and responses, customer needs, organizational transformation, strategic leadership, knowledge, operational efficiency and capability, workforce readiness, equipment readiness, and advanced technology. The complexity of these variables drives the difficulties organizations have in determining the correct innovation, and transforming their business operations toward this innovation. It is also important to realize that even though nonprofit organizations are not impacted by competitors, they can still benefit from operational innovations by improving their efficiency, productivity, and capability.

Still, most of the previous research in operational innovation has not resulted in tangible outcomes. It has also failed to develop a decision-making framework that can evaluate correctly the potential benefits of the investment in operational innovation. This happens because a holistic approach that accounts for the impacts of uncertainty, risk, and competitors has not been developed. There are only a few articles that discuss such a holistic viewpoint of operational innovation (Hammer, 2004, 2005).

Therefore, the lack of a decision-making framework for investment in operational innovation and business failures open the door for more studies in operational innovation. It is necessary to develop a more multi-dimensional approach to evaluate alternatives with regards to operational innovation, to assess predetermined consequences of change in operations, and to make a decision. This research aims to contribute to the area of engineering.

1.3 Research Question

Evaluation of the operational innovation approach has not been well addressed by traditional investment decision tools and techniques. There is a need for new methods which can support decision makers in selecting appropriate decisions in particular with high levels of uncertainty, new technologies, and the sensitivity of important factors.

This research tries to answer this question: Can we develop a new type of decision-making framework that helps to define the feasibility of transformation and return on investment (ROI) of the operational innovation considering uncertainty and the impact of a competitor, or even provide flexibility for investment decision-making which allows businesses/organizations to wait for an expectation to maximize a return on investment?

1.4 Research Objectives

This research aims to develop a Real Option Dynamic Decision (RODD) framework, to support the decision makers prior to making an investment in order to improve the business operational efficiency and effectiveness. The objectives of this research can be articulated as follows:

1. Define the significant factors of operational innovation and develop a systematic architecture of operational innovation.
2. Identify necessary changes in business operation toward operational innovation.
3. Develop a framework to determine the value of new operational innovation considering risk and the impact of a competitor.

1.5 Framework

Due to the complexity of operational innovation environments, which are influenced by various factors such as uncertainty, competitive threats, customers' requirements, advanced technologies, innovation life cycles, organizational transformation, knowledge, workforce readiness (skill and experience), and equipment readiness, it is difficult to transform business operations. As a result, many businesses heavily invest in operational innovation development, but fail to do so in a timely manner. Kodak Company and Borders Group Inc., for example, both implemented new digital technologies too late.

The traditional investment decision methods, such as the Discounted Cash Flow (DCF) method, Decision Tree Analysis, Ad-hoc Scoring model and Basic Metric (Rate of Return, Payback Period, Breakeven, etc.), have many limitations (H. K. Baker et al., 2011; Carr et al., 2010; Kodukula & Papudesu, 2006; Kong & Kwok, 2007; Nagar, 2011; Trigeorgis, 1993a). In any decisions related to operational innovation, one must take into account the entire business environment, including high risk, uncertainty, complexity, the impact of a competitor, the short life cycle of technology, and other factors. The risk factors refer to uncertainty in which has impact on a system in an undetermined path, and its consequences are unknown. It provides unlimited fluctuation in value and results. It has a time horizon that affects measurable future consequences and scenarios in regard to a benchmark over time period (Mun, 2006). The cash flow should be viewed as both non-linear and probabilistic. As a result, those traditional financial methods are not entirely applicable to support decision makers for strategic operational innovation investment.

Therefore, this research develops a Real Option Dynamic Decision (RODD) framework to support decision makers for investments in operational innovation. This approach first synthesizes the features of operational innovation into a high level architecture which consists of three phases: ideas generation, problem solving, and implementation. The RODD framework is developed by integrating a strategic investment method (Real Options Analysis), management transition evaluation (Matrix of Change), competitiveness evaluation (Lotka-Volterra), and dynamic behavior modeling (System Dynamics Modeling) to analyze the feasibility of the business operation transformations and to assess ROI of operational innovation during the problem solving phase. This approach takes impacts of risk factors and competitiveness into consideration which have not been addressed in any previous researches (Figure 1).

Real options provide the flexibility of decision making, offer an opportunity to revise the decision upon the future market conditions, and minimize risks and volatility in the market. Real options can be used for various alternative selections in order to compare different types of investment in operational innovation. The rationale of real options implementation is a part of the strategic investment decision making that can enhance the values of operating choices and business growth opportunities under uncertain environments (Benaroch, 2001; Copeland & Antikarov, 2005; Driouchi & Bennett, 2012; Mathews, Datar, & Johnson, 2007; Trigeorgis, 1993b, 2005). Monte Carlo simulation is a complementary method for the real options applied to quantify risk and uncertainty (Hacura et al., 2001).

Matrix of Change evaluates the feasibility of transition from current state to future state. If the interactions between current state and future state have more reinforcing behaviors than balancing behaviors, then the alternative option (future state) is a feasible option (Brynjolfsson, Renshaw, & Alstyne, 1997).

The concept of Lotka-Volterra is used to evaluate the impact of a competitor in the perspective of pure competition. The interaction of competitors can have both positive and negative effects on the growth of business or financial performance (Unver, 2008).

System dynamic modeling is implemented to model an operational innovation dynamic and to evaluate the consequences of changes in the business operation. It is an approach to develop a model to solve a specific problem of complex systems. The main purpose is to explore a new understanding of how the problem arises, and use that understanding to develop feasible policies for improvement (Sterman, 2000; Tan et al., 2010). System Dynamics is also recognized as the superior tool to model and simulate the supply chain at a strategic level (Angerhofer & Angelides, 2000).

System Dynamics modeling can be used to develop a dynamic model of operational innovation. This will help us to gain understanding about the causality relationship between these variables affecting the financial performance, and to minimize the complexity of the operational innovation system. This method will be combined with Lotka-Volterra to improve the financial results for the operational innovation option considering the impact of a competitor.

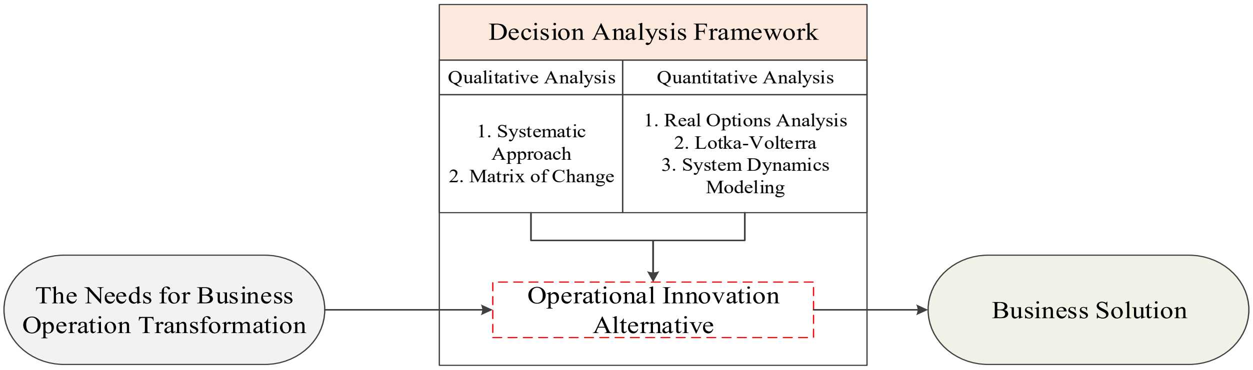


Figure 1: Decision Analysis Framework

1.6 Contributions of this Research

Our research makes a key contribution to the area of engineering by introducing a unique decision-making framework to address the features of operational innovation and its strategic investment. This research also provides the following contributions:

1. The most important features of operational innovation and its environment are identified according to the literature and cases such as competitive threats and responses, risk factor, advanced technology, organizational transformation, and operational efficiency and capability. These variables are used to develop an operational innovation architecture which aims to help business to recognize the need for change in business operations and quickly response to the market threats or customer needs.

2. The dynamics model of the operational innovation is developed. The benefits of this dynamics model are: 1) to provide a conceptual framework of the realistic operational innovation systems, 2) to represent causality relationship, 3) to provide an understanding of the problems and the consequences in different scenarios, and 4) to improve the accuracy of predicted financial results considering the impact of a competitor.
3. The RODD framework is a novel method for an investment decision that can quantify the risk and impact of competitors. This framework provides flexibility to make an investment which allows businesses/organizations to wait for an expectation to maximize a return on investment value.

Together, this framework improves analysis and prediction by focusing on a better understanding of the operational innovation process, and quantifying the ROI of a feasible option by considering risk factors and the impact of a competitor.

1.7 Thesis Outline

This thesis is organized as follows: Chapter Two discusses the literature review of innovation, operational innovation, project valuation analysis, Real Options Analysis, Matrix of Change Method, Lotka-Volterra, and System Dynamics Modeling. Chapter Three articulates the steps of the research methodology which illustrates the framework of conducting research from a literature survey throughout experimentation and analysis. Chapter Four presents a systematic architecture of operational innovation using RODD framework. Chapter Five illustrates the case studies analysis and results. Chapter six discusses conclusions and future research.

CHAPTER TWO: LITERATURE REVIEW

This section represents the relevant literature review in seven areas: Innovation, Operational Innovation, Project Valuation Analysis, Real Options Analysis, Lotka-Volterra, Matrix of Change, and System Dynamics Modeling. This literature will help to show in a systematic manner, the gaps in current research of operational innovation.

2.1. Rationale for the Literature Survey

To develop a holistic decision-making framework for investment in operational innovation, first we have to study the concepts of innovation and operational innovation. This will provide a better understanding of the needs for reinventing business operations, its environment and influencing factors. Then we investigate the definition and the stages of the innovation process. This helps us to gain an understanding of each stage and to be able to relate them to the strategic investment decision of the operational innovation. The literature survey in the operational innovation helps us to define business operation problems, significant factors of the operational innovation, its environment, and gaps of research in business analysis.

Second, a very important part of this literature survey is to identify investment methods to support the investment decision process prior to the transformation. The traditional investment decision methods and their limitations are presented.

Third, real options analysis and Monte Carlo simulation approaches are described. The motivation for studying real options is that real options can capture the strategic investment decisions and allow decision makers to revise decisions upon the future market conditions. This approach can provide the facts for decision makers in different decision structures such as defer, expand, abandon or switch, which are better than the use of a single net present value (NPV) or the DCF method from traditional investment methods. The Monte Carlo simulation can help to predict the investment results by considering the risk.

Fourth, the matrix of change method helps us to map the operational transformation of the current and future scenarios and allows decision makers to evaluate the feasibility of transformations. This method use qualitative analysis to synthesize the importance and components of those states.

Finally, we illustrate the concept of Lotka-Volterra and system dynamics modeling. These concepts can help to evaluate the impact of competitiveness and consequences of change in a business operation. The system dynamics modeling captures the influencing factors and competitiveness, and provides a conceptual model for a specific system. The results from these methods can be used to establish business policies or requirements for the new business operations considering the impact of a competitor.

2.2. Overview of Innovation

Rapid changes in advanced technologies, customers' behavior, and high market competitive pressure drive the needs for innovation. The innovation provides more convenient to customers, to deliver better value propositions to customers or suppliers, to expand new markets, to increase revenue streams, and to minimize complexity and cost for long term success (Amit & Zott, 2012; Bucherer et al., 2012; Chesbrough, 2007, 2010; Christensen, Alton, Rising, & Waldeck, 2011; Comes & Berniker, 2008; McGrath, 2011; Osterwalder, Pigneur, & Tucci, 2005; Vanhaverbeke, Van de Vrande, & Chesbrough, 2008).

2.2.1. Definition of Innovation

The famous theory of technological innovation is called the Schumpeterian Economics Growth Model, which was established by Schumpeter in 1912. Innovation is defined as the outcomes of creation, development, improvement, and manufacture of new products, new services, new production or new organizational structures in order to meet consumer needs. It is the substance of understanding economic growth (Boutellier et al., 2010; Godin, 2008; Ruttan, 1959). Innovation is described as the use of inventions (Ruttan, 1959; Schön, 1967); use of accumulative knowledge to generate new products or services, new processes, new organizational structure and new markets (Freeman, 1982); new way of doing activities through commercialization of technologies (Sullivan, 1990); commonly new things to increase business success and sustainability (Betz, 2001); invention of new technology and development through marketing based new technology and the components of novelty that increase profit (Narvekar & Jain, 2006); and substance for economic dynamics, social processes, organizational operations and structures (Peschl & Fundneider, 2012).

2.2.2. Types of Innovation

Innovations for profit or non-profit organizations are categorized within seven categories: product, process, market development, new sources, new organizational structures, business model, and operation. First, product innovation is to generate new products or to improve the product's quality in order to sell to customers and to increase sales and market competitive advantages. Generally, there are two types of product innovation: technology-push (inside-out) and market pull (outside-in). Technology-push product innovation is developed by R&D and established from new technologies (Jolly, 1997). In contrast, market pull product innovation is forced by the sale or marketing department to offer unknown needs.

Second, process innovation is a new operation of products or services in order to decrease cost and increase productivity. It is a change in production and the operational structure of a business. Third, new market development focuses on new customers. It is related to new strategies or new marketing attractiveness. Fourth, the new sources development emphasizes on new suppliers. Fifth, new organizational structure focuses on the development of management and hierarchical structure which relates to process innovation. Although these types of innovation have different characteristics, they interact with each other. When business develops and commercializes product innovations, process innovations have to change according to new requirements (Boutellier et al., 2010; Godin, 2008). For instance, when a new product innovation is developed, a process innovation has to change and coordinate to the requirements of that product. The best example is Apple Inc., which created several product innovations (i.e. iPod and iPhone). It also improves process innovations such as iTunes and iCloud systems in order to deliver high quality products to customers and to minimize their production cost at the same time.

Sixth, business model innovation is a new paradigm of business model that is defined as redesigning the structure of business and organizational structures by reinventing business activities, relationship with customers and suppliers, and stakeholders' roles. The purposes of developing business model innovation are to increase profit and value creation to customers, and to gain long term business sustainability (Amit & Zott, 2012; Boutellier et al., 2010; Chesbrough, 2010; Comes & Berniker, 2008; McGrath, 2011; Osterwalder & Pigneur, 2010; Zott & Amit, 2002). Christensen et al., (2011) suggest four options to reinvent a business model including: 1) acquiring a disruptive business model, 2) acquiring to de-commoditize, 3) acquiring in appropriate price, and 4) avoiding incompatibility business model integration. The successful companies that transform its business model are Southwest Airlines, Dell, Apple-iTune, Amazon, IBM, and HTC (Bramante et al., 2010; Jetter et al., 2009).

Finally, operational innovation is defined as *"the development and deployment of new ways of doing work such as filling orders, developing products, providing customer service, and activity that an enterprise performs"* (Hammer, 2004). Operational Innovation has significantly increased business revenue and driven new enterprise's strategic goals. The advantages of operational innovation are lower direct cost, better use of assets, faster cycle time, enhanced accuracy, higher customization or precision, higher added value, and simplified processes (Hammer, 2004, 2005). The operational innovation is explained in detail in the section 2.3. The types of innovation and their interactions are summarized in Figure 2.

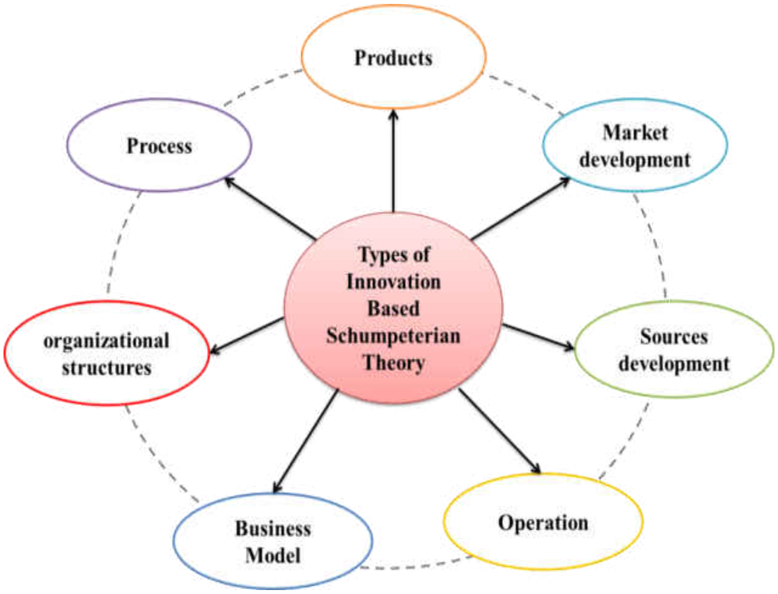


Figure 2: The Types of Innovation

Although innovations significantly help businesses to increase their financial growth, many businesses have faced several difficulties such as lack of situation awareness, lack of understanding customer needs, the impact of disruptive innovations and uncertainty, a short life cycle of innovation, and inadequate financial resources.

Motorola faced the challenge of lacking situation awareness of the changing market demand in the late 1900s when technologies were moving toward digital technology and the Global System for Mobile Communication (GSM) standard. The company also failed to understand the changing customers' need in the late 2000s when consumer demand was shifting from basic phones to smart phones that could provide direction to update one's status on social networks. The company did not recognize the development of product innovation. As a result, they lost a large number of customers following the decrease of revenues. The company ended up separating into two companies (Motorola Solutions and Motorola Mobility), and Motorola Mobility was acquired by Google in 2012 (Lerner, 2012).

Disruptive innovations are crucial challenges for most businesses. The disruptive products force a business to transform its business or operation to survive in the market. For instance, in 2009, Nano car was launched into the market as an inexpensive and affordable car, and was manufactured by Tata Motors in India. It has become a huge threat to the automobile industry. Another example is LePhone which was launched into the market by Lenovo in China. LePhone is a disruptive smartphone which offers cheaper prices when compared to the iPhone, but has similar features (Markides, 2012).

2.2.3. Innovation Process

There are numerous publications on the innovation process model. Researchers have proposed different frameworks to analyze the innovation process using various perspectives such as knowledge management, resource based management, organizational sociology, and a systematic approach.

In 1971, James Utterback proposed the theory and concept of innovation process which have become the basis of innovation process models. The innovation process is defined as the completed process of creation innovations, consisting of three phases: 1) idea generation, 2) problem-solving, and 3) implementation and diffusion (Figure 3). It helps to provide an understanding of technological revolution for innovation development. Innovation process is different from process innovation which is the new set of production methods or new workflows to minimize costs, improve productivity, and reinvent the process from manufacturing through value chain networks (Boutellier et al., 2010; J.M. Utterback & Abernathy, 1990; James M. Utterback, 1971).

The idea generation phase is the most critical process, and is necessary to recognize and understand the market needs. Typically, idea generation initiates from internal individuals, teams and organizations, respectively. Today, the innovation process does not only depend on R&D, engineering, an advanced technological business, or other outsourcings, but it also takes customers' needs, competitors' conditions, and available technologies or knowledge into consideration. After the needs of the market or customers are identified, the recognition of technical resources to satisfy the needs is determined. Finally, this idea is synthesized to establish the proposal for development of new products or other types of innovation.

The problem-solving stage is the intermediate stage of innovation development, which involves project evaluation, decision making, and alternative analysis. There are five important steps of problem-solving: classifying the problem into sub-problems, establishing goals and objectives, ranking priorities to the goals, forming alternative solutions, and evaluating alternatives. The best alternative is selected based on the business's goals and priorities. The qualitative analysis is used for the decision making process. The outcome of this process becomes a new knowledge source for the organization. The idea generation and problem solving phases obtain high uncertainty that lead to potential business success or failure (Bucherer et al., 2012; Utterback, 1971).

The final stage is implementation and diffusion. This stage is associated with creating new prototypes or inventions, deploying the first use of process, or launching new products to market. The information and customers' feedback from first use of process and product are collected as knowledge sources for future use (Bucherer et al., 2012; Chen, 2011; Utterback & Abernathy, 1990; Utterback, 1971).

Another most famous innovation process model for technological product innovation is called the normative process model which consists of three stages from ideation through improvement to commercialization. The generic path of innovation process of the normative process model includes 1) initiation phase, 2) development phase, and 3) implementation phase (Van de Ven, 1999). Gassmann & von Zedtwitz (2003) propose the innovation processes in transnational corporations on a global business scale. They stated that R&D has played a major role during the innovation process in order to establish market competitive advantages, and to expand revenue sources. The innovation process is the same as the repeated cycle process of interrelationships between technology, knowledge, invention, and market demand. The advantages of this model is to provide better understanding for managers and to minimize complexity (Ebrahim, Ahmed, & Taha, 2008).

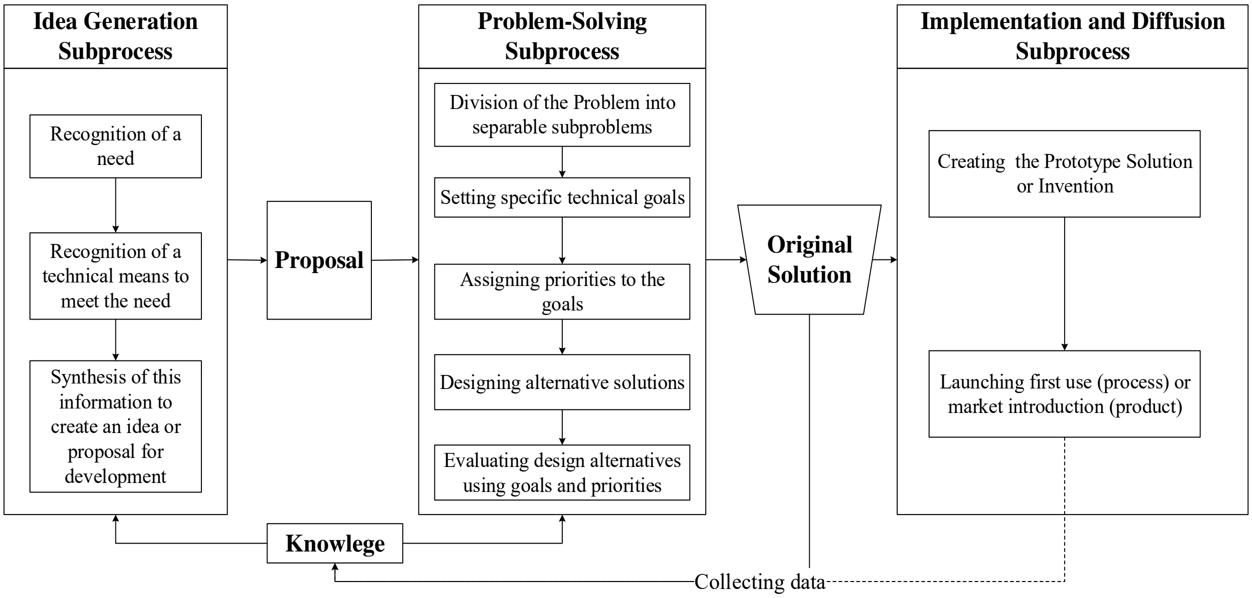


Figure 3: Innovation Process (Modified from Utterback, 1971)

However, these innovation process models seems not to be validated due to the assumption of the innovation process as linear behavior (Bucherer et al., 2012; Ebrahim et al., 2008; Gassmann & von Zedtwitz, 2003; Van de Ven, 1999). Van de Ven, (1999) proves that the innovation process tends to be fuzzy in the initial stage, and changes upon the interactions between two elements: advanced technological options and customer’s needs. With innovation, it is difficult to predict implications and to manage with restricted controls due to the high complexity.

Chen (2011) developed the system of architecture of innovation systems (Figure 4) using a resources-based perspective, and established a knowledge-based perspective. System dynamics modeling is implemented to capture important factors and their relationships, which provides new understanding and reduces complexity. The author illustrated the key factors of innovation process involving knowledge, organization, technology and psychology. Three external factors, knowledge diversity, strategic relatedness, and spatial proximity, are emphasized.

The knowledge diversity is determined to be an integrated knowledge which contributes to the success of the organization under uncertainty. It consists of two components: elements of knowledge, and architectures of knowledge, and can be used as the fundamental knowledge in the organization. Higher knowledge diversity offers more effectiveness of absorptive capacity; whereas, higher knowledge commonality enhances efficiency. The absorptive capacity is an indicator of organizational ability to modify values of internal and external knowledge during innovation development, and the ability to increase co-creation (Vanhaverbeke et al., 2008).

The knowledge diversity is vital for knowledge transfer and can increase knowledge creation. Since available external knowledge sources are imperfect, it is necessary to enhance the ability to transform and the ability to maximize utilization of limited knowledge for business growth opportunities. The strategic relatedness is a direction for seeking the potential knowledge sources and formulating the links with these knowledge sources. Finally, spatial proximity is the most important factor for mechanisms of knowledge transfer and knowledge creation, which can minimize cost for transferring external knowledge. Spatial proximity and strategic relatedness have positive impacts on the effectiveness of absorptive capacity via the effects of internal and external networks. Furthermore, dynamic capabilities are indicated as important variables that can be used to analyze innovation process sustainability (Chen, 2011).

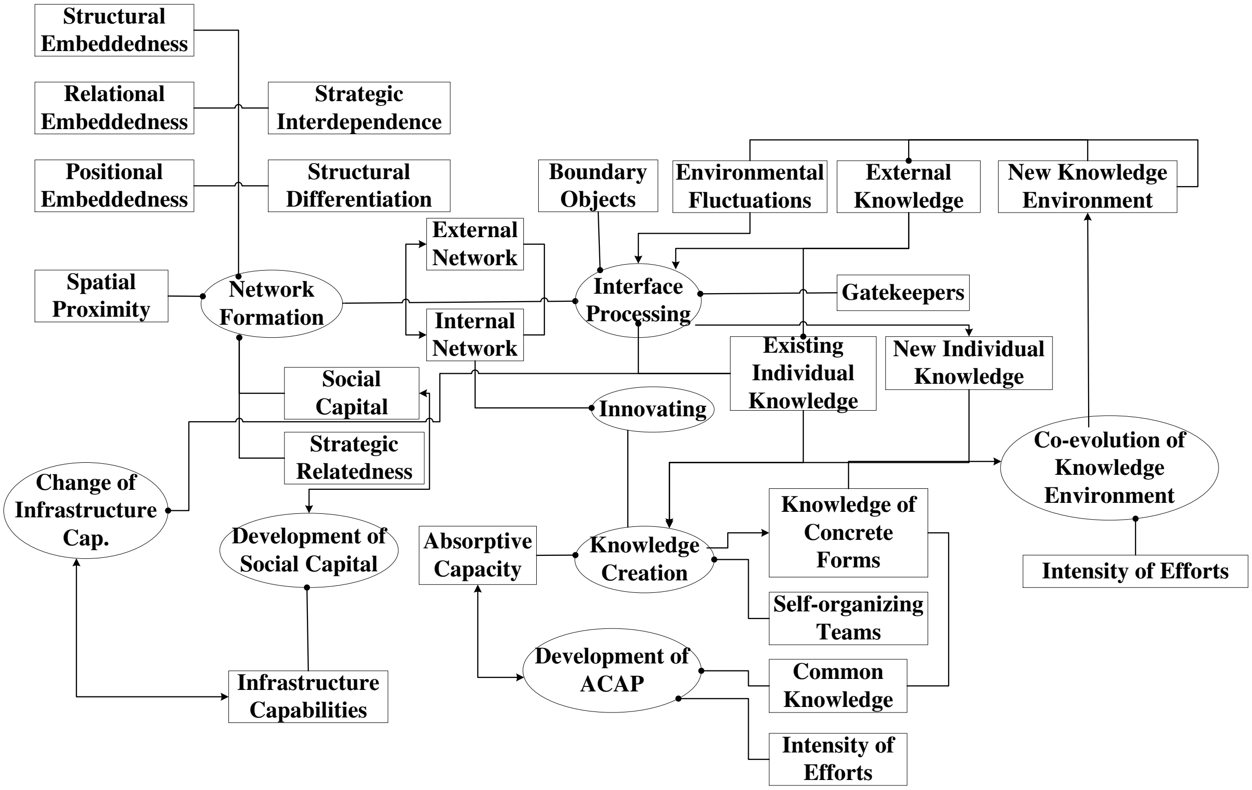


Figure 4: System Architecture of Innovation Process (Modified from Chen, 2011)

To summarize, innovation development is driven by both internal and external sources. The internal sources reflect organization capabilities associated with internal R&D and engineering, the availability of advanced technologies, workforces, and knowledge, trigger events, and organization's goals or strategies. In contrast, the external sources are related to the customer needs, the impact of competitors, knowledge diversity, strategic relatedness, and spatial proximity, advanced technology, macroeconomic, and market uncertainty (Bucherer et al., 2012; Chen, 2011; Utterback & Abernathy, 1990; Utterback, 1971).

2.3. Operational Innovation

Over the previous decades, most businesses have focused on product and process innovation. However, they still are faced with various problems such as short product life cycles, disruptive products/processes, change in customer’s preferences, and other issues. As a result, operational innovation development has become a more interesting research area for top executives, investors, policy makers, or researchers because it significantly helps businesses to gain enormous revenues and continually sustainable market competitive advantages (Hamel & Breen, 2007). However, there is much business literature on technological innovations, but only a few publications focus on operational innovation.

Operational innovation is defined as *“the development and deployment of new ways of doing work such as filling orders, developing products, providing customer service, and activity that an enterprise performs”* (Hammer, 2004). Azadegan, (2011) describes operational innovation as the new way of operating and connecting process steps together in order to increase competitive advantages. The operational innovation focuses on new activities of operating a business, and has significant impact on the entire business and enterprise’s strategic goals (Hammer, 2004, 2005). It concentrates on the organization’s business processes and innovation management correlating organization’s strategy. Typically, the operational innovation is associated with procurement, logistics, customer service support, research and development, enterprises to achieve business goals (Hamel & Breen, 2007).

Operational innovation implies operations management which initiates from managing resources through distributing goods and services to suppliers or customers. Operations management is the fundamental of the business activities that consists of strategic, tactical, and operational levels aligning with business strategies. The strategic level is associated with the size and location of manufacturing plants, structure of communication. Tactical level involves the plant layout and structure, project management methods, equipment selection, and maintenance.

Finally, the operational level is related to the internal business processes, supply chain with all stakeholders. The success of operations management is indicated by customer satisfactions, efficiency, and effectiveness. The operational efficiency is the level of utilization of resources. The operational effectiveness is the level of objectives accomplishment, flexibility, adaptability, and capability to produce the goods and services with availability of workforces, equipment, or capital during a given time period (Mussa, 2009).

Operational effectiveness relies on supply chain and innovation management and takes cost control, supply chain management, and workplace safety as performance indicators. The cost control and cycle time reduction are substantial measurement for operations. The supply chain management is a path of connected business processes to improve operational effectiveness and to accomplish the productivity and profitability goals. It consists of at least four stakeholders: suppliers, partners, collaborators, and customers. The integrated supply chain management stream usually involves capability, information, core competencies, capital, workforces, knowledge, and product/services. Supplier processes provide the benefits to enhance the performance of suppliers and partners, and entire operations. The supply chain management tends to reduce the total number of suppliers for consistency and cost reduction purpose. The emerging of management, responsiveness, financial sophistication, globalization, and digital transformation drives the need of the information technology (IT) and its investment to improve the operational efficiency and effectiveness. Workplace safety is one of important indicator to reflect how effectiveness of the operation. Organizations must guarantee that workplace safety meets minimum regulatory standards for workplace and its environment. This is comprised of establishing practical processes through personnel related to the work environment (Baldrige

National Quality Program, 2013a; Bowersox, Closs, & Cooper, 2007; COL Kays, LTC Carlton, MAJ Lee, & CPT Ratliff, 1998; Kaplan & Norton, 2007).

The advantages of operational innovation are lower direct cost, better use of assets, faster cycle time, enhanced accuracy, higher customization or precision, higher added value, and simplified processes. There are key factors to achieving operational innovation, including: recognizing role models outside of industries; focusing on end-to-end processes; engaging managers; identifying a constraining assumption; rethinking critical dimensions of work; and providing information and training to workforces (Hammer, 2004, 2005).

One operation consists of various processes and components. The operational innovation is different from process innovation and operational improvement. The process innovation is a subset of operational innovation. The outcomes of process innovation are change in procedures to gain operational efficiency and to increase production (Frishammar, Kurkkio, Abrahamsson, & Lichtenthaler, 2012). Whereas the operational improvement tends to reduce errors, costs, and delays without major changes how the work is done. Using the six sigma/lean, enterprise resource planning (ERP), customer relationship management (CRM), or supply chain management (SCM), software systems can be considered as the operational innovation unless there are new activities or changes in the way of doing work.

Operational innovation is not business model innovation, but both of these innovations are related to each other. For example, McGraw Hill Publisher technologically advanced a new distribution network or service channel by developing electronic media. Its business operation definitely changes, but not its business model. The company still is in the publisher business. However, some companies transform their business operations, and then their business models change dramatically such as Forbes and Partners Healthcare (Power, 2012). Therefore, it is necessary to understand the distinctions between these types of innovation to prevent solving wrong problems with right method/wrong method.

The best practices of operational innovation are Wal-Mart (cross-docking), Progressive Insurance (immediate response to auto claims handling), Toyota (Toyota production system), Schneider National (requests for proposals (RFPs) and acquired new business (ABN) system), and Shell (one person for all aspects of order fulfillment) (Azadegan, 2011; Hammer, 2004, 2005).

Cross-docking is one of the best examples for operational innovation. This operational innovation helped Wal-Mart become the most successful retail store business in the US. With the strategy "everyday low prices," the purpose of the cross-docking operation is to cut inventory and handling costs. In this cross-docking operation, products are constantly delivered to Wal-Mart's distribution centers, where they are selected, repacked, and shipped to stores. The process time of crossing products from one loading dock to another must be within 48 hours or less. Cross-docking requires interconnection between seven components including: 1) Wal-Mart's headquarters office, 2) strategic investment division, 3) private satellite-communication system, 4) trucks, 5) Wal-Mart retail stores, 6) suppliers, and 7) distribution centers. The information is transferred from one to another by using a private satellite-communication system. Suppliers receive the real time information of sold items from retail stores which helps them to make products and ship them instantaneously. The cross-docking system provides many benefits to Wal-Mart such as reducing the cost of frequent promotions, making prices more stable, making sales more predictable, and increasing market competitive advantages. There are also benefits for suppliers such as more accurate production forecasting, reducing the cost of raw material and inventory, and reducing time of payment transaction (Stalk, Evans, & Shulman, 1992).

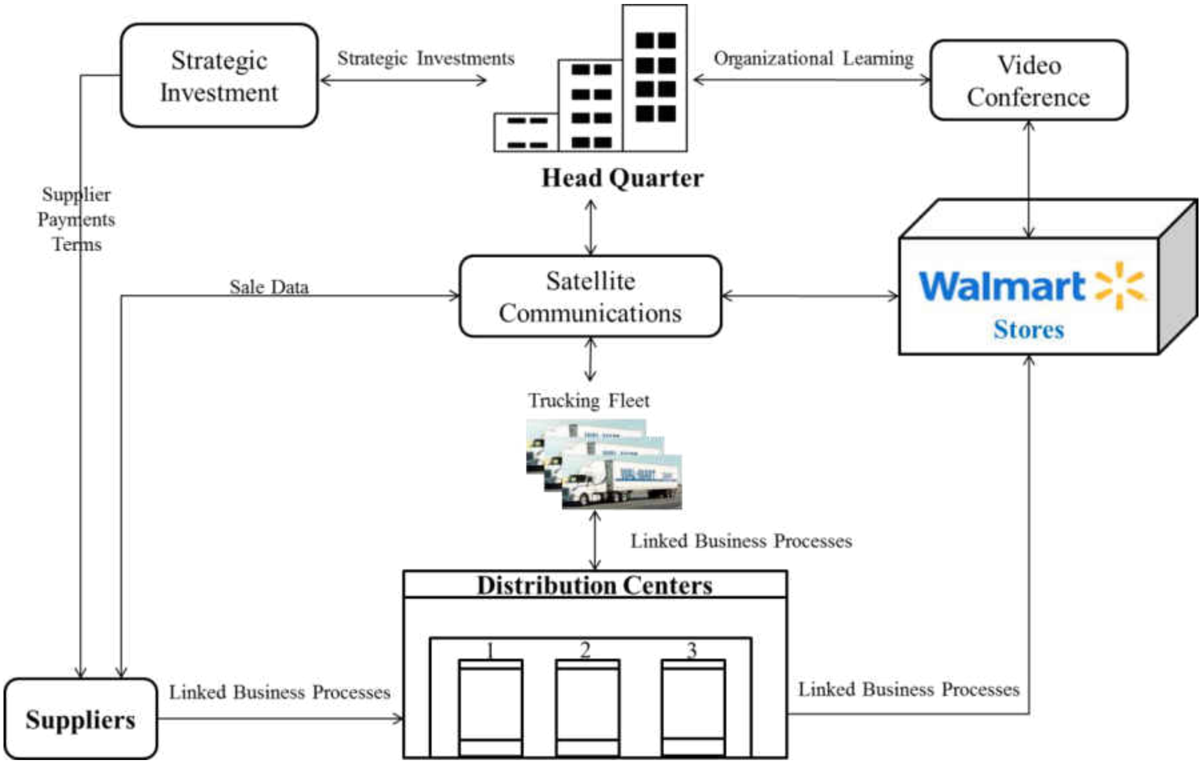


Figure 5: The Wal-Mart Cross-Docking Operation (Modified from Stalk, 1992)

Progressive Insurance provides a good example. During 1991, the company recognized the need for change in operations due to high competitiveness. To enhance competitiveness, pricing strategy and better service were key factors which drove the company to develop the operational innovation. The goal was to process auto claims within nine hours. Various new ideas for the new operation were defined such as implementing a new customer relation service operation. The company invested and focused on an information technology system, web based customer service center, rental car service, and on-site agents. The sales channel process has operated using a website and call center instead of using insurance agencies in order to reduce costs and to provide convenience to customers. Customers can get a quote directly from the website. The computer systems automatically connect with credit agencies, and the applicants' credit score is used as one of the factors for estimating a quote. Therefore, customers are able to use the website for claims and purchasing insurance policies (Hammer, 2004). This operation helps Company Progressive Insurance to increase their revenue and market competitive advantages compared to other companies.

Developing innovative supply chains lead to changes in distribution networks and service channels which are essential features of operational innovation. For example, the music industry and publishers offer electronic media on electronic devices which allow customers to access and download magazines or books from anywhere at any time. As a result, the delivery of electronic media through the electronic devices requires the new activities of business operations which eventually are one of practices of operational innovation (Amit & Zott, 2012).

The results from business cases show that the most significant factors of operational innovation, its development process, and performance indicators are shown in Table 1. It is also important to realize that the capture of the competitive threats/responses for a nonprofit organization has a different meaning because nonprofit organization has no impact from competitors but emphasizes on the efficiency of operations. The complexity of these variables drives the difficulties of transforming business operation toward operational innovation. Although businesses are heavily invested in operational innovation development, they still failed to meet the market need (i.e. Kodak, Border Group Inc.) and have faced critical problems such as lack of appropriate strategic investment decision, lack of understanding existing and new business operations, lack of systematic perspective in decision makers, and lack of leaders and authority.

Table 1: Key Factors of Operational Innovation

Internal Factors	External Factors	Operational Innovation Performance Indicators
• Trigger events • Organization’s goals or strategies • Organizational transformation • Available budget • Available technologies • Capability R&D and engineering • Operation capability • Supply chain management • Workforces • Knowledge • Leadership • Equipment readiness	• Customers’ needs • Market uncertainty • Competitive threats and responses • Advanced technology • Macroeconomic • Knowledge diversity • Strategic relatedness • Spatial proximity	• Customer satisfaction • Operational efficiency • Operational effectiveness

In addition, most of the previous research in operational innovation has not been able to result in tangible outcomes and to develop a decision-making framework that can evaluate the investment in operational innovation considering the impact of uncertainty and competitors and provide the flexibility for making decision. There are a few articles that provide the holistic viewpoint of operational innovation (Azadegan, 2011; Hammer, 2004, 2005). The complexity and challenges of operational innovation transformation drive a need for developing the alternative decision-making framework methods to prevent business failure.

2.4. Project Valuation Analysis

The innovation development requires the proper investment to achieve the business’s goals or strategies. Most of businesses tend to make an investment that it provides the high return on investment. The limited knowledge and financial resource, and short commercialization opportunities drive a high risk of trial and error during decision making process that escalates the difficult to pursue innovation strategies and to make an investment. As a final point, the innovation investment decision usually replies on the individual skills of the decision maker to make a good judgment (Katzy, 2003).

Since operational innovation has influenced with various factors such as uncertainty of the market and impact of competitors, and others as shown in Table 1; as a result, it is important for decision makers to implement an appropriate decision-making framework. Unfortunately, there is a lack of suitable decision-making framework for operational innovation development. Consequently, many businesses fail to meet the market needs and unfortunately some businesses went bankrupt.

There are five main approaches in corporate investment decision including: 1) finance, management accounting, 2) strategic management (Dempsey, 2003), 3) project portfolio approach, and 4) scenarios analysis and sensitivity analysis (Baker et al., 2011; Carmichael et al., 2011; Kodukula & Papudesu, 2006; Nagar, 2011; Moenaert et al., 2010).

First is the financial approach which aims to evaluate the return on investment of an individual project. It implies that financial return reflects cost of financial capital. The traditional discounted cash flow method (DCF) is a basic method of financial approach which estimates the net present value (NPV) of an individual project or a project life cycle. This method is a deterministic method which requires discounting future value to present value for long period (more than one year). The project NPV is the difference in value between present value of free cash flows and present value of investment costs. The positive value of NPV for a particular project is considered as an attractive project for investment, otherwise the project is rejected. When there are several alternative projects, the highest value of NPV is selected as the best solution (Kodukula & Papudesu, 2006). In addition, the financial approach assesses projects in term of the return on investment which has to be higher than the hurdle financial rates of return (Dempsey, 2003). According to Kodukula & Papudesu, (2006), the decision tree analysis is considered as one of traditional valuation methods which considers either probability of success or failure for evaluating a project. The outcome from probability of success reflects as an attractive option which obtains high bias and provides ambiguous results.

The second approach is management accounting which emphasizes qualitative analysis in regard to the capital budgeting process by implementing financial techniques (i.e. NPV, Payback, IRR, ARR and Economic Value Added (EVA)). This approach is based on organizational environment of decision making. It is a sequence process that initiates from trigger events, situation awareness, investment proposals, assessment, and approval by decision makers. The key factors of this approach are available information, standard, strategic goals, external factors, and experts' opinions, which imply a qualitative evaluation method. It is necessary to determine sunk costs, irreversible investment, risk factors, and historical data in order to define the goal of strategic decisions. However, this approach does not provide flexibility for all management, because the decisions cannot be changed upon the future market conditions.

The third approach is the strategic management approach or strategic investment. The purpose of this approach is to satisfy customers' needs, and to increase competitive advantages and revenue stream. This approach, which reflects investment decisions as risk aversion, concentrates on market opportunities and firm's competitive advantages. This approach is unlike the financial approach, because it does not take into consideration the traditional valuation methods such as NPV or payback period. The basic methods are used to evaluate projects including: Boston Consulting Group Matrix, SWOT analysis, and Balance Scorecard (Kaplan &

Norton, 2000). This approach is employed to define alternative selections of new product development, feasible project investment, competitive advantages, and novel business strategies using historical experiences (Moenaert et al., 2010). It is a purely qualitative evaluation method for an investment decision process (Alkaraan & Northcott, 2007; Dempsey, 2003; Nagar, 2011; Silvola, 2008). However, Alkaraan & Northcott, (2007) propose a pre-decision control mechanism framework based on the strategic management approach, which integrates both in quantitative and qualitative aspects to determine finance assessment, pre-determine hurdle rates, organizational strategy, operational objectives, organizational personnel expectation, formal decision processes, authorized responsibility level, and managerial awareness.

Fourth, businesses also implement a project portfolio approach to assess and to maximize return on investment. The project portfolio decision method consists of three stages: assessment, development, and production. Project idea generations are evaluated and compared against each other during the assessment stage. Various ideas are assessed, and potential alternatives are considered based on the value of return on investment. Next, it is the development stage, which initiates the selected alternative (product and service). The decision during this stage is based on contingent decisions including: defer investment, abandon, expand, contract, or continue the project on a smaller scale. The final stage is production which delivers the outcomes in term of products or services. This is called "phase-out" of products or services. If businesses desire to improve their products or services, a new project is started and repeated with the same cycle. Three important key parameters, which are required for evaluating projects, are 1) cash flow stream, 2) discount rate, and 3) contingent decision. Cash flow stream is a different value between cost and revenue. The discount rate is the rate that deducts the future value of the cash flow stream to present value. The contingent decision represents strategic decisions such as defer, abandon, expand, or contract the project depends on the management level or managers. The objective of this type of decision making method is to select a project which provides the highest value of projected cash flow (Baker et al., 2011; Carmichael et al., 2011; Kodukula & Papudesu, 2006).

Scenarios analysis and sensitivity analysis are another group. These methods are used as additional techniques to analyze uncertainty. Scenarios analysis is method to analyze multiple scenarios with variety of parameter sets. This method focuses on evaluating the alternative options and developing policy. It is a subjective treatment of probabilities based on expert opinions (qualitative data) to capture uncertainties giving different weights to the sub-problems of any optimization problems. Whereas sensitivity analysis emphasizes on change in one parameter can decrease/increase investment. These methods are implemented when businesses have a limited historical data for innovative projects (Nagar, 2011; Moenaert et al., 2010).

These traditional investment decision methods, for instance the Discounted Cash Flow (DCF) method, Decision Tree Analysis, Ad-hoc Scoring model and Basic Metric (Rate of Return, Payback Period, Breakeven, etc.), have been effectively used for strategic investment in numerous projects both in public and private sectors. However, many researchers have found that these approaches have many limitations (H. K. Baker, Dutta, & Saadi, 2011; Carr, Kolehmainen, & Mitchell, 2010; Kodukula & Papudesu, 2006; Kong & Kwok, 2007; Nagar, 2011; Trigeorgis, 1993a).

First, the traditional valuation methods cannot provide flexibility in decision making or change the decisions due to unexpected situations in the future. Second, the traditional valuation methods represent the determined cash flow stream and assume a specific objective. Third, these methods do not provide comprehensive information on the effect of market dynamics, or do not take risk and uncertainty into consideration. In addition, they do not offer information regarding stability of competitive pressures to required investments, or flexibility of keeping investment options open. In other words, the risk and uncertainty are not considered for estimating the cash flow. Fourth, they do not intensively consider the value of contingent decisions, because the value of cash flow is predetermined.

Finally, estimating the discount rate for traditional methods does not consider the uncertainty and types of risk (i.e. private risk and market risk). The discount rate, which is used to estimate the entire period of cash flow, is constant value. In reality, the cash flow stream fluctuates in every single period. The discount rate should be changed to be consistent with the future market conditions (Benaroch, 2001; Driouchi & Bennett, 2012; Kodukula & Papudesu, 2006; Mathews, Datar, & Johnson, 2007; Munoz, 2006; Nagar, 2011; Sáenz-Diez, Gimeno, & de Abajo, 2008; H. K. Baker et al., 2011; Kodukula & Papudesu, 2006; Nagar, 2011; Trigeorgis, 1993). Table 2 shows the different investment decision methods and their respective descriptions and limitations.

Table 2: Project Valuation Methods (Nagar, 2011; Moenaert et al., 2010; Demsey, 2003; Baker et al., 2011; Carmichael et al., 2011; Kodukula & Papudesu, 2006)

Valuation Methods	**Description**	**Analysis**	**Limitations**
Financial Methods	Net present value of the future cash flows discounted at opportunity cost of capital for a specific project life	A simplified approach for assessing cost, revenue and profitability of investment	- Estimate of project's predicted cash flows - Estimate of discount rate - Estimate the project's impact on the firm's future investment opportunities
Decision Tree	Modeling different flexibilities in the lifetime of projects valuing each alternatives	For evaluating of uncertainties	- Work with unknown underlying assets distributions - Can be used in complex investment scenarios - Based on either high or low values of uncertainties is not appropriate in the real situation
Management Accounting	Qualitative analysis regarding capital budgeting process by implementing financial techniques	For establishing investment decisions, defining sunk costs, irreversible investment and maximizing profits	Difficulties integrate in practical application of formal, quantitative systems of investment analysis to the business's strategic goals
Strategic Management	Focusing on market opportunities and firm's competitive advantages	Alternative selection, New Product Development	Based on historical experiences and risk aversion
Project Portfolio Approach	Assess and maximize return on investment	Alternative selection, New Product Development, and Production	- It is not a robust tool to analyze uncertainties -It can be used for small scale projects

2.5. Real Options Analysis (ROA)

Real Options Analysis (ROA) is a technique that considers risk and uncertainty, providing flexibility for making decisions, offering an opportunity to revise the decision upon the future market conditions, and minimizing risks and volatility in the market. The value of real options represents the ROI or opportunity cost of postponing investment for additional information to minimize uncertainty in future. The rationale of real options is a part of the managerial thinking or strategic management approach that can enhance the values of operating options and business growth opportunities (Benaroch, 2001; Copeland & Antikarov, 2005; Driouchi & Bennett, 2012; Mathews et al., 2007; Trigeorgis, 1993b, 2005).

In 1984, Steware Myers (Myers, 1984) articulated the limitations of the DCF method, and proposed the new idea of combining the finance threory and investment opportunities for estimating project valuation called real options anlysis. The concept of the real options was initiated from finance option pricing: calls and puts on stock market (Smith, 2005; Trigeorgis, 1993a).

The finance option pricing (calls and puts) have two different types of options: European and American options. First, European call (put) option offers the right to invest (sell) an asset (S) for a settled exercise price (X) at expiration date. As a result, the values of a call and put option on expiration are C=max (0, S-X) and P=max (0, X-S). The call value is the difference in value between the asset value at expiration date and the strike price. If the asset value at expiration date is higher than the strike price, this call option is called "in-the-money;" otherwise, the call value equals zero which is called "out-of-money." The investors will not exercise this option.

The call option has value when the stock price in the future tends to increase. In contrast, the put value is the difference in value between the strike price and the asset value at expiration date. If the strike price is higher than the asset value at the expiration date, the put option is called "in-the-money;" otherwise, the put value equals zero. The put option has value when the stock price in the future tends to be less than the current stock price. Second, the American option offers the right to invest (sell) an asset (S) for a settled exercise price (X) at any time before expiration date. The American option provides more flexibility for investors compared to the European option. Figure 6 illustrates the basic finance options both in call and put options (Benaroch, 2001; Bodie, Kane, & Marcus, 2004; Kodukula & Papudesu, 2006).

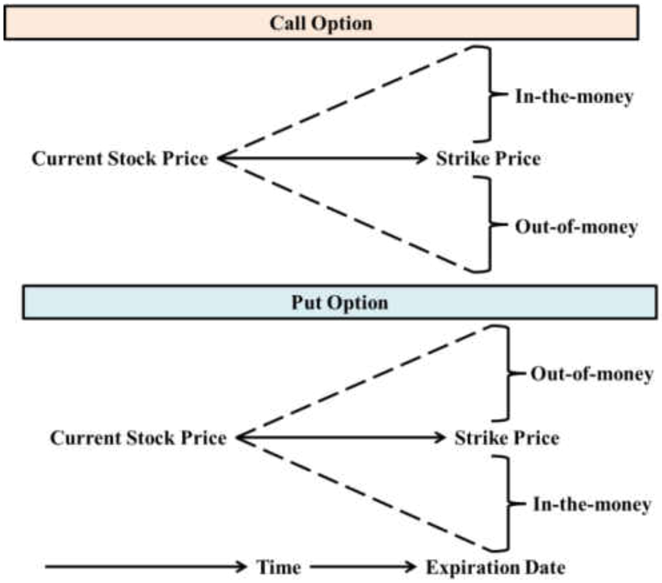


Figure 6: Types of Finance Options (Calls and Puts) (Modified from –Bodie et al., 2004)

Trigeorgis, (1993a, 1993b, and 2005) used the real option analysis for investment opportunities called strategic decisions. This method provides management flexibility for a project investment which can be changed upon the future market conditions. This author proposed the seven types of real options including: 1) option to defer, 2) time to build option (staged investment), 3) option to alter, 4) option to abandon, 5) option to switch, 6) growth option, and 7) multiple interacting options.

Benaroch, (2001) defines the real options for technology investment which are categorized within two types: growth options and operating options. The growth options represent the strategic investment in product development to create indirect, measurable, and long term payoffs in the future business. The purposes of this option are to improve core competencies, while the operating options involve technology investments and direct measurable payoffs. The growth options provide flexibility for management, especially adapting the constraints of technology investment for unpredictable scenarios. The strategic decisions for options include: defer, abandon, lease, and contract. Kodukula & Papudesu, (2006) propose eight types of real options which are similar to Trigeorgis, (1993a, 1993b, 2005) and Benaroch, (2001).

Benaroch, (2001) also proposes the option-based methodology for managing technology investment risk. The risk factors are key elements that must be identified for each investment and are used to determine the investment structures of Web-Based Sales Channel. Nagar, (2011) implemented the real options method to evaluate investments in new restructuring the Indian electricity sector. The results helped policy makers to emphasize feasible technology options. Risk is defined as the probability of unpredictable consequences with inadequate information or data; whereas, uncertainty is a probability of unpredictable conditions with insufficient information. The uncertainty is classified within two types: knowledge uncertainty (lack of information about future and complexity); and variability uncertainty (stochastic, random and unavoidable).

Therefore, the real options for the technology investment are categorized within ten types of options: defer, stage (stop-resume), outsource, alter operating scale (contract, expand, shutdown and restart), switch-use (abandon), lease, switch input/output, compound, and strategic growth, which are similar to Trigeorgis, (1993a, 1993b, 2005). Each option has different characteristics which can be used for different conditions in the decision making process. Different types of real options and their descriptions are shown in Table 3.

Table 3: Types of Real Options (Benaroch, 2001; Kodukula & Papudesu, 2006; Nagar, 2011; Trigeorgis, 1993b)

Category	**Description**	**Important In**	**Analyzed by**
Option to defer	Option to wait for an investment in anticipation to get maximum value	Natural resources; real estate development; agriculture	Tourinho 1979; Titman 1985; McDonald and Siegel 1986; Paddock, Siegel&Smith 1988; Ingersoll and Ross, 1985
Time to build option (stage/stop /resume)	Stages option with an option to abandon in midstream with more information	All R&D intensive industries especially pharmaceuticals; long development capital intensive capital	Majd&Pindyck, 1987; Carr, 1988; Trigeorgis 1996
Option to alter	Option to expand, contract, shutdown or restart the scale of operations depending upon more information	Natural resources industries (mine operations) and construction in cyclical industries	Brennan and Schwartz 1985; McDonald and Siegel 1986; Trigoergis and Mason 1987; Pindyck 1988
Option to abandon	Option to abandon the operations completely in unfavorable conditions	Capital intensive industries (airlines and railroads) and financial services	Mayers and Majd 1990
Option to switch	Option to switch between outputs, inputs or technologies	Any goods (electronic devices and autos) and all feedstock-dependent facilities (oil, power, chemical crop)	Margrable 1978; Kensinger 1987; Kulatilaka 1995; Kultilaka and Trigeorgis 1994
Growth options	Early investment in anticipation of future growth opportunities such as inter-project compound options	All infrastructure-based or strategic industries (high-tech, R&D) or multiple production business (pharmaceutical)	Myers 1987; Brealey and Myers 2000; Kester 1993; Trigeorgis 1990; Pindyck 1988; Chung and Charoenwong 1991

Category	Description	Important In	Analyzed by
Multiple interacting options	Collection of multiple options catering to real life scenarios modeling the interaction between the options	Real life projects in most industries	Brenna and Schwarts 1985; Trigeorgis 1993; Kulatilaka 1995

Generally, there are two traditional methods for estimating real options value: Binomial Lattices and Black Scholes. Binomial Lattices and Black Scholes are the methods to evaluate European options value. In addition, there is a third method that was proposed by Scott Mathews and Vinay Datar, called "Datar-Mathews methods."

Binomial Lattice is similar to Decision Tree Analysis. The value of a risky underlying asset (S) is based on a binomial distribution with initials at t_0 in one time period (Δt). Asset (S) increases to S_u with probability u or decreases to S_d with probability d, and r_f is the risk-free interest rate (interest rate market is willing to pay on an asset whose payoffs are completely predictable). Asset (S) binomially distributes and stops upon the number of time periods. The last node at the end of the binomial tree reflects the range of possible asset values at the end of the option life. The binomial lattices require two different approaches: risk-neutral probabilities and market-replicating portfolios (Kodukula & Papudesu, 2006).

Risk neutral probabilities are used to calculate certainty-equivalent cash flows that can be discounted at the risk free rate of the expected future payoff (Copeland & Antikarov, 2005; Trigeorgis, 1993b). Kodukula & Papudesu, (2006) explain that risk neutral probabilities are associated with risk adjustment of cash flows and later discount them at the risk free rate. The binomial lattice shows both upside potential *(u)* and downside risk *(d)* which are functions of the volatility of the underlying assets and can be calculated with these formulas:

$$u = \exp(\sigma\sqrt{\Delta t}) \tag{1}$$

$$d = 1/u \tag{2}$$

$$\text{Risk neutral probability } (p) = \frac{\exp(r_f \Delta t) - d}{u - d} \tag{3}$$

The value of option on asset (S) can be determined during a certain period of time *(Δt)* as follows:

$$C_u = \max(0, S_u - X) \quad \text{or} \quad C_d = \max(0, S_d - X) \tag{4}$$

$$C = [p\,(S_u) + (1-p)\,(S_d)]^* \exp(-r_f \Delta t) \tag{5}$$

Where $\Delta t = T/n$, T is the Life of the options and n is the Number of time periods

Equation 4 illustrates the call option values which are the different values between the underlying asset value and a strike price. Equation 5 shows a formula for estimating the value of real options with the risk-neutral probabilities (either p or probability $1-p$). It also considers the risk free rate with delta time period (Δt). The risk neutral probabilities are not the same as objective probabilities, but it is an intermediate value that allows discounting cash flow by using the risk free interest rate. The binomial lattice requires five basic parameters: σ, r_f, S_0, X and T (Benaroch, 2001; Bodie et al., 2004; Kodukula & Papudesu, 2006). Figure 7 shows an overview of the binomial decision method.

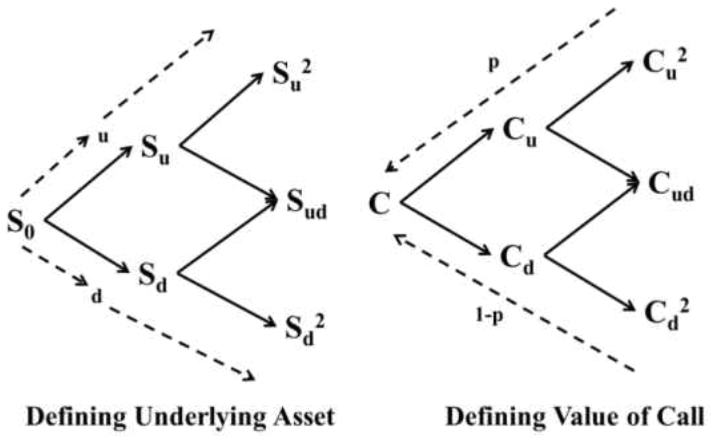


Figure 7: Binomial Lattice Decision Method (Modified from Bodie et al., 2004)

The Black Scholes method was established by three MIT economists: Fischer Black, Robert Merton, and Myron Scholes, in 1973. The equation is for estimating the European call option which is based on the stock price assumption of geometric Brownian motion (Bodie et al., 2004; Kodukula & Papudesu, 2006). The call option value with Black Scholes equation can be determined as follows:

$$C = S\ N\ (d1) - X\ e\text{-}rf\ T\ N\ (d2) \tag{6}$$

Where; $d_1 = \frac{\ln(\frac{V}{I}) r_f T}{\sqrt[\sigma]{T}} + \frac{1}{2} \sqrt[\sigma]{T}$ and $d_2 = d_1 \text{-} \sqrt[\sigma]{T}$

C indicates the option value depending on σ (standard deviation or volatility), variability of *S*, strike price of *X*, risk free rate-r_f, and *T*-the option's time to maturity. *S* has a range from zero to infinity, and the higher value of σ and longer *T* offer a higher option value C. The Black Scholes method relates to random probabilities from a standard normal distribution (range from zero to one). To conclude, this method has three main key factors: time before option expiration (*T*), risk-free interest rate (r_f), and volatility (σ) (how hard it will be to predict the underlying asset's price into the future). The initial stock price (S_0) and strike price (X) are based on the market conditions (Benaroch, 2001; Bodie et al., 2004; Kodukula & Papudesu, 2006; Sáenz-Diez et al., 2008; Trigeorgis, 2005).

The final method is the Datar-Mathews (DM) method which was established by Scott Mathews and Vinay Datar (Mathews et al., 2007). This method considers net present value (NPV), cash flow components, discount rate (corporate bond term), and probability uncertainty. Option values can be evaluated by estimating different cash flow scenarios (Optimistic, Most Likely, and Pessimistic), return on investment, and predicted future pay-off distribution, which are different from the traditional NPV methods. This method captures real options value by discounting the distribution of operating profit at certain market risk rate or risk free rate within three scenarios: Optimistic, Most Likely, and Pessimistic.

A success story of the Datar-Mathews method implementation is an Unmanned Aerial Vehicle (UAV) project at Boeing (Mathews et al., 2007). The assumptions of strategic decisions are to defer a project or not, and will this project make a profit for the long term or not. This method can provide more information in regard to strategic investments which helped Boeing during the acquisition phase. The equation of real option value based on Datar-Mathews is presented in Equation 7, and the real option value equation in the UAV case is illustrated in Equation 8 (Mathews et al., 2007; Mathews, 2011).

$$C_0 = E_0\,[\mathrm{Max}\,(S_T e^{-\mu t} - X_T e^{-rt}, 0)] \tag{7}$$

$$\text{Real Option Values} = \text{Average}\,[\text{Max}\,(\text{operating profit} - \text{launch cost}, 0)] \tag{8}$$

Monte Carlo Simulation is a supplemental method of real options analysis to evaluate the risk and uncertainty. It is a powerful mathematical technique to predict future results considering risk and uncertainty. Monte Carlo was established by Nobel physicist Enrico Fermi in 1930, aiming to estimate properties of the neutron particles. Today, it is used for various applications from finance to engineering problems. Monte Carlo simulation is used to support decision making for projects by repeated simulated paths of risk factors in order to estimate probability distributions of terminal asset value (Mun & Housel, 2010; Mun, 2006).

The Monte Carlo simulation and real options can be implemented to assess a portfolio policy by simulating large scale scenarios. These two analytical methods help decision makers to gain understanding, and to consider both the mean value and the value of risk (Fishman, 1996).

Hacura et al., (2001) used the Monte Carlo simulation to evaluate risks in investment. They stated that the expected cash flow cannot be a linear path, because it interacts with several risk factors such as sales price, sale volume, and cost. The average NPV from thousands of random runs is used to represent the value of the project.

Munoz, (2006) explains the relationship between Monte Carlo simulation and real options. Monte Carlo helps to estimate parameters such as interest rates, stock prices, and discount rates determined with a normal or lognormal probability distribution technique. The results from Monte Carlo simulation are used to estimate the value of project investment by using the real options method, such as the Black Scholes method. The real options value represents the expected project value with a probability distribution based on business strategic plans (Munoz, 2006).

Mun, (2006) and Mun & Housel, (2010) provided the basic framework of real options for complex systems (Figure 8). The options are designed, and Monte Carlo simulation and stochastic forecasting are implemented for estimating options values. The logic of real options is used to determine and estimate value in each strategic pathway, and finally a decision is made.

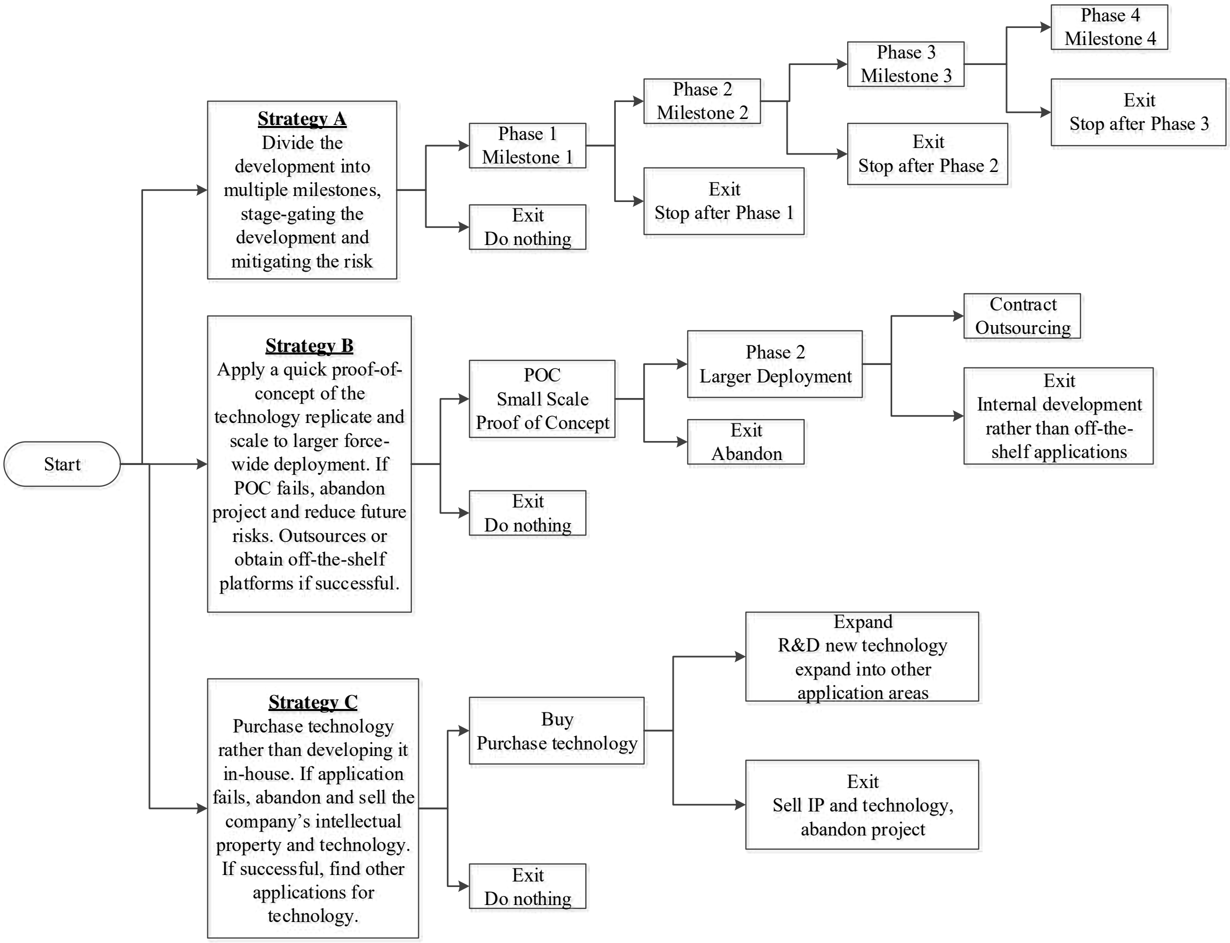


Figure 8: Framework of Real Options for Complex System
(Modified from Mun & Housel, 2010)

To conclude, real options provide benefits for project investment evaluation. First, real options offer a present value which presents the project value with flexibility and the ability to defer development. Second, defer options offer higher net present value than other options, because a decision will be made if the level of risk is minimized. Third, assessing project investment takes uncertainty and risk factors into consideration. Fourth, the real options clarify what the condition must be to exercise the option. Fifth, the real options specify realistic problems by including various scenarios such as the optimistic, the most likely, and the pessimistic scenarios. Finally, the real options methods require simple mathematics and basic intuition (Copeland & Antikarov, 2005; Mathews et al., 2007). The real options valuation method is useful for defining values of new business opportunities under uncertain environment and providing choices to execute projects in the future (Sáenz-Diez et al., 2008). Table 4 summaries the comprehensive literature of real options, its methods, and the advantage/limitations for each method.

Table 4: Summary of Real Options Analysis

Real Options Analysis Methods	**Advantages/Limitations**
Binomial lattice	-Suitable for technology investment -Similar to decision tree analysis -Require simple mathematics and enables a trace for each time period -Offer the better intuitions for estimating the value of the project in different strategic decisions
Black Scholes method	-Applicable for only a single time period -A single risk free rate is applied for entire time period -Suitable for financial investment
Datar-Mathews (DM) method	-Estimate different cash flow scenarios (Optimistic, Most Likely, and Pessimistic) -Use to predict future pay-off distribution -Applicable for only a defer strategic decisions -Good fit for high payoff outcomes and high risk situations

2.6. Matrix of change (MOC)

Matrix of change (MOC) is a tool to analyze a business transition. This tool captures the current state and future state of a particular organization or management. It was developed at the MIT Center for Coordination Science (Brynjolfsson, Renshaw, et al., 1997).

The current state represents the current way of doing business or a focused system. The future state represents the target or goal for what they want to be in future. When functions or elements of the current state or future state are identified, the relationship between elements is determined in term of (+) reinforcing behavior and (-) interfering behavior. The transition from current state to future state is evaluated. The more reinforcing behaviors (+) reflect the ease of transition. The result is presented in terms of feasibility, sequence of execution, nature of change, and stakeholder evaluations (Brynjolfsson, Short, & Lizeo, 1997).

The importance of evaluation is identified using Likert Scale from -2,-1, 0, +1, +2 (from not very important to very important rank). The outcomes articulate the feasibility of transition, sequence of execution based on the importance, location, pace and nature of change, and stakeholder evaluations. MOC can help decision makers have better insight into their organization. However, this technique does not provide the quantifiable values (Brynjolfsson, Renshaw, et al., 1997).

The example of MOC is demonstrated in Figure 9. This example is related to Company MacroMed where senior managers gathered a SWAT team from a cross-function of the staff consisting of managers, design engineers, and union workers across various different roles. The team derived a plan by assessing specific aspects of their existing hierarchical production techniques and establishing their vision of a new organization based on the perceived benefits of a decentralized production line. The existing state is shown in the left column. The general statements of practice were used to determine basic practices. The future state is illustrated in the top column. The interaction between elements is defined, which reflects the behavior between them. After the interactions of elements are defined, the transition from current state to future state and the importance of each feature are identified. In this example, the result shows that the future state is unable to achieve better results because there are several (-) interfering behaviors in the transition matrix (Brynjolfsson, Renshaw, et al., 1997).

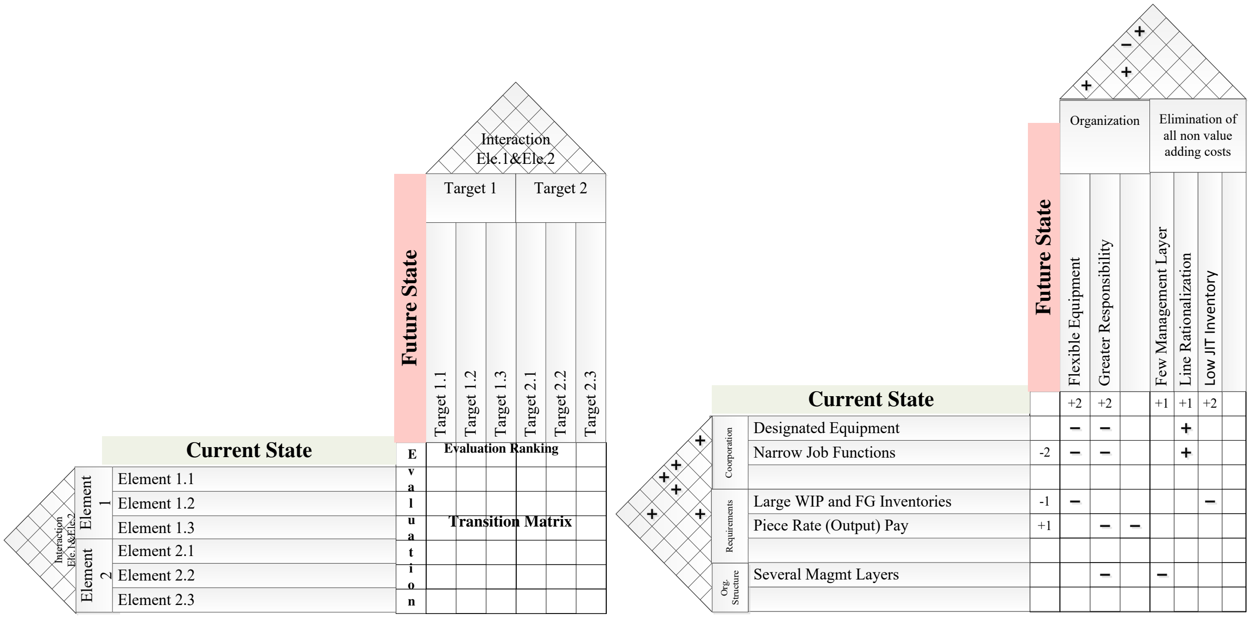


Figure 9: The Example of Matrix of Change Analysis
(Adapted from Brynjolfsson, Renshaw, & Alstyne, 1997)

2.7. Lotka-Volterra

The Lotka-Volterra concept is an approach to evaluate competitiveness. It was initially developed by the American biophysicist Alfred Lotka and the Italian mathematician Vito Volterra in 1925. They proposed the mathematical equations which defined the non-linear dynamics of biological systems. These equations estimate the population when two species interact, one of them a predator and the other, prey. However, these equations have limitations which can be solved numerically, not explicitly. The solution is to use equations in the case of pure competition. The Lotka-Volterra equations are shown in Equation 9 and 10.

$$T_1(t+1) = \frac{e^{a_1} T_1(t)}{1 - \frac{s_{11} C c_{11}(e^{a_1 - 1})}{a_1} T_1(t) + \frac{s_{12} c_{12}(e^{a_1 - 1})}{a_1} T_2(t)} \tag{9}$$

$$T_2(t+1) = \frac{e^{a_2} T_2(t)}{1 - \frac{s_{21} C c_{21}(e^{a_2 - 1})}{a_2} T_1(t) + \frac{s_{22} c_{22}(e^{a_2 - 1})}{a_2} T_2(t)} \tag{10}$$

Where; T_1 and T_2= Represent each technology

S_{ij} = Pure competition mode of two technologies

C_{ij} = Coefficients of the mode of competition

a_i = Coefficients for each technology

Pistorous and Utterback (1997) developed four uni-directional modes (multi-mode framework) based on the Lotka-Voterra concept. The multi-mode framework focuses on a positive or negative impact on the growth of an emerging technology. This framework has three types of interrelationships between technologies (A&B) including: 1) Pure competition, 2) Symbiosis, and 3) Predator-prey interaction (Figure 11). Pure competition is described as each technology having a negative influence on the other's growth. It is usually expressed in terms of substitution from one technology to another (Unver, 2008). A second interaction is symbiosis, where each technology has a positive impact on one another's growth rate.

Predator-prey interaction occurs between emerging technology and mature technology when the emerging technology launches to a niche market without the mature technology. The emerging technology has more advantages; meanwhile, the mature technology will have positive impact on the emerging technology's growth rate. As a result, the emerging technology is the predator; whereas, the mature technology is the prey (Unver, 2008).

The competition between Apple and Samsung on the smart phone market is a good example of predator-prey interaction. The advanced development of iPhone increased Apple's market share and the number of customers. This impact allows Company Samsung to improve its technology to sustain its product in the market. In this case, Company Apple is the predator; in contrast, Company Samsung is prey. Thus, the impact of new technology and competitors are very important factors that can indicate success or failure of a business.

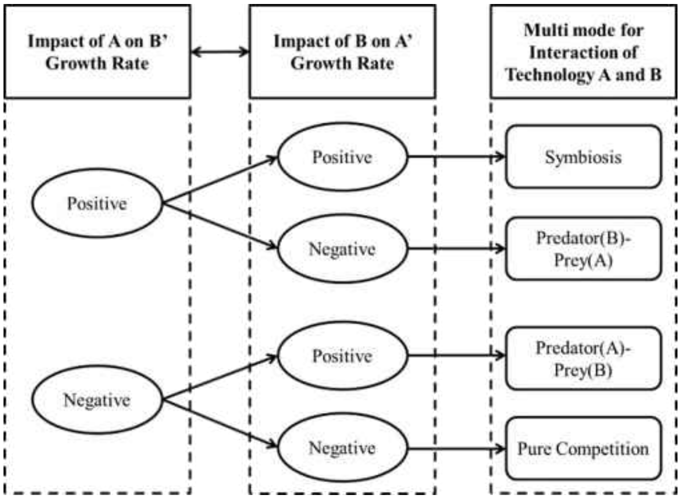


Figure 10: Multi-Mode Framework Based Lotka-Volterra Concept (Modified from Unver, 2008)

2.8. System Dynamics (SD)

Due to the complexity of the operational innovation system, it is a necessary to implement a proper tool or method to study and analyze its dynamics and problems. System Dynamics (SD) is a well-known method to map and analyze complex systems. It was originated by Jay W. Forrester at MIT in the late 1950s (Sterman, 2000). The main purpose is to explore a new understanding of how the problem arises, and use that understanding to develop feasible policies for improvement (Sterman, 2000; Tan et al., 2010).

Sterman, (2001) defines the system dynamics as a process to provide effective policies for sustainable improvement of business. It is a policy-based methodology which is used to evaluate consequences of change in policies in the system. It characterizes “cause” and “effect” relationships between variables and analyzes relevant variables of a particular system. Therefore, changes in one variable can provide several outcomes across different scenarios and an optimal result is selected upon settled goals (Damle, 2003).

The benefits of system dynamics are to provide visibility and better insight of complex systems. System dynamics have been applied to evaluate various problem areas such as business, project management, human reliability, and mental workload (Damle, 2003; Sharma et al., 2004; Sterman, 2000; Tan et al., 2010).

There are five steps of the system dynamics modeling process which are shown in Figure 11. First is problem identification, which aligns the problem boundary. The problem and root cause of the problem are defined. The relevant key variables, time horizon, and reference modes are identified. The second step is formulation of the dynamic hypothesis. It is necessary to define the current theories of the problematic behavior. Then causal loop diagrams, stock and flow maps, and policy structure diagrams are developed. The third step is the formulation of a simulation model. The specification of structure, decision rules, estimation of parameters, and initial conditions are executed in this step. The fourth step is testing the comparison between the reproduced model and the reference modes. The sensitivity can be tested during this step as well. Finally, there is policy design and evaluation. The scenario’s specification, policy design, what if scenario analysis, sensitivity analysis, and interactions of policies are developed and analyzed (Sterman, 2000).

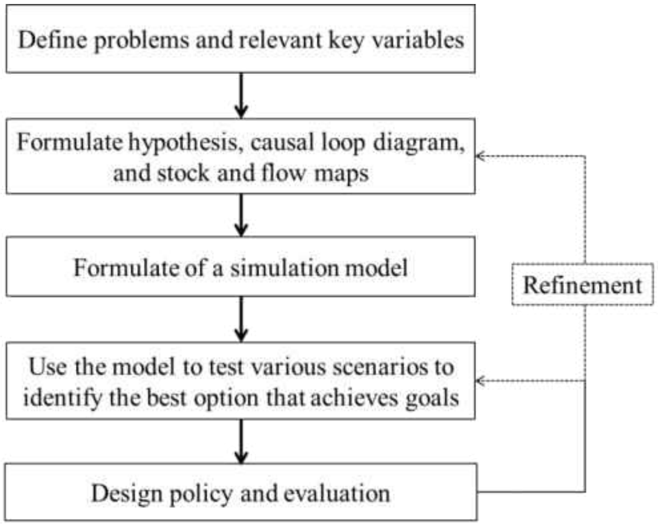


Figure 11: Procedural Steps in System Dynamics Modeling

Causal Loop Diagram

System dynamics requires a causal loop diagram which provides a conceptual framework of the real world systems in terms of feedback loops. The causal loop diagrams represent relationships between variables, holistic dynamics of the model, and characterized system behavior (Sterman, 2000).

It is used to seize the cause and effect relationship between variables in complex systems by connecting two variables with an arrow to define a direction of relationship: positive (+) and negative (-) signs, and to indicate a type of influence (Damle, 2003; Sterman, 2000; Sterman, 2001). The set of linkages represent the feedback loops in a particular system. The advantages of the causal loop diagram are mapping hypotheses and causes of dynamics regarding the problems, and providing overall insight about the problems in high, unstable complex systems (Winch, 2001).

An example for developing a causal diagram in innovation is illustrated in Figure 12. The interpretion of this causal loop diagram is that an increase of customers' needs escalates innovation development. Furthermore, an increase of innovation development grows revenue streams and advanced technology. Finally, an increase of advanced technology increases change in customers' preferences.

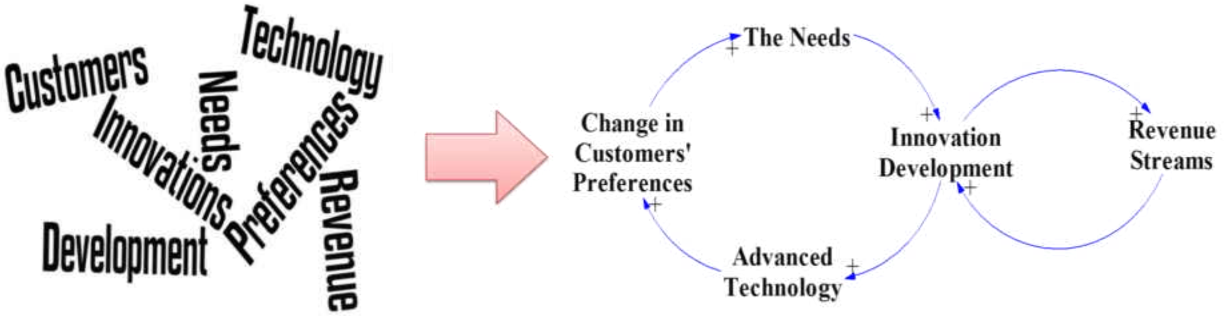


Figure 12: Steps for Developing a Causal Loop Diagram in Innovation

Stocks and Flows

The Stocks and Flows structure represents the quantitative aspects of a system. It is developed based on the causal loop diagrams by adding levels, rates, variables, and system delays. Some variables in the causal loop diagram are qualitative variables which must be formulated into the quantitative variables. Stocks and flows include information about the values of these variables, and flows represent rates of inflow and outflow. Stocks represent differentially accumulated values between inflow and outflow rates (Figure 13). For example, the stock of population is accumulated value of discrepancy between birth rate (Inflow) and death rate (Outflow). Stocks can be affected by delays in the system; for example, a government policy of one family/one child is delaying an increase in population (Sterman, 2000). The stock is shown as a rectangular shape whereas the rates are illustrated by valves that control rates of filling and draining a stock.

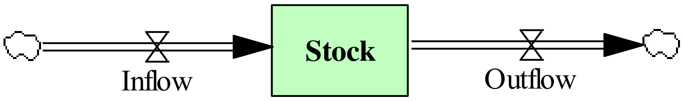


Figure 13: Stock and Flows

The mathematical notation of stock and flows is articulated in terms of integral Equation (10) and differential Equation (11). The integral equation explains a value of stock at time *t*, which is a summation of a value of stock at time t_0 and an integral of difference between inflow and outflow rates from t_0 to *t*. In contrast, the differential equation represents the rate of change in a stock, which is defined as the difference between inflow and outflow at any instance (Sterman, 2002).

$$\text{Stock (t)} = \text{Stock (t0)} + \int_{t_0}^{t} [\text{Inflow (t)} - \text{Outflow(t)}] \cdot dt \qquad (11)$$

$$\frac{d(\text{Stock})}{dt} = [\text{ Net Change in Stock}] = [\text{ Inflow(t)} - \text{Outflow (t)}] \qquad (12)$$

<u>System Dynamics Behaviors</u>

The system dynamics behaviors are typically categorized within four types. First is an exponential growth behavior which is a positive feedback or self-reinforcing loop. The basic concept is accelerating growth; however, the growth may not literally follow the pattern such as an increase of interest rate leads to an increase of the principle. Second is a goal-seeking behavior where the system initiates from above or below a goal level, and accelerates toward the goal over time. When a single negative feedback influences the system, such as corrective action, the behavior rises to a desired standpoint and then constantly balances the system and follows the trend.

Third is an oscillation behavior which is affected by negative feedback loops and delays. The state of the system constantly overshoots its goal or equilibrium state, reverses, overshoots, and so on. The overshooting increases from the presence of significant time delays in the negative loop. Fourth, S-shaped growth is initiated from the exponential growth, followed by goal-seeking behavior. This behavior articulates both positive and negative feedback loops within complex systems (Choi & Bae, 2009; Chu, 2006; Sharma et al., 2004).

The system dynamics modeling is widely applied to solve business problems. Grasl, (2008) developed the system dynamics model for business models which consists of four main components: value network, product, business transaction, and value dynamics. The model is applied by a professional service firm (small scale) through IT service providers. The first component is a value network, representing the business relationship, freelance consultants, and IT service providers. The second component is the product view which articulates services to its customers. Third, business transactions are associated with sell projects, deliver projects, hire and fire consultants, and maintaining business relationships. The basic transactions include new contracts, a network of business relationships, and sales. Finally, it is value dynamics which involve partners, contacts, projects, consultants, customers, and value.

2.9. Gap Analysis

This chapter illustrates a review of the literature that is associated with operational innovation, investment decision tools, transition analysis, and complex systems analysis techniques. The gap analysis represents the research gaps.

The review of innovation and operational innovation sections explore the current types of innovation, the key drivers of innovation, the challenges in innovation development, the steps of the innovation process and its important factors, the characteristics of operational innovation and its environment, best practices and failures, and problems. The following questions were asked when reviewing this area:

- What are the causes of business failures even though businesses heavily invested to develop operational innovation?
- Why is the operational innovation important for businesses?
- When businesses recognize the need to develop operational innovation, what are key factors that should be taken into consideration prior to transformation and investment?
- What are the features of operational innovation?
- What are the measurements of operational innovation performance?
- What are the current methods used in the operational innovation investment decision making process?

The review of the project valuation analysis and real options analysis sections explore the current types of investment decision tools, the important parameters for evaluating the project investment, and the advantages/disadvantages of each method. The following questions were asked when reviewing this area:

- What are the strategic investment decision and its approach?
- What is real options analysis and how can it be used?
- What is the potential valuation method for the operational innovation investment decision?
- What are the steps to effectively assess the operational innovation development?

The review of the matrix of change articulates an approach of business transition analysis. It shows the current methodologies for change in management and organizational structures. The following questions were asked when reviewing this area:

- What are the effective methods to manage change in business operations?
- What are the steps to evaluate the feasibility of changes in business operations toward operational innovation?

The review of the Lotka-Volterra represents an analysis of competitiveness. This review articulates the current approach to evaluate and assess the impact of a competitor. The following questions were asked when reviewing this area:

- What are the effective methods to evaluate the impact of a competitor?
- What are the steps to estimate the impact of a competitor?
- What are the parameters to take into consideration for evaluating competitiveness?

The review of system dynamics modeling illustrates an approach to analyze complex system. This review includes a method to identify the significant factors of a particular system, develop a dynamic of that system, model a mathematical simulation, evaluate outcomes from the model, and establish requirements or policies based on the results. It also presents the potential value added to a decision making process. The following questions were asked when reviewing this area:

- What are the current approaches to analyze complex systems?
- What are the steps to capture business dynamics of operational innovation?
- What are the steps to develop a mathematical model for operational innovation in order to predict the future outcomes prior to an investment?

Table 5 shows the reviewed research literature and the research questions corresponding to the research areas that are expected to answer these questions. This table shows some evidences of the current research gaps in decision-making framework for the operational innovation investment. In addition, the different approaches were extracted to develop an alternative decision-making framework to address the operational innovation and its investment value (Figure 14).

Table 5: Literature Review for Surveyed Research Areas

Research Questions	Innovations and Operational Innovation	Strategic Investment	Investment Decision Considering Uncertainty (Real Options)	Management Transition (Matrix of Change)	Competitor Evaluation (Lotka-Volterra)	Dynamics Behavior (System Dynamics)
What are the causes of business failures with regards to operational innovation?	√					
What are key factors that need to be taken into consideration prior to transformation and investment?	√					
What are the features of operational innovation?	√					

Research Questions	Innovations and Operational Innovation	Strategic Investment	Investment Decision Considering Uncertainty (Real Options)	Management Transition (Matrix of Change)	Competitor Evaluation (Lotka-Volterra)	Dynamics Behavior (System Dynamics)
What are the operational innovation performance measurements?	√					
What are the current methods used in the operational innovation investment decision making process?	√	√	√			
What is the potential valuation method for operational innovation investment decisions?	√	√	√			
What are the effective methods to manage change in business operations?				√		
What are the steps to capture and evaluate changes in business operations toward operational innovation?				√		
What are the effective methods to evaluate the impact of a competitor?					√	
What are the steps to estimate the impact of a competitor?					√	
What are the current approaches to analyze complex systems?						√
How do we develop a dynamic of operational innovation?						√
What are the steps to develop a mathematical model for operational innovation to predict the outcomes prior to the investment?						√

We investigated and found the five existing gaps related to the above questions. First, the innovation process does not recognize quantitative value and information to determine a solution during the problem solving phase. According to Utterback's model, there are five important steps of problem-solving: classifying the problem into sub-problems, establishing goals and objectives, ranking priorities to the goals, forming alternative solutions, and evaluating alternatives. The best alternative is selected based on business goals and priorities. This approach depends on the subjective opinions which frequently have a negative impact for investment decision due to inadequate knowledge and information, a lack of situation awareness, a lack of systematic perspective, and an ineffective investment decision approach. Developing operational innovation is involved with various factors and challenges, uncertainty, complexity, and non-linear behavior. Therefore, the problem-solving phase in Utterback's model is not applicable for the realistic circumstance of operational innovation.

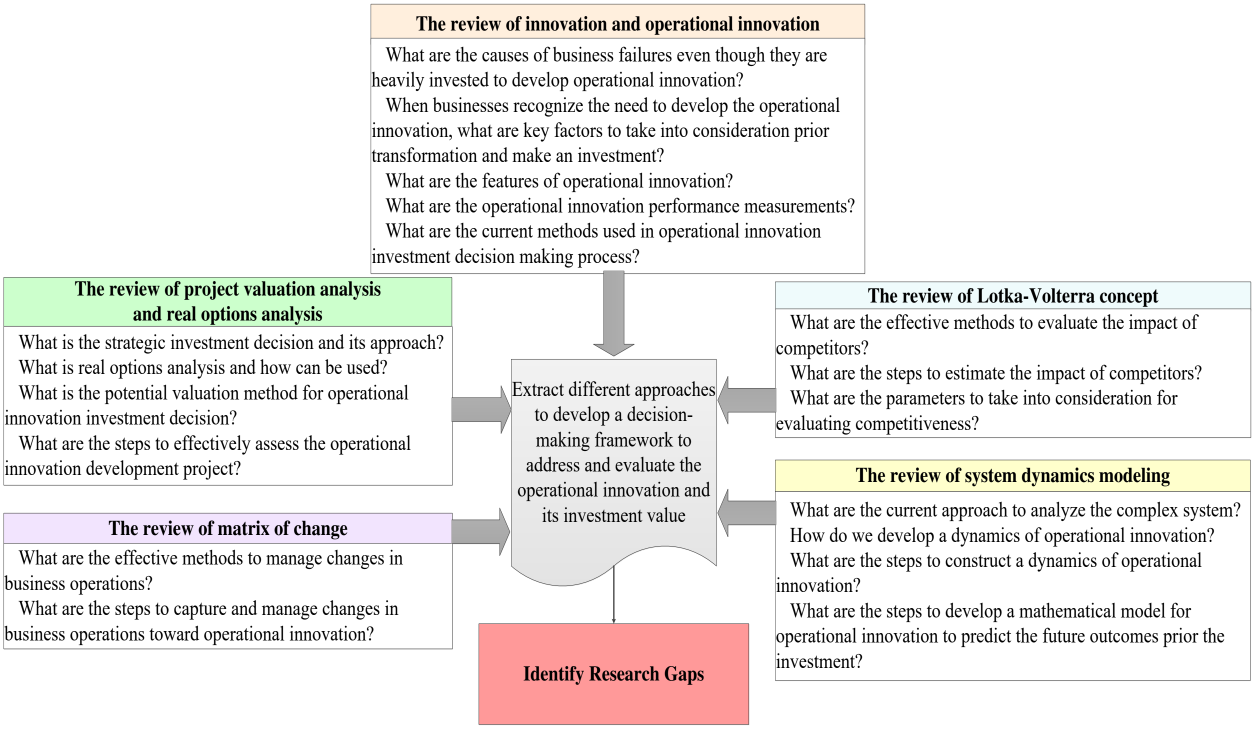


Figure 14: Research Gap Analysis Steps

Second, the literature review shows that a few articles intensely study operational innovation. Most of the previous research in operational innovation has not been able to result in any tangible outcomes that provide the holistic viewpoint of operational innovation. The majority of publications focus on five traditional types of innovation (product, process, market development, organizational structure, and resource development). Therefore, it is necessary to explore more of the operational innovation research area because it has significantly increased profits, business operational efficiency and effectiveness, and customer satisfaction (Azadegan, 2011; Hamel & Breen, 2007; Hamel, 2006; Hammer, 2004, 2005) for many businesses such as Walmart, Dell, Progressive Insurance, Toyota, and Amazon (Hammer, 2004, 2005).

Third, the important result from our gap analysis was the identification of the most important features of the operational innovation problem which have not been addressed in any publication. The results from business cases and literature show that the most significant factors of operational innovation and its environment are listed below:

- Uncertainty is the variable that is associated with an increase of the probability of unpredictable consequences with inadequate information or data. It is key elements that must be recognized to determine the investment value or benefit from the investment. The uncertainty of operational innovation relates to the change in customer's preferences, competition, and market risks (environment and technology). The high uncertainty drives high risk in project investment.
- Advanced technology is related to technology itself and technological infrastructure. Changes in advanced technology have significant impact on the way of doing business. For example, the music industry and publishers offer electronic media on electronic devices which allows customers to access and download magazines or books from anywhere at any time. As a result, the delivery of electronic media through the electronic devices requires new activities in business operations, which eventually are one of the best practices of operational innovation (Amit & Zott, 2012). Thus, advanced technology

encourages the future growth of business by improving the operational efficiency and effectiveness.

- Competitive threats and responses represent the impact of competitors and their market strategy through the businesses ‘responses to the threats in order to enhance market competitive advantages and business operation capability, and to sustain business performance. The impact of a competitor is from the opposing business who attempts to enhance their business capability which directly affects the business performance in negative way. The market strategy, number, size, and quality of the competitors have significant impact on an operational capability and on financial performance. Businesses must take the impact of competitors into consideration by gathering information related to them during the investment decision making process (Whitelock & Jobber, 2000). This behavior represents pure competition. Due to the nature of operational innovation, each business/technology has a negative influence on the other’s growth; therefore, this research assumes the impact of competitors’ behavior is the pure competition. However, the impact of competitors can influence businesses in both positive and negative ways. The competitiveness positively drives businesses to develop the operational innovation. For example, UPS recognized the need for transforming their business operations to response to FedEx’s capability in logistic service by developing Internet-based package and document delivery services across the world. At the same time, the competitive pressure has a negative impact on the UPS’s revenues and number of active customers.
- Customers’ needs are based on customer preferences, characteristics, and development of demand. It reflects the desired goods and services to meet customers’ satisfaction. This

factor has become more challenging over recent decades due to rapid changes in advanced technology and product innovations.

- Organizational transformation represents the transition from the existing business operation toward the operational innovation. It has significant impact not only on change in business operations or processes, but also changes in management, workforces, and organizational structure. The main purpose of organizational transformation is to increase revenue and to decrease cost.
- Knowledge is indicated as the key factor of the innovation process (Chen, 2011). Higher knowledge diversity offers more effectiveness of absorptive capacity which is an indicator of organizational ability to modify values of internal and external knowledge during innovation development, and the ability to increase co-creation (Vanhaverbeke et al., 2008). Most of the time available external knowledge sources are imperfect, and it is necessary to enhance the ability to transform and maximize utilization of limited knowledge for business growth opportunities.
- Workforce and equipment readiness represent the operation capability. These factors are resources that are used for operation activities from manufacturing through delivering the product or service to the end customers. This experience and skill of the individual has significantly improved productivity in a learning organization. The workforce readiness also reflects the hiring of new workers, the number of workers, and training. The learning curve of the experiences and training in the organization has proven to be an efficient assessment to monitor workers' performance.
- The operational innovation performance measurements are operational efficiency and effectiveness. The operational efficiency is defined as the level of utilization of resources.

> The operational effectiveness is the level of objective accomplishments, flexibility, adaptability, and capability to produce the goods and services with availability of the workforce, equipment, or capital during a given time period. The supply chain management and cost reduction are also indicators of the degree of operational effectiveness (Mussa, 2009).

The complexity of these variables drives the difficulties of transforming business operations toward operational innovation. It is also important to realize that the capture of the competitive threats/responses for a nonprofit organization has a different meaning because the nonprofit organization has no impact from competitors but emphasizes the operational efficiency and operation capability.

Fourth, there is a lack of proper framework for operational innovation and investment. Therefore, there is a need for a framework that evaluates the alternative option with regards to operational innovation, assessing predetermined consequences of change in operation, and makes a decision to go or not-to-go.

Fifth, the result from our gap analysis found the limitations of the traditional valuation methods, such as the discount cash flow (DCF) or internal rate of return (IRR). The single discount rate is applied for the entire period of investment, which reflects the deterministic linear cash flow. In reality, operational innovation and its environment are mostly associated with risk, uncertainty, high complexity, the impact of competitors, advanced technology development, and other factors. This investment decision requires adequate knowledge and information, capital budgeting, life cycle, and understanding the customers' needs, competitors, and the dynamics of the operational innovation. Therefore, these traditional financial methods are not completely applicable tools to support the operational innovation investment decision process.

As a result, the real option analysis is implemented to analyze the ROI of the operational innovation investment. However, there is no publication that addresses the operational innovation investment decision using the real option analysis. In addition, the real option methods do not take the impact of the competitor into consideration.

These research gaps open the door for more studies in operational innovation. Thus, there is a need for new understanding of the dynamic of operational innovation. It is necessary to develop a decision making framework to evaluate the alternative options of operational innovation. This approach should include the impact of competitors and uncertainties.

Table 6 summarizes the literature survey in the fields of innovation, operational innovation, project valuation methods, real options, Matrix of Change, Lotka-Volterra, and System Dynamics Modeling. It is clear that the integration of system thinking, real options, Matrix of Change, Lotka-Volterra, and System Dynamics Modeling have not been applied to the problems in the operational innovation area.

Table 6: Literature Review Gaps

Researchers	Innovations and Operational Innovation	Traditional Valuation Methods	Real Options	Matrix of Change	Lotka-Volterra	System Dynamics Modeling
Alkaraan & Northcott, 2007		√				
Amit & Zott, 2002 & 2012	√					
Azadegan, 2011	√					

Baker et al., 2011		√				
Benaroch, 2001		√	√			
Berman, 2012	√					
Betz, 2001		√				
Boutellier et al., 2010	√					
Bramante et al., 2010	√					
Brynjolfsson et al., 1997				√		
Bucherer et al., 2012	√					
Carmichael et al., 2011		√	√			
Chen, 2011	√					√
Chesbrough, 2007 & 2010	√					
Choi & Bae, 2009						√
Christensen, 1997	√					
Christensen et al., 2011	√	√				
Chu, 2006						√
Comes & Berniker, 2008	√					
Copeland & Antikarov, 2005		√	√			
Damle, 2003		√				√
Dempsey, 2003		√				
Driouchi & Bennett, 2012		√	√			
Ebrahim et al., 2008	√					
Ferreira & Trigeorgis, 2009		√	√			
Fishman, 1996			√			
Frishammar et al., 2012	√					
Gassmann & von Zedtwitz, 2003	√					
Gilber & Bower, 2002	√					
Godin, 2008	√					
Grasl, 2008						√
Hacura et al., 2001		√				
Hammer, 2004&2005	√					
Jetter et al., 2009	√					
Kaplan & Norton, 2000		√				
Katzy, 2003	√	√	√			
Kodukula & Papudesu, 2006		√	√			
Martzoukos & Zacharias, 2013	√	√	√			
Mathews, 2011	√	√	√			
Mathews et al., 2007		√	√			
McGrath, 2011	√					
Mun, 2006		√	√			√

Mun & Housel 2010		√	√			√
Munoz, 2006		√	√			
Nagar, 2011		√	√			
Narvekar & Jain, 2006	√					
Osterwalder & Pigneur, 2004&2010	√					
Osterwalder et al., 2005	√					
Popadiuk & Choo, 2006	√					
Razgaitis, 2003		√	√			
Sáenz-Diez et al., 2008		√	√			
Sharma et al., 2004						√
Silvola, 2008	√	√				
Smit & Trigeorgis, 2004		√	√			
Smith, 2005		√	√			
Stalk et al., 1992						
Sterman, 2000 & 2001		√				√
Tan et al., 2010		√	√			√
Trigeorgis 1993a, 1993b, 2005		√	√			
Unver, 2008					√	
Utterback & Abernathy, 1990	√					
Utterback, 1971	√					
Van de Ven, 1999	√					
Vanhaverbeke et al., 2008	√	√	√			
Winch, 2001						√
Zott, 2002	√					
Onkham, 2013	√	√	√	√	√	√

2.10. Summary

The literature review focuses on the fundamental and the most recent research ideas in the field of innovation, innovation process, and operational innovation. This literature explores a lack of quantifiable value during the problem solving phase; therefore, Utterback's innovation process is not completely applicable for the realistic implementation of operational innovation.

The literature survey in the field of project valuation methods found several limitations. Real options analysis is a method to resolve those problems by providing the facts for decision makers in different decision structures such as defer, expand, abandon or switch, which are better than the use of a single net present value (NPV) from traditional investment methods. The literature survey in the field of change management explores techniques that can be used to determine the feasibility of a transformation from current business operation to operational innovation.

The literature survey in the field of Lotka-Volterra indicates the importance of competitiveness. The literature survey in the field of system dynamics modeling shows the importance of developing the conceptual and mathematical models for a specific system. It is a method which provides a high level of the system and new business operations requirements.

Successful implementation does not always lead to successful businesses. In fact, many businesses heavily invest in operational innovation development, but fail to do so in a timely manner. Therefore, the results of the literature survey support the development of a state-of-the-art decision making framework for operational innovation addressing the impacts of risk and competitor. In the next section, the research methodology is demonstrated. The research methodology helps to conduct and provide a high level of research.

CHAPTER THREE: RESEARCH METHODOLOGY

This chapter describes the research methodology. The research design is a procedure for conducting research from general assumptions to detailed methods of data collection and analysis. The basic research method includes procedures of inquiry (called strategies) and specific methods of data collection, analysis, and interpretation. The selection of a research design depends on the nature of research problem or issue being addressed, the researcher's personal experiences, and the audiences for the study. The good research methods consist of five steps: questions, data collection, data analysis, interpretation, and write-up and validation (Creswell, 2009).

3.1. Research Design

This research is conducted to solve a particular situation and seek insights by using evidences, and to validate methods. It starts with a research question after gathering enough understanding of the problem. It uses specific case studies and contextual analysis.

Data collection of this research primarily comes from case studies. The case studies are obtained from two different organizations: United Parcel Service (UPS) annual reports (1996-2001) and the U.S. Fire Administration database. UPS recognized the needed of operational innovation to enhance customer satisfaction and its market competitive advantages. The annual report in 1997 showed the importance of operational innovation, which could help the company to increase the daily package volume as an increase of customer satisfaction. However, the challenges were the risk of the innovation investment decision and the capability of information technology systems (Brynjolfsson, Short, et al., 1997).

The second case study is a smart firefighting operation using a cyber-physical system (CPS). The high losses in both property and personnel suggest that there are still issues with firefighting operational effectiveness and safety. The cost of unwanted fires is approximately $300B per year including numerous civilian and firefighter injuries and deaths, and property loss (The National Fire Research Laboratory, n.d.). The data is retrieved from Division of State Florida-Fire Marshal, Orange County-Fire Rescue, Fire Statistics - US Fire Administration, and National Institute of Standards and Technology (NIST) database on fire statistics and the firefighting research development section.(Division of State Fire Marshal, 2012; Fire Suppression, Orange County Gov FL, 2013; U.S. Fire Administration/National Fire Academy, 2012; U.S. Fire Statistics, 2013; US Department of Commerce, 2012). The smart firefighting operation is a new way of extinguishing fires. The questions are:

1. Is it worth it for local government to establish the CPS?
2. When is the best time to make that specific investment?

The research methodology is categorized into three phases:

- Phase I: Literature survey
    - Inputs: Relevant academic publications and case studies
    - Outputs: Literature review, research question, gap of research, and research framework

Phase I presents the identification of the research problem, question, objectives, potential research contributions, and literature survey that provide the rationale of development for this dissertation. This phase describes and analyzes the relevant literatures in order to define the research gaps and research question. The information is illustrated in chapter two.

- Phase II: Baseline Model Creation
    - Inputs: System Thinking, Real Options Analysis, Matrix of Change, Lotka-Volterra, and System Dynamics Modeling
    - Outputs: A System Architecture of Operational Innovation, Real Option Dynamic Decision (RODD) Framework

Phase II develops the baseline model creation. The architecture of operational innovation is developed, which aims to provide a holistic viewpoint of operational innovation system. This architecture tends to integrate the most important factors of operational innovation and its environment. This phase presents the development of the RODD framework aiming to determine the return on investment of operational innovation considering risk and the impact of a competitor. The description of the RODD methodology and generic simulation model is presented which considers the Real Options Analysis, Matrix of Change, Lotka-Volterra, and System Dynamics Modeling.

- Phase III: Experimentation and Analysis
    - Inputs: Alternative operational innovation option
    - Outputs: Outcomes of candidate option

Phase III illustrates the experimentation and analysis. Case studies are used to validate the RODD framework which is presented in chapter five. The transformation from current state and future state of operational innovation is evaluated to determine whether it is feasible to make the transformation or not. If so, the future state is a candidate option.

The result of the candidate option is compared with other methods including the traditional DCF method and the real options analysis method using original data. The comparison with these two methods tends to validate the argument of the RODD framework. The three phases of the research methodology are shown in Figure 15.

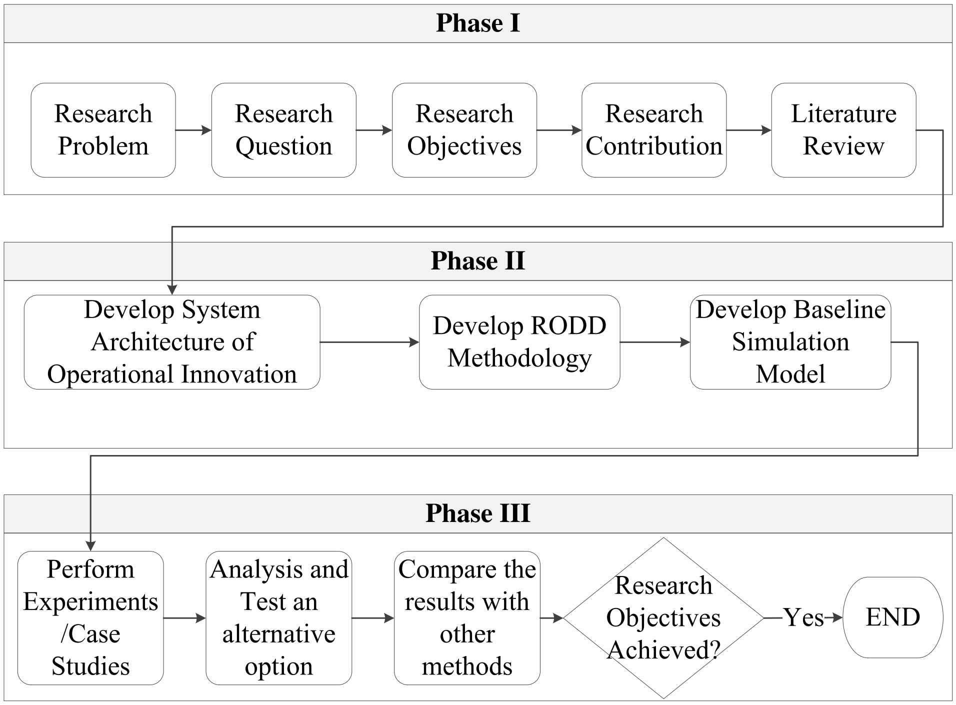


Figure 15: Holistic View of Research Methodology

3.2. Development Framework

According to the Multidimensional gap analysis, two main research requirements are necessary to achieve research objectives as follows:

- Research Requirement 1: To understand the problems in operational innovation, business environment, and its features.

- Research Requirement 2: To define particular techniques that can capture operational innovation features such as risk and the impact of a competitor, and determine expected ROI of operational innovation.

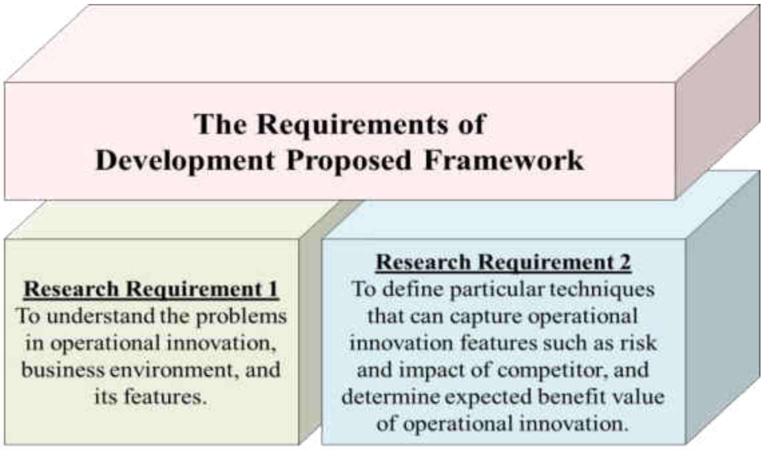


Figure 16: The Requirements of Development the Framework

A systematic approach is implemented to capture the significant factors of operational innovation and its environment in order to develop a high level architecture. This architecture represents a holistic viewpoint of operational innovation and its process including 1) Idea Generation Phase, 2) Problem Solving Phase, and 3) Implementation Phase. This architecture is modified based on the Utterback's innovation process model.

The important features of operational innovation are defined from the business results and literatures including: organizational transformations, available knowledge, available technology, workforce readiness (skill and experience), equipment readiness, operational efficiency and capacity, strategy leadership, customer needs, uncertainty, competitive threats and responses, and advanced technology. It is also to distinguish that there is no the impact of a competitor on the nonprofit organizations such as government, international organizations, but these organizations emphasize on an increase of the operational efficiency and operational effectiveness and the reduction of operating costs. As a result, this architecture offers better information with a particular operational innovation compared to the Utterback's model.

The important features of operational innovation are analyzed their characteristics and extracted into the most important features including: uncertainty, competitive threats and responses, organizational transformations, return on investment, complexity, dynamic behavior, and modeling. The complexity of these features drives the difficulties of transforming business operation toward the operational innovation as well making an investment decision. In addition to the research gaps are related to a lack of proper framework for operational innovation decision-making. Therefore, there is a need to develop a new investment decision approach that can define a feasible operational innovation, provide flexibility and information for decision makers, and address risk and the impact of a competitor.

A framework mapping (Figure 17) is established. This mapping represents an approach to develop a new decision-making framework for operational innovation development. The most important features of operational innovation can be analyzed and evaluated by using a strategic investment method (Real Option Analysis), management transition evaluation method (Matrix of Change), competitiveness evaluation (Lotka-Volterra), and dynamic behavior modeling (System Dynamic Modeling).

These techniques can capture the operational transformation, and quantify the risk and impact of a competitor to determine expected ROI. First, Real Options Analysis and Monte Carlo simulation are used to estimate the ROI of alternative selection considering risk factor and uncertainty and to develop a strategic investment decision. The real options valuation method is useful for defining values of new business opportunities in an uncertain environment and providing choices to execute projects in the future (Sáenz-Diez et al., 2008). It is a technique that considers the risk and uncertainty, provides flexibility for making decisions, and offers an opportunity to revise the decision upon the future market conditions (Benaroch, 2001; Copeland & Antikarov, 2005; Driouchi & Bennett, 2012; Landsberger, Cruz, Onkham, Rabelo, & Ajayi, 2013; Landsberger, Onkham, et al., 2013; Mathews et al., 2007; Trigeorgis, 1993b, 2005). Therefore, the value of real options represents the opportunity cost of postponing investment or the cost of gathering additional information to minimize uncertainty in future.

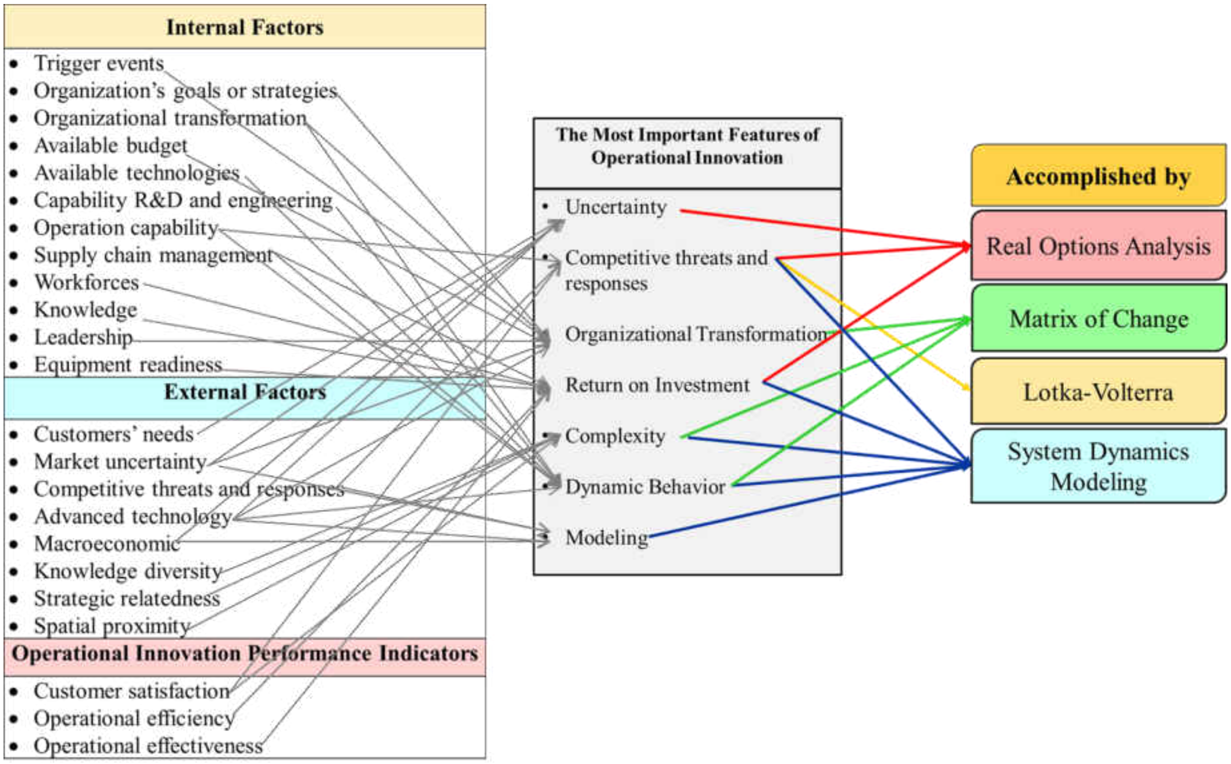


Figure 17: Framework Mapping

The defer option is more appropriate for investing in operational innovation because this option allows businesses to delay the investment until reaching the expectation of maximum value (Tourinho 1979; Titman 1985; McDonald and Siegel 1986; Paddock, Siegel&Smith 1988; Ingersoll and Ross, 1985; Trigeorgis, 1993b, 2005).

The real options analysis consists of four methods: Binomial Lattices, Black Scholes, Monte Carlo simulation, and Datar-Mathews methods. Binomial Lattice is an appropriate method for operational innovation investment decision because this method captures the probability of success and failure which matches to the complexity of the operational innovation and its environment. The risk factor is calculated in term of volatility value which is determined with a normal or lognormal probability distribution technique. The Binomial lattice method relies on the risk-neutral probabilities and market-replicating portfolios. (Kodukula & Papudesu, 2006). The risk neutral probabilities are used to calculate uncertainty-equivalent cash flows that can be discounted at the risk free rate of the expected future payoff (Copeland & Antikarov, 2005; Trigeorgis, 1993b). As a result, this method is close to the realistic business environment which expects a future high return on investment. The binomial lattice shows probability of upside potential *(u)* and downside risk *(d)* which are functions of the volatility of the underlying assets. The last node at the end of the binomial tree reflects the range of possible asset values at the end of the option life.

Monte Carlo Simulation can be used as a supplementary method for real options analysis that helps to estimate value of parameters such as interest rates, and discount rates (Munoz, 2006). Thus, real options analysis and Monte Carlo Simulation are proper techniques to define the values of new business opportunities.

Multi-modes Lotka-Volterra evaluates the impact of a competitor who attempts to enhance its own business capability in the same industry. This approach represents a non-linear behavior of the operational innovation dynamics. We assume the pure competition due to the nature of business environment which each business has negative influence on the other's growth and financial performance (Unver, 2008).

Matrix of Change assesses a transformation. This approach captures the current state and future state of an organization or operation. The matrix of change can be used to map the current operation toward the operational innovation. The result from this method shows the feasibility of the operational model transformation (Brynjolfsson, Renshaw, et al., 1997). The Matrix of Change can be used to evaluate a feasibility of alternative option.

System Dynamics Modeling is an approach to develop a model to solve a specific problem of complex systems. The main purpose is to explore a new understanding of how the problem arises, and use that understanding to develop feasible policies for improvement (Sterman, 2000; Tan et al., 2010). System Dynamics modeling can be implemented to capture and develop the operational innovation dynamics. This method can improve the accuracy of predicted financial result considering the impact of a competitor.

As a result, these techniques are suitable methods, which can be integrated to develop a new framework called Real Option Dynamic Decision (RODD) framework in order to analyze the operational innovation in both qualitative and quantitative aspects and to close the research gaps.

The RODD framework is a holistic approach to determine the feasibility of the operational innovation option, to evaluate the ROI of operational innovation considering risk and the impact of a competitor, and to provide flexibility of the decision which have not been addressed or developed in any existing researches. The expected outcomes can be used to support the investment decision making in operational innovation development prior business operations transformation. An overview of the development of systematic architecture of operational innovation (requirement 1) using RODD framework (requirement 2) is illustrated in Figure 18.

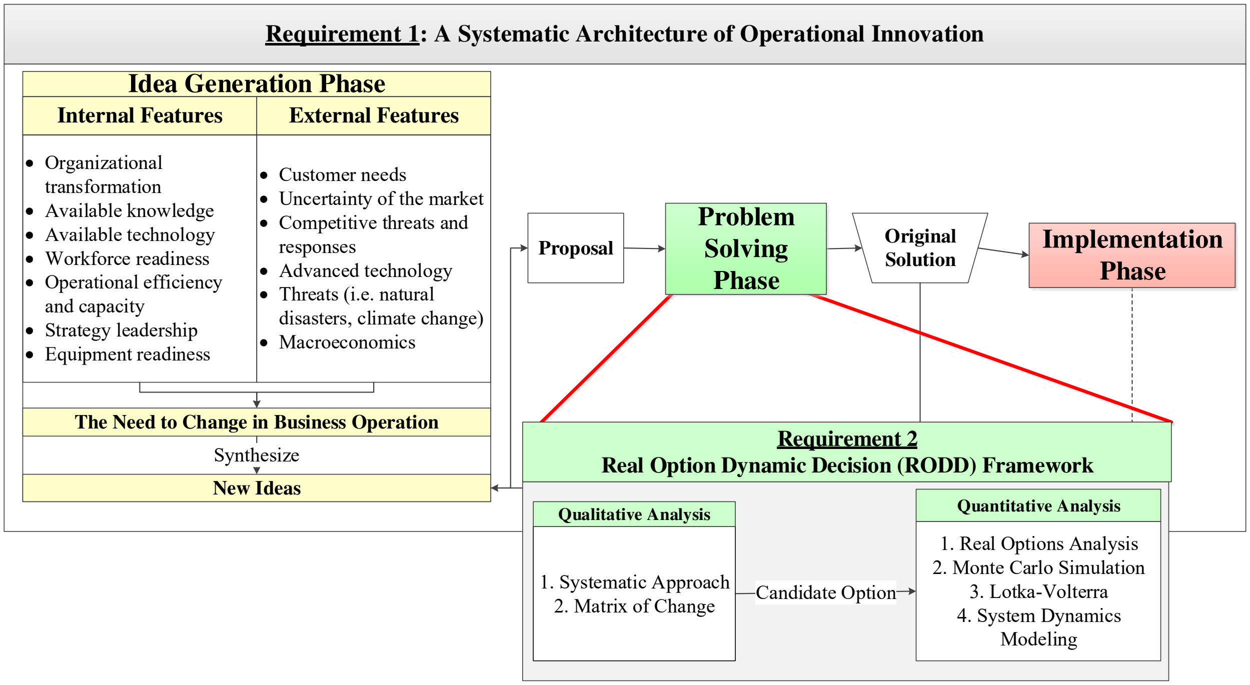


Figure 18: An Overview of a RODD Framework Development

3.3. Validation of Methodology Framework

Ghosh & Chopra, (2003) define internal validity as an absence of self-contradiction. The internal validity is the use of research methodology or an instrument that has the ability to measure what it is supposed to measure. If the methodology or instrument does not measure properly, then the results are useless. External validity is applicability and generalizability of findings which emphasize the probability of observed patterns in a sample present in the wider population from which the sample is drawn.

The RODD method will be validated by performing experiments on the framework for two case studies. These case studies are the primary data collection for this research.

3.3.1. Case Studies

Case studies are an empirical inquiry that investigates a phenomenon in a realistic context when the boundaries between the phenomenon and its context are not clear using multiple sources of evidence (Hill, 1993). Case studies can be applied using both quantitative and qualitative research from various data sources, such as archival material, artifacts, survey data, interviews, causality, observations, and experiments. Therefore, this method is suitable for a holistic investigation in the real world. There are four steps for case study designs:

- Determining the research questions and selecting the cases
- Preparation required for gathering data
- Analysis of case study evidence
- The interpretation and reporting of the case study

The validation process will be based on the effective application of the RODD method to one real company- United Parcel Service of America, Inc. (UPS) (case study A) and one case study from the government sector-The National Fire Research Laboratory (case study B). A brief description of the case studies is presented in the following sections:

Case Study A: The Electronic Supply Chain

This case is based on the work of Brynjolfsson et al., (1997) and Ross et al., (2002). United Parcel Service of America, Inc. (UPS) had faced challenges: high competitiveness especially with Federal Express, low growth rate, and inefficiency of operations. UPS recognized the need for transformation business responses to FedEx's capability in logistic service, and changes in Internet-based, package and document delivery services across the world.

The company was aware of the new opportunities of advanced technological systems, and the business's capability of existing assets to grow new emerging markets at rates of the economic needs of the large scale business. It was a challenging mission to make the transformation because UPS had a high degree of complexity associated with the resource allocation processes both formal and informal. Therefore, it was difficult to visualize and define what resources should be implemented, and where and when, and also where these resources either supplement or conflict with existing operational models.

Case Study B: The Smart Firefighting Operation

This case is a research project led by the National Institute of Standards and Technology (NIST). The high property and personnel losses raise concerns of the firefighting operational efficiency and safety. The objective of this project is to develop a new firefighting operation through the use of emerging cyber-physical systems (CPS) in buildings, apparatus, personal protective equipment, and robotics to increase situation awareness, operational efficiency, effectiveness, and firefighter safety. This firefighting operation will shift from using only the incident commander's experiences to using real time information from the CPS, computing technologies, and robotic technologies along with his/her experiences. The real time data is transferred to local incident commanders, which help them to make decisions faster.

The expected results from this project will enhance the safety, and reduce the property, environment, and personnel losses due to fire incidents. The potential next step is to establish new legislation establishing fire codes regarding the visualized equipment (wireless sensor) throughout buildings nationwide (US Department of Commerce, 2012).

3.4. Summary

This chapter summarizes the research methodology used to develop a new framework. This new decision-making framework aims to improve the effectiveness and flexibility of investment decision process compared to the existing investment decision tools such as the Discounted Cash Flow (DCF) method, Decision Tree Analysis, and Basic Metric (Rate of Return, Payback Period, Breakeven, etc.). The flexibility of investment is an opportunity for decision makers to delay the project investment until the return on investment reaches the maximum value. The RODD framework is a result of the existing gaps in these fields.

The most important features of operational innovation and its environment are synthesized into a high level architecture of operational innovation including: uncertainty, competitive threats and responses, customer needs, organizational transformation, knowledge, operational efficiency and capability, workforce readiness, equipment readiness, and advanced technology. This architecture offers better information with a particular operational innovation compared to the Utterback's model.

The RODD framework uses deeper viewpoints to provide an integrated investment decision approach using Real Options Analysis (ROA), Matrix of Change, multi-modes Lotka-Volterra, and System Dynamics Modeling. This framework aims to determine the feasibility of the operational innovation option and to evaluate the ROI of operational innovation considering risk and the impact of a competitor. The expected outcomes can be used to support the investment decision making in operational innovation development prior operations transformation. Two case studies are used (UPS and Firefighting Operation) to validate the framework. This comprehensive approach have not been addressed or developed in any existing researches.

CHAPTER FOUR: A SYSTEMATIC ARCHITECTURE OF OPERATIONAL INNOVATION USING THE REAL OPTION DYNAMIC DECISION FRAMEWORK

Today, innovation development does not only rely on R&D, engineering, and an advanced technological business, but also customers' needs, competitors' conditions, and available technologies or knowledge. We found several research gaps in the operational innovation area. Therefore, this research aims to develop a systematic architecture of operational innovation using the Real Option Dynamic Decision (RODD) framework to support decision makers prior to the operations transformation.

The systematic architecture of operational innovation represents a completed process including 1) Phase I: Generating Ideas; 2) Phase II: Problem Solving; and 3) Phase III: Implementation. The RODD framework is a comprehensive approach using Real Options Analysis (ROA), Matrix of Change, multi-modes Lotka-Volterra, and System Dynamics Modeling. Its goal is to determine the feasibility of alternative operational innovation options and to evaluate their ROI. The expectations of this decision-making framework are to provide better analysis than the traditional investment decision tools; to reduce the complexity of operational innovation; to assess investment value; and finally, to support decision makers as part of innovation development. The framework is shown in Figure 19.

4.1. Phase I: Generating Ideas

The idea generation phase is the most critical process and indicates success or failure of a business. Therefore, it is necessary to recognize and understand the needs and the dynamics of operational innovation. The idea generation phase usually starts with internal individuals, teams, and organizations, respectively. It influences both internal and external aspects. Internal features represent the resources of the internal organization involving: organizational transformation, available knowledge, available technology, operational efficiency and capability, workforce readiness (skill and experience), and equipment readiness. The external components represent the business environment involving: uncertainty of the market, customer needs, competitive threats and responses, advanced technology, threats (i.e. natural disasters, climate change), and macroeconomics. These features help to recognize the need for change in operations in order to increase business revenue, customer satisfaction, and market competitive advantages. However, these factors also drive the difficulty of operation transformation. After the customer needs are identified, the recognition of technical resources to satisfy theses needs must be determined. Finally, all ideas are synthesized to establish a proposal for the operational innovation development.

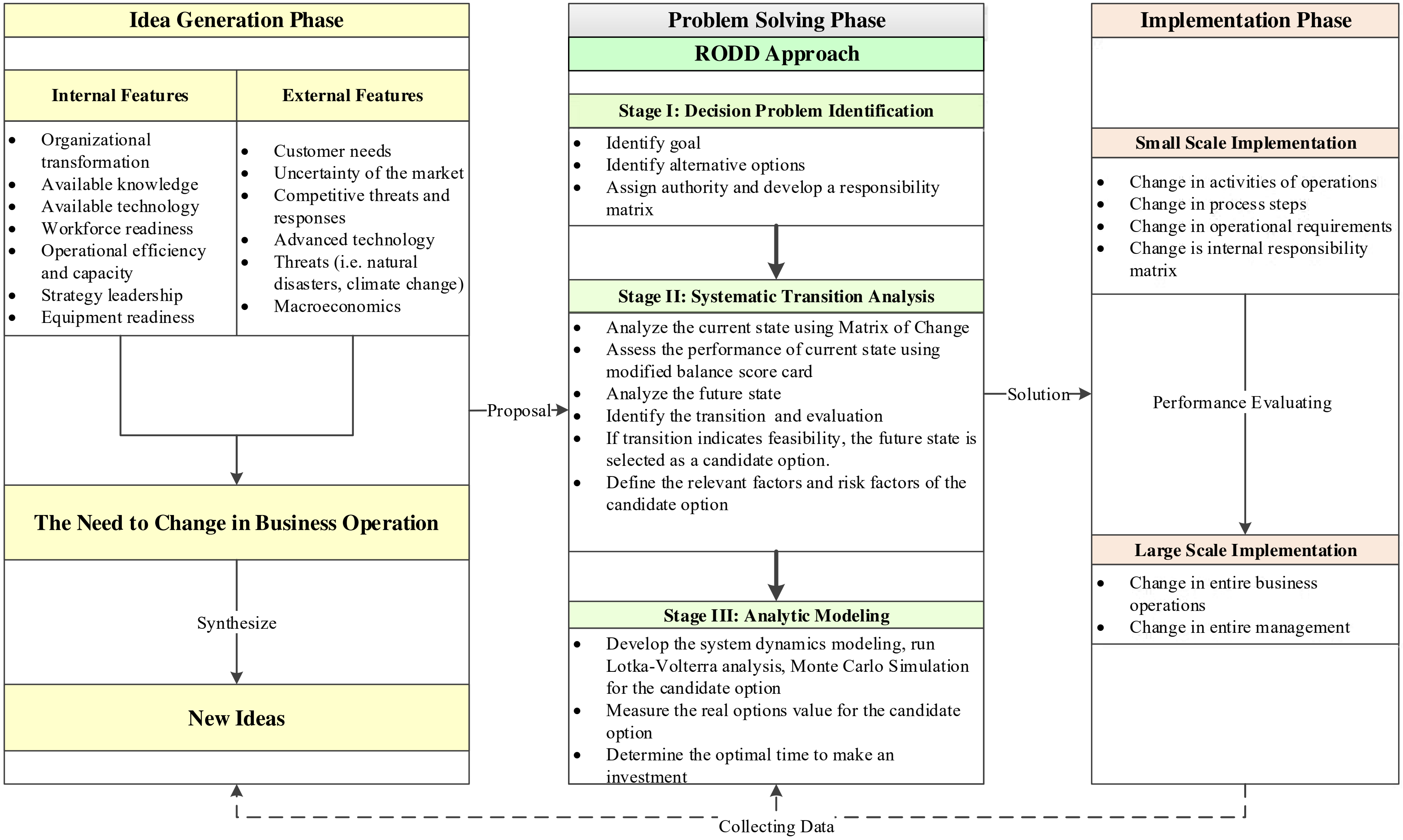


Figure 19: A Systematic Architecture of Operational Innovation Using RODD Framework

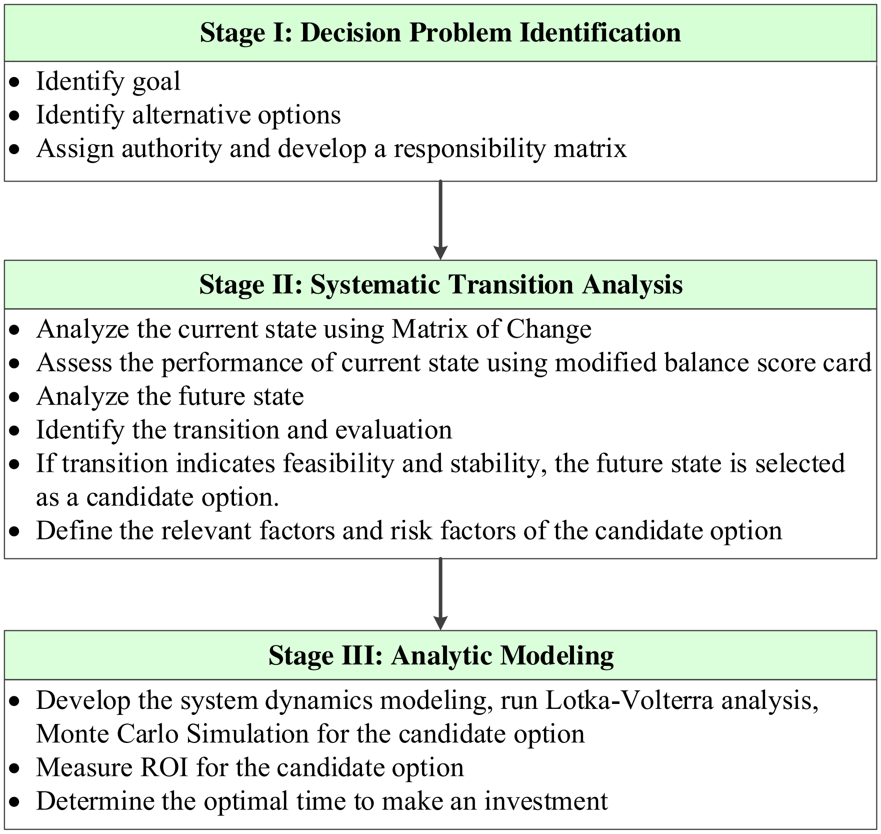
4.2. Phase II: Problem Solving

The Real Options Dynamic Decision (RODD) framework is implemented in this phase to identify the best alternative, to analyze a transformation, and to estimate the value of the new business opportunity considering the impact of uncertainty and competitiveness. This method uses the Matrix of Change (MOC) as a qualitative method to evaluate the transition of existing business operations toward the operational innovation and to measure stability. If the result from the MOC shows that the alternative operational innovation option is feasible, then this alternative option is called as a candidate option (new business opportunity). Next, this candidate option is assessed using four quantitative methods including: System Dynamics Modeling, Lotka-Volterra, Monte Carlo Simulation, and Real Options to determine the ROI and an optimal time to make an investment. The RODD consists of three stages: 1) Decision problem identification, 2) Systematic transition analysis, and 3) Analytic modeling. These steps are described in detail in the following subsections.

4.2.1. Real Option Dynamics Decision (RODD) Framework

Stage 1: Decision Problem Identification

This step is used after the businesses recognize that they need to change. The goals of the project and an alternative option are identified. The options contain at least two choices: 1) Do nothing option (current state of business operation), and 2) Alternative options (future state). If there are multiple alternatives with regards to operational innovation schemes, these options are analyzed using stage 2: systematic transition analysis to define a feasible optional innovation option.



Stage I: Decision Problem Identification

- Identify goal
- Identify alternative options
- Assign authority and develop a responsibility matrix

Stage II: Systematic Transition Analysis

- Analyze the current state using Matrix of Change
- Assess the performance of current state using modified balance score card
- Analyze the future state
- Identify the transition and evaluation
- If transition indicates feasibility and stability, the future state is selected as a candidate option.
- Define the relevant factors and risk factors of the candidate option

Stage III: Analytic Modeling

- Develop the system dynamics modeling, run Lotka-Volterra analysis, Monte Carlo Simulation for the candidate option
- Measure ROI for the candidate option
- Determine the optimal time to make an investment

Figure 20: Real Option Dynamic Decision (RODD) Framework

Leadership and authority are important factors that indicate the success of a business (Onkham, Elattar, & Rabelo, 2013). The case of Kodak shows that the lack of leadership and authority has a significant negative impact on business performance. Therefore, it is necessary to reassign the authority for the project and develop a responsibility matrix to make all team members clearly understand their job.

The responsibility matrix is useful to define team members' authority and responsibility for each activity, avoid conflict, prevent misspecification and risk, and enhance productivity (A Guide to the Project Management Body of Knowledge (PMBOK Guide), 2000).

Table 7: Stage 1-Decision Problem Identification

<table>
<tr><td colspan="5">Project Name:________________________________</td></tr>
<tr><td>Decision Problem Identification</td><td colspan="4">Description</td></tr>
<tr><td>1.1 Goal</td><td colspan="4"><i>“Enhance the capability of operation….”</i></td></tr>
<tr><td>1.2 Alternative options</td><td colspan="4">Option 1: Do nothing (Current State)
Option 2: Alternative option 1 (Future State related to operational innovation)
Option 3: ……………
Option n: ……………</td></tr>
<tr><td colspan="5">1.3 Responsibility Matrix</td></tr>
<tr><td>Activities</td><td colspan="4">Stakeholders</td></tr>
<tr><td></td><td>Stakeholder 1</td><td>Stakeholder 2</td><td>Stakeholder 3</td><td>Stakeholder 4</td></tr>
</table>

Stage 2: Systematic Transition Analysis

The systematic transition analysis stage uses a qualitative approach to analyze both the current and future states of the interested business operation, and its significant factors. There are five processes for the systematic transition analysis as follow:

Stage 2: 2.1 Analyze the current state

The Matrix of Change (MOC) is implemented to capture the important elements of the current state and the desired future state. The current state represents the current way of doing business. The future state represents the target or goal for what the businesses want to be in the future. The essentials of current state or future state are identified. The relationship between elements is determined in terms of (+) reinforcing behavior and (-) interfering behavior (Brynjolfsson, Renshaw, et al., 1997).

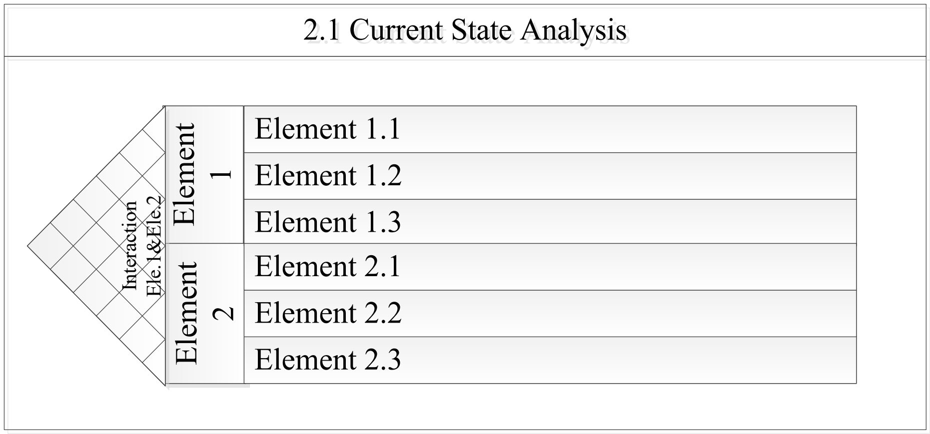


Figure 21: The Current State of Business Operation

Stage 2: 2.2 Assess the performance of yhe current state using a modified balance scorecard

The performance of the current state is assessed by using the modified balance scorecard. This assessment is developed based on the Balance Scorecard (Kaplan & Norton, 2000) and the Six Baldrige Categories for Performance Excellence (Baldrige National Quality Program: The National Institute of Standards and Technology, 2013).

The Balance Scorecard was developed by Kapland and Norton in 1992 (Kaplan & Norton, 2000, 2007). The purpose of this development was to enhance the capability of performance measurement which could evaluate both the current state and future state of businesses in both their tangible and intangible assets. The Balance Scorecard is complementing the financial measurements with three additional aspects: customers, internal business processes, and leaning and growth. It breaks down the high-level organizational scorecard to individual-level work actions to increase the effectiveness and efficiency of using the scorecard. The outcomes reflect the overall organizational performance (Kaplan & Norton, 2000, 2007).

The Six Baldrige Categories for Performance Excellence was introduced by the Baldrige National Quality Program under the National Institute of Standards and Technology in 2009.

This measurement helps organizations to improve their performance along with the management system. The Baldrige Criteria is a method for assessing an organization's processes, their impact on outcomes, and their progress to achieve targeted goals. It can be implemented in both small and large scale organizations. The recent 2013-2014 Criteria concentrates on innovation management, sensible risk, social media, and operational effectiveness. There are five focused areas: 1) Products and Processes, 2) Customers, 3) Workforce, 4) Leadership and Governance, and 5) Finance and Markets.

These two measurements are combined to evaluate organizational performance focusing on operational innovation and its impact on results. There are five dimensions of this measurement to assess the current state of the business operation: 1) Finance, 2) Operational system, 3) Leadership, 4) Customer satisfaction, and 5) Workforce focus. This assessment will also be used to evaluate the future state after implementation.

First, the financial dimension emphasizes the revenue/budget, net cash flow, and operating expenses. Second, the operational system performances are measured by operating cost, operational efficiency, operational effectiveness, work processes, and management of information and knowledge.

Second, the operational efficiency is the level of utilization of resources. The operational effectiveness is the level of objectives accomplishment, flexibility, adaptability, and capability to produce the goods and services with the availability of workforces, equipment, or capital during a given time period (Mussa, 2009). The work processes are a measurement related to work process requirements and business processes. The management of information and knowledge is measured by data and information availability and emergency availability (Baldrige National

Quality Program, 2013a; Bowersox et al., 2007; COL Kays et al., 1998; Kaplan & Norton, 2007).

Third, the leadership dimension reflects the performance of senior leaders who have major roles in the business operation. The leadership outcomes are measured by assessing the importance of high ethical standards, results to report, sanctions or adverse actions, and strategy implementation.

Fourth, the customer satisfaction dimension focuses on the voice of the customer, which can be measured by estimating the degree of customer listening, social media, and customers' satisfaction with competitors. Customer engagement can also represent the degree of customer satisfaction by assessing complaint management or customer relationship strategies.

Finally, the workforce focus dimension is related to the workforce engagement level and workforce readiness which reflect the learning and growth of the organization.

The total score of assessment is 100, which is divided based on the importance of each metric. Table 8 illustrates the five dimensions of performance assessment for the current state from Kaplan & Norton (2000, 2007) and Baldrige National Quality Program (2013).

Table 8: Performance Assessment Modified from Baldrige National Quality Program, (2013a); Kaplan & Norton, (2000, 2007)

2.2 Performance Assessment (Point Value)	
Assessment Dimensions	**Score**
1. Financial	
Revenue/Budget: • *Revenue/budget* • *Net cash flow* • *Overhead and operating expenses*	X_1
2. Operational System	
Operating Cost: • *Production costs* • *Research and developments costs*	X_2
Operational Efficiency: • *Innovation management*	X_3
Management of information and knowledge: • *Knowledge management* • *Information management*	X_4
3. Leadership	
Leadership outcomes: • *Importance of high ethical standards* • *Measures of strategy implementation*	X_5
4. Customer Satisfaction	
Voice of the Customer: • *Customer listening* • *Listening/learning and business strategy* • *Social media* • *Customers' satisfaction with competitors*	X_6
Customer Engagement: • *Engagement as a strategic action* • *Customer relationship strategies* • *Complaint management*	X_7
5. Workforce focus	
Workforce engagement: • *Education needs* • *Learning and development effectiveness*	X_8
Workforce readiness: • *Workforce capability and capacity* • *Workforce support*	X_9
Total Score	**Y/100**

Stage 2: 2.3 Analyze the future state

The Matrix of Change is implemented to map the future state, which is a target goal (alternative option) that the business desires to achieve. This research focuses on one alternative option of operational innovation. The important features of operational innovation are illustrated in section 2.9-Gap Analysis, and based on the results from business cases and literature. Therefore, the generic components of the future state of alternative operational innovation are associated with those features such as technological applications, market strategy, desired goods and services to meet customer needs, organizational transformation, new core business operation activities, workforces, knowledge, and equipment.

The technological applications are selected according to the business goal and its market strategy. The organization transformation features may involve components of a new organizational structure. New business operation activities are a set of activities from suppliers, and manufacturers throughout the products or services distribution to end-customers. These generic features represent target components of operational innovation that are to be converted into the right-top column as shown in Figure 22. However, these features of the future state can be used for similar systems with minor modifications.

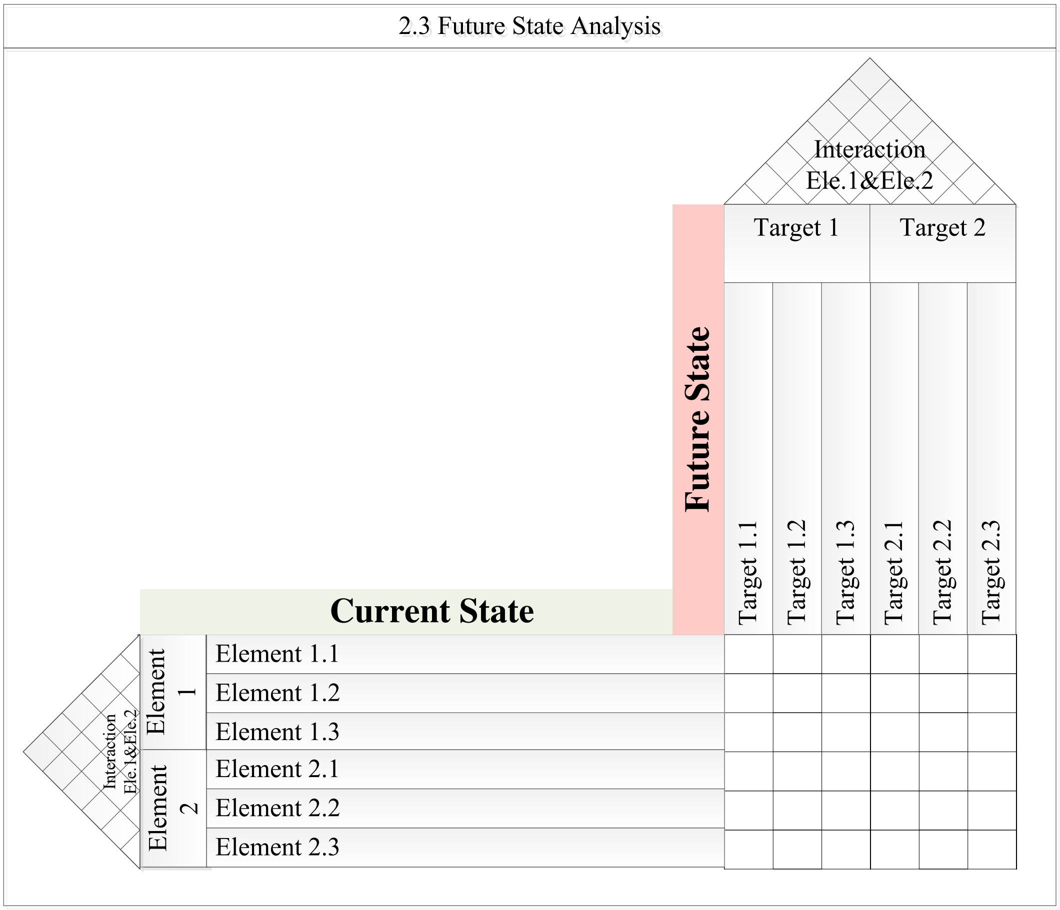


Figure 22: The Future State-Operational Innovation

Stage 2: 2.4 Identify the interactions of the transition

The interaction of all elements and their transitions are determined in terms of (+) reinforcing behavior and (-) interfering behavior. If there are more reinforcing behaviors than interfering behaviors, this transition is feasible. If the transition between current state and future state is feasible, then the alternative option is called as a candidate option. Otherwise, the process is stopped and the alternative option is revised in Step 1. The outcomes articulate the feasibility of transition, sequence of execution based on the importance, location, pace and nature of change, and stakeholder evaluations (Brynjolfsson, Renshaw, et al., 1997).

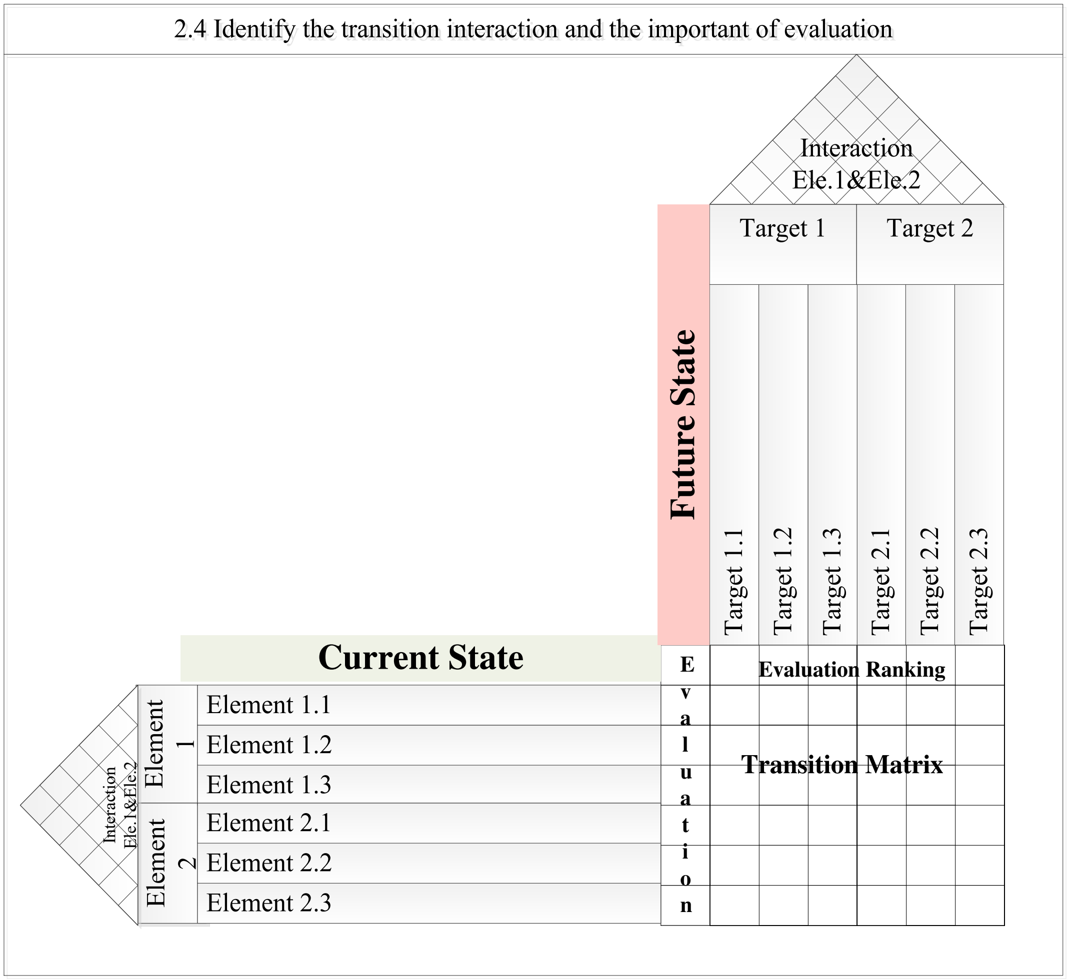


Figure 23: The Transition Interaction

2.5 Identify the relevant and risk factors for the future state (candidate option)

The relevant factors refer to the variables that have substantial impact on the expected outcome of a specific system in both positive and negative ways. The rationale of selecting the significant factors is to determine the factors that have increased/decreased the performance of operational innovation in terms of operational efficiency or customer satisfaction. This operation performance can be measured by assessing the operational efficiency and capability which are described in section 2.3 and section 2.9.

The most important factors and risk factors of the candidate option are associated with the operational innovation features and the business environment. They are described in section 2.9 and section 3.2 in both internal and external aspects. The risk factor is a variable that is associated with an increase in the probability of unpredictable consequences with inadequate information or data. There are key elements that must be recognized to determine the strategic decisions. The common risk of operational innovation development is technology and its implications. Therefore, these variables are considered as the relevant factors and risk factors in this step (Table 9). However, these relevant factors and risk factors for the candidate option can be modified to response to the interested systems.

Table 9: Stage 2- Identify the relevant factors and risk factors for the candidate option

Future State			
Functions	**Variables**	**Functions**	**Variables**
Financial Aspect	Profit	**Operation System**	Operational efficiency
	Revenue		Services capability
	Investment infrastructure capability		Operational innovation capability
	Investment in service capability		Equipment Readiness
	Operating cost	**Leadership**	Knowledge
	Maintenance cost		Leadership skill
Customers	Customer satisfaction		Organizational learning
	Number of lost customers	**Workforce Focus**	Desired number of workers
	Number of new customers		Hiring new workers
	Number of active customers		Number of workers
Risk Factors	Information Technology System or other factors		Training

Stage 3: Analytic Modeling

This section illustrates the analytic modeling which integrates four mathematical models: System Dynamics Modeling, Lotka-Volterra, Monte Carlo Simulation, and Real Option Analysis, to evaluate the value of new business operations (Figure 24).

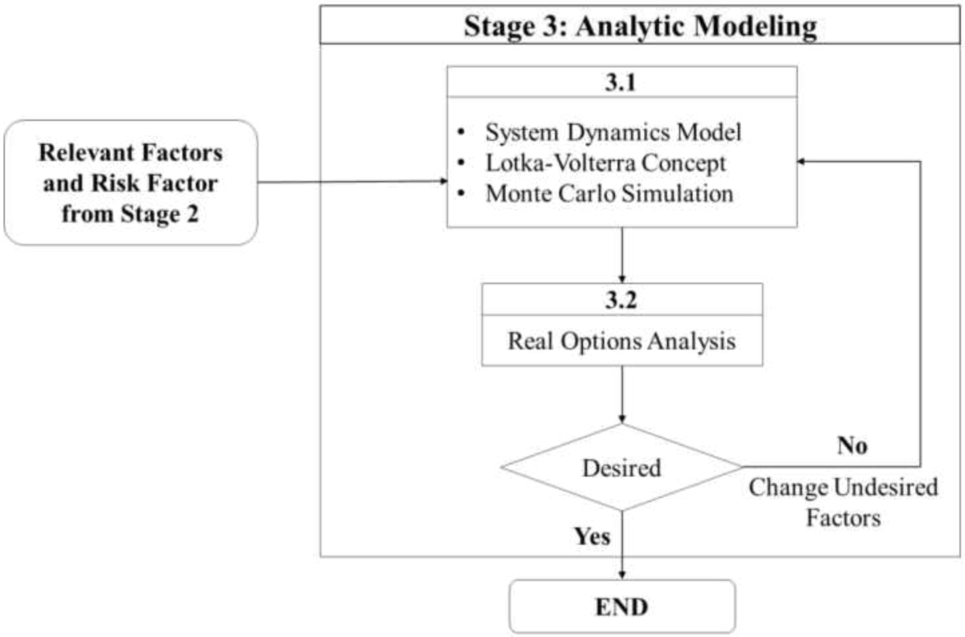


Figure 24: Procedures of Analytic Modeling

3.1 Develop the system dynamics modeling and integrate the Lotka-Volterra and Monte Carlo Simulation for the candidate option

There are five steps of the system dynamics modeling process: 1) problem identification (described in Stage 1: Decision Problem Identification), 2) formulation of dynamic hypothesis, 3) formulation of a simulation model, 4) testing, and 5) policy design and evaluation (Sterman, 2000). Damle, (2003) describes system dynamics as a policy-based methodology which is used to evaluate consequences of change in policies in the system. System dynamics represents a “cause” and “effect” relationship between variables in a complex system.

The concept of multi-modes Lotka-Volterra evaluates the impact of a competitor. The market strategy, number, size, and quality of a competitor have significant impact on an operational capability and a financial performance. Businesses must take competitors' impact into consideration by gathering information related to them during the investment decision making process (Whitelock & Jobber, 2000). Due to the nature of operational innovation this research assumes the impact of a competitor' behavior is pure competition. The impact of a competitor is represented in terms of the competitor's customer satisfaction. Lotka-Volterra is integrated with system dynamics modeling to estimate the number of active customers that is affected by the competitor's customer satisfaction.

The causal loop of the candidate option has to be developed using the relevant factors and risk factors from step 2.5. The causal loop represents the generic features of the operational innovation (candidate option) (Figure 25) which consists of three reinforcing behavior loops, and two balancing behavior loops:

- R1-Customer Satisfaction (reinforcing behavior)
- R2-Infrastructure Capability (reinforcing behavior)
- R3-Service Capability (reinforcing behavior)
- B1-Workforce (balancing behavior)
- B2-Operational Innovation Performance (balancing behavior)

The relevant factors of each loop and its behavior are explained as follows. In the Customer Satisfaction loop (reinforcing behavior), if the total potential operational capability increases, then the customer satisfaction increases above what it would have been. The competitor's customer satisfaction increases, and then the number of lost customers increases.

When the number of active customers decreases, the sales and profits decrease respectively. As a result, it requires more investment in infrastructure capacity to enhance their market competitive advantages against its competitor. The loop of the customer satisfaction represents the impact of the competitor on active customers.

The Infrastructure Capability loop (reinforcing behavior) shows the dynamic loop of infrastructure capability. If investment in infrastructure capacity increases, then the infrastructure capability and total potential of operational capability increase respectively. When the infrastructure capability increases, it requires a higher number of workers and maintenance cost. The Service Capability loop (reinforcing behavior) represents the feedback loop of service capability where the increase of training, knowledge, leadership skill, and organizational learning can increase operational efficiency. The operational efficiency increases, leading to the improvement of total potential operational capability and customer satisfaction, respectively.

The Workforce loop (balancing behavior) represents the feedback loop of the workforce. If infrastructure capability increases, then the desired number of workers and the hiring rate increase. When the number of workers increases, the salary and operation cost increases. In addition, an increase of new workers requires more training which reinforces an increase of operating cost. The Operational Innovation Performance loop (balancing behavior) represents the feedback loop of operational innovation. If profits increase, then the investment in R&D increases. An increase of investment in R&D improves the operational innovation capability which can enhance operational efficiency and service capability. Finally, a better service capability can increase the total potential operational capability and customer satisfaction. These five loops present a generic model that focuses on the features of operational innovation, organization environment, and the impact of a competitor.

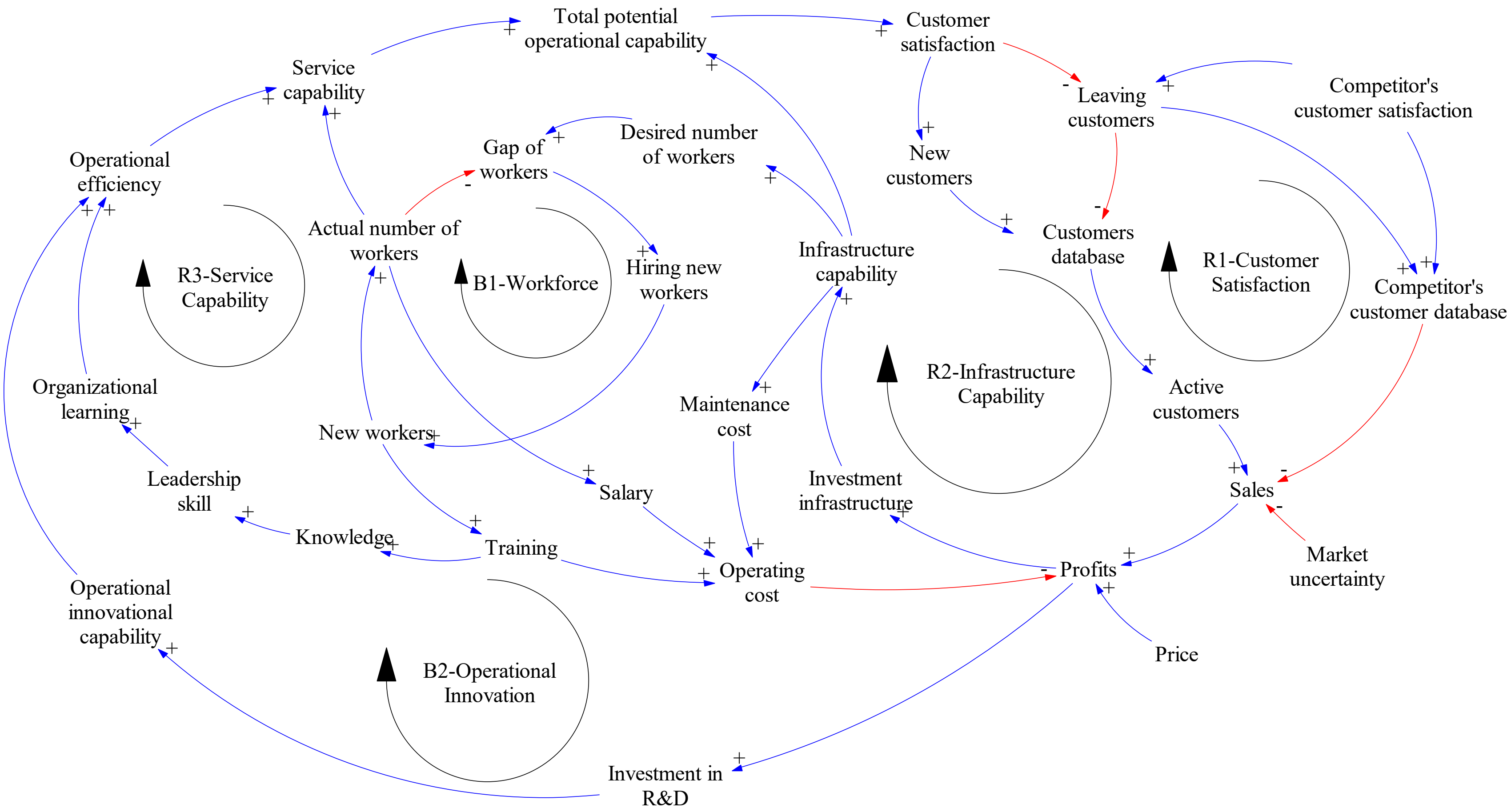


Figure 25: A Generic Causal Loop for Operational Innovation

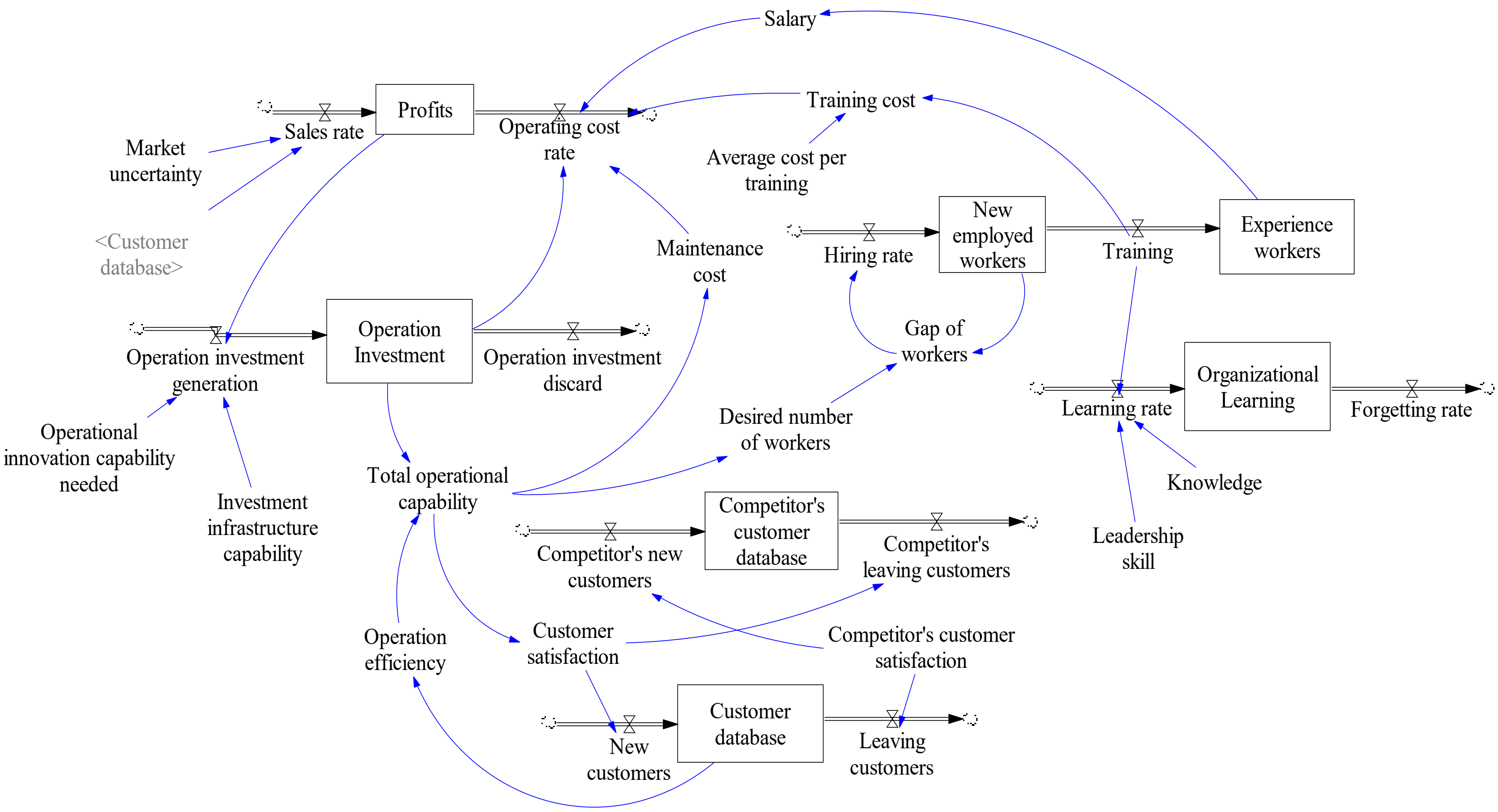


Figure 26: A Generic System Dynamics Modeling for Operational Innovation

Then, the generic system dynamics model of the operational innovation (candidate option) (Figure 26) is developed based on this causal loop diagram by adding levels, rate variables, and system delays. The mathematical notation of stock and flows is articulated in terms of integral equations. The integral equation explains a value of stock at time *t*, which is a summation of a value of stock at time t_0 and an integral of the difference between inflow and outflow rates from t_0 to *t* (Sterman, 2000). The system dynamics modeling with Lotka-Volterra aims to determine profits, operation investment, number of new workers, number of experienced workers, organizational learning, number of competitor's customer database, and number of customer database (Table 10). This historical data is used as input for this system dynamic model.

Table 10: Equations for the Generic System Dynamics Model of Operational Innovation

Variables	**Equations**
Cash Flows(t)	$\text{Cash Flows}(t_0) + \int_{t_0}^{t} [\text{Sale rate}(t) - \text{Operating cost rate}(t)] \cdot dt$
Operation investment (t)	$\text{Operation investment}(t_0) + \int_{t_0}^{t} [\text{Operation investment generation}(t) - \text{Operation investment discard}(t)] \cdot dt$
Number of new workers (t)	$\text{Number of new workers}(t_0) + \int_{t_0}^{t} [\text{Hiring Rate}(t)] \cdot dt$
Number of experienced workers (t)	$\text{Number of experienced workers}(t_0) + \int_{t_0}^{t} [\text{Training}] \cdot dt$
Organizational learning (t)	$\text{Organizational learning}(t_0) + \int_{t_0}^{t} [\text{Learning rate}(t) - \text{Forgetting rate}(t)] \cdot dt$
Number of Competitor's customer database (t)	$\text{Number of Competitor's customers database}(t_0) + \int_{t_0}^{t} [\text{Competitor's new customers}(t) - \text{Competitor's leaving customers}(t)] \cdot dt$
Number of customer database (t)	$\text{Number of customer database}(t_0) + \int_{t_0}^{t} [\text{New customers}(t) - \text{Leaving customers}(t)] \cdot dt$

The desired outcomes from the system dynamics modeling with Lotka-Volterra are cash flows which are the difference in value between revenues and operating costs over a five year period.

The cash flow is then run by using the Monte Carlo Simulation to quantify a future value of new business operation (net present value) and a risk value in terms of volatility. Volatility represents how much the expected cash flow value is changing over time. Typically, a higher volatility reflects high risk in project investment (Mun, 2006). The Monte Carlo Simulation helps to estimate value of volatility by using a normal or lognormal probability distribution technique (Munoz, 2006).

This cash flow is also used to estimate net present value using the traditional DCF to justify whether the business should make an investment. The net present value represents the calculation of ROI. If the ROI from these methods offer positive ROI, then the decision process is ended. If the cash flows from the Monte Carlo Simulation and the DCF method provide a negative ROI, then this investment should be rejected.

However, the development of operational innovation is an important key factor to help businesses with better operational capability and market competitive advantages to response to the market threat and pressure of competitors (Hamel & Breen, 2007; Hammer, 2005). The solution approach is used to invest only if the value of the new business operation provides a benefit. Therefore, the real option method is a more appropriate approach that allows decision makers to delay a project investment until it reaches the expectation of maximum value of return on investment (Tourinho 1979; Titman 1985; McDonald and Siegel 1986; Paddock, Siegel&Smith 1988; Ingersoll and Ross, 1985; Trigeorgis, 1993b, 2005).

3.2 Measure value for a candidate option using the Binomial Lattice Method and determine the optimal time to make an investment

The cash flow and volatility value from the previous step are used to estimate the return on investment using Binomial Lattice method. The rationale of using this method is that it offers a better way for estimating the ROI of the project in both Optimistic (upside potential) and Pessimistic (downside risk), and in different strategic decisions addressing the volatility of the underlying project. It requires simple mathematics and enables a trace for each time period, and is similar to Decision Tree Analysis (Copeland & Antikarov, 2005; Mathews et al., 2007).

The binomial lattice method shows both upside potential *(u)* and downside risk *(d)* which are functions of the volatility of the underlying assets. The volatility value, which is estimated from previous step, is used to calculate the return on investment considering the risk. The value of a risky underlying asset (S) is based on binomial distribution where begins at t_0 in one time period Δt. Asset (S) increases to S_u with the probability u or decreases to S_d with the probability d, and r_f is the risk-free interest rate (the interest rate the market is willing to pay on an asset whose payoffs are completely predictable). Asset (S) binomially distributes and stops upon the number of time periods. The last node at the end of the binomial tree reflects the range of possible asset values at the end of the option life. The binomial lattices require two different approaches: risk-neutral probabilities, and market-replicating portfolios (Kodukula & Papudesu, 2006). Risk neutral probabilities are used to calculate certainty-equivalent cash flows that can be discounted at the risk free rate of the expected future payoff (Copeland & Antikarov, 2005; Trigeorgis, 1993b). Kodukula & Papudesu, (2006) explain that risk neutral probabilities are associated with the risk adjustment of cash flows and later discount them at the risk free rate. Both probabilities can be calculated with these formulas:

$$u = \exp(\sigma\sqrt{\Delta t}) \text{ and } d = 1/u \tag{13}$$

$$\text{Risk neutral probability } (p) = \frac{\exp(r_f \Delta t) - d}{u - d} \tag{14}$$

The value of an option on asset (S) can be determined during a certain period of time *(Δt)* as follows in these equations:

$$C_u = \max(0, S_u - X) \text{ or } C_d = \max(0, S_d - X) \tag{15}$$

$$C = [p\,(S_u) + (1-p)\,(S_d)] * \exp(-r_f \Delta t) \tag{16}$$

Where $\Delta t = T/n$, T=Life of the options and n=Number of time periods

The call option values are the different values between the underlying asset value and a strike price (Equation 15). The values of real options with the risk-neutral probabilities (either p or probability $1-p$) are estimated by using Equation 16. It also considers the risk free rate with the delta time period (Δt). The risk neutral probabilities are not the same as objective probabilities, but it is an intermediate value that allows discounting cash flow by using the risk free interest rate. The binomial lattice requires five basic parameters: σ, r_f, S_0, X and T (Benaroch, 2001; Bodie et al., 2004; Kodukula & Papudesu, 2006). The results from using the Binomial Lattice method provide an option value representing a return on investment of new operations for each wait time period.

The result from using RODD method is compared with two methods for validation purposes. The first method is the DCF method. This comparison tends to validate the argument to use the Real Option Analysis for this research. The second method is real options analysis using the Binomial Lattice method with the original data. This comparison tends to validate the argument to use the System Dynamics Modeling with Lotka-Volterra to determine cash flows. Thus, the results from these comparisons will show the importance of using RODD. The defer option is the strategic option approach in this situation. As a result, the business/organization will make an investment in the year that initially provides positive ROI on the cash flow.

4.3. Phase III: Implementation

The final stage is implementation and diffusion. There are two steps for this phase: small scale implementation and large scale implementation (Bucherer et al., 2012; Chen, 2011; Utterback & Abernathy, 1990; Utterback, 1971).

Many business components related to a new operation are changed, which includes: activities of doing work, process steps, operational requirements, and an internal responsibility matrix for the workforce. The results of small scale implementation are evaluated using the modified performance assessment in Table 8, which reflects the success of implementing operational innovation. If the performance significantly increases, the operational innovation can be implemented for large scale operations. Therefore, the operational innovation offers a new way for operating the business and has a substantial impact on the entire business and the management structure.

4.4. Summary

Chapter Four illustrates the RODD framework step-by-step. The RODD framework is developed by integrating Real Options Analysis (ROA), Matrix of Change, multi-modes Lotka-Volterra, and System Dynamics Modeling to analyze the feasibility of the operational model transition and to assess ROI for operational innovation. This approach takes the impact of risk factors and competition into consideration, which have not been addressed in any previous research. This framework consists of three steps: 1) Decision problem identification, 2) Systematic transition analysis, and 3) Analytic modeling. The framework includes all the specific tasks to be performed in each step, and the deliverables to be expected from each step. The rationale to use these techniques is described below:

- Real Options Analysis and Monte Carlo simulation are used to define values of new business opportunities in an uncertain environment, and to develop a strategic investment decision (Benaroch, 2001; Copeland & Antikarov, 2005; Driouchi & Bennett, 2012; Mathews et al., 2007; Sáenz-Diez et al., 2008; Trigeorgis, 1993b, 2005). The Binomial Lattice method is the appropriate method for operational innovation investment decision because this method captures the probability of success and failure, which match the nature and complexity of the operational innovation and its environment. The Monte Carlo Simulation is a supplementary method for real options analysis that helps to estimate the value of risk factors in term of volatility value, and is determined by a normal or lognormal probability distribution technique (Munoz, 2006).
- Matrix of Change (MOC) assesses a management transition. This approach is used to map the current state of operation to the future state (operational innovation). The results from using this method show the feasibility of the operation transformation (Brynjolfsson, Renshaw, et al., 1997).
- The concept of multi-modes Lotka-Volterra evaluates the impact of a competitor who attempts to enhance its own business capability leading to the decrease of its opposing business's revenue growth. This represents the pure competition behavior (Unver, 2008).
- System Dynamics Modeling is an approach to develop a model to solve problems of investing in operational innovation. The main purpose is to explore a new understanding

of how the problem arises, and use that understanding to develop feasible strategies for an operational innovation. This method helps to improve the accuracy of predicted financial results for the operational innovation, considering the impact of a competitor.

CHAPTER FIVE: CASE STUDIES ANALYSIS AND RESULTS

In this chapter, we illustrate how the framework can improve the effectiveness and flexibility of investment decision-making for operational innovation. We describe United Parcel Service of America, Inc. (UPS) and “smart” firefighting operation case studies. The RODD framework is then implemented to solve these cases. The results from using the RODD framework for each case are reviewed by the relevant experts, including: 1) Mr. Bruce Gunning, Senior Industrial Engineering Manager at UPS; 2) Dr. Albert Jones, Supervisory Operations Research Analyst-Systems Integration Division Office, National Institute of Standards and Technology; 3) Fire Chief Howard Goldberg, Battalion Chief for the Orange County Fire Rescue, Florida; 4) Fire Chief Adam K. Thiel, Fire Chief for the City of Alexandria, Virginia; 5) Lieutenant Colonel Eliot Evans, Deputy Commander, 166th Mission Support Group, Delaware Air National Guard; and Michael Ferrante, Lead Systems Engineer with the Department of Defense/Reserve Sheriff's Captain, Orange County, Florida. These experts provided the feedbacks to confirm the results.

These cash flows from the RODD framework are then compared with the results from using the use of the DCF method and the Real Option Analysis using the original data from UPS and Orange County, Florida. The first comparison aims to validate the use of the Real Option Analysis for this research. The second comparison aims to validate the use of the System Dynamics Modeling with Lotka-Volterra to determine profits. Finally, the conclusions of these cases are summarized.

The case studies are used to demonstrate how the RODD framework can help decision makers to successfully make an investment in order to improve their organizational performance.

5.1. Case Study I: United Parcel Service of America, Inc. (UPS)

The competition between UPS and FedEx has intensified over recent decades. While it might not directly benefit the individual companies, the competition has benefited customers by giving them faster, better, and cheaper services. Today UPS is the most successful package delivery business in the U.S. One reason for this success is that UPS has implemented operational innovations; for example, applying advanced information technology (IT) to develop better tracking and improving on-time package delivery, and using data from customers, drivers and vehicles in a new route guidance system that helps save time, money, and energy (Schlangenstein, 2013).

In the mid-1990s, UPS had faced challenges including slow revenue growth rate, competition (especially with FedEx), and inefficient operations. Therefore, UPS's strategy was changed to enhance the competitive advantages by responding to the dramatic changes in Internet-enabled package and document delivery services worldwide (Brynjolfsson, Short, et al., 1997; Spekman & Composit, 2004). The company was also aware of the new opportunities of the advanced technological systems, and the business's capability of using existing assets to grow new emerging markets at rates that met the economic needs of large-scale businesses (Spekman & Composit, 2004).

While UPS improved its business capability by providing PC software to their customers which offer them the convenience to make labels, schedule pickups, and track shipments, FedEx had the market share over UPS by using online tracking and offering all shipping services (i.e. creating shipping labels, calculating costs, and scheduling pickups) through its own website before UPS (Spekman & Composit, 2004). FedEx was also a step ahead of UPS by offering

Internet-Ship and Business-Link software which raised its business attractiveness on the World Wide Web. This company also had a stronger brand than UPS (Levy, 2001).

The impact of FedEx was the most critical challenge for UPS. FedEx had rapidly grown in the logistics services market, continually enhancing its business capability to serve the needs of its customers. The company developed its operation by using advanced technologies and acquiring Caliber System's software package for order management, customer services, fulfillment, and part-sequencing solutions (Spekman & Composit, 2004).

UPS found a competitive tool, which was mass customization by using information technology and the development of innovation for their operations. As a result, in 1999 UPS changed their vision statement from "the leading package delivery company" to "the enablers of global e-commerce." Their mission was serving their evolving needs, sustaining a strong and employee-owned company, continuing to be a responsible employer, and acting as a caring corporate citizen. Their plans were building competencies in the integration of goods, funds, and information, by using technology to create new services, studying customer behavior and anticipating their needs, and developing an environment that enabled them to treat each customer as if he/she were the only one. The most important plans for UPS were investing in information technology systems for the core business of worldwide distribution and logistics and practicing innovation that lead to growth and competitive advantages (Levy, 2001).

It was a challenging mission to transform its operation because UPS had a high degree of complexity associated with resource allocation processes both formal and informal. Therefore, it was difficult to understand and define what, where, and when resources should be implemented , and where these resources would supplement or conflict with existing operations (Brynjolfsson, Short, et al., 1997). As a result, it was a tough decision to invest in the short term.

After slowly implementing operational innovation, in 2001 UPS had delivered about 13.6 million packages per day, with 1.8 million shippers, 7 million consignees, and 200,000 delivery vehicle drivers and package handlers. There were 1,748 operating facilities, 152,500 delivery vehicles, and 238 aircraft. UPS's profits were $2.39 billion with an operating margin of 15.3% (UPS Company-Investor Relations, 2013); whereas FedEx earned $0.55 billion in profits and had the half of UPS operating margin. FedEx announced that they would develop a new core operation by improving their information technology system and offering technology solutions to customers in order to decrease customer losses such as National Semiconductor and E-tailer SmartHome.com who rejected FedEx's business deal and went with UPS (Haddad & Ewing, 2001).

The RODD framework is being implemented to analyze the UPS case study. This research aims to illustrate how the framework can improve the effectiveness and flexibility of investment decision-making for operational innovation development.

Stage 1: Decision Problem Identification

This stage is taken after the business recognizes they need to change to a new core operational model. An operational innovation was identified as an alternative option response to FedEx's business capability and customer needs.

The goal was ***"Grow in emerging markets, Optimize resources, and Decentralize for local implementation"*** by developing a core operation in a new way. The strategy was *"To enhance competitive advantages responding to the dramatic changes in Internet-enabled,* *package and document delivery services worldwide."* UPS was interested in technological investments; however, the complexity of their organization and limited knowledge made it difficult to make decisions to invest or develop a new operation in short term (Brynjolfsson, Short, et al., 1997; Levy, 2001; UPS Company-Investor Relations, 2013).

This situation is suitable for a deferred option, which allows decision makers to obtain more information by waiting another year to better understand risk, market demand, and competitor's ability. Then the company could choose to invest in information technology systems to change operations.

At the operation level, there are five relevant stakeholders: Information Technology (IT) Department, Operations Department, Customer Call Center, Fulfillment and Return Department, and Sales Department (Ross et al., 2002). It is necessary to identify the responsibilities of each stakeholder in order to prevent confusion and enhance the effectiveness of employee engagement throughout the organization. Table 10 shows the goal and an alternative option. The responsibility matrix of operation transformation is illustrated in Table 12.

Table 11: Decision Problem Identification-UPS Operation Development

Project Name: Develop a Core Operation in New Ways	
Decision Problem Identification	**Description**
2.3 Goal	*"Grow in emerging markets, Optimize resources, and Decentralize for local implementation"*
2.4 Alternative options	Option 1: Do nothing (Current State) Option 2:Operational Innovation using Information Technology Systems (Future State)

Table 12: Responsibility Matrix for UPS Operation (UPS Company-Investor Relations, 2013)

Activities	**Stakeholder**				
	IT Department	**Operation Department**	**Customer Call Center**	**Fulfillment and Return Department**	**Sale Department**
Receiving orders from customer	N	N		R	R
Estimating arrival time	R	R	N		N
Helping customers with any inquiries	N	N	R		
Building information from database	R	R	N	N	N
Tracking packages	R	R	N	N	N
Note: C = Must be consulted; N = Must be notified; R = Direct Responsibility MR = Managerial Responsibility					

Stage 2: Systematic Transition Analysis

The systematic transition analysis stage analyzes both current and operational innovation. There are five processes for systematic transition analysis as follows:

Stage 2-2.1 Analyze the current state

The current state of UPS operations in 1996 involved four main areas: information systems, transportation network, core service, and organizational assets (Brynjolfsson, Short, et al., 1997; UPS Company-Investor Relations, 2013).

The operation started by dropping off packages by consignors at UPS stores. The packages were carried to the local center for scanning, sorting, and entering into computer systems. At the local center, the packages were sorted according to their designation. If the packages destination was domestic, they were called "inbound", and were carried to the designated local centers, where they went out for delivery to customers. If the packages designation was international, they were called "outbound", and were carried to a hub. Then they were carried to the international designated local center and went out for delivery to customers. Information was transferred using information systems which were composed of the relational database, fleet connectivity, and a tracking system all of which helped UPS to enhance operational efficiency. The Delivery Information Acquisition Devices (DIAD) helped UPS to track the package transaction from consignor and consignee. These devices transferred information and uploaded it in real-time through in-vehicle cellular service. The information systems helped UPS to monitor and track its operations.

The core service was responsible for customer call centers, logistics support, order status, and package tracking. The logistics support and customer call centers used information from a relational database and DIAD to answer customers' inquiries. The information systems did not provide real-time information directly to customers. Therefore, the delayed information throughout these systems and waiting time for customer service caused customer frustration. The organizational assets focused on operational excellence, employee-owner culture, and company brand.

During that time, UPS was faced with several problems such as the slow rate of business growth, the impact of competitors in the logistic industry, limited information during operation, brand weakness, and change in customers' references. These issues motivated UPS to innovate a new operational model to satisfy customer needs and improve its operation by leveraging advanced technology. The components of the current operational model using MOC are shown. Figure 27 and Figure 28 show the holistic viewpoint of the current operation and its matrix of change.

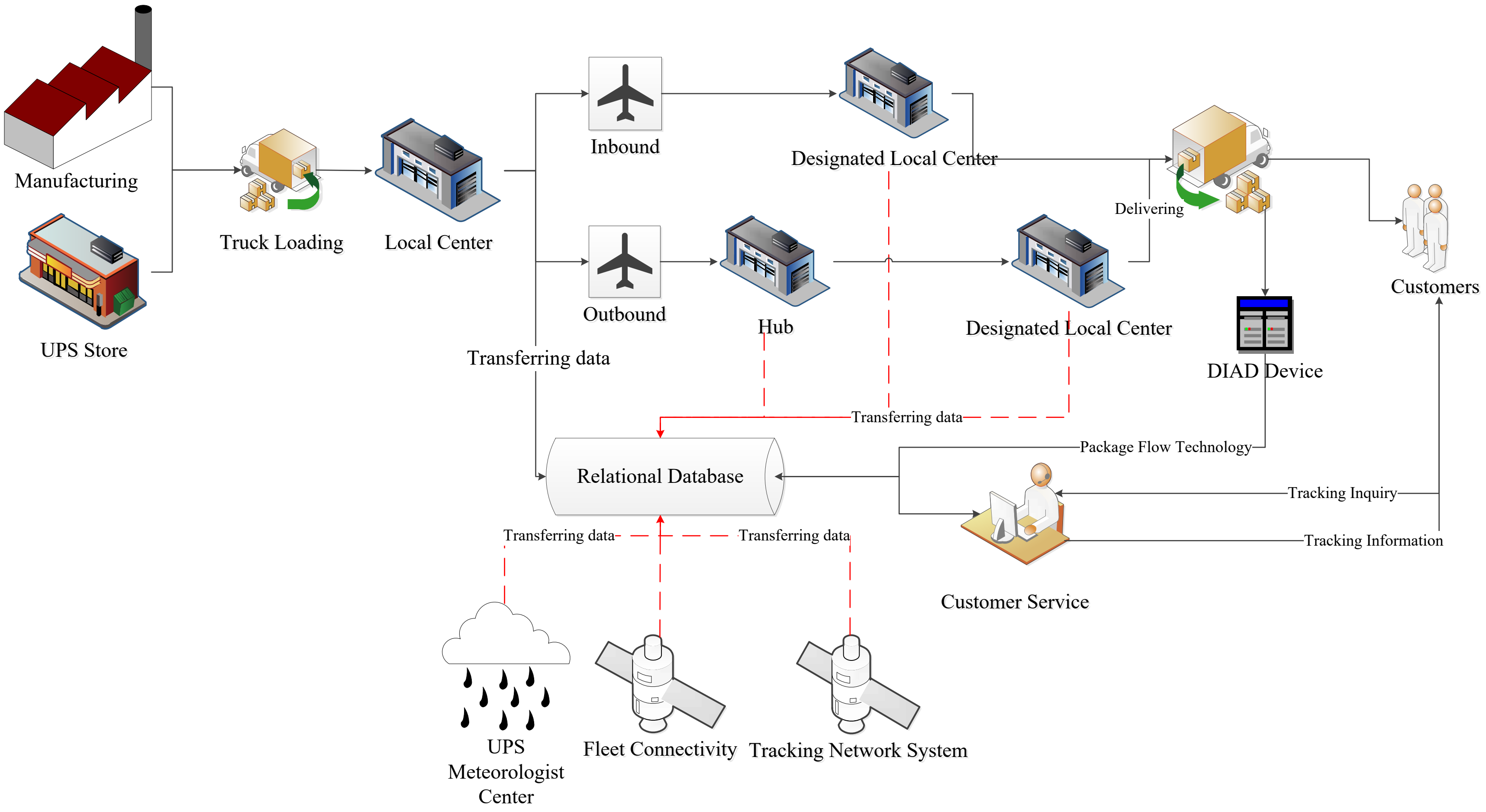


Figure 27: The Current State of UPS Operation (1996)

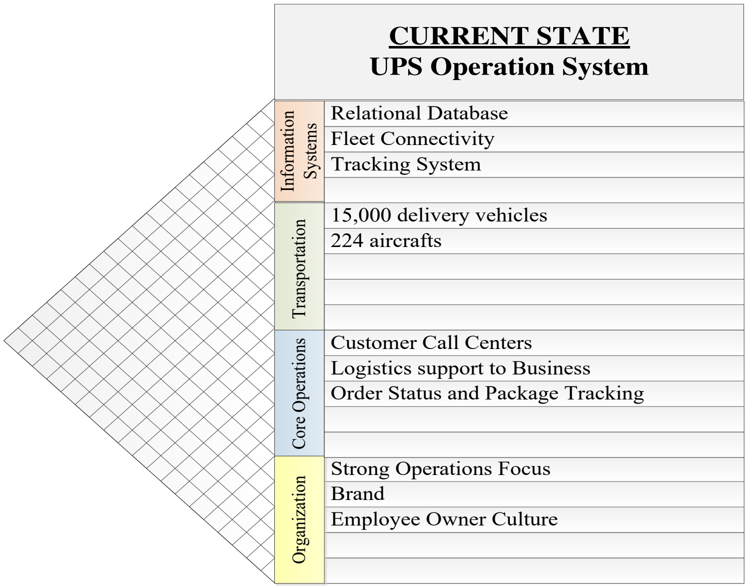


Figure 28: Matrix of Change of the Current State of UPS Operation (Modified from Brynjolfsson, Renshaw, & Alstyne, 1997)

Stage 2-2.2 Assess the performance of current state using modified balance scorecard

The performance of the current state is assessed using the modified balance score card. This assessment was developed based on the balance scorecard (Kaplan & Norton, 2000) and the six Baldrige Categories for Performance Excellence (Baldrige National Quality Program: The National Institute of Standards and Technology, 2013). The performance assessment of the UPS current operation is retrieved from the annual report (UPS Company-Investor Relations, 2013). In this annual report, UPS focused on only four dimensions: financial, operation system, customer satisfaction, and workforce focus. The operational performance in 1996 was 61.80 out of 100. This result reflected the slow business growth and workforce readiness problems. As a result, these concerns motivated UPS to innovate a new core operation in order to increase their revenues and operation's capability (Harvard Business Publishing Newsletters, 2000; UPS Company-Investor Relations, 2013). Table 13 illustrates the four dimensions of the performance assessment of UPS operation.

Table 13: Performance Assessment of the Current State of UPS Operation (UPS Company-Investor Relations, 1996)

2.2 Performance Assessment (Point Value)	
Assessment Dimensions	**Score**
1. Financial	
Revenue/Budget	11.39
2. Operation System	
Operating Cost	12.46
Operational Efficiency	18.26
3. Customer Satisfaction	
Voice of the Customer	13.02
4. Workforce focus	
Workforce readiness	6.68
Total Score	**61.80/100**

Stage 2: 2.3 Analyze the future state

UPS began its operational analysis by studying their competencies and expertise. The company estimated the assets of their infrastructure, data, communication, fleets of trucks and aircraft, and call centers. The purpose was to determine if the company could develop a new core business-service operation by using their current technology and connectivity of the internet to establish new subsidiaries of UPS (Levy, 2001).

UPS wanted to develop an operational innovation by leveraging advanced technology within three areas: 1) digital supply chain and customer service management, 2) fulfillment and returns management systems, and 3) electronic procurement and supply chain services. The company expected that this operational innovation would enhance its operational capability and response to the FedEx threat (Brynjolfsson, Short, et al., 1997).

At the operational level, operations integrated digital supply chain, fulfillment and return management, E-procurement, and the UPS website to serve customers. First, the digital supply chain management helped UPS to reach its strategy by enhancing competitive advantages to response to the dramatic changes in Internet-enabled, package and document delivery services worldwide. The digital supply chain system consisted of electronic tracking and database connectivity features which were the new operating tools in information systems. It provided real time information which allowed customers to track their packages on the UPS website.

Second, the customer service and fulfillment and returns management systems were developed. The digital supply chain supported the customer service and fulfillment and returns management. Customer service could provide immediate information to both consignor and consignee. The fulfillment and returns management system helped UPS to directly bill for their shipping charges, and allowed the customers to minimize their transportation costs. The consignors, especially commercial businesses, received benefits from this system such as the accurate prediction of their package volume, immediate offering of package status, billing, delivery confirmation, and call tag service for the shipments to their customers (UPS Company Annual Report, 1999).

Finally, the organizational assets were developed to implement E-Procurement and E-Supply Chain Services. These services were expected to enhance UPS's business capability, and allowed the company to receive and transfer data or information across the world 24/7. The operational innovation using information technology systems was developed to satisfy the company's goals. Investments would made if decision makers could foresee that this investment would provide numerous benefits and a high return on the investment to the company. Figure 30 and Figure 29 illustrate the future state of the UPS operation and its matrix of change.

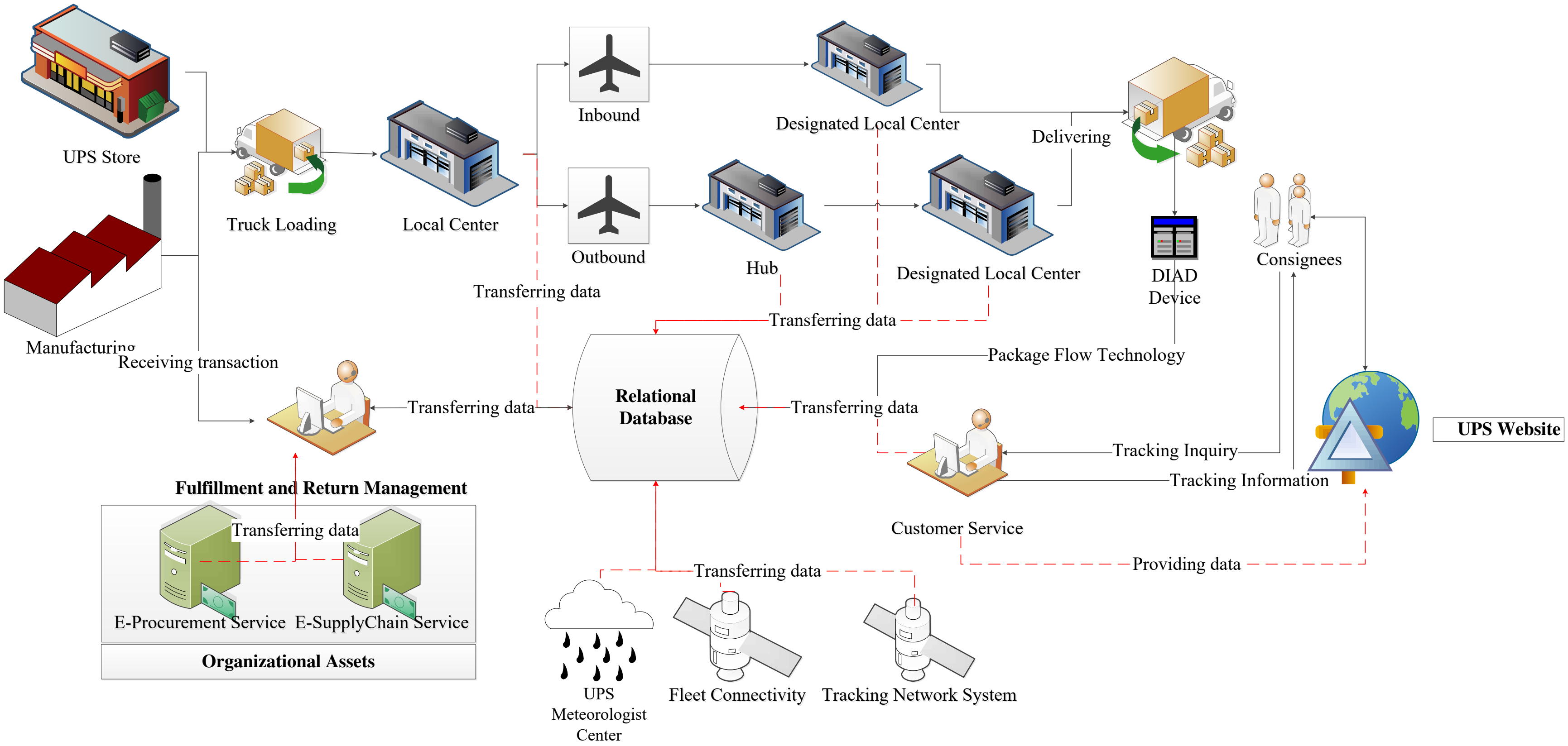


Figure 29: The Future State- UPS Operational Innovation (2001)

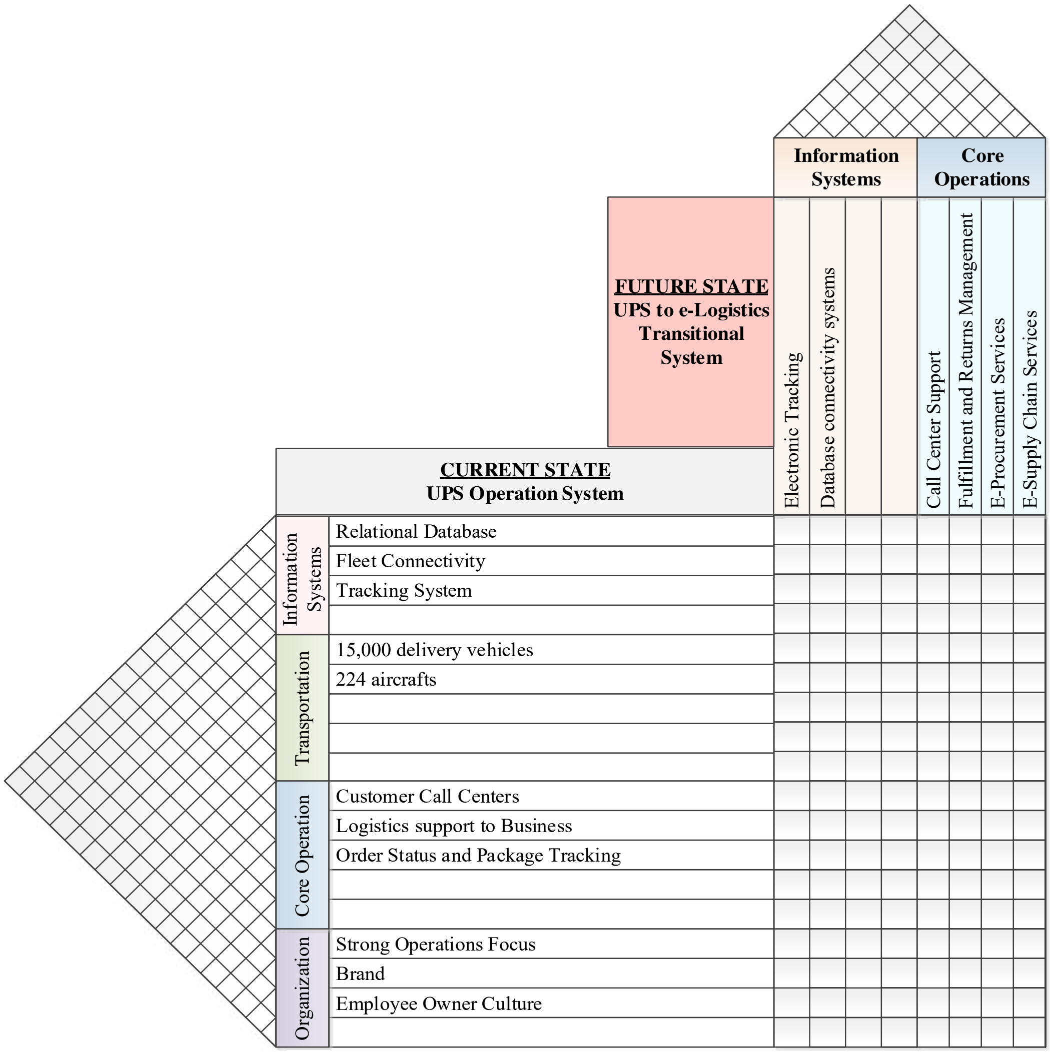
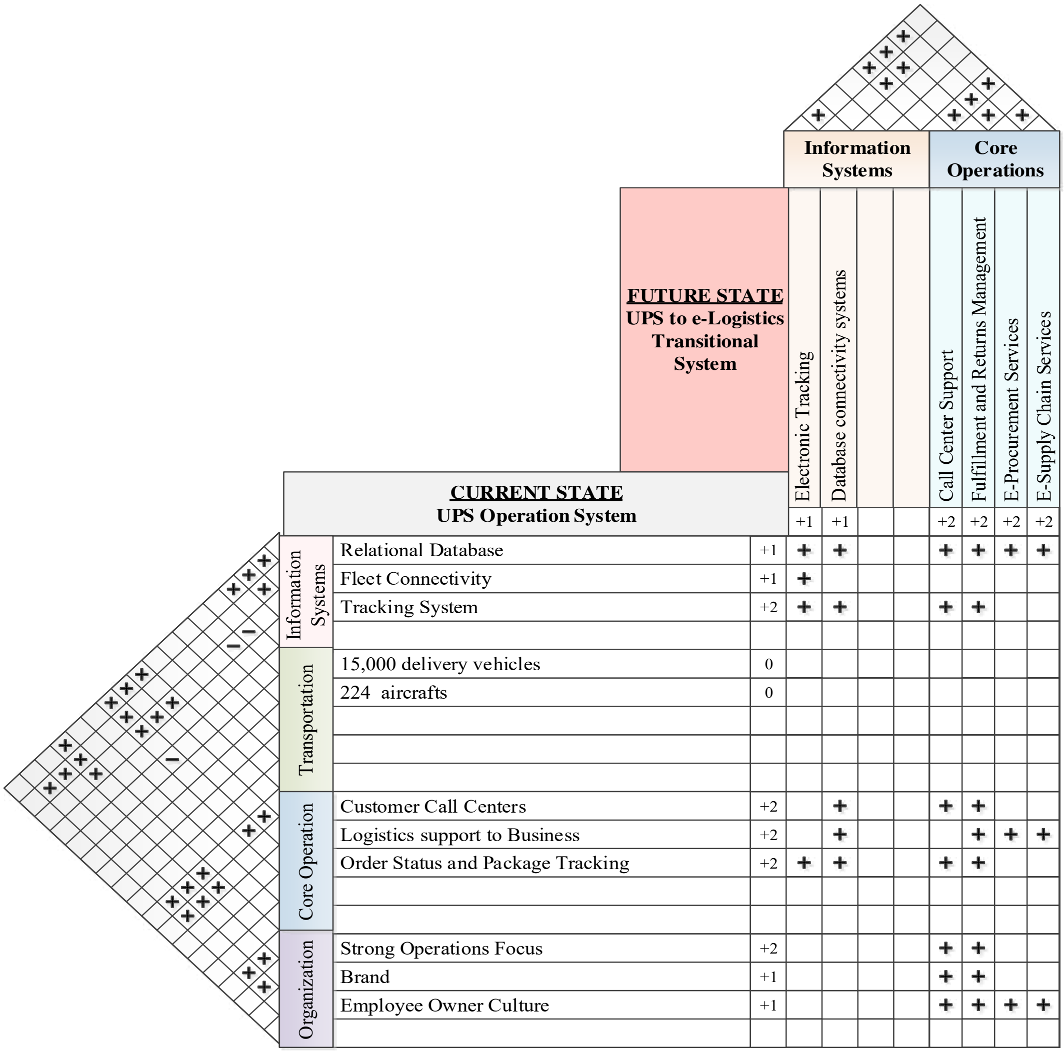


Figure 30: Matrix of Change of UPS Operational Innovation (Adapted and modified from Brynjolfsson, Renshaw, & Alstyne, 1997)

Stage 2: 2.4 Identify the transition interaction

The transition from the current state to operational innovation is determined in terms of (+) reinforcing behavior and (-) interfering behavior. The results in Figure 31 show that the transitions of the current state and future state have more reinforcing behaviors than balancing behaviors. Therefore, the operation transformation from current operation to operational innovation is feasible.



			Information Systems				Core Operations			
			Electronic Tracking	Database connectivity systems			Call Center Support	Fulfillment and Returns Management	E-Procurement Services	E-Supply Chain Services
			+1	+1			+2	+2	+2	+2
Information Systems	Relational Database	+1	+	+			+	+	+	+
	Fleet Connectivity	+1	+							
	Tracking System	+2	+	+			+	+		
Transportation	15,000 delivery vehicles	0								
	224 aircrafts	0								
Core Operation	Customer Call Centers	+2		+			+	+		
	Logistics support to Business	+2		+				+	+	+
	Order Status and Package Tracking	+2	+	+			+	+		
Organization	Strong Operations Focus	+2					+	+		
	Brand	+1					+	+		
	Employee Owner Culture	+1					+	+	+	+

Figure 31: Matrix of Change of UPS Operation Transformation (Adapted and modified from Brynjolfsson, Renshaw, & Alstyne, 1997)

Stage 2: 2.5 Identify relevant factors and risk factors for the candidate option

The relevant factors and risk factors for the candidate option are defined in order to develop the system dynamics model in the stage 3-analytic modeling. UPS studied the external factors such as e-commerce, markets, and their customers. They recognized that the dynamics of customer behavior changed from the sellers (businesses) to the buyers (customers). UPS began to invest in data networking applications to increase communications with their customers and the efficiency of operations. An information technology network and database were used to track more than 200 data elements for every single package. The expected future state would allow customers to track, rate, and address the validation package over their website. They developed an eLogistics service, small B2C (Business-to-Customer), and B2B (Business-to-Business) e-commerce, that increased the capability of logistics, the tracking system, fulfillment, and shipping for the customers (Levy, 2001; "UPS: Technology & Innovation," n.d.).

Table 14 shows the relevant factors and a risk factor of the candidate option. The relevant factors are categorized in five aspects based on the generic variables of operational innovation in Step 2.5. However, some factors are added to the characteristics of UPS operations and the environment of the organization. The information technology system is indicated as a risk factor.

Table 14: Factor Identification for the UPS Operational Innovation

2.5 Factor Identification-Future State			
Functions	**Input Variables**	**Functions**	**Input Variables**
Financial Aspect	UPS's profit	**Operation System**	UPS's operational efficiency
	UPS's sale		E-Procurement Services capability
	Investment infrastructure capability		UPS's operational innovation capability
	Investment in E-Tracking system		Number of delivered package per month
	Operating cost		Equipment Readiness
	Maintenance cost		E-Supply chain services capability
Leadership	Knowledge		Logistics support to business performance
	Leadership skill		Number of aircrafts
	Organizational learning		Number of delivery vehicles
Customers	Customer satisfaction		Number of local stores
	Number of lost customers	**Workforce Focus**	Desired number of workers
	Number of new customers		Hiring new workers
	Number of active customers		Number of workers
Risk Factors	Information Technology System		Training

Stage 3: Analytic Modeling

This section illustrates the analytic modeling which integrates four mathematical models: System Dynamics Modeling, Lotka-Volterra, Monte Carlo Simulation, and Real Option Analysis.

Stage 3: 3.1 Develop the system dynamics modeling and integrate Lotka-Volterra and Monte Carlo Simulation for the candidate option

The factors from Stage 2-Step 2.5 are used to develop the system dynamics modeling for the candidate option. The hypothesis of the system dynamics model is to develop UPS's operations model and consider the impact of the competitor and risk within a five year period. The reference model is developed to represent the development of the problem over time. UPS's profits from 1995-2001 show the oscillation behavior with high volatility (blue line) (Figure 32). The slow growth rate started from 1995-1997. During that time, UPS recognized the need for change in operation toward operational innovation. UPS slowly implemented operational innovation in 1999; as a result, the net income decreased due to high investment and operating costs. The profits grew in 2000 after gradually implementing operational innovation (UPS Company-Investor Relations, 2013). In the model, the desired profits after operational innovations implementation were an exponential growth of profits over a five year period considering the impact of FedEx in the optimistic scenario. This is represented as a reference mode (red line).

The relevant factors, risk factors, and the competitor impact of the candidate option are integrated to develop the causal loop diagram (Figure 33) which provides the high level of UPS operational innovation components, their relationship, and the system behavior. The system dynamics modeling of UPS operational innovation is illustrated in Figure 34.

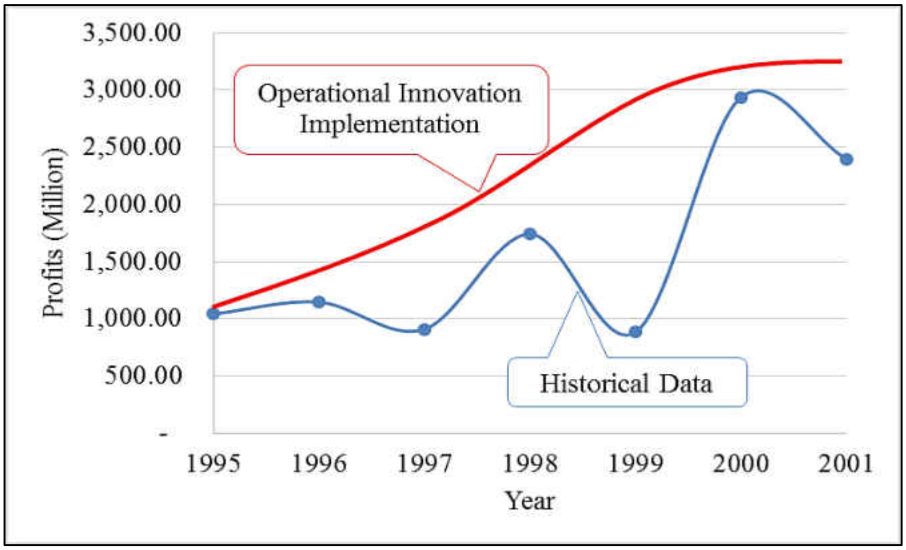


Figure 32: Reference Mode of UPS Profits Performance from 1995-2001(UPS Company-Investor Relations, 2002)

The causal loop is modified from the generic causal loop of operational innovation showed in Chapter 4.2.1. Real Option Dynamics Decision (RODD) Framework-Stage 3: Analytic Modeling. Some variables are added according to the characteristics of UPS, and the features of a desired optional model using an information technology system. This causal loop consists of three reinforcing behavior loops and two balancing behavior loops: R1-Customer Satisfaction (reinforcing behavior), R2-Infrastructure Capability (reinforcing behavior), R3-Service Capability (reinforcing behavior), R4-Operational Innovation (reinforcing behavior), and B1-Workforce (balancing behavior).

In the Customer Satisfaction loop, Lotka-Volterra is implemented to predict the number of UPS active customers considering the impact of FedEx's customer satisfaction. In this case study, we assume that this is the pure competition between UPS and FedEx. The increase of total potential operational capability increases UPS's customer satisfaction. In contrast, the increase of FedEx's customer's satisfaction decreases the number of UPS's active customers. If a high number of customers leaves UPS for FedEx, UPS's profits will decrease radically. The total potential operational capability can be improved by implementing electronic procurement service capability, electronic supply chain service capability, and infrastructure capability. Therefore, an increase of these three capabilities leads to an increase in the total operation capability.

The Operational Innovation loop (reinforcing behavior) represents the feedback loop of operational innovation implementation. If profits increase, then the investment in information technology systems increases leading to the improvement of the operational innovation capability which can enhance operational efficiency, E-procurement service capability, and E-supply chain service capability. Finally, the better these capabilities lead to the increase of the total potential operational capability and customer satisfaction, respectively. As a result, UPS should increase the total potential operation capability in order to improve the customer satisfaction.

The UPS annual reports from 1997-2001 indicated the performance in four dimensions: financial, operation system, customer satisfaction, and workforce focus. Therefore, the leadership performance and organizational learning are omitted in this system dynamics modeling. This modeling shows the quantitative analysis to determine profits, operation investment, UPS's customer database, FedEx's customer database, new employed workers, and experienced workers. The mathematical equations for the system dynamics modeling of UPS operational innovation are shown in Table 15.

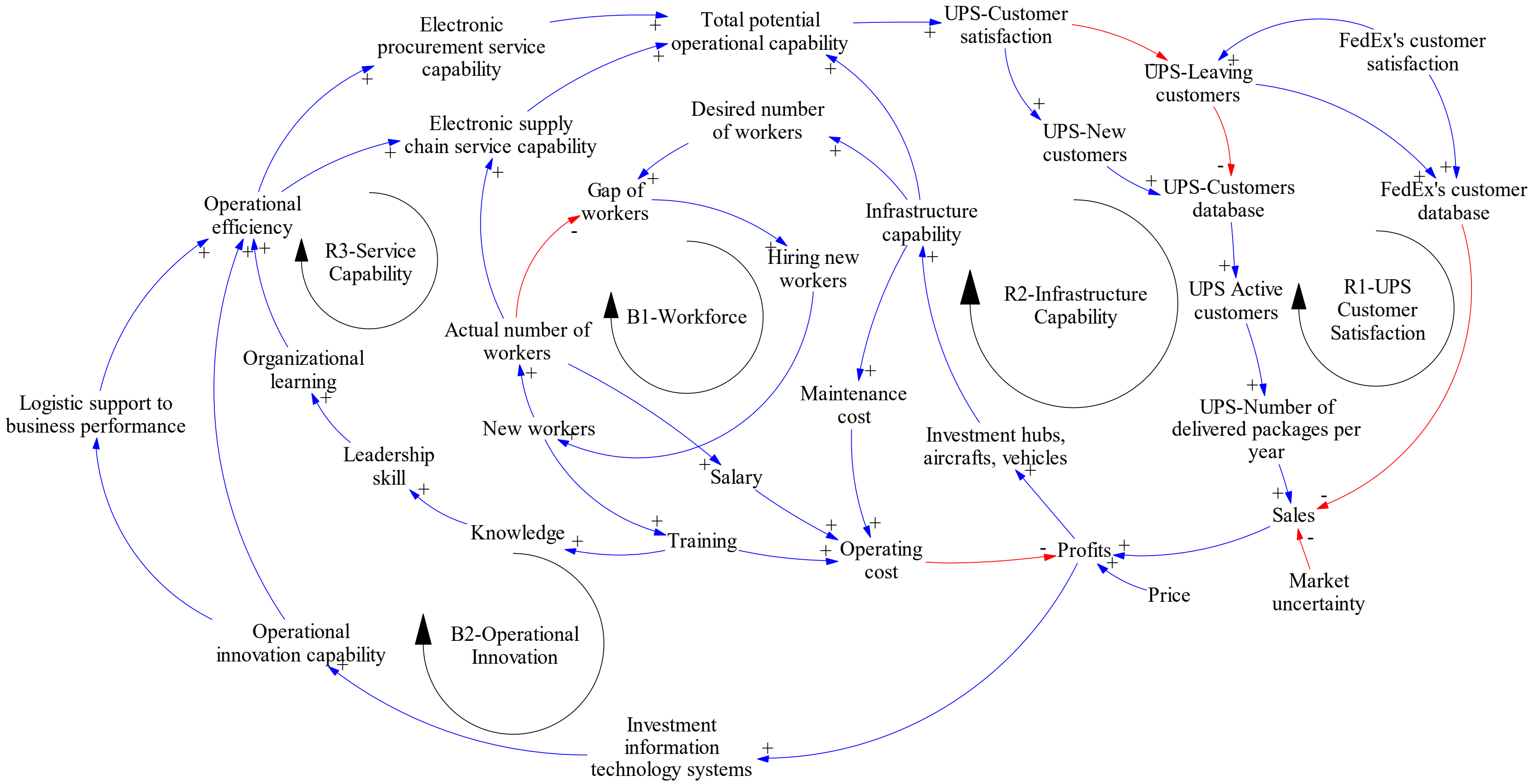


Figure 33: The Causal Loop Diagram of UPS Operational Innovation

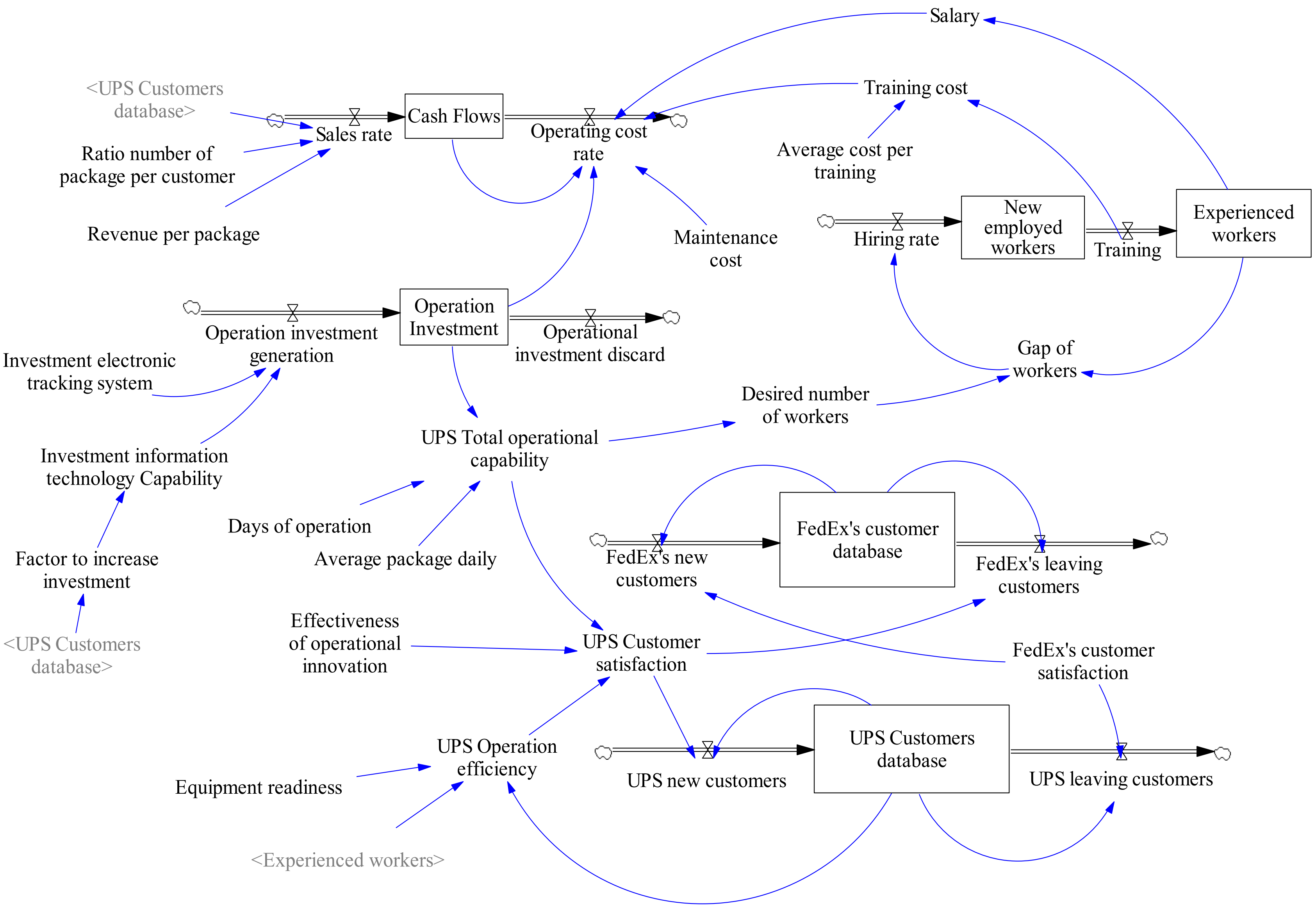


Figure 34: The System Dynamics Model of UPS Operational Innovation

Table 15: Equations for the System Dynamics Modeling - UPS Operational Innovation

Variables	Equations
Profits (t)	Profits (t_0) + $\int_{t_0}^{t}[\text{Sale rate (t)} - \text{Operating cost rate(t)}]\cdot dt$
Operation investment (t)	Operation investment (t_0) + $\int_{t_0}^{t}[\text{Operation investment generation (t)} -$ $\text{Operation investment discard(t)}]\cdot dt$
Number of new employed workers (t)	Number of new workers (t_0) + $\int_{t_0}^{t}[\text{Hiring Rate (t)}]\cdot dt$
Number of experienced workers (t)	Number of experience workers (t_0) + $\int_{t_0}^{t}[\text{Training}]\cdot dt$
UPS customer database (t)	UPS customer database (t_0) + $\int_{t_0}^{t}[\text{UPS new customer rate} *$ $\text{UPS customer satisfaction} * \text{UPS customer database(t)} -$ $\text{FedEx's customer satisfaction} * \text{UPS customer database (t)}]\cdot dt$
FedEx customer database (t)	FedEx customer database (t_0) + $\int_{t_0}^{t}[\text{FedEx new customer rate} *$ $\text{FedEx's customer satisfaction(t)} -$ $\text{UPS's customer satisfaction} *$ $\text{FedEx's customer database(t)}]\cdot dt$

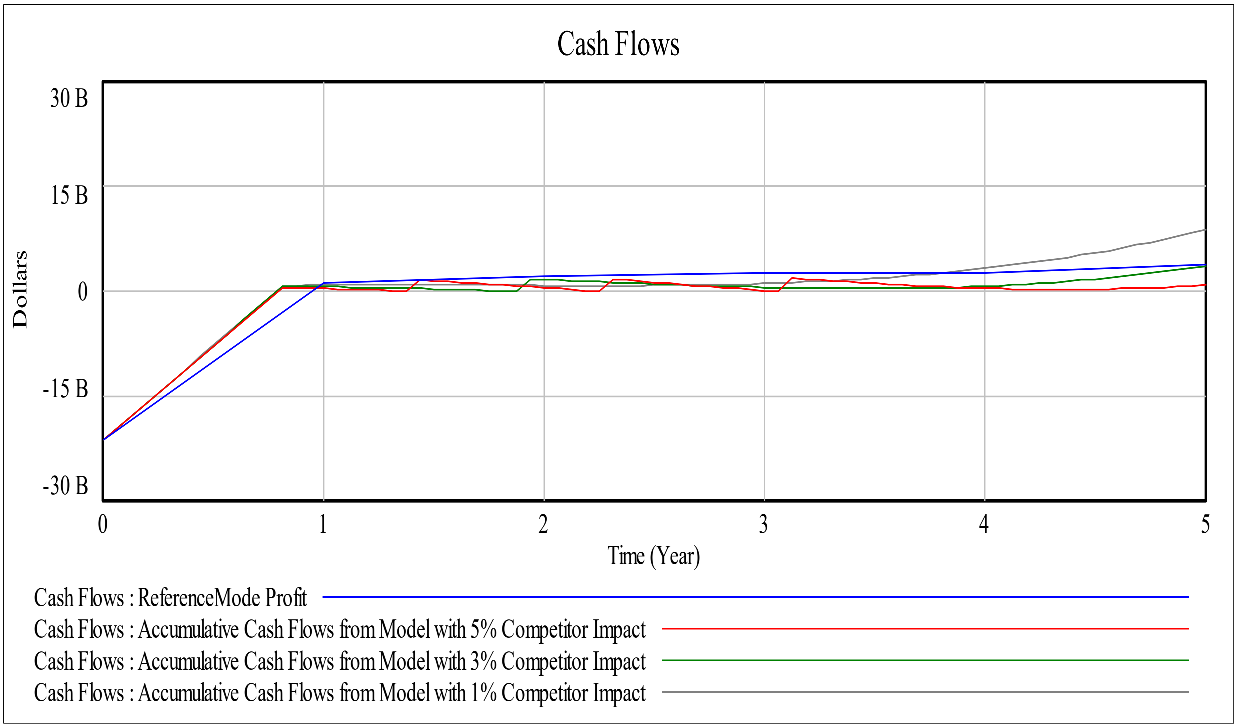


Figure 35: The Accumulative Cash Flows from System Dynamics Modeling with Lotka-Volterra-UPS Operational Innovation

Table 16: The Cash Flows -UPS Operational Innovation ($ Million)

Year	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Cost	21,325.00	28,803.63	32,429.37	37,276.03	36,131.41	42,409.47
Revenue	-	29,684.91	33,261.80	38,386.39	38,386.39	45,053.73
Cash flows	-21,325.00	881.28	832.43	1,110.36	2,254.98	2,644.26
Net Present Value (DCF method) = -$14,690.70 million						
Net Present Value with Monte Carlo Simulation = -$14,636.29 million						
Volatility = 1.25						
Risk adjusted discount factor = 4.31 %						
Competitor's customer satisfaction impact = 1% (Optimistic Scenario)						

The cash flows (1996-2001) from the system dynamics modeling with Lotka-Volterra, considering the impact of FedEx's customer satisfaction are shown in Figure 35. These cash flows are represented in three scenarios over a five year period with 1%, 3%, and 5% of competitor impacts (Optimistic, Most Likely, and Pessimistic). The first scenario obtains 1% of FedEx's customer satisfaction impact. These cash flows provided higher profits than the profits from the reference mode (data from UPS annual report- 10K).

At 3% of competitor impact, UPS's accumulative profits are slightly lower than the accumulative original profits. However, from year 1 to year 2, this level provides the same amount of profit as the reference mode. After that, the reference mode provides higher profit than the 3 % of competitor impact scenario. The rationale for this behavior is that an increase in operational capability drives the customer satisfaction and sales rate with the delay time. As a result, the profits radically grow in a certain period after the delay time.

The results of the accumulative profits for 5% of competitor impact are less than the reference mode, 1% and 3 % of competitor impacts, respectively. As a result, FedEx's customer satisfaction has a significant adverse impact on UPS's profits and the number of active UPS customers. Thus, the high level of competitor impact decreases the sales rate and profit growth. This behavior is called pure competition.

The results of this step are used for the Monte Carlo Simulation in order to quantify the risk value in terms of volatility value, and the average net present value considering the risk at a certain market discount rate (4.31%). This risk free rate is from the UPS Annual Report in 1999 (UPS Company Annual Report, 1999). The cash flows from the system dynamics modeling and Lotka-Volterra considering 1% of competitor impact (optimistic scenario) and the volatility value of 1.25. The cash flows using the Monte Carlo simulation (Figure 36 -sample for 10 runs) represent the expected cash flows moving above or below of 125% (blue color) in 10 scenarios, which is compared with the forecasted cash flow (red color).

The results of the net present values from the traditional DCF method and Monte Carlo Simulation considering uncertainty provided negative values (-$14,690.70 million and-$14,636.29 million). The volatility represents how much the expected cash flow value is changing over time. Typically, a higher volatility reflects a high risk in project investment (Mun, 2006). The volatility value of the UPS case equals 1.25. It means that at a certain time period, the cash flow values may above and below by 125% from the forecasted cash flow values (from the system dynamics modeling with Lotka-Volterra) between $1,006.28 million and $756.28 million at year 1, $957.43 million and $707.43 million at year 2, $1,235.36 million and $985.36 million at year 3, $2,379.98 million and $2,129.98 million at year 4, and $2,769.26 million and $2,519.26 million at year 5, respectively. These values represent the possible cash flow values in each year, considering risk and the impact of FedEx with an average volatility of 125 %. Therefore, this project investment is a risky project. Next questions are what is the value of a return on investment? and When is the best time to make an investment in this risky project?

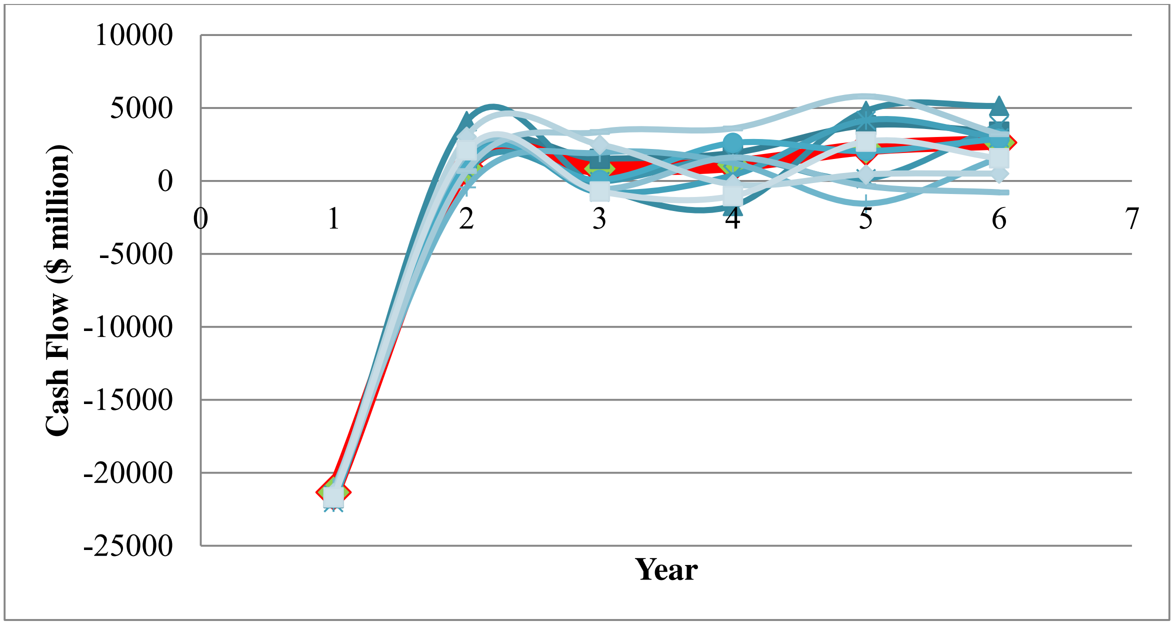


Figure 36: The Cash Flows using Monte Carlo Simulation-UPS Operational Innovation

<u>Stage 3: 3.2 Measure the real options value for the candidate option using the Binomial Lattice Method and. determine the optimal time to make an investment</u>

The approach used for the real options is the option to defer. In this step the real options analysis is used to calculate ROI. As a result, the business/organization will make an investment in the year that initially provides positive ROI. The binomial lattice equation is implemented to calculate the ROI and determine optimal time to invest for each delayed year to minimize the market risk.

As a result, the ROI is the value of a return on investment, considering risk and the impact of FedEx. There are six parameters: 1) delta time period (Δt), 2) volatility, 3) probability upside potential *(u)*, 4) probability downside risk *(d),* 5) risk free rate, and 6) risk neutral probabilities (Table 17). The ROI for each delayed year using real option are illustrated in Table 18. These ROI values are compared to ROI value using the DCF method (Figure 37).

The results show that if the company makes an investment now, then the company will lose money, or -\$14,690.70 million. If the company defers the project for one year, two years, three years, four years, and five years, the ROI equals \$439.26 million, \$3,073.91 million, \$3,267.96 million, \$4,588.99 million, and \$4,698.02 million, respectively. These values represent the ROI considering risk for delaying of the investment to clear market uncertainty and gain more information on the market need.

In contrast, the DCF method provides the negative ROI value -\$14,690.70. This method does not provide flexibility in decision making or change the decisions due to unexpected situations in the future. It does not provide comprehensive information on the effect of market dynamics, or does not take risk and uncertainty into consideration, whereas ROI values from the RODD method take the risk and the impact of competitor in optimistic scenarios into consideration. Therefore, UPS can delay investment in the information technology systems for at least one year in order to earn a positive return on investment.

Table 17: Parameters for Binomial Lattice-UPS Operational Innovation

Parameters:	
delta t	1.00
v: volatility	1.25
u	3.51
d	0.289
Risk free rate	4.31%
Risk Neutral	0.24

Table 18: The ROI Values using Binomial Lattice Method-UPS Operational Innovation ($ Million)

	1996	**1997**	**1998**	**1999**	**2000**	**2001**
Cost	21,325.00	28,803.63	32,429.37	37,276.03	36,131.41	42,409.47
Benefit	-	29,684.91	33,261.80	38,386.39	38,386.39	45,053.73
Cash Flow	-21,325.00	881.28	832.43	1,110.36	2,254.98	2,644.26
Risk Adjusted discount rate	0.0431	0.0431	0.0431	0.0431	0.0431	0.0431
Discount factor	1.00	0.96	0.92	0.88	0.84	0.81
Present value of cash flow	-21,325.00	844.87	765.06	978.33	1,904.75	2,141.28
Present value of all cash flow (S_0)		6,634.30				
Initial investment (S_t)		21,325.00				
Return on Investment	**0.00**	**439.25**	**3,073.90**	**3,267.95**	**4,588.98**	**4,698.02**

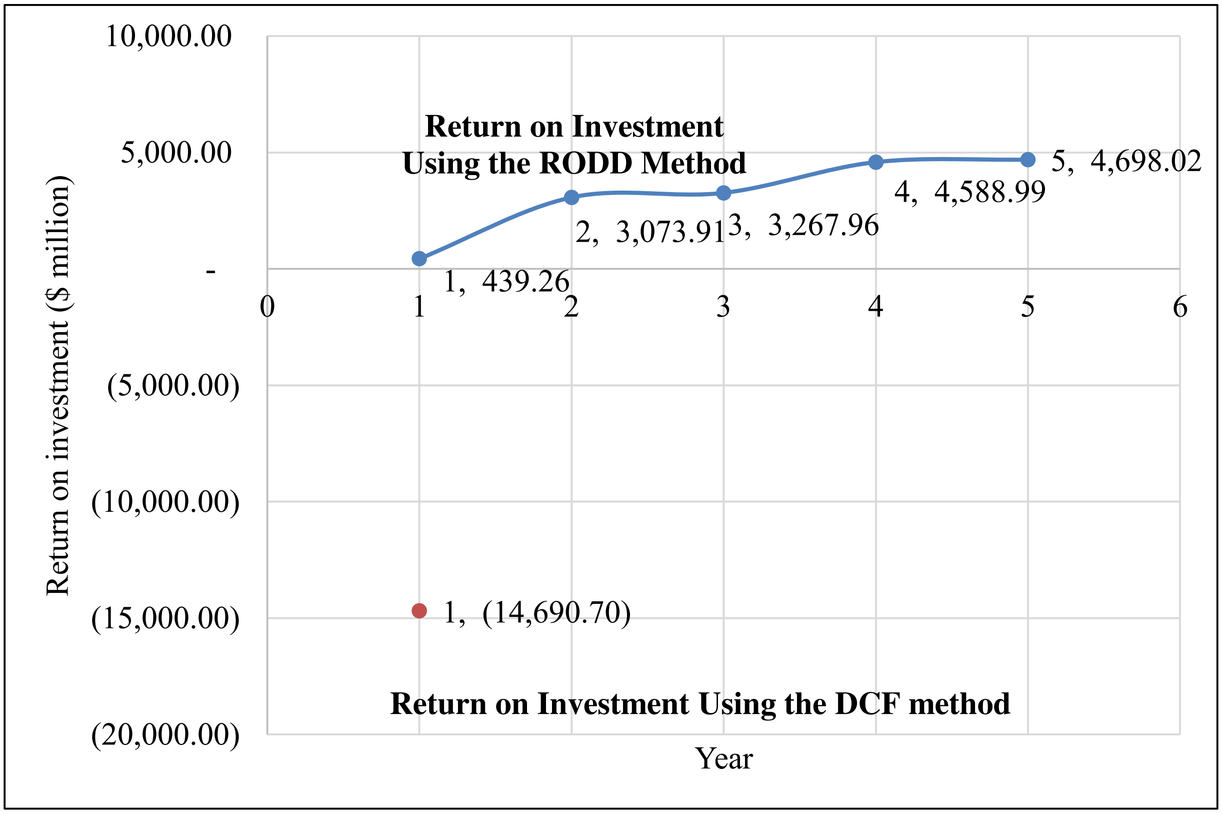


Figure 37: The ROI Values for Each Delayed Time-UPS Operational Innovation

In conclusion, due to the intensive competition in the logistics industry, the results show that delaying the investment in information technology systems for at least one year is the best solution for UPS in order to earn a positive ROI. This allows UPS to have more time to study customers' preferences, FedEx's market strategy, and the availability of advanced technologies for developing a better market strategy than FedEx. The structure of the decision process and the suggested decision is illustrated in Figure 38.

As a matter of fact, it took UPS a few years to made significant investments in information technology systems for operational innovation development. The information technology system was deployed in order to improve their operational capability response to FedEx's threat. It allowed them to provide real-time package delivery information and serve their customers globally in the most efficient ways. The digital supply chain management helped them to improve customer services, receiving, ordering management, and accounting operations. Three million customers on a daily basis viewed and tracked their package transitions through the UPS website (UPS Company Annual Report, 1999). The operational innovation implementation was shown to be an effective tool to enhance market competitive advantages, business capability, and profits (Schlangenstein, 2013; UPS Company-Investor Relations, 2013). UPS had grew the brand strength from no ranking in 1996 to second ranking of the 100-top Core Brand Power Ranking in 2001. Brand Power is a degree of size (familiarity) and quality (favorability), familiarity showing the brand and favorability showing the brand's overall reputation, perception of management, and investment potential. The Brand Power rankings provide a market-view assessment of corporate brand strength unrelatedly of industry affiliation. They have continually grew and lead the logistic sector for a decade (CoreBrand, 2013; SyncForce, 2001). Thus, the operational innovation implement was a beautiful success for UPS.

The results from using the RODD framework also match the real situation during the operational transformation at UPS.

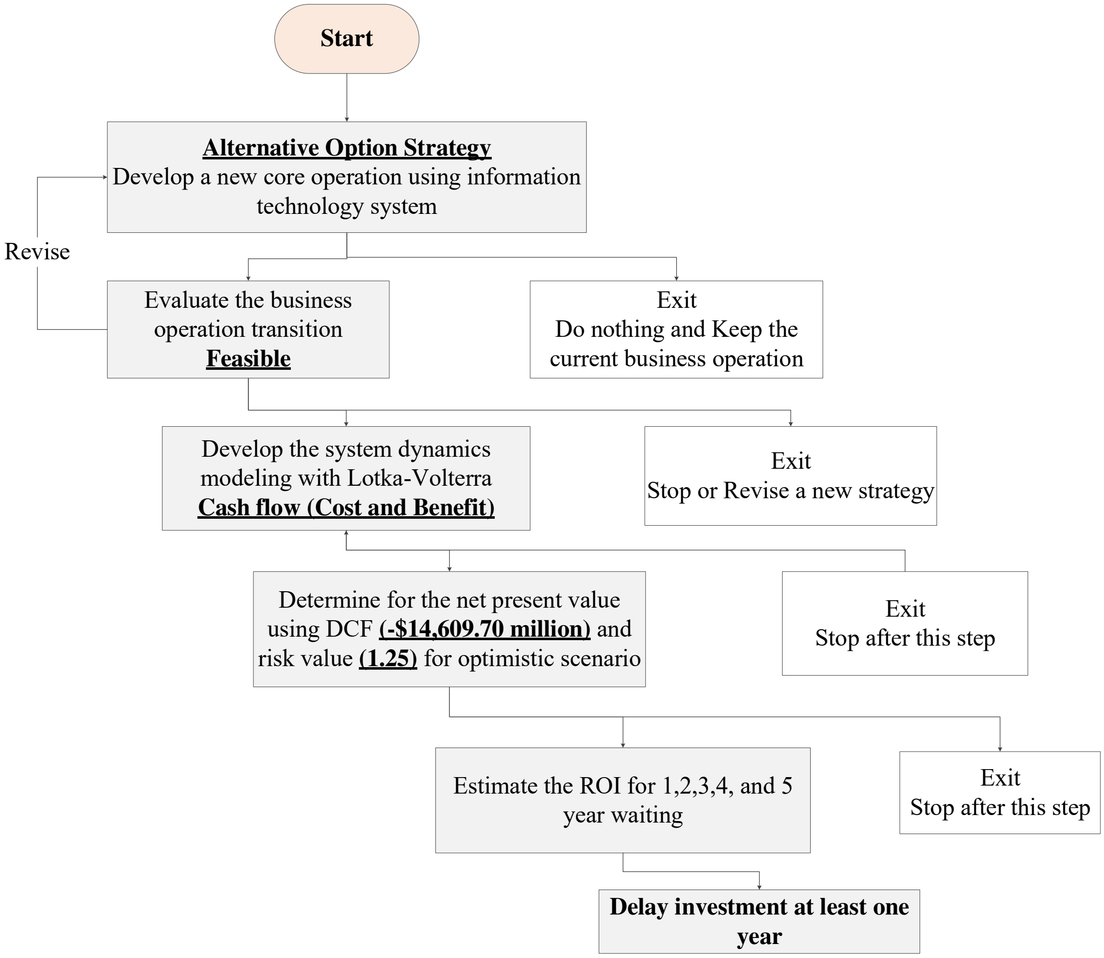


Figure 38: The Decision Process Using RODD Framework for UPS Operational Innovation Development

5.2. Results Comparisons: UPS Case Study

5.2.1. Results Comparison: the RODD Method vs. Traditional DCF Method

The ROI of UPS operational innovation using RODD is compared with the DCF method at 4.31% risk free rate. This comparison validates the argument for the use of the real option analysis for this research.

The DCF method (Table 19) provides a negative ROI value (-$14,690.70 million) (See Figure 37); as a result, this investment must be rejected. This method does not provide flexibility in decision making, comprehensive information on the effect of market dynamics, and take risk and uncertainty into consideration. It does not offer information regarding stability of competitive pressures to required investments, whereas RODD integrates both qualitative and quantitative analysis to analyze the feasibility of operation transformation, and provide more information on the uncertainty and the stability of competitive pressure to required investment.

Table 19: The Comparison ROI Results between the RODD Method and DCF Method -UPS Operational Innovation ($Million)

	1996	**1997**	**1998**	**1999**	**2000**	**2001**
Cost	21,325.00	28,803.63	32,429.37	37,276.03	36,131.41	42,409.47
Benefit	-	29,684.91	33,261.80	38,386.39	38,386.39	45,053.73
Cash Flow	-21,325.00	881.28	832.43	1,110.36	2,254.98	2,644.26
Risk Adjusted discount rate	0.0431	0.0431	0.0431	0.0431	0.0431	0.0431
Discount factor	1.00	0.96	0.92	0.88	0.84	0.81
Present value of cash flow	-21,325.00	844.87	765.06	978.33	1,904.75	2,141.28
Present value of all cash flow (S_0)	$6,634.30 million					
Initial investment (S_t)	$ 21,325.00 million					
ROI using the DCF Method	**-$14,690.70 million**					
The Results from using the RODD Method						
ROI using the RODD	**0.00**	**439.25**	**3,073.90**	**3,267.95**	**4,588.98**	**4,698.02**

Therefore, the DCF method is not applicable to use as the investment decision method for this operational innovation investment decision. RODD offers a good estimate of the ROI value of the UPS operational innovation because it offers more information, and allows UPS to delay the investment until the ROI value reaches a positive ROI.

5.2.2. Results Comparison: the RODD Method vs. ROA using Original Data

The cash flows using the RODD method are compared with the cash flows using original data from the UPS's annual report -10K (UPS Company-Investor Relations, 2013). This comparison validates the argument of the importance of using system dynamics with Lotka-Volterra to determine cash flows, i.e. profits (Benefit-Cost). There are two approaches for this comparison: 1) Validation of the results from using the system dynamics modeling with Lotka-Volterra and historical data, and 2) Validation of the ROI from the RODD method with ROI from ROA using historical data.

First, we compare the cash flows using the system dynamics modeling with Lotka-Volterra, with the cash flows from the original data (Figure 39). This aims to validate the results using from the simulation with historical data (Sargent, 2005). The results show that the cash flows from the system dynamics modeling with Lotka-Volterra are close to the original data. Therefore, the system dynamics modeling with Lotka-Volterra found to be the realistic.

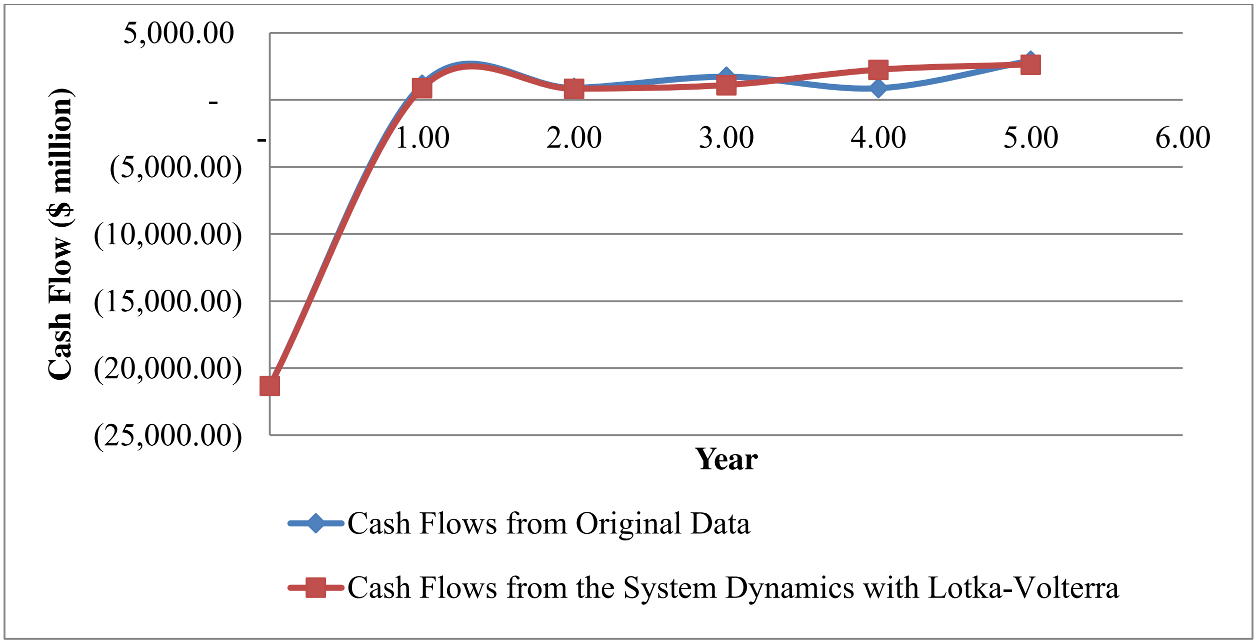


Figure 39: Cash Flows Comparison-UPS Operational Innovation

Second, we estimate the ROI using the operating cost and revenue from the original data. This comparison aims to validate the ROI from the RODD significantly showing a greater ROI than the ROI from the original data.

Table 20: The Comparison ROI Results between the RODD Method and ROA using Original Data (UPS Annual Report (UPS Company-Investor Relations, 2013)) - UPS Operational Innovation ($Million)

	1996	1997	1998	1999	2000	2001
Cost	21,325.00	21,312.00	23,879.00	25,311.00	28,888.00	27,387.00
Benefit	-	22,458.00	24,788.00	27,052.00	29,771.00	30,321.00
Cash Flow	-21,325.00	1,146.00	909.00	1,741.00	883.00	2,934.00
Risk Adjusted discount rate	0.0431	0.0431	0.0431	0.0431	0.0431	0.0431
Discount factor	1.00	0.96	0.92	0.88	0.84	0.81
PV of cash flow	-21,325.00	1,098.65	835.43	1,533.98	745.86	2,375.91
PV of all cash flow = S_0		$6,589.84				
Initial Investment (St)		-$21,325.00				
ROI Using the original data	**0.00**	**0.00**	**2,565.91**	**2,674.28**	**4,058.43**	**4,141.03**
<u>Parameters:</u> Parameters: delta t =1.00; v: volatility=1.12; u=3.068, d=0.326; Risk free rate =4.31%; Risk Neutral=0.262						
ROI Using the RODD	**0.00**	**439.25**	**3,073.90**	**3,267.95**	**4,588.98**	**4,698.02**

Since these two ROI values are independent, we use the F-test (one-sided test) with two samples for variances. The hypothesis testing is examined two opposing assumptions, H_0 and H_A. The null and the alternative hypotheses are stated below:

H_0: $\sigma_2^2 \leq \sigma_1^2$

H_A: $\sigma_2^2 > \sigma_1^2$

Table 21: F-Test: Comparison ROI Results between RODD Method and ROA using Original Data- UPS Operational Innovation

Year to Wait	ROI Using the RODD	Variance	ROI Using the Original Data	Variance
1	439.26	1,924,281.76	-	1,806,240.04
2	3,073.91	4,880.42	2,565.91	3,722.39
3	3,267.96	737.94	2,674.28	46.58
4	4,588.99	472,905.62	4,058.43	469,566.73
5	4,698.02	550,858.58	4,141.03	527,877.11
Mean	3,213.63		2,687.93	
Degree of freedom	4		4	
Variances	2,953,664.32		2,807,452.85	
F	1.05			
P(F<=f) one-tail	0.48			
F Critical one-tail	6.38			

The result shows the applicable F_{tab} = 1.05 which is lower than F_{cal} = 6.38, and the null hypothesis (no difference) is accepted (we fail to reject H_0) (see Table 21). This means that there is no difference between the standard deviations of these two methods with a significance level of $\alpha = 0.05$. Therefore, the variability for both methods is no significantly different.

A T-test (one tailed test) was used to valid whether the mean value of ROI from the RODD is higher than the mean value of ROI from the ROA using original data. The hypothesis testing is examined using two opposing assumptions, H_0 and H_A. The null and the alternative hypotheses are stated below:

H_0: $\mu_1 \leq \mu_2$

H_A: $\mu_1 > \mu_2$

Table 22: T-Test Paired Two ROI Results for Means Comparison between RODD Method and ROA using Original Data- UPS Operational Innovation

	ROI Using the RODD	**ROI Using the Original Data**
Mean	3213.62	2687.92
Variance	2953664.32	2807452.85
Observations	5	5
Pearson Correlation	0.99	
Hypothesized Mean Difference	0	
df	4	
t Stat	20.30	
P(T<=t) one-tail	1.73762E-05	
t Critical one-tail	2.13	
P(T<=t) two-tail	3.47523E-05	
t Critical two-tail	2.77	

The results confirm that the applicable $t_{\text{State}} = 20.30$ is higher than $t_{\text{Critical one-tail}} = 2.13$ with a probability value of 1.73762E-05. There is a difference between the mean values of these two methods. Therefore, the mean value of ROI from the RODD method is significantly higher than the mean value of ROI from the original data with a significance level of $\alpha = 0.05$.

The ROI from the RODD method, considering the risks and the impact of FedEx's capability, provides a better mean value of ROI than the original data. Thus, the system dynamics modeling and Lotka-Volterra are the important techniques that can enhance the effectiveness of the decision-making framework by capturing the complexity of the system and predicting the results. The RODD method goes beyond a simple yes/no decision on investments. It allows decision makers to delay making an investment until the investment earns maximum ROI. It integrates both qualitative and quantitative analysis to analyze operational innovation schemes.

5.3. Case Study II: Smart Firefighting Operation

This case is based on a research project led by the National Institute of Standards and Technology (NIST). The cost of unwanted fires is approximately $300B per year including numerous civilian and firefighter injuries and deaths, and property loss (The National Fire Research Laboratory, n.d.). The continued high property and personnel losses indicate the potential for new operational innovations to improve firefighting effectiveness and safety.

The NIST-led research project is investigating an operational innovation approach called smart firefighting. This innovation proposes the use of emerging cyber-physical systems in buildings, apparatus, personal protective equipment, and robotics to increase situation awareness, operational effectiveness, efficiency, and firefighter safety radically beyond the current level.

Emergency management and fire incident response actions depend on communications and information systems. The main problems of operations are response time to fire incidents, ineffective communication systems, lack of the real-time data/information, lack of liability of the operation, inflexibility of the management structure, and a lack of predefined methods to coordinate interagency requirements into the management structure and planning procedures. As a result, the National Incident Management System (NIMS) tends to focus on the need for sharing real-time operating visualizations to all command and coordination sites (FEMA: Emergency Management Institute, n.d.).

The cyber-physical system (CPS) is an innovative system which is a combination of communications, computer technology (hardware, software, sensors, and networks), and physical components. This system provides instantaneous interaction between computations (cyber-technology), communications, and physical components. The sensors and associated software synchronize real-time information between physical components and communications systems. The real-time information through this system can be used to support the incident commander and other stakeholders (Subrahmanian & Jones, 2013).

The CPS contains numerous feedback loops where physical processes emerge with computation platforms, network monitors, controllers, and other devices. It is important to understand the dynamics of computers, software, networks, and physical processes and their relationship as a systematic structure. However, there are several concerns with other deployed CPS. One example is the fuel management subsystem of aircraft VMS. The challenges include 1) models with solver-dependent, non-determinate, or zero behavior, 2) consistency of model components, 3) prevention of misconnected model components, 4) connections of model's functionality and implementation, 5) distributed behavior of the model, and 6) a diversified system and its platform (Derler, Lee, & Vincentelli, 2012).

The CPS has potential to improve the safety and apply various systems such as smart buildings, smart grids, smart water and gas grids, smart manufacturing, personalized health care systems, and transportation systems. The new generation of smart grids and smart water and gas grids allow customers to receive real-time information with regards to the power supplier and level of energy, water and gas storage. Customers can control power generation and use power from that grid. The potential benefits from these systems are high energy utilization and utility capabilities, reduced error of the utility system, and compatibility of household's systems and supplier's systems. The example of the use of CPS in a health care system is demonstrated in Figure 40. This system consists of four basic elements: 1) cyber-technologies (hardware and software), 2) physical components, 3) social (healthcare providers), and 4) patients. The diagnosis and treatment of patients use new cyber-physical system medical devices and equipment. The healthcare providers are able to receive patients' information through sensor networks and electronic devices from everywhere. This system helps healthcare providers to enhance effectiveness of treatment and diagnosis, whereas patients have more alternatives for healthcare options and insurer models, interaction with virtual healthcare providers, and low travel cost (Subrahmanian & Jones, 2013).

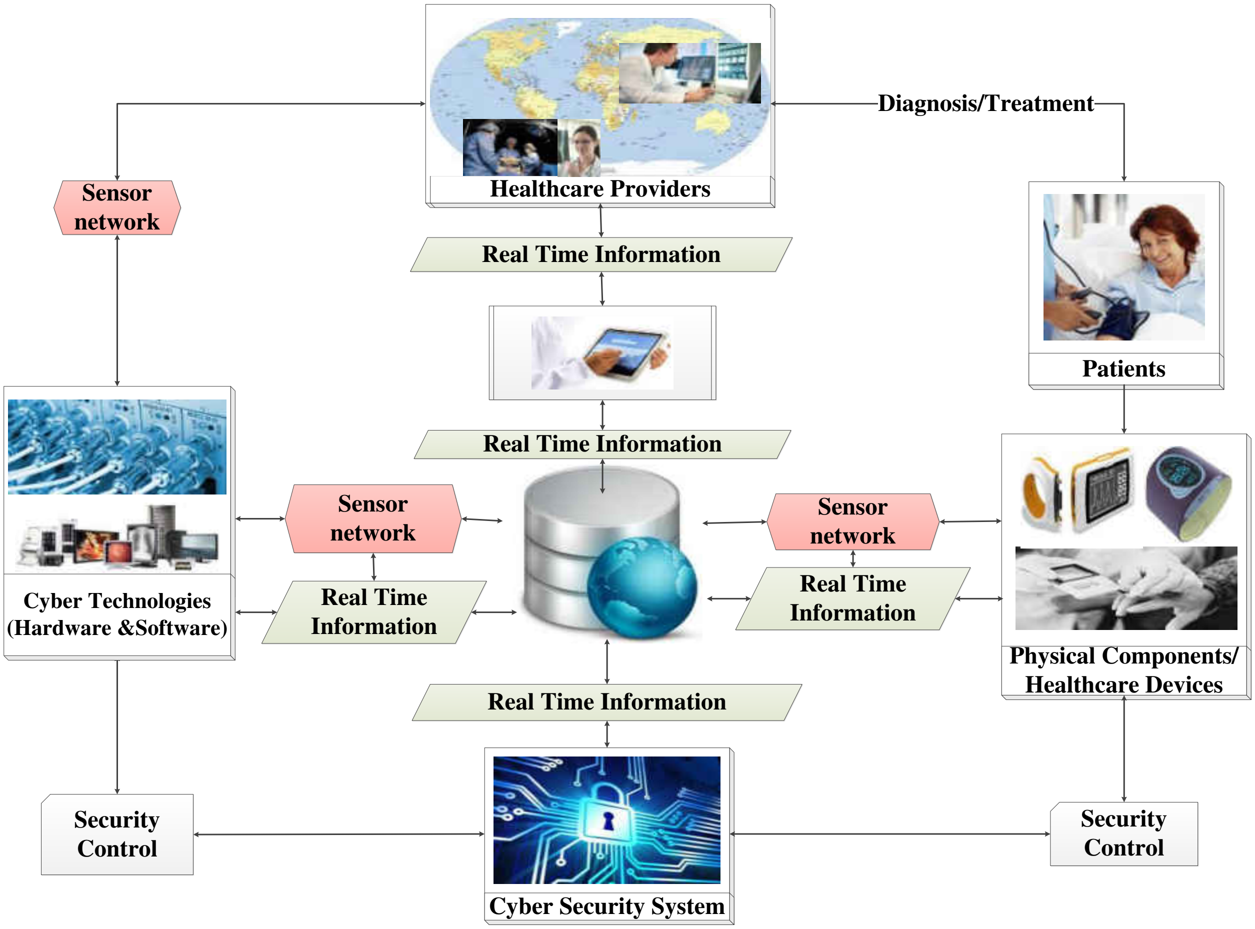


Figure 40: Cyber-Physical System for Healthcare

The integration of CPS, computing technologies, and robotic technologies will provide the foundation for a revolution in firefighting decisions and operations. Decisions are typically made by the incident commander (IC) based on his/her experiences and mental model. CPS can improve those decisions by making real-time information and high-fidelity simulation models available to the IC. The real-time information is transferred via sensor networks in buildings and by robots to the simulation model, which has knowledge about prior fires and tactics. This system allows the incident commanders to make decisions faster and better.

The potential next step is to establish new legislation of fire codes regarding the visualized equipment (wireless sensor) in buildings nationwide. However, the questions are that is it worth it for local government to establish the CPS and when is the best time to make the investment?

This smart firefighting approach is essentially an operational innovation. It enables the development and implementation of new ways of extinguishing fires by developing new innovative operations and decisions. As we saw in the UPS case study, RODD goes beyond a simple yes/no decision on investments. It allows decision makers to delay making an investment until the investment earns maximum value. If the project provides a negative return on investment in the first year, then the project is delayed for another year until the return on investment provides positive benefit.

We have implemented the RODD framework for the Fire Department of Orange County, Florida – a typical fire department in the U.S. Most fire departments share the same mission *“We provide National leadership to foster a solid foundation for local fire and emergency services for prevention, preparedness and response”*(U.S. Fire Administration/National Fire Academy, 2010). They also have the same organizational structure, core operation, and environment. Therefore, the fire department of Orange County provides a good representation of the rest of the fire departments across the nation. It is also a different kind of case study because it has no competitors per se. Nevertheless, the department still emphasizes efficiency and effectiveness. Therefore, this strategic investment decision takes only uncertainty into consideration. The goals for developing of a new way of extinguishing fires are listed in the Table 23 .

Stage 1: Decision Problem Identification

Table 23: Decision Problem Identification-the Smart Firefighting Operation Development

<table>
<tr><th colspan="2">Project Name: Develop a new way of extinguishing fires
Mission: “We provide National leadership to foster a solid foundation for local fire and emergency services for prevention, preparedness and response”</th></tr>
<tr><th>Decision Problem Identification</th><th>Description</th></tr>
<tr><td>Goal</td><td>• To collect and combine large quantities of information from a range of sources
• To process, analyze, and predict using that information
• To disseminate the results and decisions of that prediction to communities, fire departments, and incident commanders
• To enhance coordination with community services and firefighters
•</td></tr>
<tr><td>Alternative option</td><td>Option 1: Do nothing (Current State)
Option 2: Smart Firefighting Operation (Future State)</td></tr>
</table>

The success of the firefighting operation depends crucially on the incident command system. That system integrates facilities, equipment, personnel, procedures, and communications within an organizational structure with the responsibility for managing available resources to fight fires. The incident commander (IC) is responsible for developing strategies and tactics and for ordering and allocating resources. The IC has exclusive authority to form objectives, make assignments, coordinate with the general staff and people, authorize release of information to the news media, and manage resources. She/he is responsible for directing, ordering, and managing all incident operations at the incident site. The IC normally has training and experiences with numerous historical incidents (FEMA-Emergency Management Institute, 2012; U.S. Fire Administration/National Fire Academy, 2010). She/he usually assesses and commands the operations based on his/her mental model and experiences. Therefore, it has been difficult for ICs when they are faced with unexpected incidents that never occurred before in history (US Department of Commerce, 2012).

The management function of the incident command system consists of four components: finance and administration, operation, planning, and logistics. The first component controls costs related to the incident and provides accounting, procurement, time recording, and cost analyses. The second component, operation, involves the safety officer, liaison officer, public information officer, rescue team, suppression team/fire attack, ventilation team, owner/ occupants, community/municipality, and building sensors (U.S. Fire Administration/National Fire Academy, 2010; US Department of Commerce, 2012).

The IC is involved with establishing tactics and directing all operational resources during an incident. The safety officer is a member of the command staff responsible for monitoring and evaluating safety hazards or risky situations, and defining personnel safety. The liaison officer assists and coordinates interagency contacts and monitors incident operations to define current or potential inter-organizational problems. She/he supports in planning meetings and provides the current resource status. The public information officer is responsible for conducting and releasing information about the incident to the news media, to incident personnel, and to other relevant agencies and organizations. She/he develops material for use in media briefings, coordinates with the joint information center, provides important information for incident planning, and gathers current information for assigned personnel (U.S. Fire Administration/National Fire Academy, 2010).

The search and rescue team is responsible for providing the search and rescue of victims. This team provides and updates on-scene information to the incident commander. The suppression team/fire attack is responsible for conducting fire suppression systems in assigned areas and supporting the search and rescue team. The ventilation team is responsible for knowing the building construction type and systems in place (U.S. Fire Administration/National Fire Academy, 2010).

The third component is planning, which aids the incident action planning process by monitoring resources, collecting or analyzing information, and retaining documents. The final component is the logistics, which arranges for resources and required services to meet the incident objectives (FEMA-Emergency Management Institute, 2012).

For a new smart firefighting operation, the owner/occupants should provide the layout of the building and are responsible for sensor installation. The community is responsible for reporting to the fire department and law enforcement and requesting emergency medical aid if necessary when incidents occur around the community. The building network sensors are one of the most important features of the smart firefighting operation. It provides real time information and visualizations of fire incidents to incident commanders and other personnel. This system will allow the incident commander to evaluate the incident faster.

Therefore, the new smart firefighting operation is involved with eight essential stakeholders: Incident Commander, Safety Officer, Public Information Officer, Rescue Team, Suppression Team, Ventilation Team, Owner/ Occupants, and Community/ Municipality (Fire

Suppression, Orange County Gov FL, 2013). The management structure of a fire station is illustrated in Figure 41. The responsibility of stakeholders and the function of building sensors are explained in the responsibility matrix based on the National Fire Research Laboratory, which is shown in Table 24.

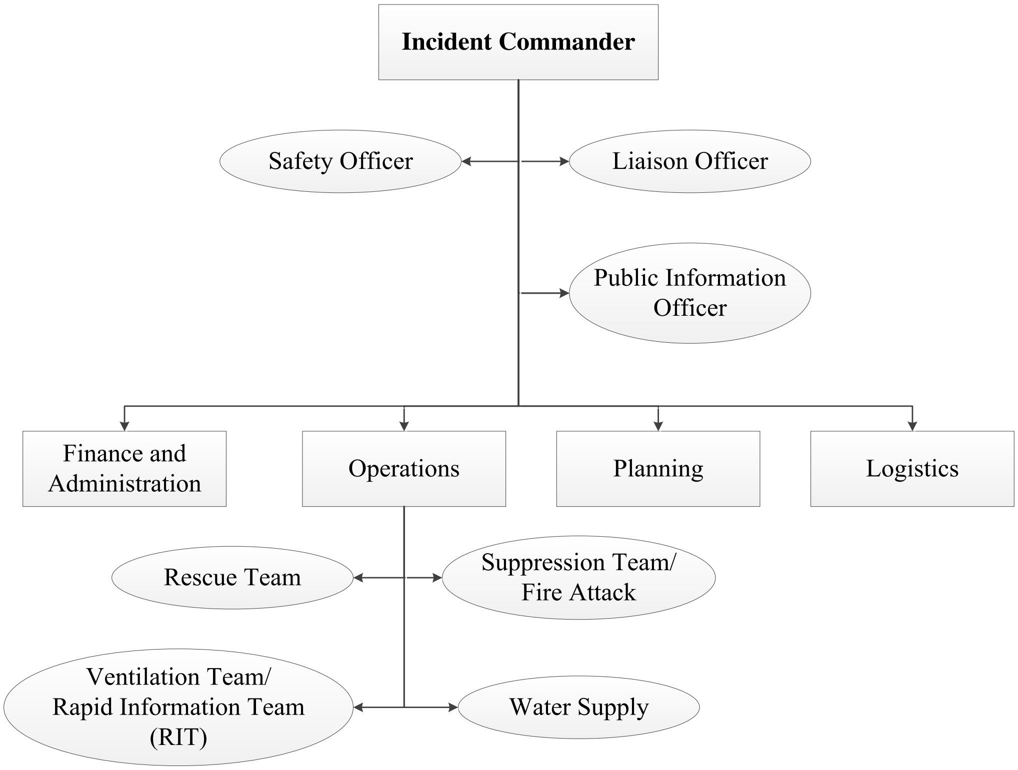


Figure 41: Management Structure of Fire Station (Modified from FEMA-Emergency Management Institute, 2012)

Table 24: Responsibility Matrix for the Smart Firefighting Operation (Modified from The National Fire Research Laboratory, n.d.)

Activities	**Stakeholder/Component**								
	Incident Commander	**Safety Officer**	**Public information officer**	**Rescue Team**	**Suppression Team**	**Ventilation Team**	**Owner/ Occupants**	**Community/ Municipality**	**Building Sensors**
Staging and surrounds, and recommended personnel placement	R								
Estimating time to arrival weighted by previous incident response time	R								
Designating sides	R								
Building information from database statuses from building itself: pre-existing hazards and their proximity to fire, utilities, assessment of structural stability	MR	R							
Conducting and releasing information about the incident to the news media, to incident personnel, and to other relevant agencies and organizations	MR		R						
Developing material for use in media briefings, coordinating with the joint information center	MR		R						
Providing important information to incident planning, and gathering current information for assigned personnel	MR		R						
Notable fire protection and security features from information in database	MR	R							
Building information especially any map	MR			R	R				

Activities	**Stakeholder/Component**								
	Incident Commander	**Safety Officer**	**Public information officer**	**Rescue Team**	**Suppression Team**	**Ventilation Team**	**Owner/ Occupants**	**Community/ Municipality**	**Building Sensors**
information									
Fire department connection location	MR				R				
Standpipe locations	MR				R				
Expected water supply pre-arrival (hydrant, reservoir, engine)	MR				R				
Active building fire suppression systems (sprinklers, etc)	MR				R				
Compartmented building map	MR					R			
Building construction type	MR					R			
Building systems in place	MR					R			
Providing layout and building plans (stairways, entrances/exits, construction, hazards, utilities, standpipes, fire dept. connections)	MR						R	R	
Staging and surrounds (external layout, environmental concerns, exposures, etc.)	R								
Staging plans and transport routes, fire equipment, ambulances, life light	R								
Staging resources, reservoirs, hydrants	R								
Establishing fire protection and security systems	R								
Defining and Managing evacuation plans	R						R		
Assigning and deploying	R	C		C	C	C	N	N	

Activities	Stakeholder/Component								
	Incident Commander	Safety Officer	Public information officer	Rescue Team	Suppression Team	Ventilation Team	Owner/ Occupants	Community/ Municipality	Building Sensors
current personnel, equipment location, and resources									
Injury forecasting from building and fire information: risk from conditions such as gas species, thermal	R	R		N	C	N		N	R
Evaluating models (fire growth, smoke generation, structural integrity, environmental conditions, air and water supply, tenability, and resource allocation)	R	N		C	N	N	N	N	R
Updating weather , wind, traffic, utility status	MR	R		R	R	R	R	R	R
Updating physiological status and location from each crew member	MR	R		R	N	N			R
Updating current building predictions and status of building	MR	R		R	R	R	R	N	R
Updating victim/occupant information from both building sensors and teams	MR	R		R	R	R			R
Updating fire progress relative to location	MR	N		R	R	N		N	R
Searching locations as noted by other members/automatically	MR	N		R	R	N	N		R
Reporting hospital location, status, occupancy, resources, victim plans	N	N		N	N	N	N	R	R
Updating police location	N	N		N	N	N	N	R	

Activities	Stakeholder/Component								
	Incident Commander	Safety Officer	Public information officer	Rescue Team	Suppression Team	Ventilation Team	Owner/ Occupants	Community/ Municipality	Building Sensors
and status, availability									
Reporting and Updating status of all local fire departments/Specifying of non-firefighting personnel deployment	N	N	R	N	N	N	N	R	R
Routing utility control to incident commander	MR	N		N	N	N	N		
Initial fire forecasting	R								R
Analyzing the risk and threats	R	N		N	N	N	N		
Changing in fire over time based upon cleared area	MR				R				
Decision Making	R	N		N	N	N	N	N	
Deciding when to pull out in a situation judged to be appropriately dangerous	MR	R		N	N	N	N	N	
Altering to off-scene planning(changes in victim plans, sequestering dangerous areas)	R	N		N	N	N		N	
Note: C = Must be consulted; N = Must be notified; R = Direct Responsibility MR = Managerial Responsibility									

Stage 2: Systematic Transition Analysis

The systematic transition analysis stage analyzes the current and future state of firefighting operations, its relevant factors, and the transition. There are five processes for systematic transition analysis as follow:

Stage 2-2.1 Analyze the current state

The components of existing operations are identified and consist of three main components: 1) communications and information systems, 2) core operations, and 3) transportation network.

The communications and information systems are key factors for fire service operations. The flexibility, accessibility, and interoperability of communications and information systems significantly enhance the effectiveness of emergency management and incident response activities. Equipment, incident command systems, and radio frequency congestion are necessary items to improve for better effectiveness of communications systems and policies. Sharing a common operating picture to response personnel and other agencies is the primary goal of the communications and information system. Typically, the communication systems have been involved with at least four networks including command net (incident command with other personnel), tactical net (planning, operations, and logistics), support net (resources), and air-to-ground net (FEMA-Emergency Management Institute, 2012; National Incident Management System, 2008).

The communication center, or the hub of fire department communications, is called the dispatch center. It connects with the public fire/rescue agency, receives information, records information on times and durations of the incident, and provides service as the main responder of emergencies. Radios, including base stations radios, mobile radios, and portable radios, are the major tools for communicating between the IC and other personnel. Whereas telephones are used for communication with other agencies and the news media, the information systems are based on pre-incident plans, mapping programs using blue prints, and high hazard procedures. Information and intelligence management establishes a process for gathering, sharing, and managing incident-related information and intelligence (U.S. Fire Administration/National Fire Academy, 2012).

Computer-aided dispatch (CAD) systems have become essential equipment for information systems during fire service operations. CAD provides a geo file, which is a database of the street and address network of the community served. A geo file is used to support dispatchers with regards to knowledge of the map and the community. The benefits of the CAD are the speed of information processing; increased precise assignment of units to specific-type incidents at reported locations; enhanced recordkeeping capabilities; and, accessibility to critical information, hazards, and resources within the location. However, there are still many limitations to communication through the computer system such as incompatible computer platforms, lack of sophisticated software, and ineffective security systems and computing incident evaluation (U.S. Fire Administration/National Fire Academy, 2012). The sources of operational information may come from risk assessments, threats involving potential for violence, surveillance of disease outbreak, weather forecasts, and structural plans and vulnerabilities (FEMA-Emergency Management Institute, 2012; National Incident Management System, 2008).

The second component is the core operation which involves the IC, personnel readiness (fire attack, rescue team, suppression team, ventilation team, and safety officer), equipment readiness, and training. The IC is the most important person, and directs the operation. He/she usually uses his/her experiences or mental model to assess and evaluate the fire incident.

When the fire incident occurs, first the IC evaluates the situation. The IC should collect, record, analyze, and illustrate the situation, resources, and any other incident-related information. The IC uses all of this information to assess situational awareness and predict the likely magnitude, complexity, and possible impact of the incident. The resources are identified in this step for further implementation and effective incident action planning. Second, the IC establishes the objectives, immediate priorities, and strategy. The potential alternative strategies are defined for the worst case scenario. The public health, safety factors, costs, environment factors, legal, and politics are taken into consideration in this step. Third, the IC develops and prepares the plan. This step consists of clarifying the tactical direction and the required resources for deploying the selected strategies and tactics for the operational period. Each member of the command and general staff gather information to support the response plan. Fourth, the plan is prepared and disseminated based on the complexity of the incident. Fifth, the planning process and its activities are executed and evaluated according to the proposed plan.

The accuracy of information used for subsequent operational periods is verified. The IC communicates with general staff members through radio, and revises the plan upon updated information from on-scene personnel. The IC must ensure the adequate safety and personnel accountability. He/she coordinates activity for all commands, general staff, law enforcement, emergency medical services, and others. The information and data of the incident are recorded and collected for future response planning. Equipment readiness and training are important components for emergency response operations. Training policy focuses on interagency training, a master training plan, and continuing education for all members of the department (National

Incident Management System, 2008). The third component is the transportation network which involves fire trucks, ambulances, and police cars. This network has significant impact on the response time to the incidents and the emergency medical aid procedures. Therefore, once an incident occurs, it is a necessary to keep these components performing their tasks effectively. An overview of the current state of the firefighting operations and its matrix of change are demonstrated in Figure 42 and Figure 43.

Stage 2-2.2 Assess the performance of current state using modified balance score card

The assessment and its metrics (Table 25) are established in order to evaluate the existing firefighting operation. In this case there are three main dimensions of assessment: Financial, Operating System, and Workforce focus. The financial dimension focuses on the adopted budgets that are provided by Orange County, Florida. The operating system focuses on operating cost and operational efficiency. The operating cost for the firefighting department includes personnel costs, capital investment, and maintenance costs. The operational performance in 2012 was 57.24 out of 100 (Fire Suppression, Orange County Gov FL, 2013; U.S. Fire Statistics, 2013; US Department of Commerce, 2012). This result reflected the inadequate budget, operational efficiency, and workforce readiness problems. As a result, these concerns motivated developing a new core operation in order to increase operational efficiency and safety.

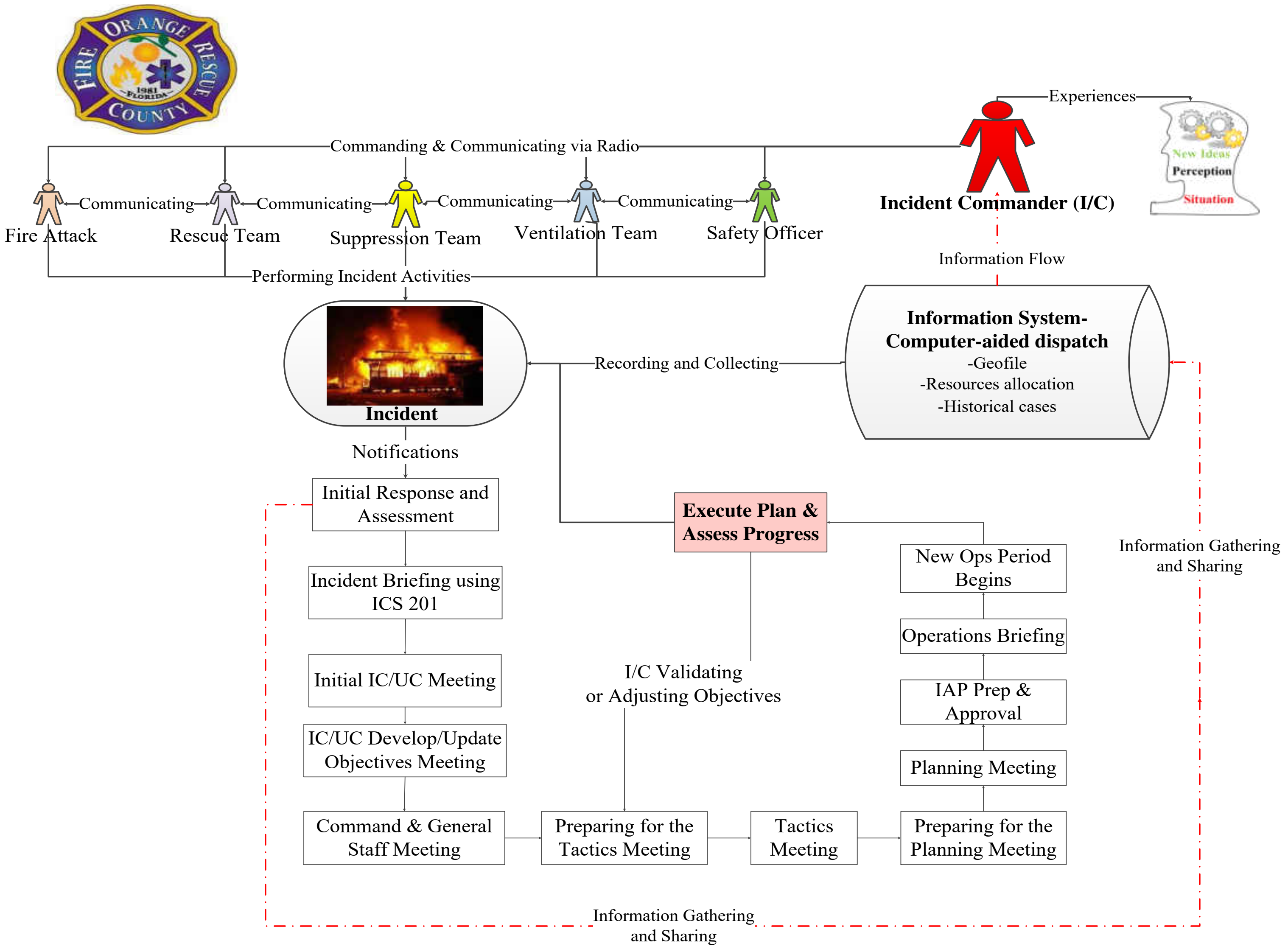


Figure 42: The Current Firefighting Operations (Modified from National Incident Management System, 2008; U.S. Fire Administration/National Fire Academy, 2010)

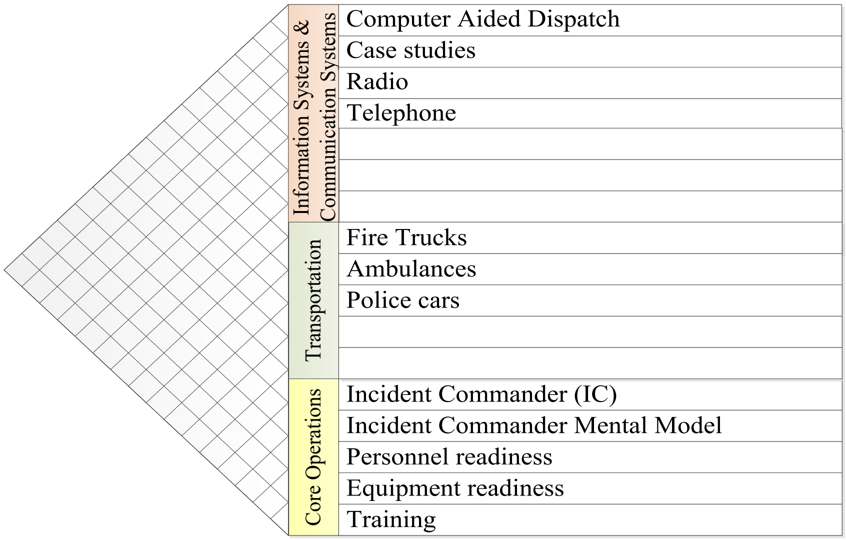


Figure 43: Matrix of Change of the Current Firefighting Operation

Table 25: Performance Assessment of the Current Firefighting Operation (Fire Suppression, Orange County Gov FL, 2013; U.S. Fire Statistics, 2013; US Department of Commerce, 2012)

2.2 Performance Assessment (Point Value)	
Assessment Dimensions	**Score**
1. Financial	
Revenue/Budget	6.00
2. Operational System	
Operating Cost	31.00
Operational Efficiency	12.44
3. Workforce focus	
Workforce readiness	7.80
Total Score	57.24

Stage 2-2.3 Analyze the future state

The future state is one in which smart firefighting innovations are implemented. The purposes of these innovations are (1) to gather and integrate large quantities of information from a range of sources, (2) to process, analyze, and predict using that information, (3) to share the results and decisions of that prediction to communities, fire departments, and incident commanders, and (4) to enhance coordination with community services and firefighters. The combination of CPSs, computing technologies, and robotic technologies are planned to develop the smart firefighting operation which is shifted from using only incident commander's experiences and his/her mental model, to using real time information from CPSs with his/her experiences.

There are two main system requirements: the information and communication systems, and core operations. These requirements need three components including 1) smart building and robotic sensor technologies, 2) smart firefighter equipment and robotic mapping technologies, and 3) smart fire department apparatus and equipment.

The first requirement is the information and communication systems, which need the sensor networks, cyber technologies, and radio equipment. The IC uses these systems to communicate and track firefighters, and fire trucks, to monitor the on-scene span of control, and to coordinate with other agencies including law enforcement, federal or state agencies, and medical units. This system focuses on real-time information systems, the visualized simulation system (3D), and wireless tracking systems. The real-time information comes in three forms: digital, audio, and video. Information is transferred to local incident commanders and other agencies through the buildings' sensor network and robotic sensors. It is gathered from different sources including community, occupants, building, firefighters, and law enforcement/police using cyber-technologies.

The community can handle data sources and up-to-date information with regards to traffic, weather, police, hospitals, and structures. The buildings have annotated computer-aided dispatch or blueprints of the architecture, materials, utilities, and fire-related sensors/equipment. The occupants are able to provide information about the number, age, condition, and health problems of any people trapped in the building. The information from the community, buildings, and occupants can support the incident commander by initiating objectives and strategies for suppression and rescue, and to immediately alert the community services.

The real time information is distributed among global databases, central information processing, and the results are provided to the local personnel. The CPSs positively support the ICs to make decisions faster after receiving notification. The ICs can instantaneously revise objectives of the proposed plan and ensure the safety of on-scene firefighters from updated information through these systems.

The second requirement is the core operation using the CPS to improve the operation performance. The CPS provides real time information and visualization of the IC. The core operation starts with the arrival of equipment and personnel at an incident. Then firefighters will set up a temporary wireless network and implement a number of different sensor technologies to evaluate the incident on the ground at the fire scene. The sensors operate as needed during the incident. The real-time information is transferred to the IC who develops and manages the operational plan and tactics for the personnel. The personnel are equipped with sensors which provide real-time data about their own conditions, their locations, the fire growth, and suppression/rescue operations to ensure their safety.

The sophisticated computation models of fire growth, smoke generation, structural integrity, evacuation, suppression, ventilation, environmental conditions, air and water supply, tenability, and resource allocation are used to support the IC in his/her decision making. The results and forecasting from models are used in two scenarios. In the first scenario, toxic compounds, fire growth and smoke generation and outputs are transmitted to personnel at the fire scene and to law enforcement to alert the community for evacuation purposes and preparing local hospitals for potential victims. In the second scenario, model outputs, predictions, and real time 3D visualization of the fire scene, equipment, and personnel help the IC to determine the potential impacts of decisions and activities before establishing any commands to the personnel. This visualization is recorded for future analysis, lessons learned, and training for better situation awareness and decision making. All components of the smart firefighting operation are demonstrated in Figure 44.

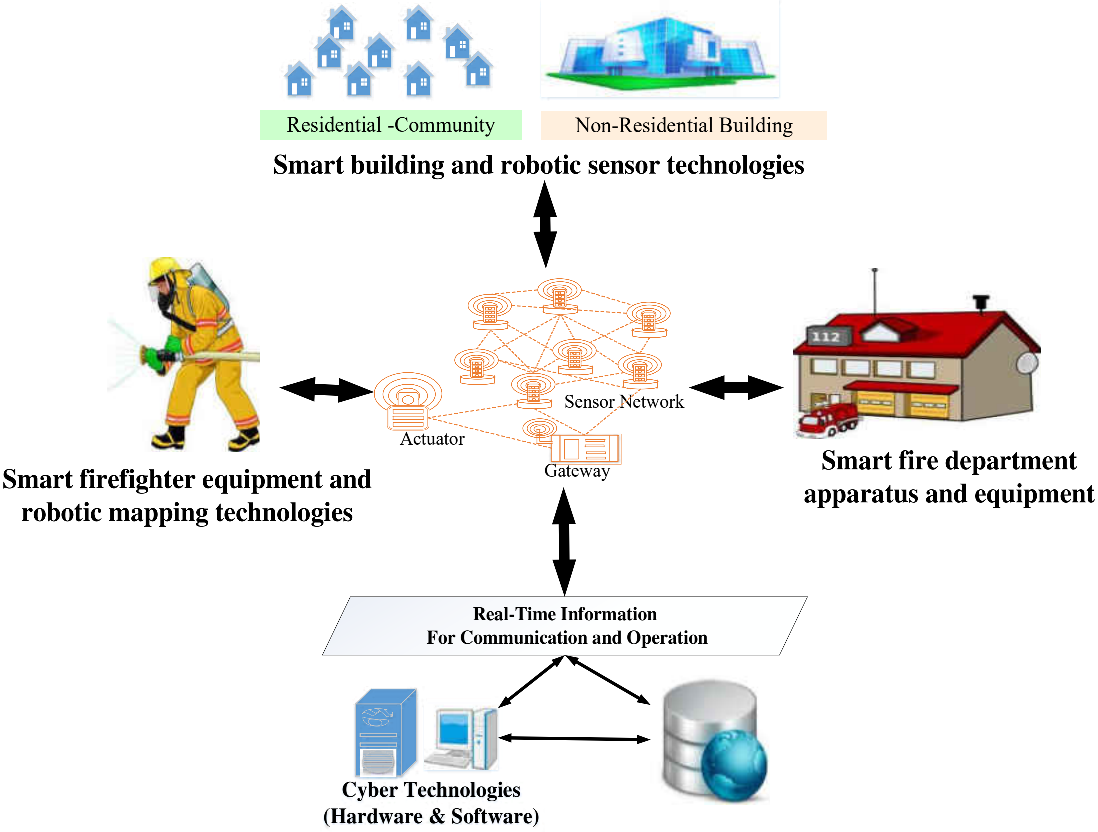


Figure 44: The Smart Firefighting System Requirements Using Cyber Physical System

The expected outcomes are improved firefighting operations and better coordination with other community services and firefighters to execute these incidents effectively. The benefits are to enhance the effectiveness of the span of control and safety, to reduce property, environment and personnel losses, and to increase the accuracy of decision making (The National Fire Research Laboratory, n.d.). The matrix of change of the future state of components and its holistic view point of the smart firefighting operation are illustrated in Figure 45 and Figure 46.

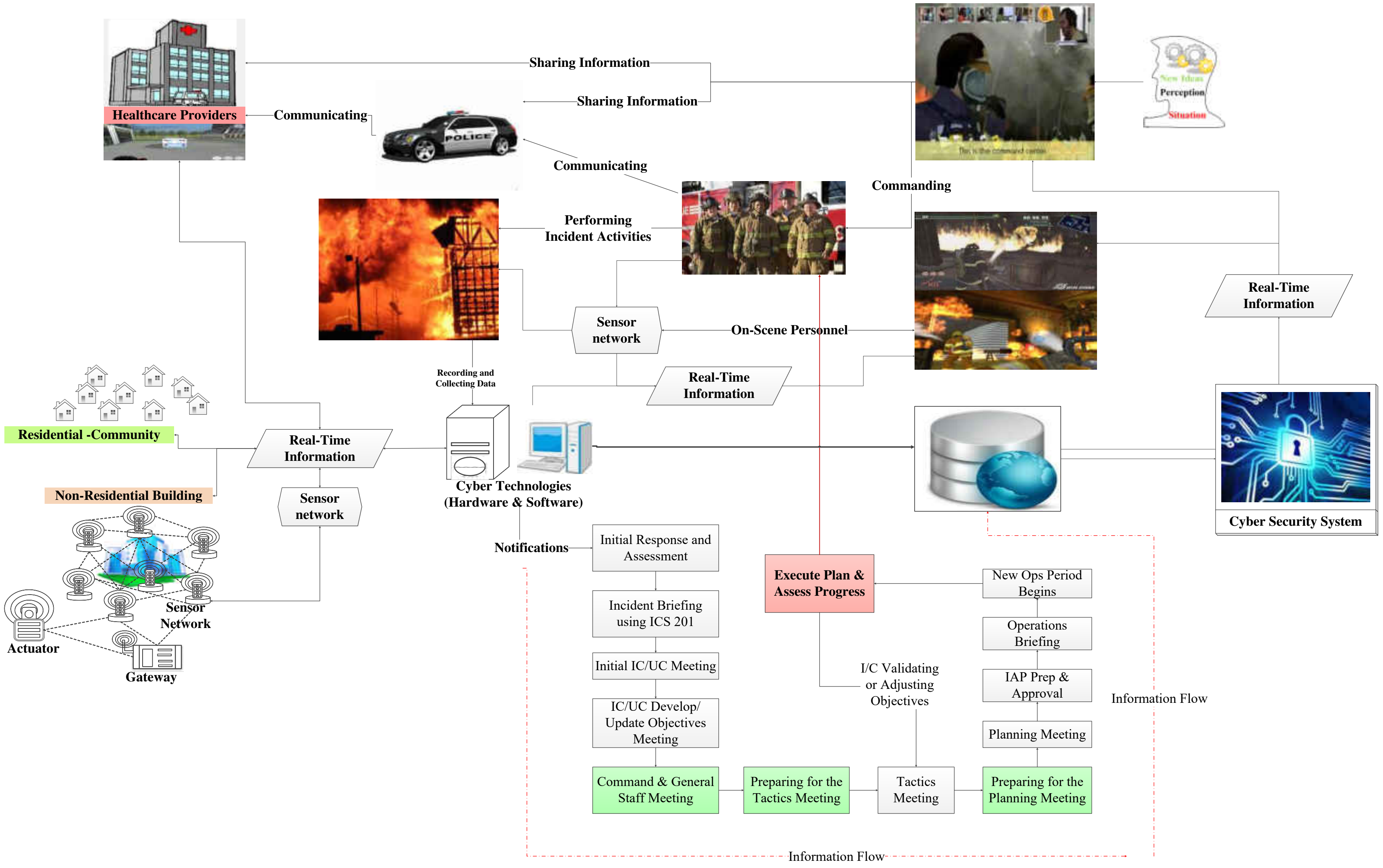


Figure 45: High Level View of the Smart Firefighting Operation

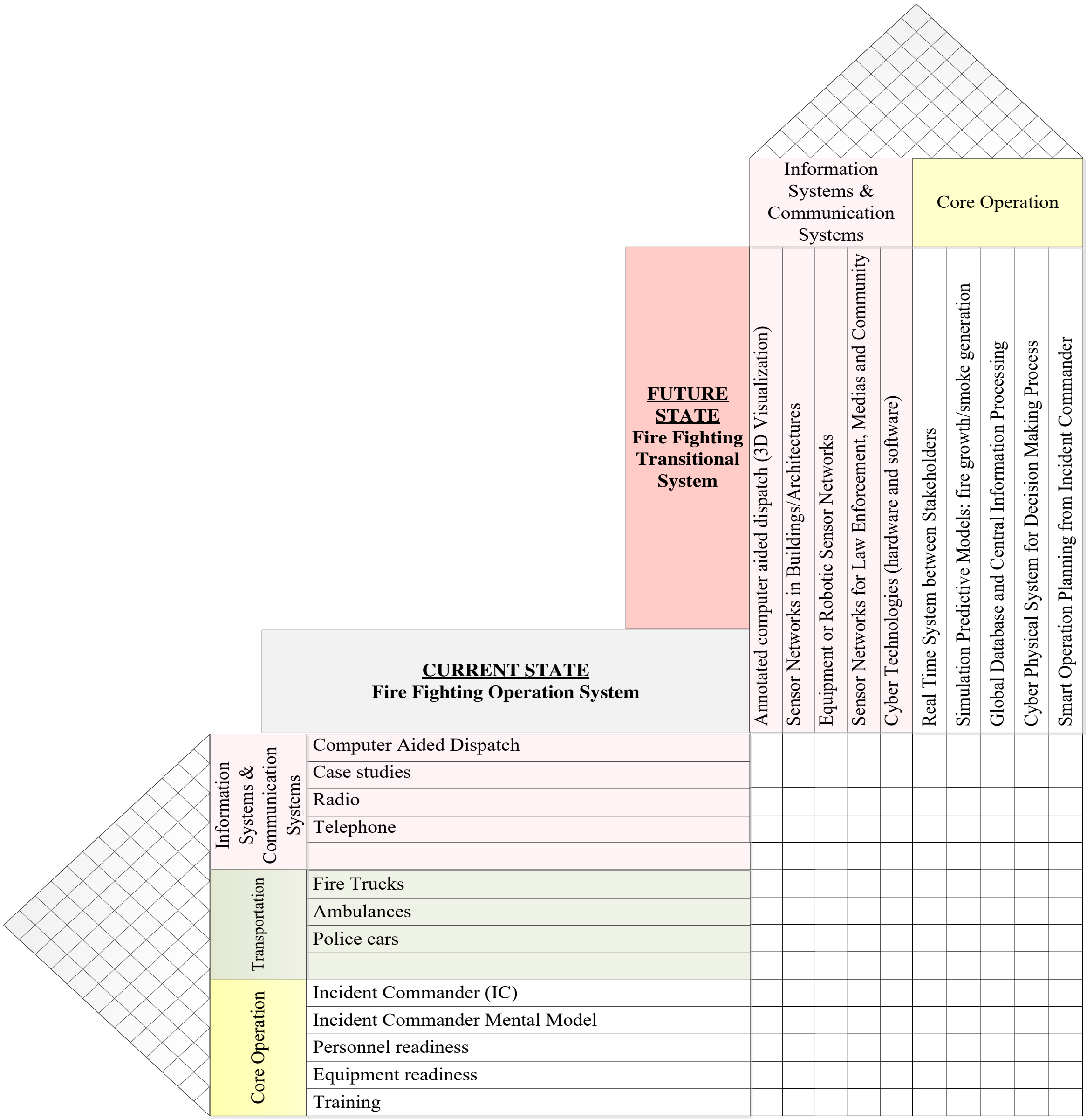


Figure 46: The Matrix of Change of the Smart Firefighting Operations

Stage 2-2.4 Identify the transition interaction

The result from Figure 47 shows the highly complementary transition matrix. As a result, the smart firefighting system is a feasible transition that can be developed in order to enhance operational effectiveness and safety.

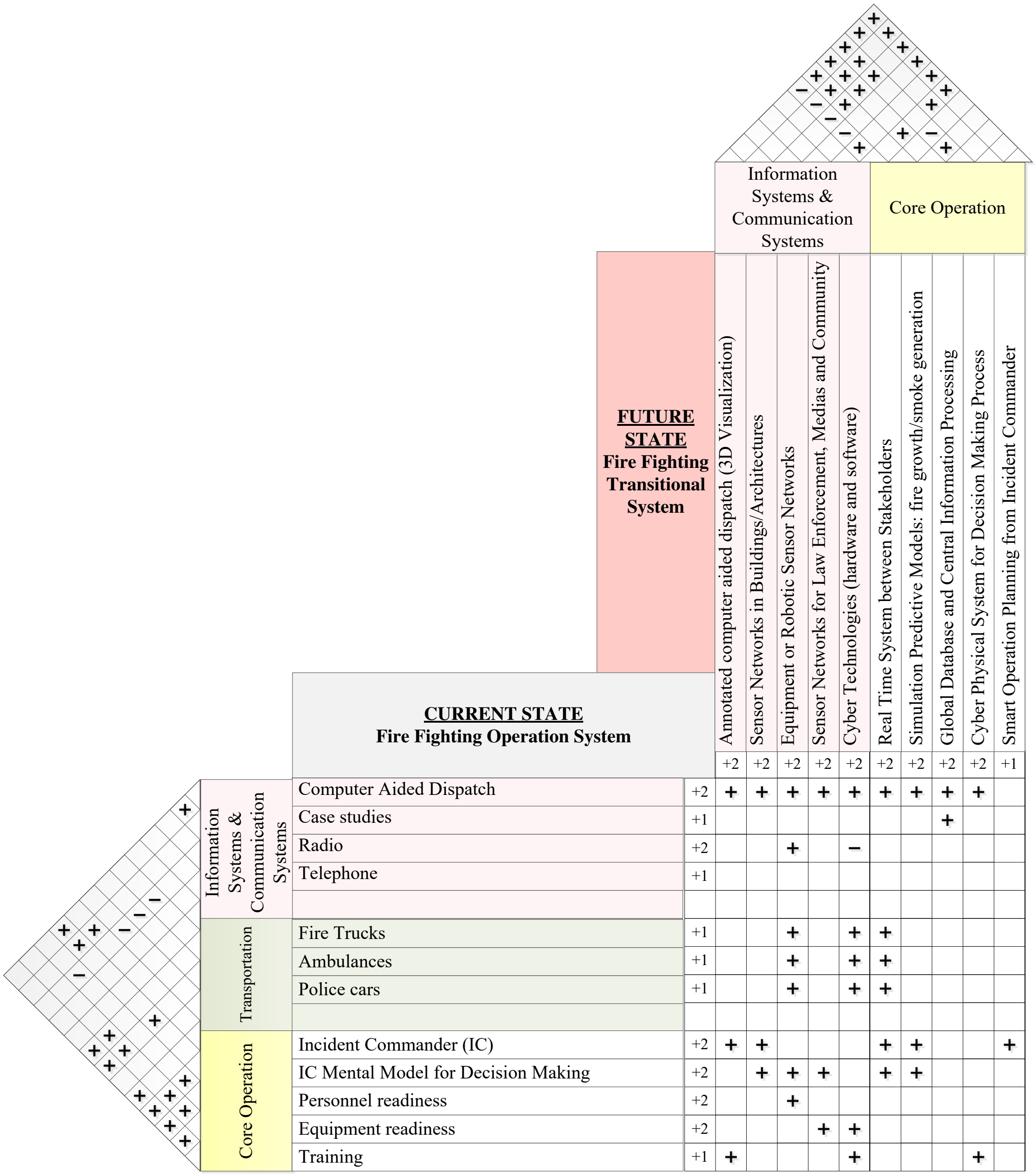


Figure 47: The Matrix of Change of the Firefighting Operations Transformation

Stage 2-2.5 Identify relevant factors and risk factors for the candidate option

This step illustrates the relevant factors, including risk, of the candidate option. According to the result in step 2.4, the transformation from the current firefighting operation toward the smart firefighting operation is feasible. Therefore, the smart firefighting operation is called the candidate option. Some variables, such as the effectiveness of the cyber physical system and complexity of the human-technical system, are added due to the nature and environment of the firefighting operation. These variables are the most important factors that can improve the entire firefighting operational efficiency and safety, and decrease the total dollar losses. In addition, the personnel reduction is one of the important factors of the firefighting operation due to the budget constraint. However, most of variables are based on the features of the operational innovation, which are articulated in section 4.2.1 step 2.5.

Table 26: Factors Identification for the Smart Firefighting Operation

Functions	Input Variable	Functions	Input Variable
Financial	Available budget	**Operating System**	Operational efficiency
	Investment in technology system		Operational innovation capability
	Investment infrastructure capability		Total potential operation capability
	Operating cost		Infrastructure capability
	Maintenance cost		Real time information
	Salary		Forecasting models
Leadership	Number of experience years of IC		Complexity human-technical system
	Knowledge		Total response time
	Leadership skill		IC decision making time
	Organizational learning	**Workforce Focus**	Training
Customers	Property losses		Safety
	Fatalities and injuries		Desired number of firefighters
Risk factor	Cyber physical system		Hiring new firefighters
			Number of firefighters
			Personnel reduction

Stage 3: Analytic Modeling

Stage3-3.1 Develop the system dynamics modeling and integrate the Lotka-Volterra and Monte Carlo Simulation for the candidate option

The factors from step 2.5 are used to develop the system dynamics model for the candidate option. This model is used to estimate the impact of effectiveness of CPS in three scenarios (Optimistic, Most Likely, and Pessimistic) on the total dollar losses within a five-year period. In building this model, as noted above, we did not incorporate any competitive threats. Therefore, this investment desires to take risk into consideration and uses the impact of effectiveness of CPS as a parameter to predicted the total losses in the next five years

The data is retrieved from the Division of State Florida-Fire Marshal, Orange County-Fire Rescue, Fire Statistics-US Fire Administration, and the National Institute of Standards and Technology (NIST) database on fire statistics and the firefighting research development section (Division of State Fire Marshal, 2012; Fire Suppression, Orange County Gov FL, 2013; U.S. Fire Administration/National Fire Academy, 2012; U.S. Fire Statistics, 2013; US Department of Commerce, 2012).

The reference model is developed to represent the development of the total dollar losses over time. The historical data of total dollar losses exhibited exponential growth in the period 2000-2005. It tended to fluctuate in the period 2006-2012. The projected total dollar losses will slightly grow from 2013 to 2017 due to the relative risk of fire incidents and complexity of the environment. In this research, the desired outcome after implementing the smart firefighting operation over a five year period is a decrease of the total dollar losses with goal seeking behavior. The reference mode is illustrated in Figure 48.

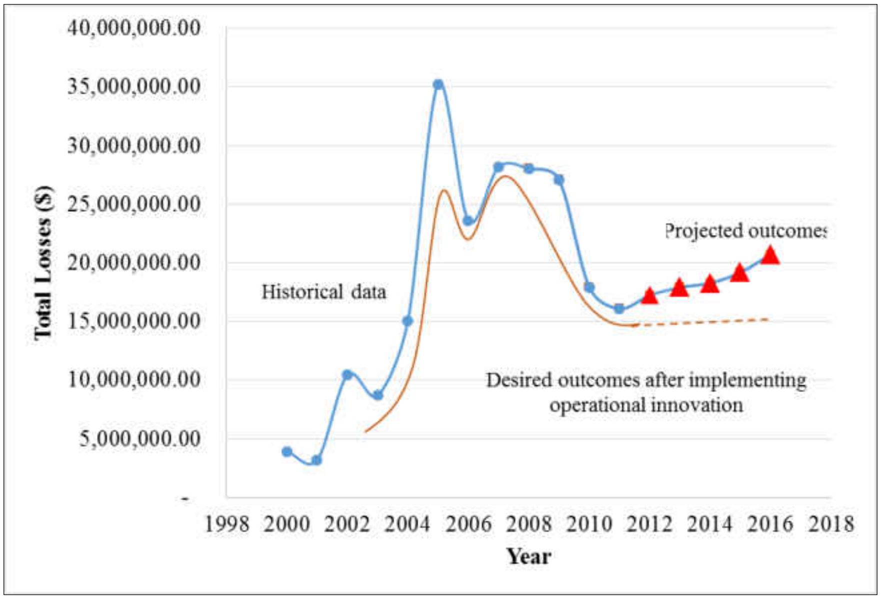


Figure 48: Reference Model of Firefighting Operation Developed with the Smart Firefighting Operation (Division of State Fire Marshal, 2012; Fire Suppression, Orange County Gov FL, 2013; U.S. Fire Administration/National Fire Academy, 2012; U.S. Fire Statistics, 2013; US Department of Commerce, 2012).

A causal loop diagram of the candidate option (smart firefighting operation) is developed and shown in Figure 49. The relevance of the smart firefighting operation, risk factor, and the impact of the cyber physical system are integrated into the model.

There are five causal loop diagrams: 1) R1-Infrastructure capability (reinforcing behavior) 2) R2-Operational innovation (reinforcing behavior), 3) B1-Personnel (balancing behavior), 4) B2-Organizational learning (balancing behavior), and 5) B3-Cyber physical system (balancing behavior). These five loops present a generic model that focuses on the smart firefighting operation. After that, the system dynamics modeling (Figure 50) is developed based on this causal loop diagram by adding levels, rate variables, and system delays.

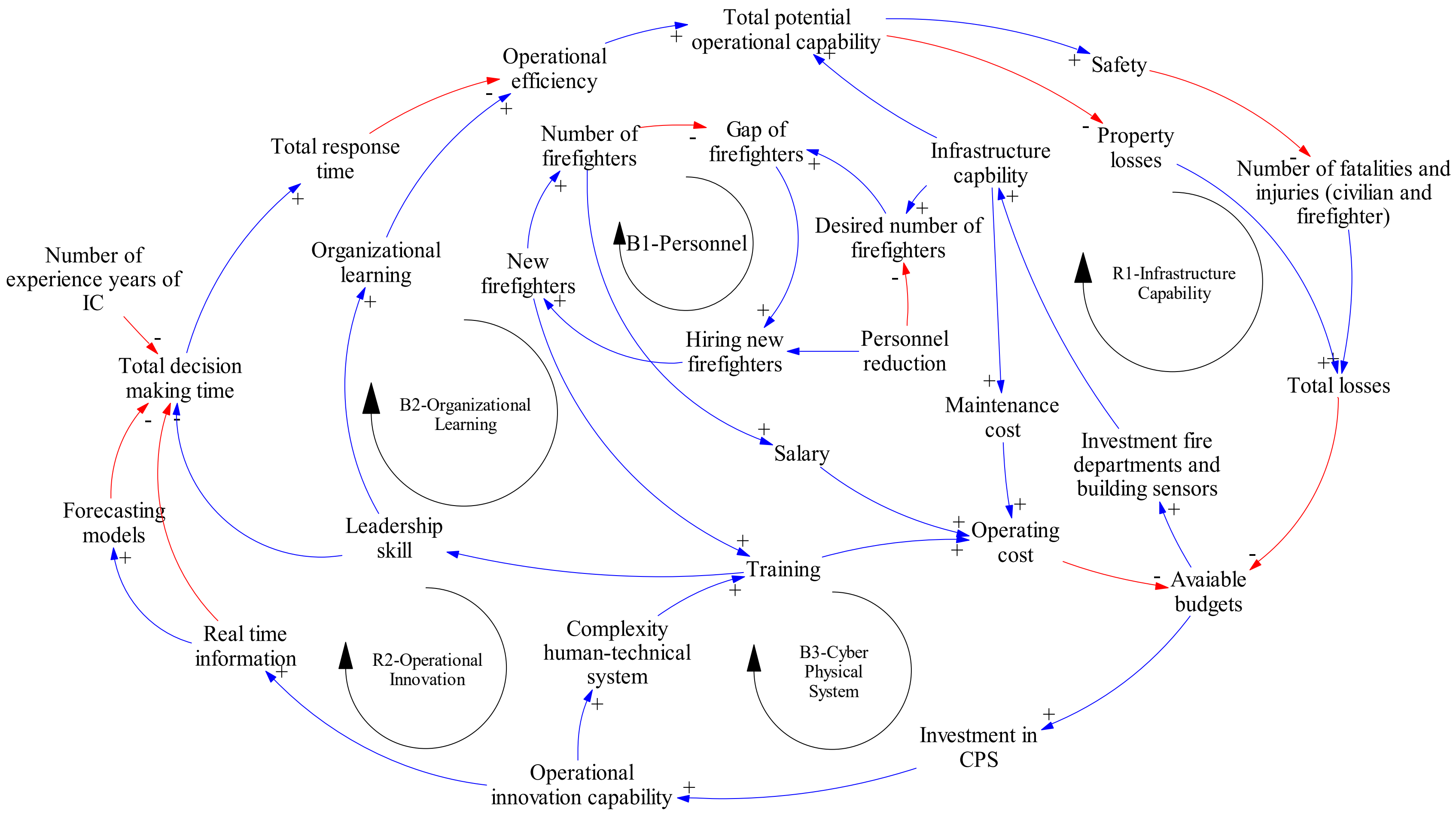


Figure 49: The Causal Loop Diagram of the Smart Firefighting Operation (Validated by Theil, 2013)

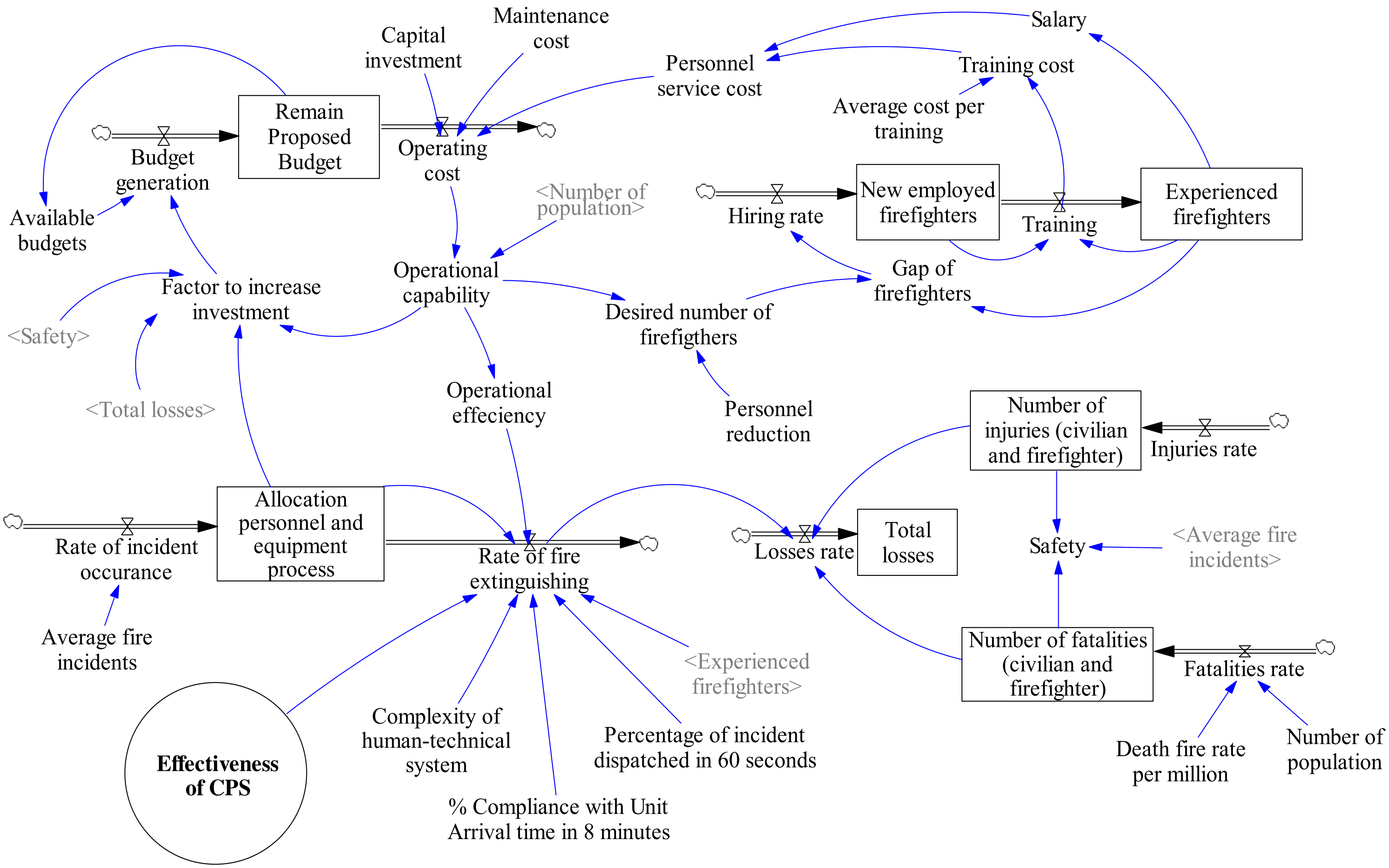


Figure 50: The System Dynamics Model of the Smart Firefighting Operation (Validated by Theil, 2013)

In R1-Infrastructure capability (reinforcing behavior) when the total potential operational capability increases, then the safety increases and property losses decrease above what it would have been. A decrease of total losses increases the available budget, which can be used for investment infrastructure capability and new technologies. When investment infrastructure capability increases, the infrastructure capability and total potential operational capability increase. As a result, to enhance the safety and minimize total losses, it requires more investments in both infrastructure and technology.

The R2-Operational innovation (reinforcing behavior) shows the dynamic loop of the operational innovation where an increase of investment in technology improves the cyber physical system capability (operational innovation) by using CPS wireless sensors, robots, and 3D visualization of buildings. The cyber physical system provides real-time information that can be used for forecasting models (fire growth, smoke generation, structural integrity, evacuation, suppression, ventilation, environmental conditions, air and water supply, tenability, and resource allocation) and supporting the incident commander for faster decision making. A decrease in decision-making time decreases total response time, which can improve operational efficiency and total potential operation capability, respectively.

The B1-Personnel (balancing behavior) represents the feedback loop of personnel. If infrastructure capability increases, then the desired number of firefighters and hiring rate increase. When the number of firefighter increases, the salary and operation cost increase. An increase of new firefighters requires more training, which enhances operating cost. However, the personnel reduction policy tends to decrease the number of old and new firefighters.

The B2-Organizational learning (balancing behavior) represents the feedback loop of organizational learning where the increase of training, knowledge, leadership skill, and organizational learning can increase operational efficiency. The training improves the firefighter's ability and time to perform the tasks. An increase of organizational learning eventually enhances the operational efficiency, which will improve potential operational capability and safety, respectively.

The B3-Cyber physical system (balancing behavior) represents the feedback loop of the cyber physical system. If the available budgets increase, then the investment in technology increases. An increase of investment in technology enhances the cyber physical system capability (operational innovation). However, the cyber physical system increases the complexity of the human-technical system, which requires more training. An increase of training increases operating cost that decreases available budgets dynamically.

The system dynamic modeling (Figure 50) provides estimates of the proposed budget, the allocation of personnel and equipment, new firefighters, experienced firefighters, organizational learning, number of fatalities, number of injuries, and total losses. The data collection focuses on fire incidents both on residential buildings and nonresidential buildings. Residential buildings are buildings where people live. They include one or two family dwellings, multifamily dwellings, manufactured housing, boarding houses or residential hotels, commercial hotels, college dormitories, and sorority/fraternity houses. Nonresidential buildings are buildings on nonresidential properties including bounded structures, subway terminals, underground buildings, and fixed/mobile structures. Institutional properties such as prisons, nursing homes, juvenile care facilities, and hospitals, though many people may reside there, are defined as nonresidential buildings as well. The response time is defined as the time from a received call by the emergency communications center to the first arrival of equipment at the scene. In fact, the response time clock for fire suppression begins at the moment of fire ignition and continues until the fire is extinguished (U.S. Fire Administration, 2013).

The mathematical notation of stock and flows is articulated in term of integral equations. The integral equation explains a value of stock at time *t*, which is a summation of a value of stock at time t_0 and an integral of difference between inflow and outflow rates from t_0 to t (Sterman, 2000). The equations are shown below.

Table 27: Equations for the System Dynamics Modeling- the Smart Firefighting Operation

Variables	**Equations**
Remain proposed budget (t)	Remain proposed budget (t_0) + $\int_{t_0}^{t}[\text{Budget generation rate (t)} - \text{Operating cost rate(t)}] \cdot dt$
Allocation personnel and equipment process (t)	Allocation personnel and equipment process (t_0) + $\int_{t_0}^{t}[\text{Rate of incident occurance(t)} - \text{Rate of incident completion(t)}] \cdot dt$
Number of new employed firefighters (t)	Number of new firefighters (t_0) + $\int_{t_0}^{t}[\text{Hiring Rate (t)} - \text{Training rate (t)}] \cdot dt$
Number of experienced firefighters (t)	Number of experienced firefighters (t_0) + $\int_{t_0}^{t}[\text{Training (t) }] \cdot dt$
Organizational learning (t)	Organizational learning (t_0) + $\int_{t_0}^{t}[\text{Learning rate (t)} - \text{Forgetting rate (t)}] \cdot dt$
Number of fatalities (civilian and firefighters) (t)	Number of fatalities (civilian and firefighters) (t_0) + $\int_{t_0}^{t}[\text{ Fatalities rate (t)}] \cdot dt$
Number of injuries (civilian and firefighters) (t)	Number of injuries (civilian and firefighters) (t_0) + $\int_{t_0}^{t}[\text{ Injuries rate (t)}] \cdot dt$
Total losses (t)	Total losses (t_0) + $\int_{t_0}^{t}[\text{ Losses rate(t)}] \cdot dt$

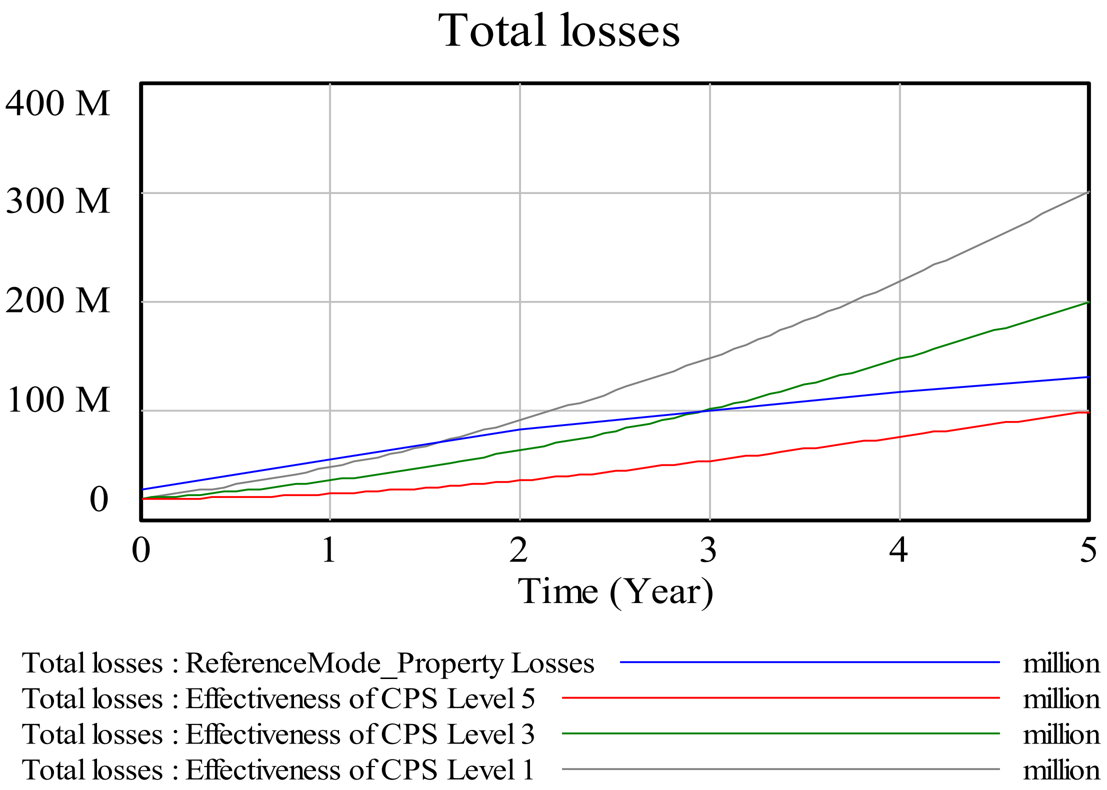


Figure 51: Total Losses Values in Three Scenarios-the Smart Firefighting Operation

The model investigates the impact of effectiveness of CPS on the total dollar losses within a five-year period in three scenarios (Optimistic, Most Likely, and Pessimistic). This parameter is assigned to each scenario with different values. The optimistic scenario uses the effectiveness of CPS at level 5. The most likely scenario uses the effectiveness of CPS at level 3. The pessimistic scenario uses the effectiveness of CPS at level 1. This will help us to understand the causality relationship between the impacts of effectiveness of CPS and total dollar losses as well the importance of this parameter for developing the smart firefighting operation.

Table 28: The Cash Flows from System Dynamics Modeling- the Smart Firefighting Operation ($ Million)

Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Cost	250.00	117.51	128.34	140.30	153.52	168.13
Benefit	-	185.09	184.33	181.71	179.07	229.49
Cash flow	-250.00	67.59	55.99	41.41	25.55	61.37
Net Present Value = $ -27.23 million						
Net Present Value with Monte Carlo Simulation =$ -27.67 million						
Volatility = 0.90						
Risk adjusted discount factor = 4.60 %						
Effectiveness of CPS at level 5 (Optimistic Scenario)						

The results in Figure 51 represent the total losses for each scenario over a 5 year period. Typically, the fire department receives the annual budget from the county. This budget is called the adopted budget, which represents the annual expenses of the entire operation (operating cost). This operating cost includes a personnel service cost, maintenance cost, and capital investment. The cash flow is a value of dollars saved, which is the difference between the total losses and the property value of Orange County for each year.

The simulation is run for three scenarios. First, the total losses of the optimistic scenario are lower than the original data (reference model). Second, the total losses of the most likely scenario are lower than the original data; however, the result in year 5 is higher than the original data. Finally, the total losses of the pessimistic scenario are higher than the original data. To conclude, the higher level of the CPS effectiveness decreases the total losses over a 5 year period. As a result, the cash flow increases radically.

We highlight the optimistic scenario and the cash flows for the 5 year period from the system dynamics modeling in Table 28. The net present value is used to calculate the ROI. Therefore, this cash flow is used to estimate the net present value using the DCF method and Monte Carlo Simulation. The results show that the net present values using the DCF and Monte

Carlo Simulation provide the negative value (-$27.23 million and -$27.67 million). It means that an investment in the CPS technology will not offer a benefit for decreasing the total losses.

The volatility represents how much the expected cash flow value is changing over time. Typically, a higher volatility reflects high risk in project investment (Mun, 2006). The volatility value of smart firefighting case equals 0.90. It means that at certain time period, the cash flow values may above and below by 90% from the forecasted cash flows (using system dynamics modeling) between $157.59 million and -$22.41 million at year 1, $145.99 million and -$34.01 million at year 2, $131.41 million and -$48.59 million at year 3, $115.55 million and -$64.45 million at year 4, and $151.37million and -$28.63 million at year 5, respectively. These values represent the possibility of the forecasted cash flow values in each year, considering risk with an average volatility of 90 %. Therefore, this project investment is a moderately risky project. Next question, it is how much for the return on investment and when is the best time to make an investment in this risky project. The cash flows using the Monte Carlo simulation (Figure 52-sample for 10 runs) represents the cash flows with probability moving of 90% (mixed colors) in 10 scenarios compared with the forecasted cash flow (red color).

The high property and personnel losses still raise the concern of firefighting operational efficiency and effectiveness, and safety. The nationwide cost of unwanted fires is approximately $300B per year including numerous civilian and firefighter injuries and deaths, and property loss (The National Fire Research Laboratory, n.d.).Therefore, it is important to develop the smart firefighting to resolve those problems by implementing CPS for buildings, apparatus, personal protective equipment, and robotics to increase situation awareness, operational efficiency and safety. As a result, the local government should wait to gain more information about the CPS and its implications. The real option analysis is the appropriate method to estimate the investment ROI when the project needs the flexibility of making investments.

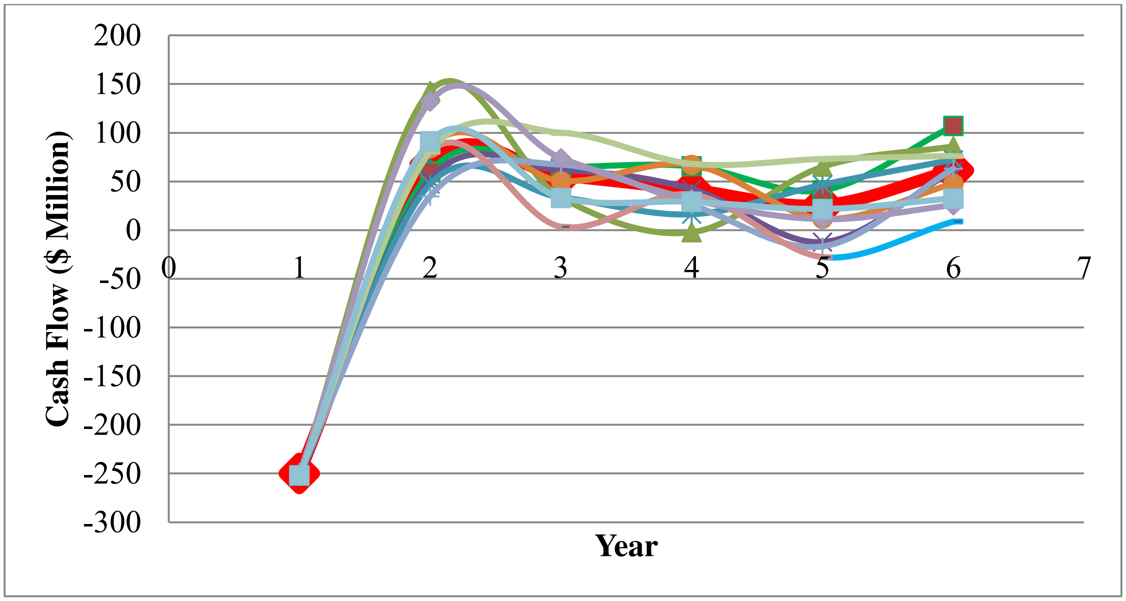


Figure 52: The Cash Flows from the Monte Carlo Simulation-the Smart Firefighting Operation

<u>Stage3: 3.2 Measure the real options value for the candidate option using the Binomial Lattice Method and. determine the optimal time to make an investment</u>

The option type to defer is an option to wait for an investment in anticipation of getting the maximum value (Tourinho 1979; Titman 1985; McDonald and Siegel 1986; Paddock, Siegel&Smith 1988; Ingersoll and Ross, 1985). The binomial lattice equation is implemented to calculate the ROI considering risk and determine optimal time to invest for each additional year. There are six parameters: delta time period (Δt), volatility, probability of upside potential *(u)*, probability of downside risk *(d),* risk free rate, and risk neutral probabilities (see Table 29). The ROI for each delayed year using real option are illustrated in Table 30. These ROI values are compared to ROI using the DCF method are shown in Figure 53.

If the local government makes an investment now, then it will not provide the benefit of property saved. If the local government delays the project for one year, two years, three years, four years, and five years, the ROI equals \$88.88 million, \$97.74 million, \$133.65 million, \$139.24 million, and \$160.71 million, respectively. These values represent the value of property saved in Orange County when the local government delays making an investment that allow decision makers to gain more information of the CPS capability.

In contrast, the DCF method provides the negative ROI value -\$27.67 million. This method does not provide flexibility in decision making or change the decisions due to unexpected situations in the future. It does not provide comprehensive information on the effect of market dynamics, or do not take risk and uncertainty into consideration. Whereas ROI values from the RODD method take the risk in optimistic scenario into consideration. Therefore, local government can delay investment in the CPS for at least one year in order to earn positive return on investment.

Table 29: Parameters for Binomial Lattice for the Smart Firefighting Operation

Parameters:	
delta t	1.00
v: volatility	0.90
u	2.47
d	0.41
Risk free rate	4.60%
Risk Neutral	0.31

Table 30: The ROI Results from Binomial Lattice Method-the Smart Firefighting Operation ($ Million)

	2007	2008	2009	2010	2011	2012
Cost	250.00	117.51	128.34	140.30	153.52	168.13
Benefit	-	185.09	184.33	181.71	179.07	229.49
Cash Flow	-250.00	67.59	55.99	41.41	25.55	61.37
Risk Adjusted discount rate	0.046	0.046	0.046	0.046	0.046	0.046
Discount factor	1.00	0.96	0.91	0.87	0.84	0.80
PV of cash flow	-250.00	64.61	51.18	36.19	21.35	49.01
PV of all cash flow = S0	222.33					
Initial Investment (St)	-250.00					
Return on Investment		**88.88**	**97.74**	**133.65**	**139.24**	**160.71**

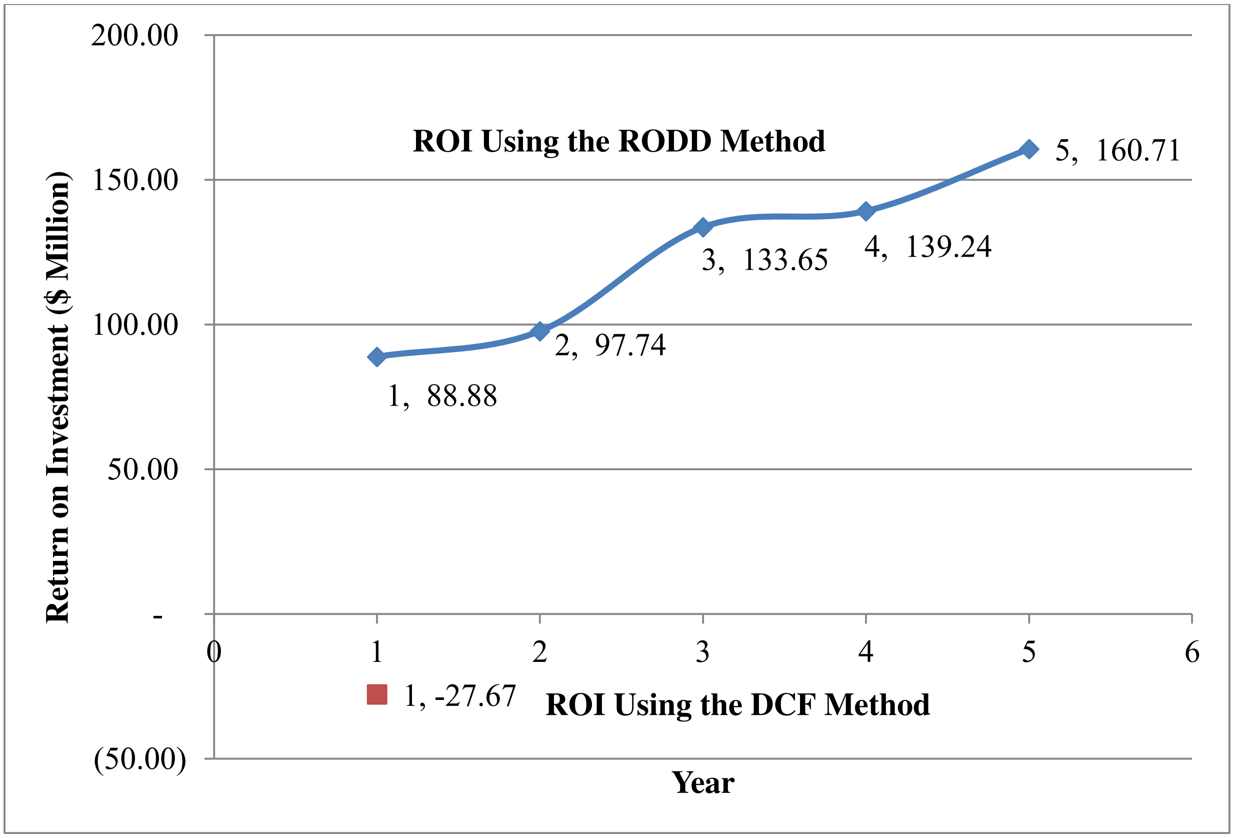


Figure 53: The ROI for Each Delayed Time-the Smart Firefighting Operation

In conclusion, the result of the RODD framework can answer the early questions that it is worthwhile for the local government to establish and invest in CPS. The results show that delaying the investment for at least one year is the best solution in order to gain more information about the CPS capability and its implications. This option will help Orange County to reduce the total losses and increase property value saved after the investment.

The smart firefighting operation using the cyber physical system (CPS) has some limitations. First, if a fire code requires the installation of wireless sensors in buildings, there will be a resistance from landlords. Therefore, the potential participants will be volunteers who allow the local government to implement the CPS into their buildings for a pilot study. Second, there is a need to illustrate the costs and benefits, and provide education to the local government and community. This will allow the local government and community to recognize the needs and advantages of using the CPS that can save civilians and firefighters, and reduce property losses. This may help to reduce a resistance.

Third, each incident uses a different person to evaluate property losses and has limited evidence; therefore, there are concerns in the consistency of subject opinions and the method for estimating property loss values. Four, there is a challenge for estimating the effectiveness of firefighting operation. Although firefighters quickly arrive at scene, the property losses, number of civilian injuries and fatalities may not decrease because of a chaotic evacuation. Fifth, the evaluation of property loss values, conducted by fire department, is estimated based on direct costs. This value excludes indirect costs such as business opportunity cost, local tax income losses, and opportunity cost for workers (loss their incomes). Therefore, this estimation should take indirect costs into consideration in order to enhance the accuracy of property loss values (Thiel, 2013).

Finally, the complexity of the human-technical system is another issue that can occur after the implementation. Therefore, we suggest to provide the training and new knowledge related to the CPS to firefighters. This will allow firefighters to improve their skill as individuals and as organizational learning, respectively (The National Fire Research Laboratory, n.d.). Thus, all these limitations support the delaying of the smart firefighting operation investment. The structure of the entire decision process and the suggested decisions are demonstrated in Figure 54.

The benefits of the RODD framework are 1) it provides increased flexibility, improved predictions, and more information to decision makers; 2) it can assess the value of the candidate option with regards to risk and impact of the effectiveness of CPS; 3) it can reduce complexity; 4) it provides insight and a new understanding of the smart firefighting operation; and 5) it supports the decision-making framework as part of the smart firefighting operation development.

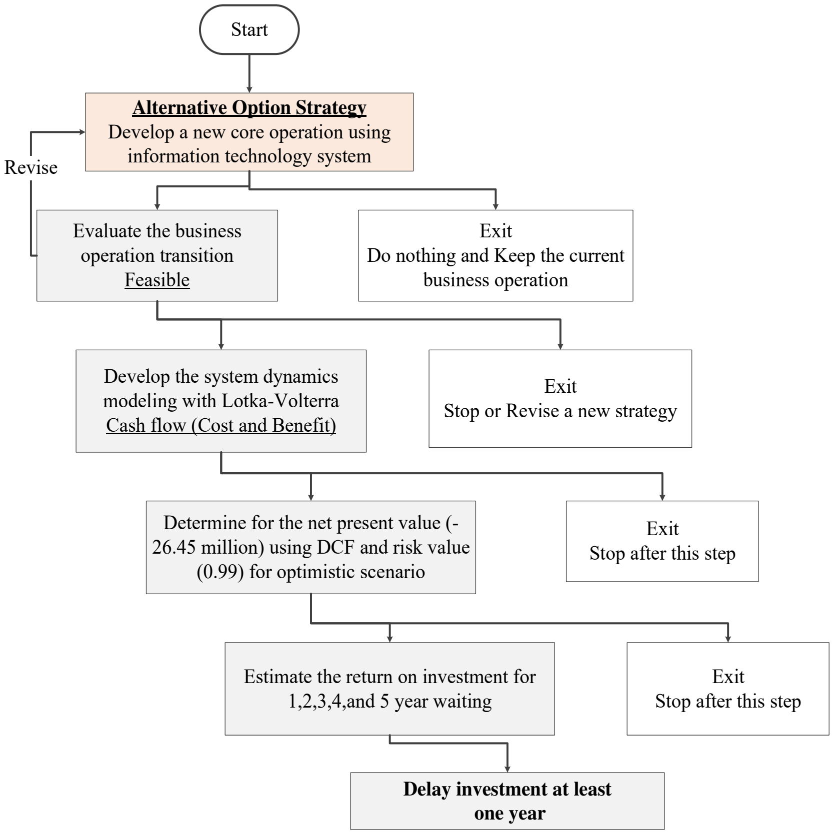


Figure 54: The Decision Process Using RODD Framework for the Smart Firefighting Operation Development

5.4. Results Comparison: the Smart Firefighting Operation

5.4.1. Results Comparison: the RODD Method vs. Traditional DCF Method

The ROI of the smart firefighting operation using the RODD method are compared with the DCF method at 4.60% risk free rate (Table 31). This comparison validates the argument for the use of the real option analysis for this research. The DCF method provides a negative ROI value (-$14,690.70 million) (See Figure 37); as a result, this investment must be rejected.

The DCF method provides the negative ROI value (-$27.67 million) (See Figure 53). As a result, this project must be rejected by using this method. This method does not provide flexibility in decision making, and take risk and uncertainty into consideration. Whereas RODD integrates both qualitative and quantitative analysis to analyze the feasibility of operation transformation, provide more information on the uncertainty, and the stability of CPS effectiveness to reduce property losses and increase safety.

Table 31: The Comparison Results between the RODD Method and DCF Method-the Smart Firefighting Operation ($Million)

	2007	**2008**	**2009**	**2010**	**2011**	**2012**
Cost	250.00	117.51	128.34	140.30	153.52	168.13
Benefit	0.00	185.09	184.33	181.71	179.07	229.49
Cash Flow	-250.00	67.59	55.99	41.41	25.55	61.37
Risk Adjusted discount rate	0.05	0.05	0.05	0.05	0.05	0.05
Discount factor	1.00	0.96	0.91	0.87	0.84	0.80
PV of cash flow	-250.00	64.61	51.18	36.19	21.35	49.01
PV of all cash flow = S0		222.33				
Initial Investment (St)		250.00				
ROI Using the DCF Method		**-27.67**				
The Results from using the RODD Method						
ROI Using the RODD	**0.00**	**88.88**	**97.74**	**133.65**	**139.24**	**160.71**

Therefore, the DCF method is not applicable to use as the investment decision method for this operational innovation investment decision. The RODD method is more proper method to estimate ROI value of CPS because it offers more information, and allows the local government to delay the investment until the ROI value reaches a positive ROI.

5.4.2. Results Comparison: the RODD Method vs. ROA using Original Data

The cash flows using the RODD method are compared with the cash flows using original data from Orange County-Fire Rescue Department. This comparison validates the argument of the importance of using the system dynamics modeling to determine the cash flows with the impact of the effectiveness of CPS. There are two approaches for this comparison: 1) Validation of the results from using the system dynamics modeling with historical data, and 2) Validation of the ROI from using the RODD method with ROI from ROA using historical data.

First, we compare the cash flows using the system dynamics modeling with the cash flows from the original data. This aims to validate the results from using the simulation with historical data (Sargent, 2005). The results show that the cash flows from using the system dynamics modeling are close to the original data (Figure 55). At the year 4, the cash flow from the system dynamics modeling is a near value with the original data. Therefore, the system dynamics modeling was structured close the realistic.

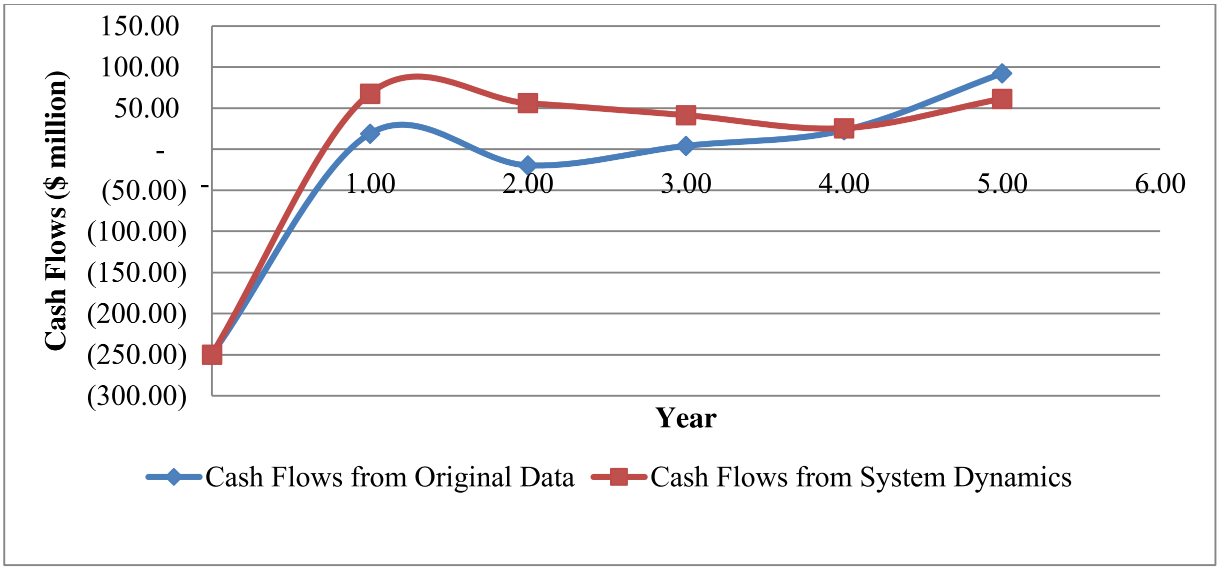


Figure 55: Cash Flows Comparison-the Smart Firefighting Operation

Second, we estimate the ROI using the operating cost and benefit from the original data. This comparison aims to validate the ROI from the RODD, significantly showing a greater ROI than the ROI from the original data.

Table 32: The Comparison ROI Results between the RODD Method and ROA using Original Data (Adopted Budget 2007-2012 ((Fire Suppression, Orange County Gov FL, 2013)) –the Smart Firefighting Operation ($Million)

	2007	**2008**	**2009**	**2010**	**2011**	**2012**
Cost	250.00	140.90	186.00	175.30	162.08	151.71
Benefit	0.00	159.83	166.44	179.47	185.23	243.97
Cash Flow	-250.00	18.93	-19.56	4.17	23.15	92.26
Risk Adjusted discount rate	0.046	0.046	0.046	0.046	0.046	0.046
Discount factor	1.00	0.96	0.91	0.87	0.84	0.80
PV of cash flow	-250.00	18.10	-17.88	3.64	19.34	73.68
PV of all cash flow = S0		96.89				
Initial Investment (St)		250.00				
ROI using the original data	**0**	**26.22**	**52.45**	**61.16**	**73.57**	**77.79**
ROI using the RODD method	**0**	**88.88**	**97.74**	**133.65**	**139.24**	**160.71**

Since these two ROI values are independent, we use the F-test (one-sided test) with two samples for variances. The hypothesis testing is examined two using opposing assumptions, H_0 and H_A. The null and the alternative hypotheses are stated below:

H_0: $\sigma_2^2 \leq \sigma_1^2$

H_A: $\sigma_2^2 > \sigma_1^2$

Table 33: F-Test: Comparison ROI Results between RODD Method and ROA using Original Data- the Smart Firefighting Operation

Year to Wait	**ROI Using the RODD Method**	**Variance**	**ROI Using the Original Data**	**Variance**
1	88.88	309.16	26.22	256.23
2	97.74	173.03	52.45	8.38
3	133.65	23.08	61.16	2.14
4	139.24	57.72	73.57	58.76
5	160.71	336.17	77.79	95.56
Mean	124.04		58.24	
Degree of freedom	4		4	
Variances	899.15		421.07	
F	2.14			
P(F<=f) one-tail	0.24			
$F_{\text{Critical one-tailed}}$	6.38			

An F-test (one-sided test) two samples for variances were used to confirm whether the ROI from the RODD provide a greater ROI than the ROI from original data. The result shows that the applicable F_{tab} = 6.38 is higher than F_{cal} =2.14; therefore, the null hypothesis (no difference) is accepted (we fail to reject H_0). This means that there is not difference between the standard deviations of these two methods with a significance level of $\alpha = 0.05$. Therefore, the variability for both methods is no significantly different.

A T-test (one tailed test) was used to valid whether the mean value of ROI from the RODD is higher than the mean value of ROI from the ROA using original data. The hypothesis testing is examined using two opposing assumptions, H_0 and H_A. The null and the alternative hypotheses are stated below:

H_0: $\mu_1 \leq \mu_2$

H_A: $\mu_1 > \mu_2$

Table 34: T-Test Paired Two ROI Results for Means Comparison between RODD Method and ROA using Original Data- the Smart Firefighting Operation

	ROI Using the RODD	**ROI Using the Original Data**
Mean	124.0429	58.2368
Variance	899.1535	421.06811
Observations	5	5
Pearson Correlation	0.9166	
df	4	
t Stat	10.61	
P(T<=t) one-tail	0.000222	
t Critical one-tail	2.1318	
P(T<=t) two-tail	0.00044	
t Critical two-tail	2.7764	

The result confirms that the applicable $t_{State} = 10.61$ is higher than $t_{Critical\ one\text{-}tail} = 2.13$ with probability value 0.00022. There is a difference between the mean values of these two methods. Therefore, the mean value of ROI from the RODD method is significantly higher than the mean value of ROI from the original data with a significance level of $\alpha = 0.05$.

The RODD method goes beyond a simple yes/no decision on investments. It allows decision makers to delay making an investment until it earns maximum ROI. It integrates both qualitative and quantitative analysis to analyze operational innovation schemes. The system dynamics modeling is an important technique that can enhance the effectiveness of the decision-making framework by capturing the complexity systems and predicting the results. The longer time to wait before investing can help the local government to gain benefit from the CPS. It requires more time for testing in pilot study. However, in the long run, the CPS has significantly improved the operational efficiency and safety.

5.5. Summary

In this chapter we applied the RODD framework to the UPS and Smart Firefighting case studies in order to validate and to show how this framework can improve the effectiveness and flexibility of the investment decision-making process of operational innovation development.

The results in both cases show that delaying for at least one year is the best solution. In the UPS case, the result from using the RODD is greater match the realistic situation during the operational transformation at UPS. It took UPS for three years to make a significant investment in information technology systems. They could not delay longer due to the intensive competition in the logistics industry. During delayed time, UPS had opportunities to study customers' preferences and FedEx's market strategy, which helped UPS to become successful logistics business, and hold the second ranking of the 100-top Core Brand Power in the end 2001. In the smart firefighting operation, the results of using the RODD framework show that it is worthwhile for the local government to establish and invest in CPS. We recommend the local government to delay the investment for at least one year in order to gain more information about the CPS capability and its implications. The resistant from landlords, the complexity of human-technical problem, and budget constraints are the critical limitations. Therefore, delaying the investment can increase the success of operational innovation implementation because it allows the local government and community to have gain understanding the benefits of using CPS.

This method provides the comprehensive viewpoint of operational innovation, articulates the feasibility of the transformation from the current operation to the operational innovation, and quantifies the ROI of the operational innovation, considering risk and the impact of a competitor.

The results from using the RODD framework in both cases provide a better comprehensive analysis. The final investment decisions should be delayed for at least one year in order to earn the positive return on investments. The longer time to delay an investment provides a higher ROI. However, due to intensive competition especially from FedEx in the UPS case, the company should invest, when the project investment firstly provides a positive ROI. In addition to the smart firefighting operation case, we recommend the local government to make an investment in the CPS technology for at least one year delaying.

The ROIs from the RODD framework are compared with the ROI from using the DCF method, and the Real Option analysis using the original data. The first comparison validates the use of the Real Option analysis for this research. The second comparison validates the use of the System Dynamics Modeling with Lotka-Volterra to determine the cash flows.

The results from these comparisons confirm that the mean values of ROI from the RODD method in both cases provide greater results leading to the increase of decision-making framework effectiveness and better quality decisions. In addition to better quality, the RODD method improves the flexibility of making decision by offering an opportunity to revise the decision upon the future conditions, especially taking into account the risk.

CHAPTER SIX: CONCLUSION AND FUTURE RESEARCH

This chapter articulates an overview of this research, a summary of the research, conclusions, contributions, research findings, and future research.

6.1. Overview

This research provides an effective decision-making framework to help organizations when they are seeking a feasible operational innovation option in order to enhance performance.

This study aims to solve the problems and close the research gaps in the operational innovation area. It provides a framework to support strategic decisions and execution of new operational schemes.

6.2. Summary of Research and Conclusions

Chapter One articulates the background for this research. It illustrates the problems in real business cases related to operational innovation development. These are used to develop the research question, research objectives, and a new idea and guidelines for a purposed framework.

Chapter Two introduces the literature survey in different areas including: innovation, operational innovation, valuation analysis, Real Option Analysis, Matrix of Change, Lotka-Volterra, and System Dynamics Modeling. These research areas help us to identify the most important factors of operational innovation and its environment. It also shows the current investment decision approaches, and techniques that can be implemented for operational innovation development. However, the research gaps analysis is clarified, showing that many businesses heavily invest in operational innovation development, but fail to do so in a timely manner. We found limitations of the traditional investment methods, and a lack of a proper decision-making framework for the operational innovation development.

Chapter Three summarizes the research methodology used to develop, test, and validate the framework. The method aims to improve the effectiveness and flexibility of the decision making in operational innovation. The purpose of the research methodology is to establish validity in the research process. This research methodology consists of research design, development framework, and validation. The development framework synthesizes the findings from the literature survey into a systematic architecture to support the implementation of operational innovation schemes.

Chapter Four introduces the systematic architecture of operational innovation using the Real Option Dynamic Decision (RODD) framework. This method aims to provide the comprehensive viewpoint of operational innovation, to articulate the feasibility of the transition from the current operation to the operational innovation, and to quantify the ROI of the operational innovation considering risk and the impact of a competitor. The systematic architecture of operational innovation illustrates the most important factors of operational innovation and its environment such as organizational transformation, knowledge, operational efficiency and capability, uncertainty of the market, customer needs, competitive threats and responses, and advanced technology.

The RODD framework uses deeper standpoints to support radical investments and allows decision makers 1) to determine the feasibility of operational innovation transformation, 2) to evaluate the ROI of an operational innovation, and 3) to offer ability to delay of the investment. This comprehensive framework is described step-by-step and consists three stages: 1) Decision problem identification, 2) Systematic transition analysis, and 3) Analytic modeling. The cash flows from the RODD framework are compared with the results from using the DCF method and the Real Option analysis using the original data. This first comparison tends to validate the use of the Real Option analysis for this research. This second comparison tends to validate the use of the System Dynamics Modeling with Lotka-Volterra to determine the profits. The RODD Framework is illustrated as follow:

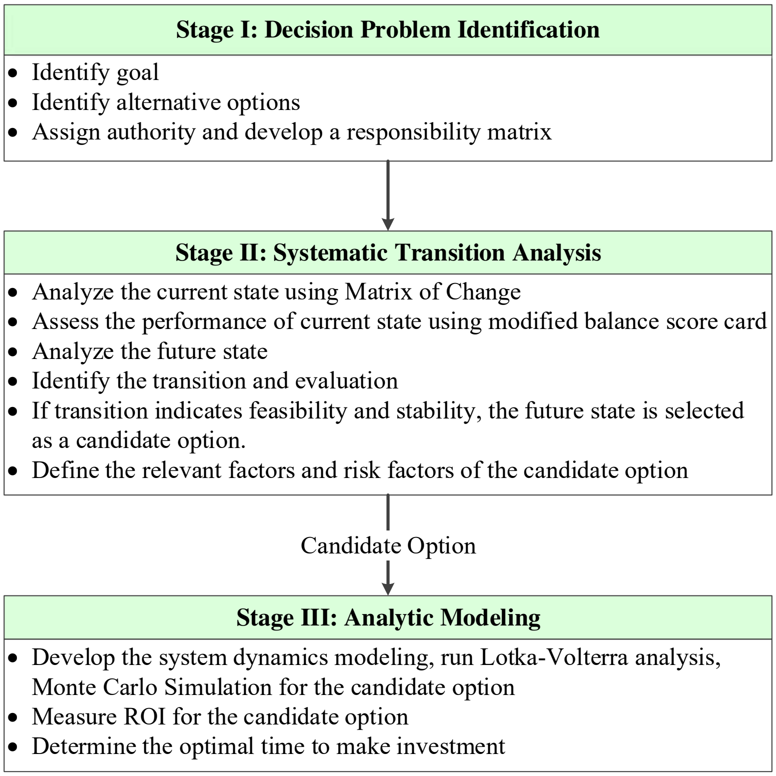


Figure 56: The RODD Framework Summary Description

Chapter Five presents two case studies: 1) UPS Company (in late 1990's) and 2) The Smart Firefighting Operation to validate RODD. The results show that the RODD method offers a new understanding and effectiveness of the operational innovation investment decision process leading to better quality investment decisions. In addition to better quality, these techniques improve the flexibility of decision making by affording an opportunity to delay projects until it reaches the maximum return on investment, especially taking the risk and the impact of a competitor into consideration.

To conclude, the RODD framework can help to solve problems with innovation. This framework takes operational innovation dynamics, business operations transformation, the impact of a competitor, and uncertainty into consideration. It is a new tool for the strategic management, and offers a significant argument for further academic research in engineering management and various operational innovation areas.

This framework is generically applicable for operational innovation models schemes. The implementations of this framework can 1) provide increased flexibility, improved predictions, and more information to decision makers; 2) assess the value alternative option with regards to risk and competitiveness; 3) reduce complexity; 4) gain new understanding of operational innovation; 5) help businesses to recognize the need for change in business operation and quickly response to the market threats or customer needs, and finally, 6) support the decision-making framework as part of business operation development.

6.3. Research Findings

The RODD framework is applied to the UPS and smart firefighting operation cases to analyze the feasibility of the business operation transformations toward operational innovations, to compute the ROI of these feasible options considering risk and impact of the competitor, and to help decision makers to decide whether organizations should make an immediate or delayed investment.

The rationale to select these cases is a diversification of using cases from profit organizations and non-profit organizations. The result of using the RODD for the UPS case shows that delaying the investment in information technology systems for at least one year is the best solution for UPS in order to earn a positive ROI. This allows UPS to have more time to study customers' preferences, FedEx's market strategy, and the availability of advanced technologies for developing a better market strategy than FedEx. As a matter of fact, it took UPS a few years to made significant investments in information technology systems for operational innovation development in 2009. The operational innovation implementation was indicated as an effective tool to enhance market competitive advantages, business capability, and profits (Schlangenstein, 2013; UPS Company-Investor Relations, 2013). Therefore, the results from using the RODD framework match the actual results from the operational transformation at UPS.

The results from using the RODD for the smart firefighting operation show that delaying the investment for at least one year is the best solution in order to gain more information about the CPS capability and its implications. This option will help Orange County to reduce the total losses and increase property values that are saved after the investment. As matter of fact, Orange County has started implementing cyber technologies in order to enhance fire extinguishing operational efficiency by offering real time information to incident commanders and other agencies. However, there are still several limitations such as the complexity of the fire extinguishing operation, resistance from landlords, and the human-technical system. Therefore, all these limitations support the delaying of the smart firefighting operation investment. Thus, the results from using the RODD in both cases show that the project investment requires at least a one year delay of the investment in order to earn the positive values of ROI. These two cases are different. For UPS, we verify the past by addressing the problem solving phase, and for the smart firefighting operation, we verify the future as they have not implemented the proposed innovation. Although these cases were in different phases (the UPS case-problem solving phase and the smart firefighting case-after idea generation) in the innovation process, RODD still worked.

The results from using the RODD are compared with three comparison approaches 1) Validation of the results from using the RODD compared with the DCF method, 2) Validation of the results from using the system dynamics modeling compared with historical data, and 3) Validation of the ROI from using the RODD method with ROI from ROA using historical data. The results confirm that there are no differences between the standard deviations of these two methods with the significance level of $\alpha = 0.05$ in both cases. Therefore, the variability for both methods is not significantly different. The results from these comparisons also confirm that the mean value of ROI from the RODD method in both cases provide greater results than the mean value of ROI from the original data leading to an increase of the decision-making framework effectiveness and better quality decisions. Therefore, the system dynamics modeling and Lotka-Volterra are important techniques that can enhance the effectiveness of the decision-making framework.

The results strongly indicate the importance of understanding the significant factors of operational innovation, the environment of organization, and the organizational transformation. The prediction of consequences after implementing operational innovation is a key factor for making decision because these projected outcomes allow decision makers to quantify the ROI of a new business operation.

The RODD method goes beyond a simple yes/no decision on investments. It integrates both qualitative and quantitative analysis to analyze operational innovation schemes. It allows decision makers to delay making an investment until the investment earns maximum ROI.

Companies can use this method for making decisions in investments prior to operational transformation in the early stages of innovation by considering the risk and the impact of a competitor.

6.4. Research Contributions

Our research makes a key contribution to the area of engineering by introducing a unique decision-making framework to address operational innovation implementation. This framework illustrates its dynamics, and investment decisions considering the uncertainty and impact of competitors. This research also provides the following contributions:

1. The most significant features of operational innovation and its environment are identified and used to develop a high level architecture of operational innovation. The implementation of this architecture reduces the complexity of the operational innovation, and help businesses to recognize the need for change in business operations and quickly response to the market threats or customer needs. This contributes a new strategic management approach, and offers a significant argument for further academic research in operational innovation areas.
2. The dynamics model of the operational innovation provides a conceptual framework of the realistic operational innovation systems, illustrates a causality relationship, offers a comprehensive analysis approach to the problems and the consequences in different scenarios, and improves the accuracy of predicted financial results when considering the impact of a competitor. The outcomes help decision makers to emphasize a feasible operational innovation option and to establish the needed policy/requirement to improve business performance.

3. The RODD approach is a tool for decision makers to justify the feasibility of a new business opportunity aligning the company's goals.
4. The RODD framework is a novel method for investment decision that captures the risk and impact of competitors. This framework provides flexibility to make an investment which allows businesses/organizations to delay the project investment until getting a ROI of a new business operation. Therefore, the RODD framework improves the manageability and effectiveness of the investment decision making process.

6.5. Limitations and Future Research

This study has focused on UPS and the smart firefighting operation led by the National Institute of Standards and Technology. This reflects a limitation because there may be an argument about the findings from these cases that may not be generalizable for other organizations due to their particular characteristics.

Second, due to the limited data in UPS (UPS Company-Investor Relations, 2013) and Orange County adopted budget report (Fire Suppression, Orange County Gov FL, 2013) related to the strategy leadership and organizational learning performance of both cases, this research excluded quantitative value of leadership and organizational performance in the system dynamics modeling. These values should be evaluated by subjective opinions in order to enhance the accuracy of the organizational performance assessment. The smart firefighting operation using cyber physical system (CPS) still has some limitations such as the lack of subject opinion consistency, lack of proper methods for property losses value evaluation and the effectiveness of firefighting operations, and lack of indirect costs estimation for property loss values evaluation (Thiel, 2013).

This research emphasizes on the risk of information technology system and the impact of a competitor. However, the decision to develop operational innovations is very complex and involves numerous factors. Therefore, the future research should conduct a study to investigate those implicit factors and their impact on investment decisions. We will also develop matrices to quantify leadership and organizational learning. These factors have been indicated as the most important factor to drive success in innovation. As a result, developing matrices to quantify leadership and organizational learning will help overcome one of the limitations (Anthony, 2012; L. Baker et al., 2012; Gilbert & Bower, 2002; Sandler, 2010).

Finally, if the companies' competitors innovate before them, then the company should not delay a project more than one year. During one year waiting, it allows companies to gain the knowledge from their competitors' strategy and operational capability, and customers' response. The other way to solve this problem is to develop the RODD method using month as time horizon, which can help decision makers to monitor an investment month by month. This method is implemented to large scale organizations. Therefore, this method can be implemented into the small businesses by modifying the features of operational innovation.

The target journals for the future publication are the International Journal of Production Economics, and Computers and Industrial Engineering Journals. First, the UPS case study using RODD will be submitted to an international journal of production economics. This paper provides a greater contribution in developing a method that evaluates the return on investment, while considering the risk of information technology systems and the impact of FedEx on the UPS's financial performance. Second, the smart firefighting operation case will be submitted to a computers and industrial engineering journal. The contribution lies in developing a method that captures the feasibility of firefighting operational transformation, and the return on investment considering the risk of cyber physical systems (CPS). This paper can encourage local governments, fire departments, and communities to recognize the need and benefits of using CPS which can minimize property losses and increase safety for both civilians and firefighters in long run.

APPENDIX A: SYSTEM DYNAMICS MODELINGS ANALYSIS

CHAPTER 5: UPS Case Study

Stage 3: 3.1 Develop the system dynamics modeling and integrate the Lotka-Volterra and Monte Carlo Simulation for the candidate option

Parameter	**Value**	**Unit**
Investment E-Tracking System	2,000	Million Dollars
Revenue per package	8.5	Dollars
Day of operation	250	Days
Average package daily	10	Million/Day
Effectiveness of Operational Innovation	0.95	Dimensionless
Ratio number of package per customer	400	Dimensionless

CHAPTER 5: Smart Firefighting Operation

Stage 3: 3.1 Develop the system dynamics modeling and integrate the Lotka-Volterra and Monte Carlo Simulation for the candidate option

Parameter	**Value**	**Unit**
Average fire incidents	1,000	Incidents
Complexity of human-technical system	1	Dimensionless
%Compliance with Unit Arrival in 8 minutes	0.77	Dimensionless
Percentage of incident dispatched in 60 seconds	0.63	Dimensionless
Person reduction	75	Firefighters/year

APPENDIX B: REAL OPTION ANALYSIS

CHAPTER 5.1: CASE STUDY I: UNITED PARCEL SERVICE INC

Stage 3: 3.2 And 3.3 Measure the real options value for the candidate option using the Binomial Lattice Method and. determine the optimal time to make an investment

Real Option Values for the UPS Operational Innovation using Binomial Lattice Method with results from System Dynamics Modeling

Period 0	**1**	**2**	**3**	**4**	**5**

Option Value to Wait for 1Year:

	23,270.48
	1,945.48
6,634.30	
439.26	
	1,891.41
	0

Option Value to Wait for 2Years

		81,623.59
		60,298.59
	23,270.48	
	13,614.41	
6,634.30		6,634.30
3,073.91		0
	1,891.41	
	0	
		539.23
		0

Option Value to Wait for 3 Years

			286,303.11
			264,978.11
		81,623.59	
		61,253.46	
	23,270.48		23,270.48
	14,151.94		1,945.48
6,634.30		6,634.30	
3,267.96		439.26	
	1,891.41		1,891.41
	99.18		0
		539.23	
		0	
			153.73
			0

Option Value to Wait for 4 Years

				1,004,237.48
				982,912.48
			286,303.11	
			266,117.87	
		81,623.59		81,623.59
		70,062.93		60,298.59
	23,270.48		23,270.48	
	18,071.90		13,614.41	
6,634.30		6,634.30		6,634.30
4,588.99		3,073.91		0
	1,891.41		1,891.41	
	694.04		0	
		539.23		539.23
		0		0
			153.73	
			0	
				43.83
				0

Option Value to Wait for 5 Years

					3,522,465.80
					3,501,140.80
				1,004,237.48	
				984,700.79	
			286,303.11		286,303.11
			267,221.47		264,978.11
		81,623.59		81,623.59	
		70,706.05		61,253.46	
	23,270.48		23,270.48		23,270.48
	18,359.32		14,151.94		1,945.48
6,634.30		6,634.30		6,634.30	
4,698.02		3,267.96		439.26	
	1,891.41		1,891.41		1,891.41
	754.26		99.18		0
		539.23		539.23	
		22.39		0	
			153.73		153.73
			0		0
				43.83	
				0	
					12.50
					0

5.2 Results Comparisons: The UPS Case Study
5.2.2. Comparison: Results from Real Options Dynamic Decision (RODD) Method vs. Real Option Analysis
Real Option Values for the UPS Case using Binomial Lattice Method with original data

Period 0	**1**	**2**	**3**	**4**	**5**

Option Value to Wait for 1 Year

	20,219.37
	-
6,589.84	
-	
	2,147.74
	0

Option Value to Wait for 2 Years

		62,038.42
		40,713.42
	20,219.37	
	10,220.90	
6,589.84		6,589.84
2,565.91		0
	2,147.74	
	0	
		699.99
		0

Option Value to Wait for 3 Years

			190,350.35
			169,025.35
		62,038.42	
		42,432.97	
	20,219.37		20,219.37
	10,652.59		-
6,589.84		6,589.84	
2,674.28		-	
	2,147.74		2,147.74
	-		0
		699.99	
		0	
			228.14
			0

Option Value to Wait for 4 Years

				584,045.49
				562,720.49
			190,350.35	
			170,078.44	
		62,038.42		62,038.42
		49,930.02		40,713.42
	20,219.37		20,219.37	
	14,350.41		10,220.90	
6,589.84		6,589.84		6,589.84
4,058.43		2,565.91		0
	2,147.74		2,147.74	
	644.16		0	
		699.99		699.99
		0		0
			228.14	
			0	
				74.35
				0

Option Value to Wait for 5 Years

					1,792,006.85
					,770,681.85
				584,045.49	
				564,129.23	
			190,350.35		190,350.35
			171,648.91		169,025.35
		62,038.42		62,038.42	
		50,629.75		42,432.97	
	20,219.37		20,219.37		20,219.37
	14,602.76		10,652.59		-
6,589.84		6,589.84		6,589.84	
4,141.03		2,674.28		-	
	2,147.74		2,147.74		2,147.74
	671.36		-		0
		699.99		699.99	
		-		0	
			228.14		228.14
			0		0
				74.35	
				0	
					24.23
					0

CHAPTER 5.3: CASE STUDY II: SMART FIREFIGHTING OPERATION

Stage 3: 3.2 And 3.3 Measure the real options value for the candidate option using the Binomial Lattice Method and. determine the optimal time to make an investment

Real Option Values for the smart firefighting using Binomial Lattice Method with results from System Dynamics Modeling

Period 0	**1**	**2**	**3**	**4**	**5**

Option Value to Wait for 1 Year

	548.79
	298.79
222.33	
88.88	
	90.08
	0

Option Value to Wait for 2 Years

		1,354.58
		1,104.58
	548.79	
	328.57	
222.33		222.33
97.74		0
	90.08	
	0	
		36.49
		0

Option Value to Wait for 3 Years

			3,343.53
			3,093.53
		1,354.58	
		1,116.97	
	548.79		548.79
	390.78		298.79
222.33		222.33	
133.65		88.88	
	90.08		90.08
	26.44		0
		36.49	
		0	
			14.78
			0

Option Value to Wait for 4 Years

				8,252.87
				8,002.87
			3,343.53	
			3,107.96	
		1,354.58		1,354.58
		1,140.87		1,104.58
	548.79		548.79	
	403.73		328.57	
222.33		222.33		222.33
139.24		97.74		0
	90.08		90.08	
	29.07		0	
		36.49		36.49
		0		0
			14.78	
			0	
				5.99
				0

Option Value to Wait for 5 Years

					20,370.64
					20,120.64
				8,252.87	
				8,022.34	
			3,343.53		3,343.53
			3,121.91		3,093.53
		1,354.58		1,354.58	
		1,185.99		1,116.97	
	548.79		548.79		548.79
	440.80		390.78		298.79
222.33		222.33		222.33	
160.71		133.65		88.88	
	90.08		90.08		90.08
	44.93		26.44		0
		36.49		36.49	
		7.86		0	
			14.78		14.78
			0		0
				5.99	
				0	
					2.43
					0

5.4. Results Comparison: The Smart Firefighting Operation

5.4.2. Comparison: Results from Real Options Dynamic Decision (RODD) Method vs. Real Option Analysis

Real Option Values for the Smart Firefighting Operation using Binomial Lattice Method with original data

Period 0	**1**	**2**	**3**	**4**	**5**

Option Value to Wait for 1 Year

	375.84
	125.84
96.89	
26.22	
	24.98
	-

Option Value to Wait for 2 Years

		1,457.90
		1,207.90
	375.84	
	251.69	
96.89		96.89
52.45		0
	24.98	
	0	
		6.44
		0

Option Value to Wait for 3 Years

			5,655.21
			5,405.21
		1,457.90	
		1,220.39	
	375.84		375.84
	273.90		125.84
96.89		96.89	
61.16		26.22	
	24.98		24.98
	5.46		0
		6.44	
		0	
			1.66
			0

Option Value to Wait for 4 Years

				21,936.61

				21,686.61
			5,655.21	
			5,422.01	
		1,457.90		1,457.90
		1,317.99		1,207.90
	375.84		375.84	
	313.85		251.69	
96.89		96.89		96.89
73.57		52.45		0
	24.98		24.98	
	10.93		0	
		6.44		6.44
		0		0
			1.66	
			0	
				0.43
				0

Option Value to Wait for 5 Years

					85,092.38
					84,842.38
				21,936.61	
				21,720.14	
			5,655.21		5,655.21
			5,438.34		5,405.21
		1,457.90		1,457.90	
		1,337.99		1,220.39	
	375.84		375.84		375.84
	324.53		273.90		125.84
96.89		96.89		96.89	
77.79		61.16		26.22	
	24.98		24.98		24.98
	13.60		5.46		0
		6.44		6.44	
		1.14		0	
			1.66		1.66
			0		0
				0.43	
				0	
					0.11
					0

LIST OF REFERENCES

Alkaraan, F., & Northcott, D. (2007). Strategic investment decision making: the influence of pre-decision control mechanisms. *QRAM*, *4*(2), 133–150.

Amit, R., & Zott, C. (2012). Creating Value Through Business Model Innovation. *Mit Sloan Management Review*, *53*(3), 41.

Angerhofer, B. J., & Angelides, M. C. (2000). System dynamics modelling in supply chain management. *Proceedings of the 32nd Conference: Winter Simulation*, 342.

Anthony, S. (2012). Kodak and the Brutal Difficulty of Transformation - Scott Anthony - Harvard Business Review. Retrieved September 23, 2012, from http://blogs.hbr.org/anthony/2012/01/kodak_and_the_brutal_difficult.html

Austen, B. (2011, November 10). The End of Borders and the Future of Books. *Businessweek*. Retrieved September 23, 2012, from http://www.businessweek.com/magazine/the-end-of-borders-and-the-future-of-books-11102011.html

Azadegan, A. (2011). Benefiting from Supplier Operational Innovativeness: The Influence of Supplier Evaluations and Absorptive Capacity. *JOURNAL OF SUPPLY CHAIN MANAGEMENT*, *47*(2), 49–64.

Baker, H. K., Dutta, S., & Saadi, S. (2011). Management Views on Real Options in Capital Budgeting. *Journal of Applied Finance*, *21*(1), 18–29.

Baker, L., Porter, M., Bishopric, C., & Change, R. (2012, January 5). Kodak prepares for Chapter 11 filing: report. *Reuters*. Retrieved August 31, 2012, from http://www.reuters.com/article/2012/01/05/us-eastmankodak-idUSTRE8031TQ20120105

Baldrige National Quality Program. (2013a). 2013-2014 Baldrige Criteria for Performance Excellence: Category and Item Commentary. Retrieved from http://www.nist.gov/baldrige/publications/upload/Category-and-Item-Commentary_BNP.pdf

Baldrige National Quality Program. (2013b). Education for Criteria for Performance Excellence. National Institure of Standards and Technology.

Benaroch, M. (2001). Option-Based Management of Technology Investment Risk. *IEEE Transactions on Engineering Management*, *48*(4), 428. doi:Article

Betz, F. (2001). *Executive Strategy : Strategic Management and Information Technology*. J. Wiley. Retrieved from http://ezproxy.lib.ucf.edu/login?URL=http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=71426&site=eds-live&scope=site

Bodie, Z., Kane, A., & Marcus, A. J. (2004). *Investments / Zvi Bodie, Alex Kane, Alan J. Marcus*. Boston, Mass. : McGraw-Hill Irwin, c2005.

Border Group, Inc. (2012, September). NYSE, New York Stock Exchange. Retrieved September 23, 2012, from http://www.nyse.com/about/listed/bgp.html

Boutellier, R., Eurich, M., & Hurschler, P. (2010). An Integrated Business Model Innovation Approach: It is Not All about Product and Process Innovation. *International Journal of E-Entrepreneurship and Innovation*, *1*(3), 1.

Bowersox, D., Closs, D., & Cooper, M. (2007). *Supply Chain Logistics Management* (Second Edition.). McGraw-Hill/Irwin series operations and decision sciences.

Bramante, J., Frank, R., & Dolan, J. (2010). IBM 2000 to 2010: continuously transforming the corporation while delivering performance. *Strategy & Leadership*, *38*(3), 35–43.

Brynjolfsson, E., Renshaw, A., & Alstyne, M. The Matrix of Change: A Tool for Business Process Reengineering (1997). Retrieved from http://ccs.mit.edu/moc/casestudyhowtouse.html

Brynjolfsson, E., Short, J., & Lizeo, E. eBusiness Transformation: Lessons from the Matrix of Change (1997). Retrieved from http://ccs.mit.edu/moc/casestudyhowtouse.html

Bucherer, E., Eisert, U., & Gassmann, O. (2012). Towards Systematic Business Model Innovation: Lessons from Product Innovation Management. *Creativity & Innovation Management*, *21*(2), 183–198.

Carmichael, D. G., Hersh, A. M., & Parasu, P. (2011). Real Options Estimate Using Probabilistic Present Worth Analysis. *Engineering Economist*, *56*(4), 295–320. doi:10.1080/0013791X.2011.624259

Carr, C., Kolehmainen, K., & Mitchell, F. (2010). Strategic investment decision making practices: A contextual approach. *Management Accounting Research*, *21*(3), 167–184. doi:10.1016/j.mar.2010.03.004

Chen, P. C. (2011). *Dynamics and architectures of innovation systems*. Massachusetts Institute of Technology, Engineering Systems Division, System Design and Management Program, Massachesetts. Retrieved from OAIster.

Chesbrough, H. (2007). Business model innovation : it's not just about technology anymore. *Strategy & leadership : a publication of Strategic Leadership Forum*, *35*(6), 12–17.

Chesbrough, H. (2010). Business Model Innovation: Opportunities and Barriers. *Long Range Planning*, *43*, 354–363.

Choi, K., & Bae, D. (2009). Dynamic Project Performance Estimation by Combining Static Estimation Models with System Dynamics. *Information and Software Technology*, *51*, 162–172.

Christensen, C. M., Alton, R., Rising, C., & Waldeck, A. (2011). The New M&A Playbook. *Harvard Business Review*, *89*(3), 48–57.

Chu, X. (2006). *System Dynamics Modeling for Human Performance in Nuclear Power Plant Operation* (Doctoral Dissertation). Massachusetts Institute of Technology, Engineering Systems Division, System Design and Management Program.

COL Kays, J., LTC Carlton, W., MAJ Lee, M., & CPT Ratliff, W. (1998). Analysis of Operational Readiness Rates. United States Military Academy West Point, New York 10996.

Comes, S., & Berniker, L. (2008). Business model innovation (pp. 65–86). Retrieved from http://ezproxy.lib.ucf.edu/login?URL=http://search.ebscohost.com/login.aspx?direct=true&db=edszbw&AN=EDSZBW560404522&site=eds-live&scope=site

Copeland, T. E., & Antikarov, V. (2005). Real Options: Meeting the Georgetown Challange. *Journal of Applied Corporate Finance*, *17*(2), 32–51. doi:10.1111/j.1745-6622.2005.00030.x

CoreBrand. (2013). CoreBrand Releases Annual Brand Power Top 100 Rankings Report. Retrieved November 22, 2013, from http://www.prnewswire.com/news-releases/corebrand-releases-annual-brand-power-top-100-rankings-report-149660305.html

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches (3rd ed.).* Thousand Oaks, CA US: Sage Publications, Inc. Retrieved from http://ezproxy.net.ucf.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2008-13604-000&site=eds-live&scope=site

Damle, P. (2003). *A System Dynamics Model of the Integration of New Technologies for Ship Systems*. Virginia Polytechnic Institure and State University.

Dempsey, M. J. (2003). A Multidisciplinary Perspective on the Evolution of Corporate Investment Decision Making. *Accounting, Accountability and Performance*, *9*(1).

Derler, P., Lee, E., & Vincentelli, A. (2012). Modeling Cyber–Physical Systems. *Proceedings of the IEEE*, *100*(1), 13–28.

Division of State Fire Marshal. (2012). Division of State Fire Marshal. Retrieved October 8, 2013, from http://www.myfloridacfo.com/division/sfm/#.UlROIBDvyk8

Driouchi, T., & Bennett, D. J. (2012). Real Options in Management and Organizational Strategy: A Review of Decision-making and Performance Implications. *International Journal of Management Reviews*, *14*(1), 39–62. doi:10.1111/j.1468-2370.2011.00304.x

Ebrahim, N., Ahmed, S., & Taha, Z. (2008). Dealing with Virtual R&D Teams in New Product Development. In *Proceedings of the 9th Asia Pasific Industrial Engineering & Management Systems Conference*.

FEMA: Emergency Management Institute. (n.d.). IS-100.b – Introduction to Incident Command System (ICS 100). Retrieved August 28, 2013, from http://emilms.fema.gov/IS100b/ICS0101000.htm

FEMA-Emergency Management Institute. (2012). Introduction to the Incident Command System (ICS 100). Retrieved from http://emilms.fema.gov/IS100b/ICS0102000.htm

Fire Suppression, Orange County Gov FL. (2013). Fire Suppression | Orange County Gov FL (official). Retrieved October 8, 2013, from http://www.orangecountyfl.net/EmergencySafety/FireSuppression.aspx

Fishman, G. S. (1996). *Monte Carlo : concepts, algorithms, and applications*. New York : Springer-Verlag, 1996.

Freeman, C. (1982). Economics of Industrial Innovation. *Economics of Industrial Innovation, 2nd*.

Frishammar, J., Kurkkio, M., Abrahamsson, L., & Lichtenthaler, U. (2012). Antecedents and Consequences of Firms' Process Innovation Capability: A Literature Review and a Conceptual Framework. *IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT*, *59*(4), 519–529.

Gassmann, O., & von Zedtwitz, M. (2003). Innovation Processes in Transnational Corporations. *The International Handbook of Innovation, Part 4*, 702–714.

Ghosh, B., & Chopra, P. (2003). *A Dictionary of Research Methods*. Leeds, UK: Wisdom House Publication.

Gilbert, C., & Bower, J. L. (2002). Disruptive change. When trying harder is part of the problem. *Harvard Business Review*, *80*(5), 94.

Godin, B. (2008). In the Shadow of Schumpeter: W. Rupert Maclaurin and the Study of Technological Innovation. *Minerva: A Review of Science, Learning & Policy*, *46*(3), 343–360.

Grasl, O. (2008). Business Model Analysis: A Multi-Method Approach. In *Proceedings of the System Dynamics Society*.

Hacura, A., Jadamus-Hacura, M., & Kocot, A. (2001). Risk analysis in investment appraisal based on the Monte Carlo simulation technique. *The European Physical Journal B - Condensed Matter and Complex Systems*, *20*(4), 551–553. doi:10.1007/s100510170238

Haddad, C., & Ewing, J. (2001). UPS vs. FedEx: Ground Wars - Businessweek. *Bloomberg Businessweek Magazine*. Retrieved October 31, 2013, from http://www.businessweek.com/stories/2001-05-20/ups-vs-dot-fedex-ground-wars

Hamel, G. (2006). The Why, What, and How of Management Innovation. *Harvard Business Review*, *84*(2), 72–84.

Hamel, G., & Breen, B. (2007). *The future of management / Gary Hamel ; with Bill Breen.* Boston, Mass. : Harvard Business School Press, c2007. Retrieved from http://ezproxy.net.ucf.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cat00846a&AN=ucfl.021737123&site=eds-live&scope=site

Hammer, M. (2004). Deep Change. *Harvard Business Review*, *82*(4), 84–93.

Hammer, M. (2005). Six Steps to Operational Innovation. *Harvard Business Review*. Retrieved December 1, 2012, from http://hbswk.hbs.edu/archive/4927.html

Harvard Business Publishing Newsletters. (2000). *United Parcel Service: The Balanced Scorecard Delivers the Goods for a Company on the Move*. Harvard Business Review.

Hill, F. (1993). Research Methodology and the management disciplines: The need for heterogeneity. *Irish Journal of Management*, *14*(2), 46–57.

IBM Archives: History of IBM. (n.d.). Retrieved November 3, 2012, from http://www-03.ibm.com/ibm/history/history/history_intro.html

Jetter, M., Satzger, G., & Neus, A. (2009). Technological Innovation and Its Impact on Business Model, Organization and Corporate Culture - IBM's Transformation into a Globally

Integrated, Service-Oriented Enterprise. *Business & Information Systems Engineering*, *1*(1), 37–45.

Jolly, V. K. (1997). Commercializing new technologies : getting from mind to market. Retrieved from http://ezproxy.lib.ucf.edu/login?URL=http://search.ebscohost.com/login.aspx?direct=true&db=cat00846a&AN=ucfl.023541387&site=eds-live&scope=site

Kaplan, R. S., & Norton, D. P. (2000). *The strategy-focused organization : how balanced scorecard companies thrive in the new business environment / Robert S. Kaplan, David P. Norton.* Boston, Mass. : Harvard Business School Press, c2001. Retrieved from http://ezproxy.lib.ucf.edu/login?URL=http://search.ebscohost.com/login.aspx?direct=true&db=cat00846a&AN=ucfl.020483423&site=eds-live&scope=site

Kaplan, R. S., & Norton, D. P. (2007). Using the Balanced Scorecard as a Strategic Management System. *Harvard Business Review*, *85*(7/8), 150–161.

Kary, T., & Sandler, L. (2012, February 16). Borders Files Bankruptcy, Is Closing Up to 275 Stores. *Bloomberg*. Retrieved September 23, 2012, from http://www.bloomberg.com/news/2011-02-16/borders-book-chain-files-for-bankruptcy-protection-with-1-29-billion-debt.html

Katzy, B. (2003). Integrating Real-Options Reasoning and the Innovation Diffusion Curve for Decision-Making Under Uncertainty. CeTIM Working Paper 1603,University BW Munich, Neubiberg.

Kodukula, P., & Papudesu, C. (2006). *Project Valuation Using Real Options A Practitioner's Guide*.

Kong, J. J., & Kwok, Y. K. (2007). Real options in strategic investment games between two asymmetric firms. *European Journal of Operational Research*, *181*(2), 967–985. doi:10.1016/j.ejor.2006.07.006

Landsberger, M., Cruz, L., Onkham, W., Rabelo, L., & Ajayi, R. (2013). International Technology Investments Using Real Options: A Case Study in Telecommunications. *Journal of Management and Engineering Integration*, (Summer 2013).

Landsberger, M., Onkham, W., Cruz, L., Rabelo, L., Ajayi, R., & Figueroa, L. (2013). Hybrid Real Options for Emerging Technologies, Green Energy, and Innovation. In *Proceedings of the 2013 Institute of Industrial Engineers Annual Research Conference*. San Juan, Puerto Rico.

Lerner, J. (2012). *The Architecture of Innovation: The Economics of Creative Organizations*. Boston, Massachusetts: Harvard Business Review Press.

Levy, M. (2001). Case Study: United Parcel Service, Inc. (UPS). Pearson. Retrieved from http://www.peachpit.com/articles/article.aspx?p=20881

Markides, C. (2012). How Disruptive Will Innovations from Emerging Markets Be? *Mit Sloan Management Review*, *Fall 2012*. Retrieved from http://sloanreview.mit.edu/the-magazine/2012-fall/54120/how-disruptive-will-innovations-from-emerging-markets-be/

Mathews, S. (2011). Innovation Portfolio Architecture Part 2: Attribute Selection and Valuation. *Research Technology Management*, *54*(5), 37–46. doi:10.5437/08956308X5405005

Mathews, S., Datar, V., & Johnson, B. (2007). A Practical Method for Valuing Real Options: The Boeing Approach. *Journal of Applied Corporate Finance*, *19*(2), 95–104. doi:Article

McGrath, R. (2011). Finding Opportunities in Business Model Innovation. *The European Financial Review*, 14–17.

Moenaert, R. K., Robben, H., Antioco, M., de Schamphelaere, V., & Roks, E. (2010). Strategic Innovation Decisions: What You Foresee Is Not What You Get. *Journal of Product Innovation Management*, *27*(6), 840–855. doi:10.1111/j.1540-5885.2010.00755.x

Mun, J. (2006). *Modeling risk : applying Monte Carlo simulation, real options analysis, forecasting, and optimization techniques / Johnathan Mun*. Hoboken, N.J. : John Wiley & Sons, c2006.

Mun, J., & Housel, T. (2010). A Primer on Applying Monte Carlo Simulation, Real Options Analysis, Knowledge Value Added, Forecasting, and Portfolio Optimization. NAVAL POSTGRADUATE SCHOOL.

Munoz, C. (2006). *A real option strategic scorecard decision framework for IT project selection*. Orlando, Fla. : University of Central Florida, 2006. Retrieved from http://ezproxy.lib.ucf.edu/login?URL=http://search.ebscohost.com/login.aspx?direct=true&db=cat00846a&AN=ucfl.025837129&site=eds-live&scope=site

Mussa, Y. (2009). *A System Dynamics Model for Operations Management Improvement in Multi-plant Enterprise*. Delft University of Technology.

Myers, S. C. (1984). Finance Theory and Financial Strategy. *Interfaces*, *14*(1), 126–137.

Nagar, N. (2011). Modeling Investment under Uncertainty in Indian Electricity Sector with Real Option Approach: A Review. *International Journal of Business Insights & Transformation*, *5*(1), 32–41. doi:Article

Narvekar, R. S., & Jain, K. (2006). A new framework to understand the technological innovation process. *JOURNAL OF INTELLECTUAL CAPITAL*, *7*(2), 174–186.

National Incident Management System. (2008). Appendix B: Incident Command System. Federal Emergency Management Agency (FEMA). Retrieved from http://www.fema.gov/pdf/emergency/nims/NIMS_AppendixB.pdf

Onkham, W., Elattar, A., & Rabelo, L. (2013). Effective Leadership using System Dynamics and the Matrix of Change. In *Proceedings of the 2013 Institute of Industrial Engineers Annual Research Conference*. San Juan, Puerto Rico, May 18-22, 2013.

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. Hoboken, NJ: Wiley & Sons.

Osterwalder, A., Pigneur, Y., & Tucci, C. (2005). Clarifying Business Models: Origins, Present, and Future of the concept. *Communications of AIS*, *2005*(16), 1–25.

Peschl, M. F., & Fundneider, T. (2012). Spaces enabling game-changing and sustaining innovations: why space matters for knowledge creation and innovation. *Journal of Organisational Transformation & Social Change*, *9*(1), 41–61.

Power, B. (2012). Business Model Innovation Through Process Change. *Harvard Business Review*. Retrieved from http://blogs.hbr.org/cs/2012/08/business_model_innovation_thro.html

Ross, J., Draper, W., Kang, P., Schuler, S., Gozum, O., & Tolle, J. (2002). United Parcel Services: Business Transformation through Infomation Technology. *Massachusetts Institute of Technology Sloan School of Management: Center for Information System Research*.

Ruttan, V. W. (1959). Usher an Schumpeter on Invention, Innovation, and Technological Change. *Quarterly Journal of Economics*, *73*(4), 596–606.

Sáenz-Diez, R., Gimeno, R., & de Abajo, C. (2008). Real Options Valuation: A Case Study of an E-commerce Company. *Journal of Applied Corporate Finance*, *20*(2), 129–143. doi:Article

Sandler, L. (2010, August 21). Kodak Investor Asks U.S. Trustee to Probe "Secretive" Bid. *Bloomberg*. Retrieved August 31, 2012, from http://www.bloomberg.com/news/2012-08-20/kodak-investor-asks-u-s-trustee-to-probe-patent-bidding.html

Sargent, R. (2005). Verification and Validation of Simulation Models. In *Proceedings of the 2005 Winter Simulation Conference*.

Schlangenstein, M. (2013). UPS Crunches Data to Make Routes More Efficient, Save Gas - Bloomberg. *Bloomberg*. Retrieved October 31, 2013, from http://www.bloomberg.com/news/2013-10-30/ups-uses-big-data-to-make-routes-more-efficient-save-gas.html

Schön, D. A. (1967). Technology and change; the new Heraclitus. Retrieved from http://ezproxy.lib.ucf.edu/login?URL=http://search.ebscohost.com/login.aspx?direct=true&db=cat00846a&AN=ucfl.023006671&site=eds-live&scope=site

Sharma, D., Sahay, B., & Sachan, A. (2004). Modelling Distributor Performance Index Using System Dynamics Approach. *Asia PacificJournal of Marketing and Logistics*, *16*(3), 37–67.

Silvola, H. (2008). Capital Budgeting Methods, Management Control Systems and the R&D Intensity of the Firm. *International Journal of Accounting and Finance*, *1*(2), 168–192. doi:http://www.inderscience.com/browse/index.php?journalID=231

Smith, J. E. (2005). Alternative Approaches for Solving Real-Options Problems. *Decision Analysis*, *2*(2), 89–102. doi:10.1287/deca.1050.0041

Spekman, R., & Composit, J. FedEx and UPS-The War Continues. , Darden School of Business (2004).

Stalk, G., Evans, P., & Shulman, L. E. (1992). Competing on Capabilities: The New Rules of Corporate Strategy. *Harvard Business Review*, *70*(2), 57–69.

Sterman, J. (2000). *Business dynamics : systems thinking and modeling for a complex world*. Boston : Irwin/McGraw-Hill, c2000.

Sterman, J. (2001). System Dynamics Modeling: Tools for Learning in a Complex World. *California Management Review*, *43*(4), 8–25.

Subrahmanian, E., & Jones, A. (2013). Systems Engineering from Cyber-Physical Systems to Cyber-Physical Social Systems. *Procedia Computer Science*.

Sullivan, M. (1990). The Competitive Advantage of Nations. *Magill's Book Reviews*, 1–1.

SyncForce, R. the B. (2001). UPS Brand Ranking. Retrieved November 22, 2013, from http://www.rankingthebrands.com/Brand-detail.aspx?brandID=29

Tan, B., Anderson, E., Dyer, J., & Parker, G. (2010). Evaluating system dynamics models of risky projects using decision trees: alternative energy projects as an illustrative example. *System Dynamics Review*, *26*(1), 1–17.

The National Fire Research Laboratory. (n.d.). Project: Smart Firefighting. Retrieved August 28, 2013, from http://www.nist.gov/el/fire_research/firetech/project_sff.cfm

Thiel, A. (2013). Fire Department | City of Alexandria, VA. Retrieved October 30, 2013, from http://www.alexandriava.gov/Fire

Trigeorgis, L. (1993a). Real Options and Interactions with Financial Flexibility. *Financial Management*, *22*(3), 202–224.

Trigeorgis, L. (1993b). The Nature of Option Interactions and the Valuation of Investments with Multiple Real Options. *Journal of Financial & Quantitative Analysis*, *28*(1), 1–20.

Trigeorgis, L. (2005). MAKING USE OF REAL OPTIONS SIMPLE: AN OVERVIEW AND APPLICATIONS IN FLEXIBLE/MODULAR DECISION MAKING. *Engineering Economist*, *50*(1), 25–53. doi:10.1080/00137910590917026

U.S. Fire Administration. (2013). Fire Estimates: Residential and Nonresidential Buildings. Retrieved September 14, 2013, from http://www.usfa.fema.gov/statistics/estimates/

U.S. Fire Administration/National Fire Academy. (2010). Field Operations Guide: ICS 420-1. Federal Emergency Management Agency (FEMA). Retrieved from http://www.usfa.fema.gov/downloads/pdf/publications/field_operations_guide.pdf

U.S. Fire Administration/National Fire Academy. (2012). Fire Department Communications Manual - A Basic Guide to System Concepts and Equipment (FA-160). Federal Emergency Management Agency (FEMA). Retrieved from http://www.usfa.fema.gov/fireservice/ops_tactics/radio_communications/

U.S. Fire Statistics. (2013). U.S. Fire Statistics | Reports, Estimates and Trends. Retrieved October 8, 2013, from http://www.usfa.fema.gov/statistics/

Unver, H. (2008). *A comparative study of Lotka-Volterra and system dynamics models for simulation of technology industry dynamics* (Master of Science in Engineering and Management). Massachusetts Institute of Technology.

UPS Company Annual Report. (1999). UNITED PARCEL SERVICE INC - 10-K Annual Report - 12/31/1999. Retrieved October 29, 2013, from http://www.investors.ups.com/phoenix.zhtml?c=62900&p=irol-reportsannual

UPS Company-Investor Relations. (2013). UPS - Investor Relations - Annual Reports. Retrieved October 29, 2013, from http://www.investors.ups.com/phoenix.zhtml?c=62900&p=irol-reportsannual

UPS:Technology & Innovation. (n.d.). Retrieved June 26, 2013, from https://ups.managehr.com/technology-innovation.htm

US Department of Commerce, N. (2012). Project: Smart Firefighting. Retrieved June 4, 2013, from http://www.nist.gov/el/fire_research/firetech/project_sff.cfm

Utterback, J.M., & Abernathy, W. J. (1990). A dynamic model of process and product innovation. *The Economics of Innovation*, 10–27.

Utterback, James M. (1971). The Process of Technological Innovation Within the Firm. *Academy of Management Journal*, *14*(1), 75–88. doi:10.2307/254712

Van de Ven, A. H. (1999). *The innovation journey*. New York : Oxford University Press, 1999. Retrieved from http://ezproxy.lib.ucf.edu/login?URL=http://search.ebscohost.com/login.aspx?direct=true&db=cat00846a&AN=ucfl.025626434&site=eds-live&scope=site

Vanhaverbeke, W., Van de Vrande, V., & Chesbrough, H. (2008). Understanding the advantages of open innovation practices in corporate venturing in terms of real options. *Creativity and Innovation Management*, *17*(4), 251–258.

Whitelock, J., & Jobber, D. (2000). An Exploratory Investigation into the Impact of Competitor Environment and the Role of Information on the Decision to Enter a New, Non-Domestic Market. *Journal of Global Marketing*, *13*(2), 67–83. doi:10.1300/J042v13n02_05

Winch, G. W. (2001). Management of the “skills inventory” in times of major change. *SYSTEM DYNAMICS REVIEW*, *17*, 151–160.

Zott, C. (Sonstige beteiligte P., & Amit, R. (Sonstige beteiligte P. (2002). Measuring the performance implications of business model design : evidence from emerging growth public firms. *Faculty & research*. Retrieved from http://ezproxy.lib.ucf.edu/login?URL=http://search.ebscohost.com/login.aspx?direct=true&db=edszbw&AN=EDSZBW345546121&site=eds-live&scope=site