# STARS

University of Central Florida
STARS

Electronic Theses and Dissertations, 2004-2019

2013

# Exploring The Innovation Environment Within The Systems Engineering Context Of A Defense Organization: A Preliminary Framework

Khaled Odeh University of Central Florida

Part of the Industrial Engineering Commons Find similar works at: https://stars.library.ucf.edu/etd University of Central Florida Libraries http://library.ucf.edu

This Doctoral Dissertation (Open Access) is brought to you for free and open access by STARS. It has been accepted for inclusion in Electronic Theses and Dissertations, 2004-2019 by an authorized administrator of STARS. For more information, please contact STARS@ucf.edu.

#### **STARS Citation**

Odeh, Khaled, "Exploring The Innovation Environment Within The Systems Engineering Context Of A Defense Organization: A Preliminary Framework" (2013). *Electronic Theses and Dissertations, 2004-2019.* 2671.

https://stars.library.ucf.edu/etd/2671



# EXPLORING THE INNOVATION ENVIRONMENT WITHIN THE SYSTEMS ENGINEERING CONTEXT OF A DEFENSE ORGANIZATION: A PRELIMINARY FRAMEWORK

by

# KHALED S ODEH

# B.S. Embry-Riddle Aeronautical University, 1994 M.S. Webster University, 2001

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

# Summer Term 2013

Major Professors: Luis Rabelo Ahmad Elshennawy © 2013 Khaled Odeh

#### ABSTRACT

Innovation may involve the introduction of ideas for designing or producing new products, or introducing improvements to products, processes, services or any other aspect of an organization to the market place. A major element for measuring organizational strength is its perception of innovation and the ability of the organization to build on and sustain such strength. While there is no shortage of research and study materials on innovation, there is, however, a shortage of thorough and realistic analysis of the intersection of innovation management, and measurement of innovation within the systems engineering context of defense organizations. In addition, while most research studies seem to adopt strictly quantitative innovation factors in determining innovation success and performance, they seem to have overlooked the qualitative side of it.

An objective of this research study is to address the need for exploring the innovation environment within the systems engineering context of a defense organization. In addition, the research presents a new model for exploring innovation factors within the examined environment, using both quantitative and qualitative factors. The research uses a number of data collection instruments that include a survey construct to gather quantitative and qualitative data. The study identified significant factors that could be used to properly determine innovation within the systems engineering context of defense organizations using traditional statistics and data mining modeling. New indicators such as security and organizational leadership are discovered as important to define, monitor, and assess the innovation of the defense industry within the context of systems engineering.

iii

#### ACKNOWLEDGMENTS

First and foremost, I'd like to thank Almighty God for giving me the chance of being. I am grateful for the countless bounties he's bestowed upon me. I pray that this humble effort of mine may become of benefit to my fellow humans.

Second; I'd like to offer my deepest gratitude to Professors Luis Rabelo and Ahmad Elshennawy for his enduring patience, everlasting encouragement, and enlightened guidance during the last three years. Professor Rabelo and Professor Elshennawy were an inspirational role model. I'd also like to thank the elite Doctoral Committee for their guidance, vision, and encouragement.

I also would like to take this opportunity to express my indebtedness to all my friends and coworkers for their great assistance with this study.

Words can't express the many things I want to say to my wife Ofelia and two kids Ahmad and Ali. I love you all from the bottom of my heart.

I wish if I can give individual acknowledgment to all those who had contributed somehow to this work, but I can't, so I am truly grateful to each and every one who has participated by any means to this study. Your contributions are highly appreciated.

#### **Khaled S Odeh**

LIST OF	FIGURESvi	ii
LIST OF	TABLES	х
LIST OF	ACRONYMS/ ABBREVIATIONS	ĸi
СНАРТЕ	R 1. INTRODUCTION	1
1.1	Background	1
1.2	Research Intent	3
1.3	Research Question	4
1.4	Limitations	4
1.5	Significance of Study	5
1.6	Scope and Focus	6
1.7	Background and Contribution of the Researcher	6
1.8	Structure of the Dissertation	7
1.9	Definitions	8
СНАРТЕ	R 2. LITERATURE REVIEW 1	1
2.1	Innovation1	3
2.2	Innovation Models 1	5
2.3	Evolution of Process of Adoption of Innovation 2	1
2.4	Innovation Management	2
2.5	Measuring Innovation	7
2.6	Systems Engineering	7
2.7	Defense Organizations 4	1
2.8	Documentations	9
2.9	Direct Observation	2
2.10	Discussion of Research Gaps	5
CHAPTE	R 3. RESEARCH METHODOLOGY5	7
3.1	Introduction5	7
3.2	Methodology Outline	7
3.2.	1 Conceptualization 6	0
3	.2.1.1 Potential Research Problem 6	0
3	.2.1.2 Define Research Questions 6	0
3	.2.1.3 Literature Review	1
3	.2.1.4 Gap Analysis 6	1
3	.2.1.5 Defining Success	2
3	.2.1.6 State Constructs	2
3.2.	2 Operationalization	4
3	.2.2.1 Data Collection	4
3	.2.2.2 Survey	5
3	.2.2.3 Data Analysis and Modeling 6	6
3	.2.2.4 Traditional Statistics	7

## TABLE OF CONTENTS

3.2.2.5 Data Mining Modeling	67
3.2.2.6 Compare & Contrast with Literature	68
3.2.3 Conclusion	68
3.2.3.1 Infolding Literature	68
3.2.3.2 Reaching Conclusion	69
3.3 Summary	69
CHAPTER 4. KNOWLEDGE DISCOVERY AND ANALYSIS	71
4.1 Introduction	71
4.2 Preliminary Innovation Model - Quantitative and Qualitative Factors	72
4.2.1 Quantitative Factors	73
4.2.2 Qualitative Factors	74
4.2.3 Potential Quantitative and Qualitative Innovation Factors	75
4.3 Expert Evaluation	84
4.4 Survey Construct	85
4.5 Validity, Reliability, and Consistency of the Construct	87
4.5.1 Factor Analysis	92
4.6 Modeling	96
4.7 Principal Component Analysis (PCA) to Visualize Linear Separability	97
4.8 Factorial Analysis and Logistic Regression	. 100
4.8.1 Forward with Factorial Analysis	. 102
4.9 Data Mining Modeling	. 106
4.9.1 Neural Networks	. 106
4.9.1.1 The Selection of a Neural Network Architecture	. 108
4.9.1.2 Elimination of Input Variables (i.e., Factors)	. 111
4.9.2 Classification/Regression Trees	. 116
4.10 Summary of Data Analysis and Findings	. 121
4.10.1 Survey Construct Data Analysis and Findings	. 121
CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS	. 127
5.1 Introduction	. 127
5.2 Research Summary	. 128
5.3 Conclusions	. 131
5.4 Contributions to the Body of Knowledge	. 133
5.5 Case Study (Recipe)	. 134
5.5.1 Agent: The Innovator Assessor	. 136
5.5.2 Agent: Project Review Board (PRB)	. 136
5.5.3 Agent: The Chief Technological Officer (CTO)	. 137
5.6 Future Research	. 137
APPENDIX A: SURVEY QUESTIONS	. 139
APPENDIX B: IRB HUMAN SUBJECTS PERMISSION LETTER	. 145
APPENDIX C: SURVEY QUESTIONS CODED TO BE USED IN THE DATA ANALYSIS	. 147

APPENDIX D: COLLECTED SURVEY DATA	
LIST OF REFERENCES	

## LIST OF FIGURES

Figure 2-1: First generation technology push models (1950s to mid-1960s). Source: Rothwell (1991, Ref. 9, p. 33; amended)
Figure 2-2: Second generation demand pull models. Source: Rothwell (1991, Ref. 9, p. 33) 17
Figure 2-3: The coupling or interactive model of innovation. Source: Rothwell (1993, Ref. 7, p. 21)
Figure 2-4: An integrated (fourth generation) innovation model. Source: Rothwell (1993, Ref. 7, p. 22)
Figure 2-5: An example of systems integration and networking model. Source: Trott (1998), cited in Mahdi (2002, Ref. 61, p. 45)
Figure 2-6: Funnel Model Nine Stages Measuring Innovation, Morris (2008)
Figure 2-7: (DAU 2001)
Figure 2-8: Literature Review for Innovation Measurement Models
Figure 3-1: Methodology Phase and Flow 59
Figure 4-1: Proposed Innovation Measurement Model (Preliminary)
Figure 4-2: Visualization of the entire survey results using Weka (http://www.cs.waikato.ac.nz/ml/weka/)92
Figure 4-3: Total Variance Explained
Figure 4-4: First Principal Component vs. Second Principal Component displaying a good level of linear separability
Figure 4-5: Most Important Variables Using Logistic Regression
Figure 4-6: A Multilayer Neural Network 108
Figure 4-7: Selection of the Neural Network Architecture with two (2) Hidden Units
Figure 4-8: Importance of Input Variables (e.g., factors) via Sensitivity Analysis
Figure 4-9: Elimination of Input Variables (i.e., factors)113
Figure 4-10: Finalized Neural Network Developed with the Most Important Factors. The Neural Network uses 13 Factors as Inputs, 2 Hidden Neurons in one Hidden Layer, and One Output Neuron in the Output Layer representing Innovation
Figure 4-11: CART Classification Tree for Diagnostic Biomarker for Bacterial Infection (adapted and modified from http://1.salford-systems.com/case-study-new-biomarker-discovered-for-critically-ill-childeren-diagnostic/)
Figure 4-12: Example of Classification/Regression Tree Developed for Innovation using the

Figure 4-13: Classification/Regression Tree using CART to model the Innovation Env	/ironment
Factors of this research. As an example: IF ProfitGrowth is greater than 3.5 and IF S	ecurity is
greater than 2.5 Then is BLUE (Innovative Yes)	120
Figure 4-14: Most Importance of Variables Using Classification/Regression Tree usir the Training Data Set of 200.	ng CART and 121
Figure 4-15: Analysis of Significant Factors of all Three Methods	124

## LIST OF TABLES

Table 2-1: Evolution of Innovation Metrics by Generation; Source: Center of AcceleratingInnovation, George Washington University (2006).16
Table 2-2: Systems Engineering Definitions Evolution (Adapted from Teper (2010))
Table 4-1: Eliminated Factors.    85
Table 4-2: Respondents' Innovation Determination Classifications (Yes and No)
Table 4-3: Respondents' Innovation Determination Classifications (1 to 3 Scale)
Table 4-4: Respondents' Innovation Determination Classifications (1 to 4 Scale)
Table 4-5: Respondents' Innovation Determination Classifications (1 to 5 Scale)
Table 4-6: Total Variance Explained
Table 4-7: Rotated Factor Matrix
Table 4-8: Reliability Statistics.    95
Table 4-9: Modeling Methodologies
Table 4-10: Basic Features of each Modeling Methodology.         96
Table 4-11: PCA Using MATLAB
Table 4-12: Forward LR Variables in the Equation.         102
Table 4-13: Logistic Regression Performance with FA (SSE is Summatory of the Squared Error).
Table 4-14: Neural Network Performance
Table 4-15: Classification/Regression Tree Performance
Table 4-16: Performance for Factors for all Three Methods (Logistic Regression, Neural Networks, and Classification/Regression Trees). An ensemble is a voting strategy of the different methods
Table 5-1: Recipe Innovation Project Data       135

## LIST OF ACRONYMS/ ABBREVIATIONS

BSC	Balanced Scorecard
BCG	Boston Consulting Group
CART	Classification and Regression Tree
CEO	Chief Executive Officer
CSIIC	Canadian Science and Innovation Indicators Consortium
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GPS	Global Positioning System
INCOSE	International Council on Systems Engineering
KM	Knowledge management
LR	Logistic Regression
NN	Neural Networks
NPD	New Product Development
OECD	Organization for Economic Co-operation and Development
PCA	Principal Component Analysis
R&D	Research and Development
R2I	Return on Innovation Investment
ROI2	Return on Innovation Investment
RT	Regression Trees
SPSS	Statistical Package for Social Sciences
S&T	Science and Technology

- SMEs Small and Medium-sized Enterprises
- TCI Team Climate Inventory
- UK United Kingdom
- USA United States of America

#### **CHAPTER 1. INTRODUCTION**

#### 1.1 Background

Innovation capability is the most important determinant of firm performance (Mone et al., 1998). Innovations are described with different emphasis. Narvekar and Jain (2006) describe innovation from the dimension of new technologies and their development through marketing-based new technology and inventions. Betz (2001) thinks of innovation as new things/artifacts to increase business success and sustainability. Sullivan (1990) has a more commercial viewpoint emphasizing new ways of doing activities through commercialization of technologies. Finally, Freeman (1982) has a more radical viewpoint considering innovation as formed by different components of novelty that increase profit by the use of knowledge to generate new products or services, new processes, new structures and new markets. Onkham et al., (2013) explains very well that Innovations are categorized within five categories: product, process, market development, new sources, and new organizational structures. In addition, a sixth one can be added that is business model innovation that is the most radical one.

- Product innovation generates new products or improves the product's quality and/or performance.
- Process innovation is a new task or activity to manufacture products or services in order to decrease cost and/or increase productivity.
- New market innovation focuses on new customers. This can involve new strategies or new marketing attractiveness.

- Sources of development suppliers innovation focuses in increasing the number of suppliers in way to reduced cost and/or get strategic advantages and higher levels of quality.
- **Organizational structure innovation** focuses on the development of management and its structure which relate to process innovation.
- **Business model innovation** is the change of the entire business model (i.e., how it makes money) and reason for existence of the organization.

The literature presents enough evidence to show that competitive success is dependent upon an organization's management of the innovation process and proposes factors that relate to successful management of the innovation process (cf. inter alia Balachandra and Friar, 1997; Cooper, 1979 a,b; De Brentani, 1991; Di Benedetto, 1996; Ernst, 2002; Globe et al., 1973; Griffin, 1997; Rothwell, 1992). This process should be assessed to ensure effectiveness. To assess innovation capability, organizations should have a meaningful way of measuring innovation and how it is managed within the organization. A diversity of approaches, prescriptions and practices have been implemented and searched that can be confusing and contradictory. Farther more one of the engines of economy growth in the United States of America (USA) is the defense industry and at the heart of the defense industry is systems engineering.

This study is concerned with identifying the significant and critical factors that could determine if a project is a successful innovation project within the context of systems engineering in defense organizations as related to the engineered systems/products built by

them. The defense industry has a history of creating revolutionary innovations. Innovations such as the jet engine, spacecrafts, nuclear weapons and nuclear power, spaceflight, computers, and the internet each transformed our society. Therefore, this research is based on engineered systems/product innovations.

#### 1.2 Research Intent

There is no shortage of research and study materials on innovation. There is, however, a shortage of thorough and realistic analysis of the intersection of innovation, management, and the measurement of innovation, within the context of defense organizations. Within such environment of a large defense company (and, both directly and indirectly, other organizations within the same industry), the purpose of this research is to explore the management and the measuring of innovation.

The objective of this research is to identify the elements that contribute to the management and measurement of innovation in defense-related organizations and propose models to access these factors. Our research is focus on the systems engineering organization quantifying its contribution to the organization's value of innovation.

#### 1.3 <u>Research Question</u>

#### Based on extensive literature search, the following research questions have been identified:

- What are the current factors that contribute to the innovation within the systems engineering context of a defense organization?
- Are the proposed factors effective in determining innovation within the examined environment?

The first research question seeks to explore the nature, characteristics, challenges, opportunities, environment, culture, and the key factors of measuring innovation within the systems engineering context of a defense company.

The second research question seeks to investigate and assess the effectiveness of the proposed models in measuring innovation within the examined environment.

#### 1.4 Limitations

Although a defense organization could be rich in innovation resources, it could be argued that lack of innovation management and measurement model may influence the organization current post. Another potential limitation of the study is that it relied mainly on the findings in the major defense industry organizations in 2013. The primary data were collected within the systems engineering context of defense industry, which represents the viewpoint of the selected personnel towards the study in hand. Nevertheless, many parallels can be drawn from this study that is applicable to other organizations, not only in the defense industry, but also other industries.

#### 1.5 Significance of Study

While most if not all studies that pertain to measuring innovation has been conducted within the context of private organizations, no significant study has been conducted within the context of systems engineering in defence organization. Systems engineering effectively 'gives birth' to missions, turning an initial idea into a full system description, with all necessary elements integrated into a complete whole (www.esa.int).

In addition, while most existing studies seem to adopt a technical/quantitative approach, they seem to overlook in their majority the socio-cultural and organizational aspect of the management and their impact on innovation. This study addresses the identified gaps by exploring multiple factors from deferent viewpoints (organization structure, organization leadership, education, experience, motivation, etc.). The findings can have a practical impact on currently existing practices, and introducing changes that may directly affect the way academics and practitioners approach the management of innovation and how to study their impact.

#### 1.6 Scope and Focus

The scope of this research is encapsulated in the main research questions, examining organizational and human issues such as the organizational structure, organizational culture, and employees educational and experience, and their impact on innovation within the organization.

This research is conducted in defense organizations using various data collection instruments including interviews, documentations, and observations. The study was carried primarily using interviews representing the major organization in the USA defense industry (Lockheed Martin, Boeing, Northrop Grumman, Raytheon, Cubic, and SAIC).

In addition to the contribution of the findings of this research study to the existing body of knowledge, the findings can also have a practical impact on currently existing practices, and introducing changes that may directly affect the way academics, practitioners, executives, and policy makers approach the management of innovation.

#### 1.7 Background and Contribution of the Researcher

The Researcher has over twelve years of experience in the area of engineering with different defense organization. The researcher's received his B.S. degree in Avionics Engineering from Embry-Riddle Aeronautical University, and M.S. Computer Science from Webster University.

The researcher current role is a Systems Engineer Architect Manager in a defense organization. His current responsibilities include systems design, systems software and hardware integrations and test, systems acceptance testing and user evaluation on variety of real time simulation systems. Working on proposals and capturing new businesses. The researcher manages over 20 systems engineers across multiple programs, responsibilities include employees' career development, performance assessment and evaluation, and mentoring and support programs staffing needs. As a manager and leader, the researcher encourages his employees to be creative and bring new ideas to drive innovation within his department and the organization.

#### 1.8 Structure of the Dissertation

**Chapter 1** - Introduction: This chapter provides the reader with a background on the thesis, aim of the study, significance of the study, research questions, and background on the researcher.

**Chapter 2** – Literature Review: This chapter provides the Literature review and theoretical framework: covers innovation definitions, innovation models, process of adoption of innovation, innovation management, measuring innovation, and defense organizations.

**Chapter 3** – Research Methodology: This chapter includes a review of the principles of research, a description of the derivation of the research questions for the thesis, and the chosen methodology, including the methods and survey instruments developed to collect the

necessary data. The chapter reflects on methodological strengths and weaknesses, lessons learnt and how the method has evolved throughout the study.

**Chapter 4** – Findings and Data Analysis: This chapter presents the case study data findings from the conducted interviews, documentation, and observation in the examined organization, along with an analysis that address all research questions. This chapter draws together all of the elements from the preceding chapters to enable the research questions to be answered and conclude the thesis.

**Chapter 5** - Conclusions and Recommendations: This chapter presents the conclusions of the study, and some of the implications for practice that arise from the findings. The chapter includes a summary of the thesis, the contribution of the thesis, limitations of the research, and suggestions for possible future research. The appendices for reference and copies of the survey instruments developed and used within the research methodology are also included.

#### 1.9 Definitions

**Defense Industry**, also called the military industry, comprises government and commercial industry involved in research, development, production, and service of military materiel, equipment and facilities.

**Engineering** is the science, skill, and profession of acquiring and applying scientific, economic, social, and practical knowledge, in order to design, build, and maintain structures, machines, devices, systems, materials and processes. In layman's terms, it is the act of using insights to conceive, model and scale a solution to a problem.

**Innovation** is production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production; and establishment of new management systems (Acs and Audretsch, 1990).

**Innovation management** describes the decisions, activities, and practices that move an idea to realization for the purpose of generating business value. It is managing the investment in creating new opportunities for generating customer value that are needed to sustain and grow the business or company.

**Innovation Strategy** is generally understood to describe an organization's innovation posture with regard to its competitive environment in terms of its new product and market development plans (Dyer and Song, 1998).

*Knowledge Management (KM)* The organization's ability to identify, acquire and utilize external knowledge can be critical to a firm's successful operation (Zahra and George, 2002).

*Logistic Regression* The organization's ability to identify, acquire and utilize external knowledge can be critical to a firm's successful operation (Zahra and George, 2002).

**Organization Culture** is the collective behavior of humans who are part of an organization and the meanings that the people attach to their actions. Culture includes the organization values, visions, norms, working language, systems, symbols, beliefs and habits. It is also the pattern of such collective behaviors and assumptions that are taught to new organizational members as a way of perceiving, and even thinking and feeling. Organizational

culture affects the way people and groups interact with each other, with clients, and with stakeholders (Schein, 1985).

**Project Management** is having an efficient process that is able to manage the ambiguity of the innovation is universally agreed to be critical to innovation (Globe et al., 1973).

*Qualitative Methods* are ways of collecting data which are concerned with describing meaning, rather than with drawing statistical inferences. What qualitative methods (e.g. case studies and interviews) lose on reliability they gain in terms of validity. They provide a more in depth and rich description.

*Quantitative Methods* have come under considerable criticism. In modern research, most psychologists tend to adopt a combination of qualitative and quantitative approaches, which allow statistically reliable information obtained from numerical measurement to be backed up by and enriched by information about the research participants' explanations.

*Systems Engineering* is an interdisciplinary approach and means to enable the realization of successful systems. Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation (Ryen, 2008).

#### **CHAPTER 2. LITERATURE REVIEW**

The mere act of measuring innovation activity will have an effect on the overall innovative capability of the organization. 'If you don't measure it, you can't improve it' the famous quotation from economist and quality management academic, W. Edwards Deming forms the fundamental basis for this research. Many organizations claim to be innovative, creative and ahead of their competitors despite the fact they are not using appropriate metrics for innovative processes and outputs. There must be organisational support for the development of more accurate policies to ensure innovation cultures are developed from organization inception.

This chapter follows research motivation and purpose mentioned in chapter 1 and discusses background knowledge, terminologies and definitions through literature review. The topics included in this literature review are directly relevant to innovation and its surrounding environment. Understanding them should provide the reader with a holistic view of innovation and its key components. This chapter covers the following topics:

*Section 2.1:* Innovation - Before beginning to identify innovation models, it is first necessary to define innovation. This section presents a wide variety of innovation definitions.

Section 2.2: Innovation models - This section look at the main innovation models and the innovation models generations.

*Section 2.3:* Processes of innovation – This section presents a variety of phases in the process of adoption of innovation in organizations.

Section 2.4: Innovation management – This section explore need and importance of managing the innovation within an organization. It also presents the steps that are needed to achieve innovation management.

Section 2.5: Measuring innovation – This section presents how innovation is measured in the private and defense sectors and industry. The section explores the existing innovation measurements metrics and factors of measuring innovation.

*Section 2.6*: Systems Engineering – This section presents definitions of systems engineering, systems engineering process, and the importance of systems engineering specifically in defense industry.

*Section 2.7*: Defense organizations – This section presents the definition, culture, and characteristics of defense organizations and innovation with the defense organization.

Section 2.8: Discussion of Research Gaps – This section presents a review of the literatures that are related to innovation.

#### 2.1 Innovation

Innovation is central to achievement in the business climate in the 21st century and as such organizations, large and small, have begun to reevaluate their resources, including products, services, and operations in an attempt to develop a culture of innovation (Hidalgo and Albors, 2008)

The real challenge organizations are faced with is to manage to continually generate good ideas and convert them into products and services that are successful in the marketplace. This is what is understood by the term "innovation" (CIDEM, 2002). Traditionally, innovation has been associated with Research and Development (R&D) activities. This can be explained by the fact that all the examples shown in business literature were based on fundamental research that has given rise to innovations that have changed the course of history (penicillin, nylon and microprocessors)

However, Innovation can also refer to the changes made in a company's set of processes. Redesigning the production processes of a company can help increase the value of a final product due to lowered manufacturing costs, reduced response time and higher quality (CIDEM, 2002).

The latest industry trend is the transition from the knowledge economy to innovation economy. Creativity and innovation are the two key factors that contribute to giving a new form to the corporate model. Innovation has become a top priority for chief executive officers (CEOs) because organizations cannot compete on cost alone. CEOs need to take a more

systematic, improved process that caters to different needs of their businesses (Microsoft, 2007).

The literature provides many definitions of innovation, each emphasizing a different aspect of the term. The first definition of innovation was introduced by Schumpeter in the late 1920s (Hansen and Wakonen, 1997).

The definition stressed the novelty aspect of innovation. According to Schumpeter, "innovation is reflected in novel outputs: a new good or a new quality of a good; a new method of production; a new market; a new source of supply; or a new organizational structure, which can be summarized as 'doing things differently'". Hansen and Wakonen believe that Schumpeter's definition is practically impossible; they state, 'it is practically impossible to do things identically' (Hansen and Wakonen, 1997, p. 350), which makes any, change an innovation by definition.

Schumpeter positioned his definition of innovation within the domain of the organization and outlined its extent as product, process, and business model, however, the debates continue over various aspects of invention such as: its necessity and sufficiency (Pittaway et al., 2004), its intentionality (Lansisalmi et al., 2006), its beneficial nature (Camison-Zornoza et al., 2004), its successful implementation (Hobday, 2005; Klein and Knight, 2005), and its diffusion (Holland, 1997) to qualify as innovation.

Wilson and Stokes (2006) describe innovation as a 'fundamentally social process', which is based on people and culture within the organization. Wolf and Pett (2006) found that

process/product development was a key focus for directing innovation efforts resulting from leadership and people and culture constructs. 'leadership, people and culture'; 'total quality/continuous improvement'; 'product and process'; and 'knowledge and information' each have construct validity and reliability as elements of innovation implementation (McAdam et al., 2010).

Acs and Audretsch, (1990) adopted a comprehensive definition of innovation. They say "Innovation is: production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production; and establishment of new management systems."

It is both a process and an outcome, this definition includes internally conceived and externally adopted innovation; it highlights innovation as more than a creative process, by including application ('exploitation'); it emphasizes intended benefits ('value-added') at one or more levels of analysis; it leaves open the possibility that innovation may refer to relative, as opposed to the absolute, novelty of an innovation; and it draws attention to the two roles of innovation (a process and an outcome) (Crossan and Apaydin, 2010).

#### 2.2 Innovation Models

Since the 1950s, there has been a proliferation of innovation models, each aiming to explain the process of innovation.

Innovation indicators can be roughly categorized into four generations, progressively becoming more complex and meaningful (Milbergs, 2006). Table 2-1 illustrates the development of these generations.

First Generation Input Indicators (1950s-60s)	Second Generation Output Indicators (1970s-80s)	Third Generation Innovation Indicators (1990s)	Fourth Generation Process Indicators (2000s plus emerging focus)
<ul> <li>R&amp;D expenditu res</li> <li>S&amp;T personnel</li> <li>Capital</li> <li>Tech intensity</li> </ul>	<ul> <li>Patents</li> <li>Publications</li> <li>Products</li> <li>Quality change</li> </ul>	<ul> <li>Innovation surveys</li> <li>Indexing</li> <li>Benchmarking innovation capacity</li> </ul>	<ul> <li>Knowledge</li> <li>Intangibles</li> <li>Networks</li> <li>Demand</li> <li>Clusters</li> <li>Management techniques</li> <li>Risk/return</li> <li>System dynamics</li> </ul>

Table 2-1: Evolution of Innovation Metrics by Generation; Source: Center of AcceleratingInnovation, George Washington University (2006).

Rothwell (1991) summarizes the evolution of innovation models from the 1950s to the 1990s in five successive generations:

#### 1. First Generation Models: Technology Push (1950s–Mid 1960s)

The first generation models of innovation, also called technology push models, describe a simple linear model developed in the 1950s (see Figure 2-1). The model treated innovation as a sequential process.

The models assumed that scientific discovery preceded and 'pushed' technological innovation via applied research, engineering, manufacturing and marketing. This model was often used to justify R&D spending by firms and governments as, which would lead to greater innovation and, in turn, faster economic growth.



Figure 2-1: First generation technology push models (1950s to mid-1960s). Source: Rothwell (1991, Ref. 9, p. 33; amended).

#### 2. Second Generation: Demand Pull Models (Mid 1960s-1970s)

Rothwell argues that in the latter half of the 1960s empirical studies of innovation processes began to emphasize market led (or need pull) theories of innovation (see Figure 2-2).

These were also linear in nature, emphasizing the role of the marketplace and market research in identifying and responding to customer needs, as well as directing R&D investments towards these needs. In these models, the marketplace was the chief source of ideas for R&D and the role of R&D was to respond to market demands.



Figure 2-2: Second generation demand pull models. Source: Rothwell (1991, Ref. 9, p. 33).

#### 3. Third Generation: Coupling or Interactive Models (1970s)

In the 1970s, detailed empirical studies showed that the two linear models (technology push and market pull) were extreme and atypical examples of industrial innovation. In particular, (Mowery and Rosenberg, 1978) argued that innovation was characterized by the interaction between and the coupling of science and technology (S&T) and the marketplace. Unlike the two previous models, the interactive model explicitly links the decision making of firms to the S&T community and to the marketplace (see Figure 2-3).



Figure 2-3: The coupling or interactive model of innovation. Source: Rothwell (1993, Ref. 7, p. 21).

#### 4. Fourth Generation: Integrated Models (1980s)

Although third generation models were non-linear with feedback loops, they were essentially sequential in nature.

During the 1980s, integrated models began to be developed that involved significant functional overlaps between departments and/or activities (see Figure 2-4).

These models attempted to capture the high degree of cross functional integration within firms, as well as their external integration with activities in other companies including suppliers, customers and, in some cases, universities and government agencies.





#### 5. Fifth Generation Systems Integration and Networking Models (Post 1990)

Fifth generation systems suggest that innovation was generally and fundamentally a distributed networking process. These networking models emphasized the learning that goes on within and between firms, especially with the increase in corporate alliances, partnerships.

These interpretations were extensions of fourth generation integrated models, further emphasizing vertical relationships (e.g. strategic alliances with suppliers and customers) and with collaborating competitors.

Rothwell's fifth generation process also relied on the use of sophisticated electronic tools in order to increase the speed and efficiency of new product development across the entire network of innovation. Figure 2-5 presents a recent version of a fifth generation model. The main difference between fourth and fifth generation models according to Rothwell was the use of an electronic toolkit operating in real time to speed up and automate the process of innovation within the firm. More recently, some versions of business process re-engineering also emphasized the application of information technology systems in corporate strategy and innovation.

#### Learning from External Resources



Figure 2-5: An example of systems integration and networking model. Source: Trott (1998), cited in Mahdi (2002, Ref. 61, p. 45).

#### 2.3 Evolution of Process of Adoption of Innovation

The literature presents a variety of phases in the process of adoption of innovation in organizations; while Hage and Aiken (1970) divide the process into: evaluation, initiation, implementation and routinization; Klein and Sorra (1996) divide it into awareness, selection, adoption, implementation and routinization; Zaltman, Duncan, and Holbek (1973) divide it into knowledge awareness, attitudes formation, decision, initial implementation and sustained implementation; and Angle and Van de Van (2000) view it as: initiation, development, implementation and termination. However, these phases can be grouped into three more general phases of preadaptation, adoption decision and post-adoption, often referred to as initiation, adoption (decision) and implementation (Rogers, 1995; Pierce and Delbecq, 1977; Zmud, 1982). Initiation consists of activities that pertain to recognizing a need and searching for solutions. In this phase organizational members learn of the innovation's existence, consider its suitability for the organization, communicate with others and propose its adoption (Meyer and Goes, 1988).

Adoption decision reflects evaluating the proposed ideas from technical, financial and strategic perspectives, making the decision to accept an idea as the desired solution, and allocating resources for its acquisition (Meyer and Goes, 1988). In this phase the organization decides to adopt the innovation and allocate resources to it. Implementation consists of events and actions that pertain to modifying the innovation, preparing the organization for its use, trial use, and acceptance of the innovation by the users and continued use of the innovation until it becomes a routine feature of the organization (Duncan, 1976; Meyer and Goes, 1988; Rogers, 1995). In this phase the innovation is put into use by organizational members, clients or customers.

#### 2.4 Innovation Management

Innovation management emerged as a discipline in the 1890s. Edison changed the image of the sole inventor by converting innovation to a process, laying the basic design of the R&D department. These steps include idea generation, concept development, feasibility studies, product development, market testing and launch.

Innovation management is thus corresponds to the development of new products, processes and services. In cases where the organization does not make or offer products (goods or services), innovation lies in improving the way jobs are done to meet the organization's mission (AL-Ali, 2003)

The high demand for innovation in the knowledge economy – brought about by shorter technology and product life cycles as well as the sophistication of customers – increased the organizational demand for new ideas. This meant two things first innovation has to be pushed down to the frontline where knowledge of the customer is and where the number of ideas generated is greater. Second, it meant that top management has to adopt appropriate innovation strategies to lead the surge of the innovative activity. As a result innovation needed to be systemized as a business process into the way that the organization does business – and hence the need for innovation management (AL-Ali, 2003).

The main goal of innovation management is to enable the organization to reach and communicate with its intellectual capital. The innovation management stage is concerned with the processes that convert knowledge resources into intellectual property and products (AL-Ali, 2003).

It is important that the culture of the organization empowers employees and encourages them to submit their ideas. The following summarizes the various objectives that management should aim for under the innovation management stage:
- Effect a shift in the way the organization sees itself where innovation is recognized as the way of doing business
- Deciding upon the innovation strategy that best fits the organization's situation, and enable it attain its vision.
- Creating a portfolio of innovation projects to translate competitive strategies and to manage risk across the whole organization.
- 4. Define a criteria for the selection and prioritization of projects within the portfolio to weed out less probable projects as soon as possible
- 5. Effect the necessary structural changes to arrange skills throughout the organization in competence centers, to enable the formation of the right team for the purposes of the innovation project.
- Arrange current and potential future alliances in a portfolio that can be tapped when needed, and define when and how such alliances are to be made (governing conditions).
- 7. Foster an organizational culture that promotes innovation by allowing employees time to innovate and the implementation of their own ideas for improving job performance.
- 8. Develop and implement methods that enable tapping into the organization's intellectual capital. (AL-Ali, 2003)

Al-Ali (2003) added that, achieving the objectives of innovation management involves undertaking a number of steps including the following:

- A. Creating an Innovation Portfolio, this involves managing innovation projects across the whole organization as a portfolio.
- B. Selection & Evaluation Criteria to effectively manage the innovation portfolio it is important that management decides upon the selection criteria used to decide which projects will be included in the portfolio.
- C. Idea Banks Idea banks serve as databases for ideas submitted by employees and customers that can be later reviewed by the new product development or R&D department for new projects.
- D. Competence Centers (internal networks) With the increased decentralization of organizations and the specialization of various business units or departments in certain areas of knowledge, specialized centers started to form.
- E. Alliance Portfolio (external networks) Based on the network-based model of innovation, innovation networks extend outside the enterprise to customers, partners and experts from industry and academia.
- F. Competitive intelligence tools –The past few years have seen a flood in competitive intelligence tools and software programs. The choice of such tools or programs depends on the industry as well as the strategy of the organization. (AL-Ali, 2003).

According to CIDEN (2003), the innovation process may be comprised of four core activities: Creating New Concepts, Redesigning the Production Processes, Managing Knowledge, and Developing Products. CIDEN (2003), details each of the four core activities as follow:

- Creating new concepts involves identifying new concepts of products and services, anticipating customers' needs by analyzing the market trends, encouraging new ideas and creativity among staff, identifying the mechanisms and criteria used for selecting the ideas to be developed, and planning the creation of new product concepts.
- Redesigning the production process involves redesigning the production processes to achieve greater flexibility and/or productivity, together with higher quality and/or reduced production costs, changes in the production processes to allow for changes to products, assessing the introduction of new technologies and management and organizational tools into the production processes to increase product value.
- Managing Knowledge involves innovation through technology, how do companies decide on which technologies to develop in house (ongoing training, creation of an R&D department, and to what extent do companies procure external technology.
- Finally, Developing Product involves questions such as how do companies go from an idea to putting a new product or service on the market, how do companies develop a new product in the shortest time possible, how do

companies coordinate internal staff and external teams, and what project management methods do companies implement.

#### 2.5 Measuring Innovation

Is it possible to measure innovation? Clearly, this is a question that attracts a lot of attention among business experts, policy makers, academics and investors (Grunfeld et al., 2011). Over the last decade, many organizations have successfully implemented enterprise-wide as well as localized innovation programs. A holistic measurement system needs to have three perspectives: performance, strength of the competence, and strategic application of the competence. The performance perspectives report out the results of an organization's innovation program(s) while the competence perspectives report out the ability to envision and implement innovative opportunities. The strategy perspective outlines the criticality and impact of innovation in the organization's strategic direction. These three perspectives help managers understand the results, the capacity for performance, and application of innovation (Chen and Muller, 2010).

Measurement of the process of innovation is critical for both practitioners and academics, yet the literature is characterized by a diversity of approaches, prescriptions and practices that can be confusing and contradictory (Adams, 2006). Evaluating innovation competence is a significant and complex issue for many organizations (Frenkel et al., 2000).

Measuring innovation performance in private sector organizations is a relatively new area. Many companies have little experience in determining suitable metrics for innovation. Innovation performance measurement in the private sector varies widely according to how each organization defines innovation, and requires careful scrutiny in order to realize the usefulness of their innovation metrics.

However, a number of metrics are commonly used for measuring innovations in the private sector (Mark, 2004):

- Revenue growth from new products: Most widely used metric by the leading firms.
- Patent submission: An increasingly popular approach that is widely abused by many firms outside of the high tech and pharmaceutical industries.
- Idea submission and flow: The ideas flowing through an idea management system provide a visible reference point to the volume and quality of submissions.
- Innovation capacity: Companies measure innovation capacity using survey tools such as KEYS and the Innovation Climate Questionnaire.

Forrester researchers revealed from a survey of 20 manufacturing firms worldwide that 70 percent of the firms used "revenue from new products" to measure the success rate of their innovations. Another 60 percent used "profits from new products"; 50 percent used "gains in market share"; 35 percent used "time-to-market"; 25 percent used "number of patents filed", while 10 percent used "conversion rate of patents into products" to measure the success of their innovations (Radjou, 2004). Another example is the Boston Consulting Group, which assessed senior managers' views and experiences concerning "innovation-to-cash" (Boston Consulting Group, 2003), majority of the respondents (48 percent) measure their success with innovation using the "overall revenue growth" indicator.

Other popular indicators include: customer satisfaction (34 percent), percentage of sales from new products (33 percent), number of new products or services (25 percent), etc.

Mark Turrell (2004) believes that many organizations realize that a single metric, such as revenue growth or idea submission, is a poor indicator of innovation performance, and that a series of metrics provide a more balanced view of innovation. Some organizations have used the Balanced Scorecard to measure innovation. The Balanced Scorecard (BSC) is a strategic management and measurement system developed by Drs. Robert Kaplan (Harvard Business School) and David Norton in the early 1990's. It looks at the organization from four perspectives: financial perspective, customer perspective, internal process perspective and learning and growth perspective. Some of the indicators used in the BSC are relevant to the outcomes of innovation (Inforserv, 2004). Another view point is given by (Thomas D Kuczmarski, 2000) who provided a comprehensive look at measuring innovation at the corporate level. He divided innovation metrics into two types:

- Innovation performance metrics (those that measure growth); and
- Innovation program metrics (those that measure and reflect program management and control).

Innovation performance metrics include return on innovation investment (ROI2 or R2I), new product success rate, new product survival rate, cumulative new product revenue and cumulative new product profit, and growth impact; while program metrics include R&D innovation emphasis ratio, innovation-portfolio mix, process-pipeline flow, innovation revenues per employee, and speed to market.

In addition to measuring innovation at the private sector level, governments around the world sought innovation to increase public value. Countries like the United States, United Kingdom, Australia, New Zealand and the European countries have developed one form of indices or another to measure their innovation performance. For example, Australia introduced nine initiative to promote science and innovation over five years from 2001-02 to 2005-06. An innovation scoreboard was designed to benchmark Australia against other Organization for Economic Co-operation and Development (OECD) countries. The scorecard uses 15 indicators to measure innovation performance. The indicators are grouped into six categories: Knowledge creation, Human resources; Finance; Knowledge diffusion; Collaboration; and Market outcomes. The innovation scorecard is comparable with scorecards from the OECD, the European Union, Canada, New Zealand, and some States of the USA (Australia Department of Education, 2004). Canada on the other hand has abundant data on science and innovation. There are over 100 different indicators used to assess science and technology in the country and the provinces. Recently the conference Board of Canada and the Canadian Science and Innovation Indicators Consortium (CSIIC) conducted the first national exercise to benchmark science and technology in the country. It arrived at 16 indicators, they are: Knowledge performance, which is the gross domestic expenditure on R&D as a percentage of Gross

Domestic Product (GDP) (GERD/GDP); Business enterprise expenditure on R&D as a percentage of GDP (BERD/GDP); Publication of scientific papers per 1 million population; Triadic patent families; University-Industry Collaboration in R&D; Technology balance of payments; Skills Performance; Educational attainment in the labor force; Adult participation in continuing education; Innovation Environment; Economy-wide regulatory environment; Total corporate tax as a percentage of GDP; R&D tax treatment; Investment in venture capital; World competitiveness ranking; Relocation of R&D facilities; Foreign Direct Investment (FDI) confidence Index; Community-Based Innovation; Broadband subscribers per 100 population (Canadian Science and Innovation Indicators Consortium, 2004).

In the United Kingdom, the U.K. government has set out specific targets to a basket of indicators to measure U.K. science and innovation progress. Indicators of progress are identified in six main areas: World-class excellence, financial sustainability, responsiveness, business investment and engagement, skills, and public engagement (United Kingdom. HM Treasury, 2004). Finally, the United States of America uses the Innovation Index, devised by Michael E. Porter and Scott Stern. The Innovation Index is a quantitative measure that captures three main contributors to a nation's overall innovative performance: need the source

- Common innovation infrastructure that supports innovation in the economy as a whole (e.g., investment in basic science);
- Cluster-specific conditions that support innovation in particular groups of interconnected industries (e.g., automotive, information technology); and

 Strength of the linkages among them (e.g., the ability to connect basic research to companies and the contribution of corporate efforts to the overall pool of technology and skilled personnel)

The indicators employed in the Index are:

- Total R&D personnel
- Total R&D investment
- Percentage of R&D funded by private industry
- Percentage of R&D performed by the university sector
- Spending on higher education
- Strength of intellectual property protection
- Openness to international competition
- Nation's per capita GDP

While most of the previously listed innovation measuring approaches are quantitative in nature, Morris (2008) is one of few researchers to adopt both qualitative and quantitative approaches to measuring innovation (see Figure 2-6). His version of the funnel consists of nine elements, or stages, with two metric types. The 'soft' metrics are qualitative, sometimes in the form of provocative questions that are intended to get people to think more deeply and

effectively about the work they're doing. The 'hard' metrics are quantitative, and amenable to statistical analysis.



Figure 2-6: Funnel Model Nine Stages Measuring Innovation, Morris (2008).

In stage (-1) strategic thinking, Morris (2008) describes the following qualitative Metrics and Provocative Questions: are we targeting the right parts of our business for innovation, can we change as fast as our markets do, are we flexible enough, is our strategy clear enough that we can translate it into innovation initiatives, how well do our strategies match with the way the market is evolving, do we have an effective innovation dashboard, and, are we measuring innovation adequately. In addition, he also describes the following Quantitative Metrics: time senior managers invest in innovation, time required from development of strategic concept to operational implementation, money invested in innovation, money invested in innovation of each type, and growth expected from the innovation process, in percent, and in dollars.

In stage (0) Portfolio Management, Morris (2008) describes the following qualitative Metrics and Provocative Questions: how does our portfolio compare with what we think our competitors may be planning, do we have the right balance of incremental and breakthrough projects, are we introducing breakthroughs at a sufficient rate to keep up with or ahead of change, what are our learning brands, the brands that we use to push the envelope to track the evolution of the market, are we developing new brands at an adequate rate, are our metrics evoking the innovation behaviors that we want from the people in our organization, and, are our metrics aligned with our rewards and reward systems. In addition, he also describes the following Quantitative Metrics: Ratio of capital invested in the early stages vs. return earned in sales stage, actual portfolio composition in the sales stage compared with planned/intended portfolio composition in the planning stage, and expected metrics vs. actual performance achieved.

In stage (1) Research, Morris (2008) describes the following qualitative Metrics and Provocative Questions: How well do we understand the tacit dimensions of our customers' experiences, how well do we understand the implication and applications of new technologies, how well do we understand the emerging future, how good have our past predictions been at anticipating change, and, is our research helping to target the right innovation opportunities. In addition, he also describes the following Quantitative Metrics: Number of customer groups we have examined, applications of research results in new products, services, and processes,

breadth of participation from throughout our organization in the research process, time invested in research, and money invested in research.

In stage (2) Ideation, Morris (2008) describes the following qualitative Metrics and Provocative Questions: Do we have a broad enough range of models of technology possibilities, tacit knowledge models, and societal trends, how good are we at creating an open sandbox that can accommodate a tremendous range of possible concepts and ideas, and, are we encouraging people sufficiently to share their ideas. In addition, he also describes the following Quantitative Metrics: Number of ideas developed, number of ideas contributed by our staff, number of ideas introduced, percent of ideas from outside, number of people inside the organization who are participating in the ideation process, number of ideas collected in the 'idea gathering' system, number of collected ideas that were developed further, and, number of collected ideas that were implemented.

In stage (3) Insight, Morris (2008) describes the following qualitative Metrics and Provocative Questions: Are we getting enough solid insight/concepts, and, are the insights we're developing across a broad enough range of business ideas. In addition, he also describes the following Quantitative Metrics: Unsuccessful technology and customer mash-ups attempted, and, successful technology and customer mash-ups achieved

In stage (4) Targeting, Morris (2008) describes the following qualitative Metrics and Provocative Questions: Is our innovation portfolio balanced correctly, and, are we using the right management processes for the different types of innovations that we are working on. In

addition, he also describes the following Quantitative Metrics: Percent of investment in noncore innovation projects, total funds invested in non-core innovation projects and, senior management time invested in growth innovation.

In stage (5) Innovation Development, Morris (2008) describes the following qualitative Metrics and Provocative Questions: Are the right people involved in the innovation process, and, do we have enough failures to assure that we're pushing the envelope sufficiently. In addition, he also describes the following Quantitative Metrics: Prototyping speed, number of prototypes per new product, average time it takes to get from Stage 1 to Stage 5, number of patents applied for, number of patents granted, percent of ideas that are funded for development, and, percent of ideas that are killed.

In stage (6) Market Development, Morris (2008) describes the following qualitative Metrics and Provocative Questions: How well are we balancing our attempts to reach existing versus new customers, how well do we really understand our customers, and, are we positioned properly for changes in the attitudes, beliefs, ideals, etc. of our customers. In addition, he also describes the following Quantitative Metrics: Return on marketing investment, number of new customers added, and growth rate of customer base.

In stage (7) Selling, Morris (2008) describes the following qualitative Metrics and Provocative Questions: How well does our sales process match our customers' needs. In addition, he also describes the following Quantitative Metrics: Sales growth, profit growth, and overall ROI, Gross sales revenue, gross sales margin, expected results compared with actual results, percent of projects are terminated at each stage, successful results per type of

innovation, cost savings achieved in the organization due to innovation efforts, number of new customers, percent of sales from new products / services, average age of products / services, number of new products / services launched, percentage of revenue in core categories from new products / services, percentage of revenue in new categories from new products / services, percentage of profits from new products / services, percentage of new customers from new products / services, time to market from research through to sales, and, customer satisfaction with new products / services.

### 2.6 Systems Engineering

Systems are becoming more complex and in most cases, they require integration with other system. Although there have been numerous definitions of systems engineering presented over the years, as shown in Table 2-2; the term "Systems Engineering" could still mean different things to different people. The traditional view of systems engineering view it as a way of thinking or approach to design, whereas recent views tend to see system engineering as an engineering discipline. The table shows how system-engineering definitions have evolved over the last 25 years to include the role of management in systems engineering and the increasing importance of life cycle considerations.

For the sake of this study, we will use the definition of the International Council on Systems Engineering (INCOSE), "Systems-Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and

then proceeding with design synthesis and system validation while considering the complete problem".

The importance of system today is not debatable. Systems are expected to be more efficient and more effective. They are expected to perform at higher capacity, and yet at lesscost. The discipline of Systems Engineering has emerged in response to ever increasing system complexity and requirements. It drives the balanced development of systems in terms of cost, schedule, performance, and risk and verifies that the technical solutions satisfy customer requirements. Systems Engineering has been proven as an effective way to manage complex and often technologically challenging problems (Teper (2010)). Table 2-2: Systems Engineering Definitions Evolution (Adapted from Teper (2010)).

Source	Definition of Systems Engineering
Mil-Std 499A (1974)	The application of scientific and engineering efforts to: (1) transform an operational need into a description of system performance parameters and a system configuration through the use of an iterative process of definition, synthesis, analysis, design, test, and evaluation; (2) integrate related technical parameters and insure compatibility of all related, functional and program interfaces in a manner that optimizes the total system definition and design; (3) integrate reliability, maintainability, safety, survivability, human, and other such factors into the total technical engineering effort to meet cost, schedule, and technical performance objectives.
Chase (1974)	The process of selecting and synthesizing the application of the appropriate scientific and technical knowledge to translate system requirements into system design and subsequently to produce the composite of equipment, skills, and techniques that can be effectively employed as a coherent whole to achieve some stated goal or purpose.
Sailor (1990)	Both a technical and management process; the technical process is the analytical effort necessary to transform an operational need into a system design of the proper size and configuration and to document requirements in specifications; the management process involves assessing the risk and cost, integrating the engineering specialties and design groups, maintaining configuration control, and continuously auditing the effort to ensure that cost, schedule, and technical performance objectives are satisfied to meet the original operational need.
Wymore (1993)	The intellectual, academic, and professional discipline the primary concern of which is the responsibility to ensure that all requirements for a bioware/hardware/software system are satisfied throughout the life cycle of the system.
Ramo (1993)	A branch of engineering that concentrates on the design and application of the whole as distinct from the partslooking at the problem in its entirety, taking into account all the facets and variables and relating the social to the technical aspects.
INCOSE - International Council on Systems Engineering (1999)	An interdisciplinary approach and means to enable the realization of successful systems. If focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem.

The Systems Engineering Process (SEP) is a comprehensive, iterative and recursive problem solving process, applied sequentially top-down by integrated teams. It converts requirements into a set of system product and process descriptions, generates information for decision makers, and provides input for the next level of development (DAU 2001)

Figure 2-7 shows the systems engineering process currently instructed at the Defense Acquisition University (DAU). Not all processes are the same, but the one represented here is fairly typical across the systems engineering community. The process includes Inputs/Outputs, Requirements Analysis, Functional Analysis and Allocation, Requirements Loop, Synthesis, Design Loop, Verification, and System Analysis and Control.



Figure 2-7: (DAU 2001).

The systems engineering process begins by identifying the stakeholders and gathering their needs, goals, and objectives. This is represented by —Process Inputs and is essentially a list of customer requirements. The first step of the systems engineering process is Requirements Analysis. The given customer requirements are translated into functional and performance requirements ensuring that they are unambiguous, measurable, verifiable, comprehensive, and concise.

The next step is Functional Analysis/Allocation in which the top level system functions are analyzed and decomposed into lower-level functions creating the systems functional architecture. A functional architecture expresses the detailed functional, interface, and temporal aspects of the system (DAU 2010). The Synthesis phase represents the physical decomposition of the system and it evolves together with the requirements and functional architecture. The lower tier functional and performance requirements are allocated to the lower level components, thus creating the physical architecture. Synthesis is complete when the physical architecture has been decomposed down to the lowest system element. Verification is a critical part of the systems engineering process to ensure that the system design satisfies requirements (DAU 2001).

### 2.7 Defense Organizations

Innovation has long been a hallmark of the defense industry, both in allowing individual companies to remain competitive in an uncertain and rapidly evolving market environment, and in achieving unprecedented technical advances for the fields of science and engineering.

Innovation in the defense industry has defined our age and culture with examples such as jet age, nuclear age, space age, information age (CRA, 2010).

By the same token, there may be no industry more dependent on continued innovation than the defense industry. Contemporary indicators that the industry retains the capacity to innovate are not uncommon. The Global Positioning System (GPS) has literally transformed entire industries, and society itself in many ways. Yet there also are troubling indicators that all is not well. Compared to other parts of the economy, aerospace and defense is not what it once was (CRA, 2010). The results of a research conducted by Charles River Associated in 2009 identified a number of challenges that impede the industry's capacity to innovate, these include, high profile program execution failures, too little capital invested towards innovation, defense firms not effectively organized to promote innovation, and defense industry struggling to attract the best and brightest talent (CRA, 2010).

The defense industry comprises government and commercial industry involved in research, development, production, and service of military materiel, equipment and facilities. It includes Defense Contractors such as business organizations or individuals that provide products or services to a defense department of a government; The Arms Industry, which produces guns, ammunition, missiles, military aircraft, and their associated consumables and systems; and Private Military Contractors such as private companies that provide logistics, manpower, and other expenditures for a military force (Druckman *et al.*, 1997). A defense industry can be defined as an industry that sells a large share of its output to military users, and produces at least some products or services that are strategic differentiators (Reppy, 2000).

While organizations are studied in general terms because they share regularities and common features, all organizations are different in some respects. And these differences often have an effect on the organization's structure and function, so that similar changes in different organizations have different impacts (Druckman *et al.*, 1997). The defense industry is like any other industry. Its character and operations pose technological, economic, political, and security problems not present in other industries. The lines between defense and civilian technology have been blurred by the increased importance of information technology and by changes in government policies that aim to increase procurement from civilian sources. Many suggested that the most efficient way to defense innovation should involve commercial industries and suppliers firms outside the defense industry firms. However, statistics show that the existing defense industrial base firms are relatively well positioned to support the network aspects of the defense innovation. (Reppy, 2000).

To illustrate with an example, we discuss in this section the characteristics of one of the key defense organizations, the United States Military. The United States military is a large and complex organization that is not corporate in nature. There are differences between the military and corporate organizations. The following is a list of features within military organizations that are not likely to appear in similar form in nonmilitary organizations.

1. First and foremost is the military's distinct mission. The military is the only organization with the mission to destroy and kill enemies of the nation. Although the military may be charged with a host of other missions, the use of deadly force in

aggressive and defensive actions against the nation's enemies is its defining characteristic.

- 2. The budget for the military is approved by Congress on a year-by-year basis, which poses limitations on the military's ability to make organizational plans beyond the current fiscal year and means that funds unspent in a given fiscal year cannot be carried over to the next. The annual budget also drives end-of-the-year spending, which in turn creates disincentives for the implementation of various improvements in efficiency and undercuts the rationale for prudent spending. The budget also has an impact on authorized number of personnel for each year.
- 3. There are several separate but related sets of personnel in the military, such as active-duty service members, civilian employees, reserves, and the National Guard. Both the military and civilian sets cover the breadth and depth of the organization, from clerk to secretary of defense on the civilian side and from recruit to chairman of the joint chiefs on the active-duty side. The President, a civilian, is designated commander in chief by the Constitution. The active-duty component can be further divided in a number of ways: officer versus enlisted, flag, field, and company grade, and so forth.
- 4. These several sets of personnel are recruited differently, managed differently, evaluated differently, often held to different performance standards, serve different terms of office, and differ from each other in a number of other ways.

- 5. The military has a fixed rank structure. There are at least 15 standard levels of rank (9 enlisted and 6 officer); others, such as warrant officers and flag rank officers (generals and admirals), add additional ones. The rank structure is determined by federal law, and the number of incumbents at each rank is fixed. This requirement has as one of its consequences, for example, that the military has no ability on a short-term basis to change its organizational management strategy by flattening or expanding its rank structure to better accommodate its mission-based needs.
- 6. Military personnel cannot organize for the purposes of collective bargaining, or for the negotiation of working conditions, pay, or benefits. Service members can join voluntary organizations, but they cannot advocate for such changes either. Even civilians employed by the military are limited compared with their private-sector counterparts. They are executive branch employees and are prohibited by law from trying to influence pending legislation. Needless to say, strikes or other work actions are out of the question for the military.
- 7. Military enlisted personnel serve fixed terms of enlistment. They cannot resign or quit unilaterally, unless they are at the end of their terms. Even then, resignation is with the permission of the service and can be refused. Employee dissatisfaction cannot always be translated into immediate resignation or separation from duty. There are even limits on the ability of personnel to voice their dissatisfactions publicly.

- 8. The pay structure of the military is fixed. It is entirely determined by rank and time in service. In some cases, there may be supplementary special pay, as in the case of extra salary awarded to physicians whose medical specialties are in short supply. A key issue is that bonuses or merit pay are not and cannot be used in individual cases for either rewards or incentives. Merit is recognized through the issuance of (nonmonetary) awards and medals.
- 9. The use of salary-based incentives and rewards occurs through the promotion system, but, for many officer ranks, that system is not under the control of the immediate commander but rather goes through a complex Promotion Board review procedure.
- 10. Unlike most other organizations, the military's rules of conduct have the force of law. In most organizations, a violation of company policy may result in being fired; in the military, violation of company policy may result in formal charges, trial, and imprisonment. In addition to the U.S. criminal and civil codes, the Uniform Code of Military Justice also governs the conduct of military personnel. And to enforce its standards of conduct, the military maintains its own judicial and penal systems. The mechanism of control of military members stands in sharp contrast to the treatment of civilians employed by the organization. They have the employee protections of the Civil Service Code, have a number of avenues of appeal, and are not subject to the procedures of the Uniform Code of Military Justice.

In the civilian world, certain conduct may result in loss of employment but is not criminal, such as unbecoming conduct and certain forms of disrespect to one's superiors. In the military, these are crimes and one is under threat of imprisonment for such lapses.

- 11. The military regulates not only the conditions of employment and conduct of its members but also aspects of their personal life. Mandatory drug screening and a prohibition on abortions at military hospitals represent a type of involvement in members' personal lives to an extent that is not usual in the civilian world.
- 12. All active-duty military personnel are on permanent 24-hour call. Except for times when they are on official authorized leave status; all active-duty military may be called in to a duty station at any time. Even their leave is subject to cancellation.
- 13. The military operate under a distinctive retirement scheme. Personnel must serve a threshold amount of time in the service to qualify for a retirement pay. The minimum time requirement is 20 years. Separation from the military before this length of service, either voluntary or involuntary, means no retirement pay.
- 14. Major decisions in the military are often confounded with civilian political issues that are not necessarily related to the military's plans or effectiveness. Almost all aspects of higher levels of mission, structure, and function of the military, including discretionary acquisition of weapons and other equipment, are controlled by

elements in the larger political system rather than determined solely by the organization itself.

- 15. The budget of the military is imposed from outside, even to the point of subcategory specification. The budget is not directly linked to organizational performance, and it may contain mandates for specific programs or operations that have absolute priority.
- 16. The structure of the officer force in the military is pyramidal in nature: the higher the rank, the fewer the incumbents. The military has an internal system of organizational culture that lends support to its personnel. The military organization is made up of several sub organizations, the most prominent of which are the component services: Army, Navy, Air Force, and Marines. These subunits both cooperate and compete.
- 17. The military operate under a series of mission-driven constraints about the assignment of personnel to various operational roles and even about the suitability of individuals for military service.
- 18. The military does not determine all of its own standards for its personnel. Such rules as age requirements and limits, physical standards, and other aspects of policy regarding the attributes of the officer component are partially determined by legislation. In particular, the Defense Officer Personnel Management Act sets some of the standards for service (Druckman *et al.*, 1997).

The defense industry has a history of creating revolutionary innovations. Innovations such as the jet engine, spacecraft, nuclear weapons and nuclear power, spaceflight, computers, and the internet each transformed our society. Some of these innovations came from entrepreneurial individuals and small firms such as the Wright Flyer and General Atomics' Predator unmanned aerial vehicle. However, the assumption that the entrepreneur-inventor is the sole font of innovation is, of course, only a part of the larger story of innovation in the defense industry. The most iconic innovations of the defense industry, the kind that transformed society, were generally not created by individual entrepreneurs. Instead, these innovations reflected collective development efforts, the result of large-complex programs that typically featured technologies and innovations in multiple disciplines and consumed vast resources over long periods. The Manhattan Project and Apollo Program, for example, each consumed about 4% of GDP during their peak funding years. The pursuit of innovations in the defense sector will continue to attract funding. However, the particular range and focus of those investments are changing (CRA, 2010).

#### 2.8 **Documentations**

This section presents a review of the literatures that are related to innovation from existing documents in the examined environment of the defense organization. The data for this research study was both primary and secondary. The primary data was derived from the sources of interviews, observation, and documentation. The secondary data was derived from the publications of national and international organizations, and the literature.

Found documents usually exist prior to the research, and are used to support or refute the research argument. A policy manual is an example of a found document. Researchgenerated documents on the other hand are generated only for the purpose of the research and would not have existed otherwise.

Documentation such as systems logs, reports, forms, systems manuals, training manuals, policies procedures, knowledge management systems and similar type of documentations from a defense organization were used and included to support the research findings. Each data collection method has disadvantages in some respect (Henerson et al, 1987; Patter, 1990).

The search focused on two types of documentation, the first is documents that directly pertain to innovation and innovation management and measurements, and the second list pertains to documents that are used by the examined units in general in their development processes, and more specifically to the areas of technology and security.

For the first group of documents, no documents were found concerning innovation and innovation management and measurements. That includes no policies, no published goals, no standards, no guidelines, no training manuals, etc.

For the second group of documents, the researcher examined the units' intranet sites, business development plans, system engineering management plans, software management plans, hardware management plans, program management plans, unit policies, training manuals, job descriptions, organization structure, and annual evaluation forms.

The examination of these documents revealed no evidence to support innovation and innovation management. The business developments plans examined were concerned with the process of capturing new business, defining the policies and procedures for proposals, and defining the organization pricing policy. The systems engineering management plan was mainly concerned with defining the tools used in the program, defining the entrance and exist criteria of each phase of the program such as preliminary design and critical design reviews, defining the peer reviews process across the program, defining the tools and process of capturing troubles and problems related to software, hardware and documentations, and defining the matrices collection process. The software management plan defines the software development tools used in the program, defines and outlines the software phases such coding and codes unit testing, and it includes and define the templates and guidelines for the software engineering. The Hardware management plan defines the tools for the hardware team in regard to tools used for drawings, drafting, and checking. The hardware management plans define the systems components and assemblies. The program management plans define the program milestones, reference the program integrated master schedule, define the program risks and opportunities, define the program earn value management, and define the program staffing. Unit policies include the assets access, controls access privileges, export control, and staffing training. The training manuals include the required training for each staff member depending on the employee level, training materials, training schedule, and training location. The examination of job descriptions in the examined units did not revealed any inclusion of innovation-related requirements or task descriptions that are specific to innovation. Similarly the annual evaluation forms for the examined job descriptions did not any criteria in the evaluation that

was specific to innovation. The organization structure of the examined units did not show any reporting lines for innovation and or innovation related tasks.

Finally policies found in the units intranet sites were mainly concerned with human resources, organization structure, security, and access related issues. No policies regarding innovation were found. The aspects of technology and security were heavily emphasized in many of the examined documents and plans. Specific systems analysis and design approaches and templates were required. The use of certain technologies was forbidden for technology and security reasons. Access to the company's equipments, systems, and databases is heavily controlled and guarded by a number of policies.

### 2.9 Direct Observation

This section presents a review of the literatures that are related to innovation that observed directly by the researcher. Researchers used observation as a data generation method in the literature review to discover what people do instead of what people claim they do. Observing is seeing, watching, and paying attention. Observation is a data generation method that can be used with any research study (Oates, 2006). Observation can be divided into:

• Covert observations where the observed is not aware that he/she/it is being watched.

• Overt observation where the observed is aware that he/she/it is being watched.

The advantage of the covert approach is that the setting is not disturbed and people behave naturally. The disadvantage however, is that the observer is restricted and is hidden. The advantage of the overt approach is that the people observed can give their consent; the researcher has more of a free-hand and can move more freely. One major disadvantage, however, is that people altering their behavior when they are being watched? Observation is considered to be one of the most effective methods of data collection (Whitten, et al, 1994). In this research, direct observation was used to provide detailed description of people's activities, actions, organizational process, and to conform the results of other data gathering tools.

The role of the researcher as an observer varied during the study period. While the researcher was a practitioner researcher on some occasions, he was participant observer, complete participant, and complete observer at other times. Observation is a time consuming process. The process started with the commencement of this study in early 2012 and lasted until May 2013. It initially started by being non-selective in what the researcher observed and it progressed and advanced into focused observation on selective areas. The main idea behind observation is to discover what people do rather than what they say they do.

The findings of the direct observation confirmed the finding of the other data collections sources. The researcher found no evidence to a formal process for innovation across the defense organizations and/ or the examined units. For the most part innovation was an encouraged practice and was usually managed either informally or within the unit or sub units based on the manager or supervisor preference; and while some projects by nature required

more innovation than others, innovation was dealt with as part of the requirements, but not as a separate part that requires management and measurement.

The researcher found no specific model for innovation and innovation management and measurement. No quantitative or qualitative predefined measures were found. Innovation measurement was usually measured by the success of the failure of meeting a specific requirement or solution by the customer.

The researcher found no formal incentive system that would support and encourage innovation. Also innovation was not found to be part of the performance evaluation criteria used to evaluate employees performance. For the most part innovation is self-initiated, selfmanaged, and to a big extend self-funded.

There is no doubt that employees in the examined units value innovation and believe that the successful management and measurement of innovation would increase the productivity and the quality of their work, and believe that they can contribute to the success of any implemented model if given the opportunity. What was not clearly evident is the higher management commandment and support to innovation throughout the organization.

Emphasis on organization leadership and security aspects was clear throughout the examined units. Access to specific locations, systems, documents, and products was highly controlled. Emphasis on specific technologies, hardware, software, programing languages, and design approach was also highly visible. The culture of the industry and the organization

encourages innovation, yet a thought through uniformed and consistent process to manage innovation was lacking.

## 2.10 Discussion of Research Gaps

This section presents a review of the literatures that are related to innovation. The following research gaps that require further research and implementation have been identified:

- While most studies that pertain to measuring innovation have been dealt with civilian organizations, no significant studies have been conducted within the systems engineering context of defense organization. There is a shortage of thorough in realistic analysis of the intersection of innovation and organizational factors.
- Most existing models for measuring innovation seem to adopt quantitative factors; they seem to overlook, in their majority, the qualitative factors innovation.
- Most existing models for measuring innovation are generic. No known model has been identified or associated with the defense industry.

Figure 2-8 summarizes the literature research done innovation measurement models. It is clear from the table that none of the models address both the quantitative and the qualitative methods of measuring innovation in the context of defense organization.



Figure 2-8: Literature Review for Innovation Measurement Models.

# **CHAPTER 3. RESEARCH METHODOLOGY**

#### 3.1 Introduction

This chapter outlines the research design and methodology upon which this dissertation is based, and discusses the rationale behind their selection, while explaining the process of their implementation. In addition, this chapter also presents data collection instruments and the justification for selecting them.

As it was documented in chapter two, thorough and realistic analysis of the innovation environment, characteristics, and factors within the systems engineering context of defense organization is sparse. The purpose of this research is to explore the nature, characteristics, challenges, opportunities, environment, culture, and the key and significant factors of innovation within the systems engineering context of a defense organization; and test the validity of a quantitative and qualitative significant innovation factors models within the systems engineering context of a defense organizations that proposed by the researcher.

### 3.2 Methodology Outline

Data collected from the selected organizations will be used to respond to the research questions by using different methodologies (Eisenhardt, 1989).

It has been postulated that the four most common methodological areas of weakness within research of this type are: (1) quality of data; (2) definition of new product; (3) factor

selection and definition; and (4) measurement of factors (Balachandra, et al., 1997). So, particular attention will be paid to ensure that these areas either are not problems here, or that they are adequately mitigated.

In researching innovation and exploring the innovation factors and characteristics in defense organizations, the methodology will be broken into three top level categories: Conceptualization, Operationalization, and Conclusion. These categories and their individual components flow according the diagram in Figure 3-1.



Figure 3-1: Methodology Phase and Flow.
### 3.2.1 Conceptualization

This section includes the potential research problem, define research questions, literature review, and gap analysis.

### 3.2.1.1 Potential Research Problem

While there is no shortage of research and study materials on innovation, there is, however, a shortage of thorough and realistic analysis of the innovation environment and innovation factors within the systems engineering context of defense organizations. In addition, while most research studies seem to adopt strictly quantitative factors of innovation, they seem to have overlooked the qualitative side of it.

#### 3.2.1.2 Define Research Questions

The results of this research will be refinement of our knowledge and understanding innovation within the systems engineering context of a defense organization. This research explores the nature, characteristics, challenges, opportunities, environment, culture, and the key and significant factors of innovation within the systems engineering context of a defense organization. The research will also investigate and assess three modelling methods (Logistic Regression (LR), Neural Networks, (NN), and Regression Trees (RT)) in determining the significant and most important factors of innovation with defense organizations.

As a consequence of the literature gaps, the problem statement, and the research goals and research objectives, questions are built in order to be answered. To ascertain this, the following questions will be answered.

- What are the current factors that contribute to the innovation within the systems engineering context of a defense organization?
- Are the proposed factors effective in determining innovation within the examined environment?

### 3.2.1.3 Literature Review

A prerequisite to researching innovation and developing an effective innovation measurement model that fits the need of a defense organization is the establishment of an understanding of the innovation environment in general, and within the context of defense organizations in specific. In order to achieve that, the researcher conducted a thorough and indepth literature review that covers a wide array of areas that directly impact innovation, including innovation definitions, innovation models, process of adoption of innovation, innovation management, measuring innovation, and defense organizations. The emphasis is on journal articles and the most recent ones are the most important ones. Innovation has been one of the leading topics of the 21<sup>st</sup> Century. This literature survey will help us define the research goals based on the literature gap analysis conducted in Chapter 2.

# 3.2.1.4 Gap Analysis

The following research gaps that require further research and implementation have been identified:

• While most studies that pertain to explore innovation have been dealt with civilian organizations, no significant studies have been conducted within the systems

engineering context of defense organization. There is a shortage of thorough in realistic analysis of the intersection of innovation and organizational factors.

- Most existing models for innovation seem to adopt a quantitative approach; they seem to overlook, in their majority, the qualitative aspect of innovation.
- Most existing models for innovation are generic. No known model has been identified or associated with the defense industry.

#### 3.2.1.5 Defining Success

A prerequisite to researching an effective and significant innovation factors within the systems engineering context of a defense organization is to establish an understanding of the innovation environment with the defense organizations. That understanding could be achieved by collecting relevant information concerning the nature, characteristics, challenges, opportunities, environment, culture, and the factors of innovation within the systems engineering context of a defense organization.

In addition, it's essential to ensure that the validated defense organizations takes in consideration key and significant innovation factors relevant to the defense industry, such as organizational leadership, security, and performance.

### 3.2.1.6 State Constructs

The foundation for this research is the belief and understanding that in order to effectively determine innovation success is influenced, certain factors have to exist. An exploration of the ideas and findings of similar research discussed in chapter two is evidence that a relationship exists between the significant innovation factors and the innovation success.

The basic constructs for this research are:

- Successful identification of significant and most important innovation factors in defense organizations.
- Innovation success should not be based on a single metric.
- Innovation factors should be both quantitative and qualitative factors.
- Effective innovation factors should be reflective of the internal and external environments.
- Innovation has a profound impact on the defense industry.
- Organizational and cultural environmental factors influence the success innovation.

It is the belief that innovation plays a key role in the success of a defense organization (Hering & Philips 2005). This construct will guide the tone of the survey, documentations, and direct observations data collection instruments.

### 3.2.2 Operationalization

This section describes those practical activities necessary to answer the research questions and refine the proposed innovation factors; it is the operationalization of the research.

As data is collected and as data collection progresses, this study will be developing a converging lines of inquiry (Yin, 1994; Patton, 1999). The process of combining multiple data sources is called triangulation (Jick, 1979). For the purpose of this research, survey construct, documentations, and observation data sources were combined to deliver more accurate and convincing findings.

# 3.2.2.1 Data Collection

A major strength to data collection is the opportunity to use many different sources of evidence to provide a better picture of events than would be provided by any single method (Yin 1994; Sawyer 2001). A multi-method approach to research involves several data collection techniques, such as a survey construct and documentation, organized to provide multiple but dissimilar data sets regarding the same phenomena (Jick 1979; Gallivan 1997). While not all resources are essential to develop and refine the proposed framework; the importance of multiple sources of data to the reliability of the study is well established (Stake, 1995; Yin, 2003).

In order to provide multiple data sets regarding the phenomena in this research study, a combination of qualitative and quantitative evidence and observations was used including survey construct, documentation, and direct observation data. Documentation and direct

observation used early in the research as part of the literature review to help understanding the innovation environment and culture within the examined defense organizations and to asset in developing the survey questions.

#### 3.2.2.2 Survey

Survey is defined as the systematic assembling of information from respondents with the intention of understanding an aspect or more of a particular population. It has become an established and effective method among researchers (Newsted, et al., 1998). Hence, the survey method was viewed to be a suitable technique to incorporate within this research.

The aim of this research was to establish a survey procedure that would elicit reliable and unbiased information from experts in innovation and systems engineering fields. The survey was pre-tested by 10 experts and then modified before deployment. To enhance the validity and reliability of the survey, it was decided to build the questions in a structured format and to conduct a survey in short face-to-face mode. This will ensure that all questions were answered and will minimize communication error, and allow the researcher to farther investigate questions as need it.

The sample size of the surveyed was 112 experts in the field of innovation and systems engineering from major defense organization: Lockheed Martin, Boeing, Northrop Grumman, Raytheon, Cubic, and SAIC. Data for 300 (unique) projects were collected where participants provided data for more than one project. Data collected was randomly divided into two groups (i.e., the participants were divided randomly in two groups). The first group of participants corresponded to a set of 200 projects was used to study and find the significant innovation

factors from the surveyed 22 factors. The second group of participants corresponded to a set of 100 projects and it was used to test the different models.

Initially twenty nine factors were identified. At the complementation on the survey and the data collection, seven factors were not used in the data analysis and model building. The recommendation to not use these factors was recommended by experts in the fields of innovation and systems engineering. Reasons such as future prediction and strong correlation among some factors were behind the recommendations to not use these factors. Relevant factors as it relates to the aforementioned topics is listed and defined in chapter 4.

#### 3.2.2.3 Data Analysis and Modeling

As stressed by (Eisenhardt, 1989), qualitative analysis is both the most difficult and the least codified part of the data analysis process. Therefore, it was important that we assessed the extent to which we elucidated the data analysis procedures. As per the findings of (Miles, et al., 1994), a series of methods was used to help the research in place cycle back and forth between thinking about existing data and generating strategies for collecting new, often better, data.

In order to analyze the collected data of the interviews, several techniques were used utilizing different tools, applications, and methodologies were undertaken: MS Excel, Statistical Package for Social Sciences (SPSS), MATLAB, Data Mining, Neural Networks, Classification and Regression Tree (CART), Cronbach's Alpha, logistic regression, regression trees, and Principal Component Analysis (PCA).

Information revealed in casual conversation was recorded in the form of field notes. These field notes were as complete as possible. They have also included not only verbal information but nonverbal communication and description of the context of the conversation (Maanen, 1988). Visual displays were also used as an important part of qualitative analysis as displaying data is a powerful means for discovering connections between coded segments (Crabtree, et al., 2000).

#### 3.2.2.4 Traditional Statistics

The study utilized the traditional logistic regression that is one of the mechanisms recommended for this type of studies (Rahal 2005). We decided to use a 2-step process. The first step is the utilization Factor Analysis (PCA) in order to determine the best combination of factors. The second step is to use logistic regression in order do have a predictive model.

### 3.2.2.5 Data Mining Modeling

Data mining is the term used to describe the process of extracting value from a database. Data mining is a very useful technique that has become dominant and well developed in the last twenty years. Frawley et al. (1994) have defined data mining as "the nontrivial extraction of implicit, previously unknown, and potentially useful information from data." Another interesting definition is the one from Witten and Frank (2005) that makes emphasis on the non-statistical part: "Discovery of useful, possibly unexpected, patterns in data using statistical and non-statistical techniques." We have used different techniques from the data mining domain: neural network regression networks and trees. neural and regression/classification trees are used to analyze and build predictive models. Neural networks

to study potential nonlinearities and the inter-relationships of the factors. On the other hand, regression/classification trees are well known to outperform logistic regression in data landscapes with specific features and these trees are deceptively simple and easy to understand.

# 3.2.2.6 Compare & Contrast with Literature

Subsequent to the data collection and data analysis processes, the findings were compared and contrasted with the literature to identify gaps, commonplaces, and possible discrepancies. This process helped with solidifying the findings and conclusion of the study.

### 3.2.3 Conclusion

This section represents the final aspects of the research. It is where the findings are contrasted with existing literature, and the point where closure is attained.

### 3.2.3.1 Infolding Literature

The final stages of case study research include contrasting existing literature to the relationships and constructs established within the data analysis phase. The literature comparison is an essential component of this process. It is to answer the questions: what are similarities between the literature and observed relationships and constructs; what are the contradictions; and why? The reconciliation of agreement and contradiction between the research and literature are vitally important. Legitimate agreement can serve to boost confidence in the overall conclusions; while contradictions may provide meaningful insight. In

either case, the comparisons will be carefully analyzed and explored. As well, the literature comparison will serve to tie together underlying similarities that would not otherwise be linked.

Eisenhardt (1989) concludes that linking emergent theory to existing literature enhances validity, generalizability, and theoretical level of theory building from case study research. Furthermore, it is critically important within the context of case study research because of the very limited number of cases.

#### 3.2.3.2 Reaching Conclusion

This is the end product of the research design process. In this stage the research questions have been answered, and the enough evidence to support the answers to the research questions have been collected, analyzed, and discussed to persuade the researcher and the reader of the final results. In this stage, knowledge of the innovation environment within defense organizations has been established, and a modelling for innovation significant and most important factors has been developed, tested, and validated. Recommendations concerning for further work will be made based on the limitations of this research work.

#### 3.3 Summary

This chapter described the research design process, and its rationale. The three phases of design; conceptualization, operationalization, and conclusions have been delineated. Each phase and it associated processes were explained to illustrate the flow of the research design, starting from literature review and defining research goals and questions and ending with reaching a conclusion that would satisfy the research questions.

# CHAPTER 4. KNOWLEDGE DISCOVERY AND ANALYSIS

### 4.1 Introduction

This chapter presents the findings of the research conducted. The main research questions of the study are examined and illustrated with data and information that have been gathered. The study utilized both quantitative and qualitative data. The data and information for this study were obtained mainly through interviews (see Appendix A), documentations, and observations.

In order to assess an organization's initiatives propensity for innovation, there has to be an appropriate way to study the organization's environment. The system chosen must take a range of factors into account and select the most critical of these in the case of defense organizations. As discussed earlier, many of the examined innovation models are not specific to the defense industry, and they lack the measures, which represent factors that are known to be critical by experts. It can be safely stated that there is no clear system which fits all organizations or business sectors (Davila et al, 2006).

The ability to measure innovation and monitor the appropriate indicators affords the organization a number of advantages: it assists the organization with understanding its current innovation practices/capabilities; development of portfolio composed of best initiatives, and clarifies where the organization needs to focus to maximize innovation success. It also allows the organization to tailor programs to address areas of weakness in order to enhance innovation process capabilities. Moreover, it identifies areas of strength to capitalize on, and

assist the organization identify and control the barriers that stifle creativity and innovation. Also, it allows the organization to develop a firm-level Innovativeness Index and benchmark against other organizations. Last but not least, it spreads the awareness of the importance of innovation concepts and fosters the innovation culture in the organization (TIEC, 2011). In this chapter we explain the development of the proposed framework by the researcher and the rationale behind it. We also illustrate the significant of the innovation factors associated with the models.

# 4.2 Preliminary Innovation Model - Quantitative and Qualitative Factors

Based on the identified gaps mentioned in chapter two and based on the researcher experience with innovation and systems engineering, it can be reported that:

- Most examined innovation measuring models were solely quantitative
- The defense industry does not have a specific innovation measuring model that takes in consideration organizational factors specific to the industry
- Many of the examined models did not have established consistent quantitative or qualitative measure
- Some of the models used a single metric to measure innovation
- Many of the examined models don't utilize users' input

The proposed model of this study for measuring innovation addresses the identified gaps. Unlike many of the examined models, the proposed model is designed to use both quantitative and qualitative measures in measuring innovation. Moreover, the proposed model uses criteria that are specific to the context of a defense organization. Innovation efforts that don't yield enough return can be eliminated or modified. Innovation efforts that appear to yield enough return can be continued and expanded.

In addition to the above scenario, which assumes that an investment in an innovation product that already has taken place, the model may be used for forecasting purposes, or to compare one or more innovation proposals, assuming that there is enough data and there are more than an innovation product in question.

The indicators of an innovation model should be designed to allow the organization the following advantages: Generate/show value for the organization, provide policy makers with information for decision support, provide detailed insight on what hinder innovation within the organization, and they should be simple and effective. The proposed model uses a number of effective metrics both quantitative qualitative.

### 4.2.1 Quantitative Factors

The model uses a number of financial measures. Financial measures are widely used to measure the success of many products. According to Forrester researchers, 70 percent of firms used "revenue from new products" to measure the success rate of their innovations. Another 60 percent used "profits from new products"; 50 percent used "gains in market share"; 35 percent used "time-to-market"; 25 percent used "number of patents filed", while 10 percent used "conversion rate of patents into products" to measure the success of their innovations (Radjou, 2004). Many organizations measure their success with innovation using the "overall

revenue growth". Other popular indicators include: customer satisfaction (34 percent), percentage of sales from new products (33 percent), number of new products or services (25 percent), etc. (Boston Consulting Group 2003).

However, many organizations realize that a single metric, such as revenue growth is a poor indicator of innovation performance, and that a series of metrics provide a more balanced view of innovation. Financial ratios are useful indicators of a firm's performance and financial situation. Financial ratios can be used to analyze trends and to a unit/product's financials to those of other (www.papercamp.com).

In general, financial ratios can be classified according to the information they provide. The following types of ratios frequently are used: Asset turnover ratios, Financial leverage ratios, and Profitability ratios. Attention should be given to the following issues when using financial ratios: a reference point is needed. To be meaningful, most ratios must be compared to historical values; most ratios by themselves are not highly meaningful. They should be viewed as indicators, with several of them combined; ratios are subject to the limitations of accounting methods. Different accounting choices may result in significantly different ratio values.

# 4.2.2 Qualitative Factors

In regards the qualitative factors, defense organizations/products are influenced by number of factors, some of which are technology, security, and performance. Today, more than ever before strong defense systems are those that have state-of-the-art technology and security. Systems such as fighter get, ballistic missiles, precision guided weapon systems, and

integrated air defense systems, they all require a high levels of technological, security, and performance sophistication (Louscher et al., 1998); Dvir and Tishler ,2000). Thus, it is extremely important that those factors (technology, security, and performance) are considered when evaluating and innovation proposal.

It is common for military technology to have been researched and developed by scientists and engineers specifically for use in battle by the armed forces. Many new technologies came as a result of the military funding of science. Weapons engineering is the design, development, testing and lifecycle management of military weapons and systems. It draws on the knowledge of several traditional engineering disciplines, including mechanical engineering, electrical engineering, mechatronics, electro-optics, aerospace engineering, materials engineering, and chemical engineering. Weapon systems are sophisticated engineered system products.

Organizational and individual factors are elements and descriptors that define an organization's character, property, function, and impact. Examples of organizational factors include organizational leadership, organizational structure, management and size. Examples of individual factors include education, experience, and motivation.

#### 4.2.3 Potential Quantitative and Qualitative Innovation Factors

The following are the potential quantitative and qualitative factors for determining innovation in a project:

- Security: Security in defense systems is the practice of defending systems from unauthorized access, use, disclosure, disruption, modification, perusal, inspection, recording or destruction (<u>www.answers.com</u>). On the other hand, confidentiality refers to preventing the disclosure of information to unauthorized individuals or systems.
- 2. **Competition:** Competition has the potential to promote innovation by reducing the value of failing to invest in research and development. However, with non-exclusive intellectual property rights, competition can reduce innovation incentives by lowering post-innovation profits (<u>www.scholarship.org</u>).
- 3. **Project Duration:** "Refers to the total sum of working periods that characterize the time length of project work and are required to complete all the activities listed in the project schedule and all the components of the work breakdown structure, considering the allocation and consumption of all necessary human resources and financial resources" (www.mymanagementguide.com). For example, a project's duration can be equal to 80 hours, or 10 days, or 2 workweeks.
- Cost: "A project cost is usually a monetary valuation of (1) effort, (2) material, (3) resources, (4) time and utilities consumed, (5) risks incurred, and (6) opportunity forgone in production and delivery of a good or service" (www.businessdictionary.com).

- 5. **Job Creation:** Innovation is the most difficult but the most effective way to create long-term employment. It truly is the hardest way but the best way to continually grow an economy (i.e., organic growth) that can support its citizens.
- Recognition: "Recognition programs at workplaces are important because they encourage employees to work harder and build up appreciation for the company" (www.examiner.com).
- 7. **Project Scope:** The scope of a project such as new product, improving existing product, new process, improving existing process, new service or improving exiting service. All of these elements are related to the definition of innovation and they could be considered innovation.
- 8. **Procurement:** Project procurement involves a systematic process of identifying and procuring, through purchase and/or acquisition, necessary project services, goods, or results from outside vendors (<u>www.wisegeek.com</u>). The process of procurement is often part of a company's strategy.
- 9. **Project Nature:** Projects can be software oriented, hardware oriented or both software and hardware oriented. The nature of the project could determine its success. It will be important to look at the nature of the project to know if it is important to factor for the project innovation success as well.
- 10. **Communication:** "Communications management is about keeping everybody in the loop. A project communication is getting the right information to the right

project stakeholders at the right time. Each stakeholder has different requirements for information as they participate in the project in different ways. For information to be used, it has to be delivered to its target users timely" (www.small-business-guru.com)..

- 11. **Logistics:** Some projects are very complex and require quite a bit of planning and logistics management.
- 12. Supply Chain Management: "Supply chain management is the active management of supply chain activities to maximize customer value and achieve a sustainable competitive advantage. It represents a conscious effort by the supply chain firms to develop and run supply chains in the most effective & efficient ways possible. Supply chain activities cover everything from product development, sourcing, production, and logistics, as well as the information systems needed to coordinate these activities" (www.thomaspoutas.de).
- 13. **Operational Management:** The efficiency of a project is important because it is one of the reasons why business may cease to operate.
- 14. **Well Defined Requirements:** Requirements describe the characteristics of the deliverable. They may also describe functionality that the deliverable must have or specific conditions the deliverable must meet in order to satisfy the objective of the project. A requirement is an objective that must be met. The project requirements defined in the scope plan describe what a project is supposed to

accomplish and how the project is supposed to be created and implemented (www.cnx.org).

- 15. **Quality:** Companies must make the right product to suit stakeholders' needs. "Quality means making sure that you build what you said you would and that you do it as efficiently as you can" (<u>www.cnx.org</u>). Too many mistakes are not acceptable. The organization must keep the different projects working toward the goal of creating the right product!
- 16. **Design:** Project design and complexity is a factor that determines the success of the project. Design level such as simple, complex and very complex is a factor in determining if the project is an innovation project or not.
- 17. **Technology:** Technology is the systematic study of techniques for making and doing things (concerned with the fabrication and use of artifacts). Technological development and innovation is one of the most important factors for economic development.
- 18. Performance: "The accomplishment of a given task measured against preset known standards of accuracy, completeness, cost, and speed. In a contract, performance is deemed to be the fulfillment of an obligation, in a manner that releases the performer from all liabilities under the contract" (Richard et al., 2003).

- 19. Projected ROI: Return on investment. To calculate ROI, the benefit (return) of an investment is divided by the cost of the investment; the result is expressed as a percentage or a ratio. The return on investment formula: (Gain from investment cost of investment)/cost of investment. Return on investment is a very popular metric because of its versatility and simplicity. That is, if an investment does not have a positive ROI, or if there are other opportunities with a higher ROI, then the investment should be not be undertaken.
- 20. **Cost Saving:** The amount of money saved as a result of changes to plans or polices that reduce the expense associated with the business activity.
- 21. **Profit Growth:** The percentage increase in net profit over time. This is generated by comparing or analyzing the percentage the profit grows from one period to another.
- 22. **Potential Market Success:** Aggregate of all individuals and organizations in a particular market that have some level of interest in the product. In other words, it is the volume of output a market is expected to achieve. This is indicated by key Factors such as an increase in buyers or sellers within this market or general trend of sales volume increasing (www.answers.com).
- 23. **Organization Size:** "Basically, an organization in its simplest form (and not necessarily a legal entity, e.g., corporation or LLC) is a person or group of people intentionally organized to accomplish an overall, common goal or set of goals.

Business organizations can range in size from one person to tens of thousands" (www.tek-9.org).

- 24. **Organization Structure:** The arrangement of lines of authority, communications, rights and duties of an organization. This arrangement determines how the roles, power and responsibilities are assigned, controlled, and coordinated..
- 25. **Organization Leadership:** The management staff that typically provides inspiration, objectives, operational oversight, and other administrative services to a business. Effective organizational leadership can help prioritize objectives for subordinates and can provide guidance toward achieving the overall corporate vision (www.businessdictionary.com).
- 26. **Organization Management:** Organization management refers to the art of getting people together on a common platform to make them work towards a common predefined goal. Organization management gives a sense of direction to the employees. The individuals are well aware of their roles and responsibilities and know what they are supposed to do in the organization (www.managementstudyguide.com).
- 27. Education: The level of formal education with the respective degrees (e.g., BS, MS, Ph.D).
- Experience: Years of experience in the environment and/or organization related to the current job functions.

29. **Motivation:** Factors that stimulate people to be interested and committed to the project.

So, a proposed model towards exploring the innovation environment within the systems engineering context of a defense organization that incorporates many of the factors and ideals identified as relevant within similar contexts in the literature review is proposed in Figure 4-1 and described below.

innovation Factors
Qualitative and Quantitative
and Qualititative
Security
Competition
Project Duration
Cost
Job Creation
Recognition
Project Scope
Procuremen
Project Nature
Communication
Logistics
Supply Chain Management
Operational Management
Well Defined Requirements
Quality
Design
Technology
Performance
Projected ROI
Cost Saving
Profit Growth
Potential Market Success
Organization Size
Organization Structure
Organization Leadership
Organization Management
Education
Experience
Motivation



Figure 4-1: Proposed Innovation Measurement Model (Preliminary).

#### 4.3 Expert Evaluation

Expert-based evaluation techniques are also referred to as expert analysis techniques. Expert evaluation is the appraisal of a product or service by someone who has the professional training or experience to make an informed judgment on the design. Expert evaluation is a useful tool in that it is efficient and provides prescriptive feedback. It is also less expensive than other techniques requiring subject involvement and experts often provide solutions to the problems that they identify. There are several common techniques that can be used when performing an expert evaluation. These are: Heuristic evaluation, Pluralistic walkthrough, and Cognitive walkthrough. In Heuristic evaluation, one or more experts evaluate the system or product against a list of design principles (commonly referred to as heuristics); in a Pluralistic walkthrough the evaluators conduct a series of paper-based tasks that represent using the proposed product or system. The tasks are first completed individually and then the findings discussed as a group, highlighting the usability issues associated with completing that task; finally, in cognitive walkthrough a group of evaluators walkthrough a specific sequence of steps or actions required by a user to accomplish a predetermined task, highlighting and discussing issues along the way. Regardless of the stage of development, expert evaluation can always benefit innovation (Nielsen 1994). At an early stage of development, expert evaluation can provide a significant improvement in the design of a product for a relatively small outlay of capital. At the later stages of development expert appraisal can detect critical problems and provide priorities for exploration with users. In this study expert evaluation was used to evaluate the significance of each factor listed in relation to innovation, and then eliminate insignificant factors. Initially 29 factors were chosen (see section 4.2.2). After the expert

evaluation, it was determined to reduce the factors to 22 factors. The eliminated factors are shown in Table 4-1.

Eliminated Factors	Reason for Elimination
Recognition	Recognition cannot be predicted in advanced. It is the effect of a successful and important project. It is dependent on many political
	factors too.
Project Scope	Project scope factors/question is basically included in the innovation definition.
Technology	Usually innovation projects are technology projects and all defense organization projects are dealing with technology.
Cost Saving	Cost saving of a project is hard to be predicted. It is taking into consideration in Project ROI.
Potential Market Success	Required a lot of study and research prior to any project and it is some time very costly.
Organization Structure	The definition overlaps some of the aspects of organization leadership.
Organization Management	The definition overlaps some of the aspects of organization leadership.

# Table 4-1: Eliminated Factors.

# 4.4 Survey Construct

Survey is defined as the systematic assembling of information from respondents with the intention of understanding an aspect or more of a particular population. It has become an established and effective method among researchers (Newsted et al., 1998). Hence, the survey method was viewed to be a suitable technique to incorporate within this research.

The aim of this research was to establish a survey procedure that would elicit reliable and unbiased information from experts in innovation and systems engineering fields. The survey was pre-tested by 10 experts and then modified before deployment. To enhance the validity and reliability of the survey, it was decided to build the questions in a structured format and to conduct a survey in short face-to-face mode. This will ensure that all questions were answered and will minimize communication error, and allow the researcher to farther investigate questions as need it.

Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (IRB). This research has been reviewed and approved by the IRB (see Appendix B).

The entire data collection file is part of this research and it is submitted as a separate Excel file under this dissertation. Please refer to it for more details on the collected data.

The sample size of the survey was 112 experts in the field of innovation and systems engineering from major defense organization: Lockheed Martin (www.lockheedmartin.com), Boeing (www.boeing.com), Northrop Grumman (www.northropgrumman.com), Raytheon (www.raytheon.com), Cubic (www.cubic.com), and SAIC (www.saic.com). 300 projects were identified from the defense organization listed above. 22 questions were identified and developed, one question for each innovation variable/factor. Surveyed people were identified to provide the answers for their projects. Data for each project was collected from one participant to ensure information was not duplicated for each project. The data for 300 (unique) projects were collected where surveyed participants provided data for more than one project. The surveyed individuals were briefed about the survey and the objectives of the

study. Face-to-face interviews were conducted to collect the data and in some cases survey questions were emailed to participants.

Data collected was randomly divided into two groups (i.e., the participants were divided randomly in two groups). The first group of participants corresponded to a set of 200 projects was used to study and find the significant innovation factors from the surveyed 22 factors. The second group of participants corresponded to a set of 100 projects and it was used to test the different models.

#### 4.5 Validity, Reliability, and Consistency of the Construct

Validity is the amount of systematic or built-in error in measurement (Norland 1990). Validity is established using a panel of experts and a field test. Which type of validity (content, construct, criterion, and face) to use depends on the objectives of the study. You can confirm validity with a number of questions. For example: Is the construct valid? In other words, is it measuring what it intended to measure? Does it represent the content? Is it appropriate for the sample/population? Is the construct comprehensive enough to collect all the information needed to address the purpose and goals of the study? Addressing these questions coupled with carrying out a readability test enhances construct validity.

Reliability refers to random error in measurement. Reliability indicates the accuracy or precision of the measuring instrument (Norland 1990). The pilot test seeks to answer the question, does the construct consistently measure whatever it measures. The use of reliability

types (test-retest, split half, alternate form, internal consistency) depends on the nature of data (nominal, ordinal, interval/ratio).

As previously mentioned, validity and reliability were established using a pilot test by collecting data from 10 expert evaluators not included in the sample. Data collected from pilot test was analyzed using SPSS (Statistical Package for Social Sciences). SPSS (v21.0) provides two key pieces of information. These are "correlation matrix" and "view alpha if item deleted" column. Make sure that items/statements that have 0s, 1s, and negatives are eliminated. Then view "alpha if item deleted" column to determine if alpha can be raised by deletion of items. Delete items that substantially improve reliability. The reliability coefficient (alpha) can range from 0 to 1, with 0 representing an instrument with full of error and 1 representing total absence of error. A reliability coefficient (alpha) of .70 or higher is considered acceptable reliability.

The collected data was analyzed initially by calculating the average response rate for all factors and questions. The data was grouped into categories to allow the researcher for a preliminary visual evaluation of the collected data and the responses.

The first group includes the respondents' innovation determination classification for the "yes' and "No" questions as shown in Table 4-2. For the "Innovation Yes" answers section of the table the data was calculated by dividing the responses to survey question by 227 (number of responses with yes to innovation projects from the 300 projects). For the "Innovation No" answers section of the table the data was calculated by dividing the responses by dividing the responses to survey question by 73 (number of responses with no to innovation projects from the 300 projects).

	Innovat	ion Yes	Innovation No		
Innovation Factors	Yes	No	Yes	No	
Competition (survey question # 3)	0.39	0.61	0.52	0.48	
Logistics (survey question # 10)	0.52	0.48	0.59	0.41	
Well Defined Requirements (survey question # 13)	0.79	0.21	0.77	0.23	

Table 4-2: Respondents' Innovation Determination Classifications (Yes and No).

The second group includes the respondents' innovation determination classification for the 1 to 3 scale questions as shown in Table 4-3. The values represent the percentage of the answers to the questions in the table. For the "Innovation Yes" answers section of the table the data was calculated by dividing the responses to survey question by 227 (number of responses with yes to innovation projects from the 300 projects). For the "Innovation No" answers section of the table the data was calculated by dividing the responses to survey question by 73 (number of responses with no to innovation projects from the 300 projects). The average is the sum of three values where each value was multiple by the scale associated with the answer (1, 2, or 3).

е 		Innovat	tion Yes	i i	Innovation No				
Innovation Factors	Ans (1)	Ans (2)	Ans (3)	Average	Ans (1)	Ans (2)	Ans (3)	Average	
Procurement (survey question # 3)	0.38	0.26	0.36	1.98	0.18	0.33	0.49	2.31	
Project Nature (survey question # 7)	0.23	0.14	0.63	2.4	0.16	0.11	0.73	2.57	

Table 4-3: Respondents' Innovation Determination Classifications (1 to 3 Scale).

The third group includes the respondents' innovation determination classification for the 1 to 4 scale questions as shown in Table 4-4. The values represent the percentage of the answers to the questions in the table. For the "Innovation Yes" answers section of the table the data was calculated by dividing the responses to survey question by 227 (number of responses with yes to innovation projects from the 300 projects). For the "Innovation No" answers section of the table the data was calculated by dividing the responses to survey question by 73 (number of responses with no to innovation projects from the 300 projects). The average is the sum of three values where each value was multiple by the scale associated with the answer (1, 2, 3, or 4).

р	Innovation Yes						Innovation No				
Innovation Factors	Ans (1)	Ans (2)	Ans (3)	Ans (4)	Average	Ans (1)	Ans (2)	Ans (3)	Ans (4)	Average	
Supply Chain Management (survey question # 11)	0.01	0.59	0.36	0.04	2.43	0.03	0.55	0.42	0	2.39	
Operational Management (survey question # 12)	0	0.41	0.39	0.2	2.79	0.01	0.51	0.43	0.05	2.52	
Quality (survey question # 14)	0	0.27	0.44	0.29	3.02	0.01	0.37	0.41	0.21	2.82	
Education (survey question # 21)	0.02	0.44	0.54	0	2.52	0.62	0.37	0.01	0	1.39	

Table 4-4: Respondents' Innovation Determination Classifications (1 to 4 Scale).

The fourth group includes the respondents' innovation determination classification for the 1 to 5 scale questions as shown in Table 4-5. The values represent the percentage of the answers to the questions in the table. For the "Innovation Yes" answers section of the table the data was calculated by dividing the responses to survey question by 227 (number of responses with yes to innovation projects from the 300 projects). For the "Innovation No" answers section of the table the data was calculated by dividing the responses to survey question by 73 (number of responses with no to innovation projects from the 300 projects). The average is the sum of three values where each value was multiple by the scale associated with the answer (1, 2, 3, 4, or 5).

9	Innovation Yes						Innovation No					
Innovation Factors	Ans (1)	Ans (2)	Ans (3)	Ans (4)	Ans (5)	Average	Ans (1)	Ans (2)	Ans (3)	Ans (4)	Ans (5)	Average
Security (survey question # 2)	0	0.02	0.04	0.35	0.59	4.51	0	0,62	0.3	0.08	0	2.46
Project Duration (survey question # 4)	0.58	0.35	0.05	0.018	0.002	1.51	0.47	0.48	0.05	0	0	1.58
Cost (survey question # 5)	0.43	0.4	0.07	0.04	0.06	1.9	0.32	0.53	0.11	0.04	0	1.87
Job Creation (survey question # 6)	0.85	0.12	0.03	0	0	1.18	0.88	0.11	0.01	0	0	1.13
Communication (survey question # 9)	0	0	0.04	0.44	0.52	4.48	0	0.64	0.32	0.03	0.01	2.41
Design (survey question # 15)	0.03	0.27	0.2	0.32	0.18	3.35	0.02	0.21	0.21	0.44	0.12	3.43
Performance (survey question # 16)	0	0.01	0	0.44	0.55	4.53	0.18	0.48	0.27	0.07	0	2.23
Projected ROI (survey question # 17)	0	0.01	0.12	0.44	0.43	4.29	0.27	0.61	0.11	0	0.01	1.87
Profit Growth (survey question # 18)	0	0.01	0	0.48	0.51	4.49	0.38	0.55	0.04	0.03	0	1.72
Organization Size (survey question # 19)	0.6	0.3	0.06	0.04	0	1.54	0.64	0.3	0.06	0	0	1.42
Organization Leadership (survey question # 20)	0	0	0	0.41	0.59	4.59	0.44	0.14	0.36	0.04	0.02	2.06
Experience (survey question # 22)	0	0.17	0.46	0.32	0.05	3.25	0.16	0.74	0.06	0.04	0	1.98
Motivation (survey question # 23)	0	0	0.02	0.44	0.54	4.52	0	0.59	0.34	0.06	0.01	2.49

Table 4-5: Respondents' Innovation Determination Classifications (1 to 5 Scale).

In addition, many different graphs were build using different software packages such as Excel(<u>http://office.microsoft.com/enus/excel/</u>),Matlab(<u>http://www.mathworks.com/products/matla</u>b/),Weka (<u>http://www.cs.waikato.ac.nz/ml/weka/</u>), Minitab (<u>http://www.minitab.com</u>), and SPSS (<u>http://www-01.ibm.com/software/analytics/spss/</u>). As an example, we are showing Figure 4-2 that represents an overview of the different factors and results.



Figure 4-2: Visualization of the entire survey results using Weka (<u>http://www.cs.waikato.ac.nz/ml/weka/</u>).

# 4.5.1 Factor Analysis

Factor analysis is a technique used for summarizing a large number of variables by a smaller number of factors. Generally, these factors should pertain to coherent subsets of variables, where the subsets themselves are, more or less, unrelated. A more striving goal than just summarizing is to measure a particular area of interest and to find underlying processes that determine the observed scores on the variables.

Factor analysis for the levels 4 and 5 was done to group related survey items (excluding demographic variables, if any) into a few factors. Two factors were extracted from level 5 factors (shown in Table 4-6) while only one factor was extracted from level 4 factors. From

Table 4-6, it is evident that two factors explains the the greatest percentage of variance. The Scree plot (Figure 4-3) further confirms the number of factors to be extracted.

		Initial Eigenvalu	es	Rotation Sums of Squared Loadings						
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %				
1	5.978	49.817	49.817	5,569	46.404	46.404				
2	2.646	22.054	71.871	2.419	20.161	66.565				
3	0.704	5.865	77.735							
11	0.182	1.516	98.619							
12	0.166	1.381	100	(						
Extraction	Method: P	Principal Axis Factor	ing.							

Table 4-6: Total Variance Explained.



Scree Plot

Figure 4-3: Total Variance Explained.

The resulting extracted factors can be seen in Table 4-7. To maximize the sum of the variances of the squared correlations between variables and factors, a varimax rotation method was adopted. Varimax rotation ensured that each variable can be easily identified with a single factor.

Rotated Factor Matrix <sup>a</sup>						
	Facto	tor				
Variables	1	2				
Cost		0.943				
JobCreation		0.656				
Communication	0.857					
Design		0.518				
Performance	0.861					
ProjectedROI	0.843					
ProfitGrowth	0.916					
OrganizationLeadership	0.857					
Experience	0.638					
Motivation	0.858					
Security	0.807					
ProjectDuration		0.802				
Extraction Method: Principal Axis Factoring.	64. 64.					
Rotation Method: Varimax with Kaiser Normalization.						
a. Rotation converged in 3 iterations.						
Can you talk about what you called factors 1 and 2 and th	e implication of this grouping?					

Table 4-7: Rotate	d Factor Matrix.
-------------------	------------------

The following variables/factors were treated as demographic factors and were not included in

the factorial analysis:

- Project Nature (survey question # 8)
- Organization size (survey question # 19)
- Education (survey question # 21)

- Logistics (survey question # 10)
- Well defined Requirements (survey question # 13)
- Competition (survey question # 3)

The Cronbach's coefficient alpha was used to judge the reliability and the internal consistency or homogeneity among each of the construct's items. The data was exported to analytical software (SPSS V21.0) and the reliability of the construct was determined to be at a very acceptable level. The Cronbach's alpha for the factor/construct 1 is 0.947 and the Cronbach's alpha for the factor/construct 2 is 0.774 as shown in Table 4-8.

Table 4-8: Reliability Statistics.

Reliability Statistics							
Cronbach's Alpha Based on Construct Cronbach's Alpha Standardized Items N of Items							
1	.947	.948	8				
2	.774	.816	4				

As a measure of content validity, the survey instrument provided adequate coverage of the important elements (innovation environment determinants) of the systems engineering context in the defense industry as defined by the experts. Thus we can assume that the content of the construct have already been validated.
### 4.6 Modeling

This research uses multiple data analysis modeling. It uses traditional statistics such as logistic regression and data mining modeling such as neural networks and regression/ classification trees. Table 4-9 shows the task accomplished by using each modeling methodology. Table 4-10 shows the different features of each modeling methodology. Logistic regression is a generalized linear model. Neural networks are well recognized by its non-linearity features. On the other hand, regression/classification trees are dominant when simplicity is a requirement.

### Table 4-9: Modeling Methodologies.

Modeling Method	Task Accomplished
Principal Components Analysis	Linear Separability
Factor Analysis / Logistic Regression	Model with Respective Coefficients
Neural Networks	Model with Respective Coefficients
Regression/ Classification Trees	Model with Respective Variables

Table 4-10: Basic Features of each Modeling Methodology.

Modeling Methodologies	Coefficients of the Model	Measuring the Importance of Variables
Factor Analysis / Logistic Regression	Maximum Likelihood	Likelihood-Ratio Test
Neural Networks	Gradient Descent	Sensitivity Analysis
Regression/ Classification Trees	Exhaustive Search	Gini Impurity Index

#### 4.7 Principal Component Analysis (PCA) to Visualize Linear Separability

In this section, we utilized the traditional logistic regression that is one of the mechanisms recommended for this type of studies (Rahal 2005). We decided to use a 2-step process. The first step is the utilization of Principal Component Analysis (PCA) in order to determine the best combination of factors (and avoid problems and take advantage of larger variances). PCA is used to reduce the number of factors. In our case, we will perform PCA to generate some of most informative features (i.e., fewer number than the original feature set).The second step is to use logistic regression in order to have a predictive model.

Principal component analysis (PCA) is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components.

The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has the largest possible variance, and each succeeding component in turn has the highest variance possible under the constraint that it be orthogonal to (i.e., uncorrelated with) the preceding components. Principal components are guaranteed to be independent only if the data set is jointly normally distributed. PCA is mostly used as a tool in exploratory data analysis and for making predictive models. The results of a PCA are usually discussed in terms of component scores (Brooks et al., 1988).

PCA is very important in particular when the reduction of the number of the variables is needed (in our case we would like to go from 22 to a lesser number). As well stated by Yatani

(<u>http://yatani.jp/HCIstats/PCA</u>) "More mathematically, PCA is trying to find some linear projections of your data which preserve the information your data have."

MATLAB was utilized in order to obtain the principal components. Table 4-8 and Figure 4-4 provide details of the principal components. It is easy to see from Figure 4-4 that using the first two components the problem is linearly separable.

# Table 4-11: PCA Using MATLAB.

РСА	Equations
Factors	
PCA 1	0.315Experience + 0.309Organization Leadership + 0.308Performance +
	0.304Profit Growth + 0.297Communication + 0.296Motivation +
	0.296Education + 0.278Projected ROI + 0.277Security + 0.208Organization Size
	+ 0.202C0SL
PCA Z	- 0.29Design - 0.261Procurement - 0.234Project Nature - 0.225Supply Chain
	Management
PCA 3	0.441 Competition + 0.347Logistics + 0.328Project Nature - 0.295Job Creation
	+ 0.294Well Defined Requirements - 0.292Cost - 0.246Organization Size +
	0.245Procurement + 0.2 Design
PCA 4	-0.605Well Defined Requirements - 0.486Quality - 0.365Operational
	Management + 0.295Supply Chain Management + 0.288Procurement
PCA 5	-0.658Quality - 0.481Logistics + 0.395 Competition + 0.221Operational
	Management
PCA 6	-0.666Operational Management-0.373Design+0.362 Competition-
	0.295Procurement+0.237Well Defined Requirements
PCA 7	-0.586Project Nature + 0.521Logistics + 0.428Well Defined Requirements +
	0.212Supply Chain Management - 0.21 Competition
PCA 8	-0.528 Competition + 0.476Well Defined Requirements - 0.394Logistics +
	0.301Procurement - 0.271Operational Management + 0.244Supply Chain
	Management + 0.212Project Nature
PCA 9	0.62/Supply Chain Management + 0.439Quality - 0.375Project Nature -
DCA 10	0.520E0gistics + 0.294 Competition
PCA 10	-0.54Procurement + 0.310Supply Chain Management + 0.381Operational Management + 0.33 Project Nature - 0.222Design - 0.213 Competition
DCA 11	0.757Dosign_0.405Drocuroment_0.2025dusation
PCA 11	0.757 Design - 0.495Procurement - 0.308Education
PCA 12	0.625Job Creation - 0.498Education + 0.318Security + 0.268Project Nature -
DCA 42	
PCA 13	0.663Projected ROI - 0.465Education - 0.337Security + 0.221Communication -
DCA 1/	0.219 Motivation 0.388 Organization Leadership - 0.321 Security -
1 CA 14	0.308Projected ROI - 0.235Education
PCA 15	0.533Security - 0.448Communication - 0.444Job Creation - 0.374Education +
	0.218Organization Size
PCA 16	0.628Motivation - 0.433Security + 0.35 Organization Leadership -
	0.341Experience - 0.336Communication



Figure 4-4: First Principal Component vs. Second Principal Component displaying a good level of linear separability.

### 4.8 Factorial Analysis and Logistic Regression

Logistic regression is a type of regression analysis used for predicting the outcome of a categorical dependent variable based on one or more predictor variables. That is, it is used in estimating empirical values of the parameters in a qualitative response model. Logistic regression is used to refer specifically to the problem in which the dependent variable is binary—that is, the number of available categories is two—and problems with more than two categories are referred to as multinomial logistic regression or, if the multiple categories are

ordered, as ordered logistic regression. Logistic regression measures the relationship between a categorical dependent variable and one or more independent variables (Strano and Colosimo, 2006).

The data was then exported into SPSS Version 21.0 for processing to establish a relationship between the outcome and the set of predictors as provided by factorial analysis. The logistic regression was used due to the binary (dichotomous) state of the outcome were a one (1) was assigned to Innovation (Yes), while a zero (0) was assigned to Innovation (No). The standard logistic regression formula for a multi-variable model is given by the following equation:

Probability(event) = 
$$\pi_j = \frac{1}{1 + \exp(-(b_0 + b_1 X_1 + b_2 X_2 + ... + b_i X_i))}$$

Where b0 represent the intercept representing the value of the dependent variable, and the b's coefficients represent the change in the dependent variable associated with a unit change in the independent variable (Rahal 2005).

The statistical software (SPSS V21.0) features several methods for stepwise selection of the "best" predictors that contribute significantly to the model using either a backward elimination or a forward inclusion stepwise logistic regression.

### 4.8.1 Forward with Factorial Analysis

As a further measure to check the goodness of the stepwise forward logistic regression model, a backward stepwise logistic regression model was built and compared to the previous forward stepwise model.

The data (The Factors and Demographic Variables) was then exported to SPSS and the forward inclusion regression stepwise method was used and yielded the variables and coefficients listed in Tables below. These variables were retained in the regression model as they proved to be significant.

Table 4-12: Forward LR Variables in the Equation.

Variables in the Equation <sup>h</sup>								
	B S.E. Wald df Sig. Exp(B)							
Step	ProjectNature	-2.222	.970	5.250	1	.022	.108	
4 <sup>a</sup>	SupplyChainManagement	-4.556	1.797	6.429	1	.011	.010	
	Quality	-3.117	1.219	6.543	1	.011	.044	
	FA1	1.034	.314	10.826	1	.001	2.813	

In the table above, labeled Variables in the Equation we see the coefficients, their standard errors, the Wald test statistic with associated degrees of freedom and p-values, and the exponentiated coefficient (also known as an odds ratio). The following are considered to be significant:

- Project Nature (survey question # 8)
- Supply Chain Management (survey question # 11)
- Quality (survey question # 14)

- FA1
  - Organizational Leadership (survey question # 20)
  - Profit Growth (survey question # 18)
  - Projected ROI (survey question # 17)
  - Motivation (survey question # 23)
  - Performance (survey question # 16)
  - Security (survey question # 2)
  - Communication (survey question # 9)
  - Experience (survey question # 22)

Logistic regression coefficients give the change in the log odds of the outcome for a one

unit increase in the predictor variable (Menard 2002).

- For Project Nature, the log odds of innovation (versus non-innovation) decrease by 2.222 every one unit.
- For Supply Chain Management, the log odds of innovation (versus non-innovation) decrease by -4.556 every one unit change.
- For Quality, the log odds of innovation (versus non-innovation) decrease by -3.117 every one unit change.
- A one unit increase in FA1, the log odds of being innovation project increase by 1.034.

- Step 4 This is the fourth step (or model) with predictors in it. In this case, it is the full model that we specified in the logistic regression command.
- B These are the values for the logistic regression equation for predicting the dependent variable from the independent variable. They are in log-odds units.
- S.E. Standard errors associated with the coefficients. The standard error is used for testing whether the parameter is significantly different from 0; by dividing the parameter estimate by the standard error you obtain a t-value. The standard errors can also be used to form a confidence interval for the parameter (www.ats.ucla.edu/stat/spss/output/logistic.htm).
- Wald and Sig. Provide the Wald chi-square value and 2-tailed p-value used in testing the null hypothesis that the coefficient (parameter) is 0. If you use a 2-tailed test, then you would compare each p-value to your preselected value of alpha. Coefficients having p-values less than alpha are statistically significant (Pample, 2000).
- df Lists the degrees of freedom for each of the tests of the coefficients.
- Exp(B) Odds ratios for the predictors, they are the exponentiation of the coefficients.

The most important variables are indicated in Figure 4-5 using the likelihood ratio test where each predictor is evaluated by testing the improvement in the model fit when that predictor is added to the model when using the stepwise forward logistic regression (O'Connell 2005). In addition, the performance of logistic regression with the training and testing sets is displayed in Table 4-13.



Figure 4-5: Most Important Variables Using Logistic Regression.

Table 4-13: Logistic Regression Performance with FA (SSE is Summatory of the Squared Error).
--

Training / Validation			Testing/ Prediction			
SSE	Misclassification	Performance	SSE Misclassification Performa			
2.84	5/200	97.5%	1.59	2/100	98%	

#### 4.9 Data Mining Modeling

Data mining is the term used to describe the process of extracting value from a database. Data mining is a very useful technique that has become dominant and well developed in the last twenty years. Frawley et al. (1994) have defined data mining as "the nontrivial extraction of implicit, previously unknown, and potentially useful information from data." Another interesting definition is the one from Witten and Frank (2005) that makes emphasis on the non-statistical part: "Discovery of useful, possibly unexpected, patterns in data using statistical and non-statistical techniques." We decided to use different techniques from the data mining domain: neural network and classification/regression trees. Neural networks and classification/regression trees are used to analyze and build predictive models.

#### 4.9.1 Neural Networks

A neural network is a mathematical/computational model based on biological neural networks, in other words, is an emulation of biological neural system. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In other words, it is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase (Yashpal Singh, Alok Singh Chauhan. 2009). Neural networks have emerged as advanced data mining tools in cases where other techniques may not produce satisfactory predictive models. Neural networks are statistical modeling tools. In more practical terms neural networks are non-linear statistical data modeling tools. They can be used to model complex relationships between inputs and outputs or to find patterns in data. Using neural networks as a tool, data

warehousing firms are harvesting information from datasets in the process known as data mining. The difference between these data warehouses and ordinary databases is that there is actual manipulation and cross-fertilization of the data helping users makes more informed decisions. Neural networks essentially comprise three pieces: the architecture or model; the learning algorithm; and the activation functions. Neural networks are programmed to recognize, and associatively retrieve patterns or database entries; to solve combinatorial optimization problems; to filter noise from measurement data; to control ill-defined problems. It is pattern recognition and function estimation that make neural networks a prevalent a utility in data mining (King 2011).

Analysis was performed by the use of neural networks to determine the most important factors and to build a competing predictive model. Neural networks are well suited to this type of analysis because of their focus on the relationships between the components of the model. This study involved the use of supervised learning systems. In supervised learning with neural networks, we try to adapt a neural network so that its actual outputs ( $\mu$ ) come close to the target outputs (t) for some training set. The goal is to adapt the parameters of the network so that it performs well for samples from outside of the training set. Back propagation (type: minimizing errors) (Rumelhart et al., 1989; Werbos 1994) was selected (See Figure 4-6).



Figure 4-6: A Multilayer Neural Network.

#### 4.9.1.1 The Selection of a Neural Network Architecture

It is important to select the right architecture (i.e., the number of hidden neurons) for a Back propagation neural network. It is known from theoretical developments (Moody 1994) and from empirical results (Plate et al., 1997) that the generalization ability (GA) of a neural network depends on a balance between the information in the training examples and its complexity (i.e., weights and hidden neurons). On the other hand, it is also clear that neural networks with too few weights and hidden neurons ( $\lambda$ ) will not have the capacity to represent the information accurately. Traditionally in supervised neural networks GA is defined as the expected performance on future data and can be approximated by the expected performance on a finite test set. Therefore, several architectures (different hidden units and hidden layers) are "trained" and the one with the best GA is selected. This method is effective especially when there are enough data samples (i.e., a very large number). Unfortunately, in the problem faced,

there are not enough observations to calculate GA. Therefore it was decided not to use the traditional method. It was decided instead to use cross validation (CV). As stated by Moody (1994), CV is a "sample re-use method that can be used to estimate GA. CV makes minimal assumptions on the statistics of the data. Each instance of the database in turn is left out, and the supervised neural network is trained on all the remaining examples (N - 1)." The results of all n judgments, one for each member of the dataset, are averaged, and that average represents the final error estimate (i.e., GA) and expressed by the following equation (Moody 1994):

$$CV(\lambda) = \sum_{j=1}^{N} (t_j - \widehat{\mu}_{\lambda(j)}(x_j))^2$$

This form of  $CV(\lambda)$  is known as leave-one-out CV.

However, leave-one-out CV is computationally expensive. We use a variation of the method denominated v-fold cross-validation. Instead of leaving out only one observation for the computation of the sum, we delete larger subsets of the data set (D).

Moody (1994) explains very well the procedure "Let the data D be divided into v randomly selected disjoint subsets Pj of roughly equal size:  $\bigcup_{j=1}^{v} P_j = D$  and  $\forall i \neq j, P_i \cap P_j = \emptyset$ . Let Nj denote the number of observations in subset Pj. Let  $\hat{\mu}_{\lambda(p_j)}(x)$  be an estimator trained on all data except for  $(x,t) \in Pj''$  and U is the universe of data samples. Then, the cross-validation average squared error  $(CV_{vi}(\lambda))$  for subset j is defined as (Moody 1994):

$$CV_{p_j}(\lambda) = \sum_{(x_k, t_k) \in P_j} (t_k - \widehat{\mu}_{\lambda(p_j)}(x_k))^2$$

And

$$CV_p(\lambda) = \sum_j CV_{p_j}(\lambda)$$

Our choice for v was 10.

We initially trained neural networks with all 22 available input variables (representing the corresponding factors) but with the number of hidden units  $\lambda$  varying from 0 to 5. After the building and validating took more than 60 neural networks, it was decided to use the architecture with 2 hidden neurons that has the lower  $CV_p(\lambda)$ . Figure 4-7 shows the graph with the entire process depicted.



Figure 4-7: Selection of the Neural Network Architecture with two (2) Hidden Units.

4.9.1.2 Elimination of Input Variables (i.e., Factors)

Next, we eliminated some of the input factors. To test which factors are most significant for determining the neural network output using the neural network with 2 hidden neurons, we performed a sensitivity analysis and the respective results are depicted in Figure 4-8. We defined the "Sensitivity" of the network model to input variable  $\beta$  as (Moody 1994):

$$S_{\beta} = \sum_{j=1}^{N} ASE(\overline{x_{\beta}}) - ASE(x_{\beta}) \text{ with } \overline{X_{\beta}} = \frac{1}{N} \sum_{j=1}^{N} X_{\beta_j}$$



Figure 4-8: Importance of Input Variables (e.g., factors) via Sensitivity Analysis.

Moody (1994) explains very well this process as follows "Here,  $x_{\beta_j}$  is the  $\beta$ th input variable of the jth exemplar. S $\beta$  measures the effect on the average training squared error (ASE) of replacing the  $\beta$ th input x $\beta$  by its average  $\overline{x_{\beta}}$ . Replacement of a variable by its average value removes its influence on the network output". Again we use 10-fold cross-validation to estimate the prediction risk CV  $P_{\lambda}$ . A sequence of models by deleting an increasing number of input variables in order of increasing  $S_{\beta}$ . A minimum was attained for the model with  $I_{\lambda} = 13$ input variables (9 factors were removed) as depicted in Figure 4-8. We had to build more than 120 neural networks in order to get the different results displayed in Figure 4-9.



Figure 4-9: Elimination of Input Variables (i.e., factors).

After that, the final neural network was trained using 200 data samples and 2 hidden neurons in one hidden layer. The neural network is displayed in Figure 4-10 with the most important factors. The inputs are the most important factors based on neural networks.



Figure 4-10: Finalized Neural Network Developed with the Most Important Factors. The Neural Network uses 13 Factors as Inputs, 2 Hidden Neurons in one Hidden Layer, and One Output Neuron in the Output Layer representing Innovation.

This finalized neural network has the following training and testing performance as shown in Table 4-14. It is important to remember that the training set was of the 200 projects selected and the testing set was composed of the remaining projects.

Training / Validation				Testing/ Prediction		
SSE	Misclassification	Performance	SSE Misclassification Performan			
0.002	0/200	100%	0.950	1/100	99%	

Table 4-14: Neural Network Performance.

#### 4.9.2 Classification/Regression Trees

There are many different types of classification/regression trees. The one selected due to its high performance capabilities was the Classification and Regression Tree (CART) (Steinberg and Colla, 1995). CART analysis is a form of binary recursive partitioning. The analysis determines the best possible variable to split the data into two separate sets. The variable for splitting is chosen based on maximizing the average purity of the two child nodes. Each node is assigned a predicted outcome class. This process is repeated recursively until it is impossible to continue. The result is the maximum sized tree which is perfectly fit to the input data. Consequently, the tree is pruned to create a generalized model that can work with outside data sets. This pruning process is performed by reducing the cost-complexity of the tree while maximizing the prediction capability. An optimal tree is selected which provides the best prediction capability on outside data sets and has the least degree of complexity (Breiman et al., 1984).

CART (http://www.salford-systems.com/products/cart) was developed by Stanford University and University of California at Berkeley statisticians. An example of a tree developed using CART is presented below in Figure 4-11. This tree using CART is for differentiating between sterile inflammation and bacterial infection in critically ill patients with fever and other signs of the systemic inflammatory response syndrome (SIRS) (http://1.salfordsystems.com/case-study-new-biomarker-discovered-for-critically-ill-childeren-diagnostic/). The objective included the mining of an "existing genome-wide expression database for the discovery of candidate diagnostic biomarkers to predict the presence of bacterial infection in critically ill children." Each node provides the total number of patients in either the sepsis ("infected") or systemic inflammatory response sysndrome (SIRS) ("Not infected") classes-- and the respective rate. Each node also provides the decision rule based on either an Interleukin 27 (IL27 -the protein encoded by this gene is one of the subunits of a heterodimeric cytokine complex

(http://www.ncbi.nlm.nih.gov/gene?cmd=Retrieve&dopt=full report&list uids=246778)) or a concentration cut point of procalcitonin (PCT). The successful and deceptively simple decision tree generated three terminal nodes having two factors to predict the infection (http://1.salford-

systems.com/Portals/160602/case%20studies/a%20novel%20candidate%20diagnostic%20biom arker%20for%20bacterial%20infection%20in%20critically%20ill%20children %20critical%20car e.pdf?submissionGuid=35782408-9250-4e58-859e-1179e7adc6f1).



Figure 4-11: CART Classification Tree for Diagnostic Biomarker for Bacterial Infection (adapted and modified from <u>http://1.salford-systems.com/case-study-new-biomarker-discovered-for-critically-ill-childeren-diagnostic/</u>).

Using the CART implementation of Salford Systems (<u>http://www.salford-systems.com/</u>), we were able to developed several trees using the training data. For example, the CART tree depicted in Figure 4-12 had 5 nodes and uses the following factors: Profit Growth, Projected ROI, Communication, and Security. Figure 4-13 displays the CART tree developed and optimized. The most important variables are shown in Figure 4-13. The most important variables are selected by using the Gini Impurity Index. Gini impurity is a measure of how often a randomly chosen element from the set would be incorrectly labeled if it were randomly labeled according to the distribution of labels in the subset. As explained by (Gonzales 2010)

"Gini impurity can be computed by summing the probability of each item being chosen times the probability of a mistake in categorizing that item. It reaches its minimum (zero) when all cases in the node fall into a single target category." Table 4-15 shows the performance results of the tree depicted in Figure 4-13.



Figure 4-12: Example of Classification/Regression Tree Developed for Innovation using the Training Data Set. This tree has 5 nodes.



Figure 4-13: Classification/Regression Tree using CART to model the Innovation Environment Factors of this research. As an example: IF <u>ProfitGrowth</u> is greater than 3.5 and IF <u>Security</u> is greater than 2.5 Then is **BLUE** (Innovative Yes).



Figure 4-14: Most Importance of Variables Using Classification/Regression Tree using CART and the Training Data Set of 200.

Table 4-15: Classification/Regression Tree Performance.

	Training / Validation			Testing/ Prediction			
SSE	Misclassification	Performance	SSE Misclassification Performa				
N/A	0/200	100%	N/A	3/100	97%		

# 4.10 <u>Summary of Data Analysis and Findings</u>

### 4.10.1 Survey Construct Data Analysis and Findings

In order to analyze the collected data of the interviews, several techniques were used utilizing different tools, applications, and methodologies were undertaken: MS Excel, Statistical Package for Social Sciences (SPSS), MATLAB, Data Mining, neural networks, Classification and Regression Tree (CART), Cronbach's Alpha, logistic regression, classification/regression trees, and Principal Component Analysis (PCA). One of the first steps was to judge the reliability and the internal consistency or homogeneity among each of the construct's items using the Cronbach's coefficient alpha. The data was exported to analytical software (SPSS V21.0) and the reliability of the construct was determined to be at a very acceptable level (Cronbach's alpha = 0.883) as shown in Table 4-6. As a measure of content validity, the survey instrument provided adequate coverage of the important elements (innovation environment determinants) of the systems engineering context in the defense industry as defined by the experts. Thus we can assume that the content of the survey have already been validated.

MATLAB was utilized in order to obtain the principal components. Table 4-8, provides details of the principal components. It is easy to see from Figures 4-3 that using the first two components the problem is linearly separable.

All methodologies and tools gave similar results in regard to the most significant innovation factors. The following most significant factors resulted from the logistic regression (LR) method, refer to Table 4-5:

- Education (survey question # 21)
- Competition (survey question # 3)
- Operational management (survey question # 12)
- FA1, which includes the following factors/ variables:
  - Security (survey question # 2)
  - Communication (survey question # 9)
  - Performance (survey question # 16)
  - Projected ROI (survey question # 17)

- Profit Growth (survey question # 18)
- Organizational Leadership (survey question # 20)
- Experience (survey question # 22)
- Motivation (survey question # 23)

The following most significant factors resulted from the neural networks (NN), refer to Figure 4-10:

- Organizational Leadership (survey question # 20)
- Profit Growth (survey question # 18)
- Projected ROI (survey question # 17)
- Motivation (survey question # 23)
- Performance (survey question # 16)
- Security (survey question # 2)
- Communication (survey question # 9)
- Education (survey question # 21)
- Supply Chain Management (survey question # 11)
- Logistics (survey question # 10)
- Experience (survey question # 22)
- Well Defined Requirements (survey question # 13)

The following most significant factors resulted from the classification/regression trees method, refer to Figure 4-14:

- Performance (survey question # 16)
- Organizational Leadership (survey question # 20)
- Profit Growth (survey question # 18)
- Communication (survey question # 9)
- Motivation (survey question # 23)

- Experience (survey question # 22)
- Projected ROI (survey question # 17)
- Experience (survey question # 22)

The findings from all three methods (logistic regression, neural networks, and classification/regression trees) clearly show that eight factors of the most important innovation factors are common across the methods. The eight common factors are: Organizational Leadership, Profit Growth, Projected ROI, Motivation, Performance, Security, Communication, and Experience). Also there was one common factor between LR and NN which is Education. Venn diagram, Figure 4-15 shows the intersection between all three methods.



Figure 4-15: Analysis of Significant Factors of all Three Methods.

The performance of the models created from all three methods was calculated, see Table 4-16. 200 records of the data used to training and validation, 100 records used for testing and prediction. The LR method indicates 2.84 SSE and 5 records for misclassification, which give 97.5% performance for the training and validation data set. For the testing group, LR indicates 1.59 SEE and 2 records for misclassification, which give 98% performance.

The NN method indicates 0.002 SSE and 0 records for misclassification, which give 100% performance for the training and validation. For the testing and validation group, NN indicates 0.95 SEE, and 1 record for misclassification, which give 99% performance.

The RT method indicates 0 records for misclassification, which give 100% performance for the training and validation data set. For the testing group, 3 records for misclassification, which gives 97% performance.

The total collaborative ensemble for the three methods indicates 0 records for misclassification, which give 100% performance for the training and validation data set. For the testing group just 1 record for misclassification, which gives 99% performance.

Table 4-16: Performance for Factors for all Three Methods (Logistic Regression, Neural Networks, and Classification/Regression Trees). An ensemble is a voting strategy of the different methods.

	Training / Validation			Testing/ Prediction		
Model		Misclassificatio	Performanc		Misclassificatio	Performanc
	SSE	n	е	SSE	n	е
Logistic Regression 2.84		5/200	97.5%	1.59	2/100	98%
	0.00					
Neural Networks	2	0/200	100%	0.950	1/100	99%
<b>Classification/Regression</b>						
Tree (CART)	N/A	0/200	100%	N/A	3/100	97%
Ensemble	N/A	0/200	100%	N/A	1/100	99%

The most important factors are very important indicators that capture the innovation environment. In addition, this is a statistical proof that financial factors (quantitative factors) are not the only important factors driven innovation in the defense industry. True financial is one of the most critical factor for determining innovation, but the results indicate that there are other important qualitative innovation factors such as Organizational leadership, Performance, and Security. The knowledge discovery from the survey indicates that organization leaders and managers should consider both quantitative and qualitative factors to determine and predict if a project is innovative project or not.

The consistency of the results from the three methodologies used in this study (logistic regression, neural networks, and classification/regression trees) provide defense organization high confidence in using one or more from the presented methods to predict the innovation in their organizations' projects.

From the viewpoint of the logistic regression, neural networks, and classification/regression trees is possible to create a benchmark/framework which can be used as a decision support system to assist directors in engineering and executives in the Defense Industry to assess and predict the likelihood of the potential viability of an initiative for innovation.

# **CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS**

This chapter provides an overview of this dissertation, a summary of the final results and findings, conclusions, contributions, and recommendations for future research.

### 5.1 Introduction

This research sought to explore the innovation environment, characteristics, culture, and innovation factors that are significant to determine innovation within the systems engineering context of the defense industry. In addition, this study provides a framework to be used by defense organizations to determine the innovation success of projects within their organizations. The early chapters of this study presented literature review related to innovation, innovation models, process of adoption of innovation, innovation management, measuring innovation, systems engineering and defense organizations. The research methodology, findings and discussion of the research conducted along with a summary of the findings were presented in latter chapters.

The purpose of this chapter is to synthesize the discussion of the foregoing chapters in the context of the research questions and the original aims and purpose of the study as outlined in Chapter one. The chapter presents a brief summary of the study, conclusions, and areas of future research.

#### 5.2 Research Summary

The literature review process identified 29 potential innovation factors deemed important and relevant to the innovation within the context of systems engineering in a defense organization. To understand the innovation factors and identifies the most important and significant factors, a survey construct were conducted with systems engineers, leaders, managers and innovation experts within the defense industry.

The aim of this research was to establish a survey procedure that would elicit reliable and unbiased information from experts in innovation and systems engineering fields. The survey was pre-tested by 10 experts and then modified before deployment. To enhance the validity and reliability of the survey, it was decided to build the questions in a structured format and to conduct a survey in short face-to-face mode. This will ensure that all questions were answered and will minimize communication error, and allow the researcher to farther investigate questions as need it.

Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (IRB). This research has been reviewed and approved by the IRB (see Appendix B).

The sample size of the survey was 112 experts in the field of innovation and systems engineering from major defense organization: Lockheed Martin, Boeing, Northrop Grumman, Raytheon, Cubic, and SAIC. Data for 300 (unique) projects were collected where surveyed participants provided data for more than one project. Data collected was randomly divided

into two groups (i.e., the participants were divided randomly in two groups). The first group of participants corresponded to a set of 200 projects was used to study and find the significant innovation factors from the surveyed 22 factors. The second group of participants corresponded to a set of 100 projects and it was used to test the different models.

One of the first steps was to judge the reliability and the internal consistency or homogeneity among each of the construct's items using the Cronbach's coefficient alpha. The data was exported to analytical software (SPSS V21.0) and the reliability of the construct was determined to be at a very acceptable level. As a measure of content validity, the survey instrument provided adequate coverage of the important elements (innovation environment determinants) of the systems engineering context in the defense industry as defined by the experts. Thus we can assume that the content of the survey have already been validated.

MATLAB was utilized in order to obtain the principal components. Table 4-11 and Figure 4-4 provide details of the principal components. It is easy to see from Figure 4-3 that using the first two components the problem is linearly separable.

The findings from all three methods (logistic regression, neural networks, and classification/regression trees) clearly show that eight factors of the most important innovation factors are common across the methods. The eight common factors are:

- Organizational Leadership (survey question # 20)

- Profit Growth (survey question # 18)
- Projected ROI (survey question # 17)

- Motivation (survey question # 23)
- Performance (survey question # 16)
- Security (survey question # 2)
- Communication (survey question # 9)
- Experience (survey question # 22)

Also there was one common factor between LR and NN which is Education.

The performance of the models created from all three methods was calculated. 200 records of the data were used for training/validation, 100 records used for testing/prediction. The total collaborative ensemble for the three methods indicates 0 records for misclassification, which gives 100% performance for the training/validation. For the testing/prediction group, 1 record was misclassified, which gives 99% performance.

The consistency of the results from the three methodologies used in this study (logistic regression, neural networks, and classification/regression trees) provides high confidence in using one or more from the presented methods to predict the innovation in their organizations' projects.

## 5.3 Conclusions

These are the conclusions for this research:

1. The first tier of important factors that executives and directors of system engineering projects in the defense organization must monitor and nurture are:

- Organizational Leadership (survey question # 20)
- Profit Growth (survey question # 18)
- Projected ROI (survey question # 17)
- Motivation (survey question # 23)
- Performance (survey question # 16)
- Security (survey question # 2)
- Communication (survey question # 9)
- Experience (survey question # 22)
- Education (survey question # 21)

These factors could become indicators and being monitored in "executive dashboards" in order to stimulate innovation in the defense organization. In addition, these factors can be used to benchmark corporate initiatives among themselves to establish a ranking of priorities.
This is very important for well-established methods such as the funnel. These indicators can help in the selection of the appropriate projects.

2. The second tier of important factors is mainly to support/complement the first tier of factors in good execution of the projects. These factors are:

- Supply Chain Management (survey question # 11)
- Logistics (survey question # 10)
- Project Nature (survey question # 8)
- Well Define Requirements (survey question # 13)
- Competition (survey question # 3)
- Operational Management (survey question # 12)

3. Neural networks, logistic regression, and classification/regression trees can be used to develop models to measure innovation. This was important and the models developed had a very high performance. These models can be used by executive and directors of system engineering groups. The framework requires answers to a set of questions that the innovation assessor will need to provide. As a result of these answers, the framework will then predict the innovation probabilities (in particular with the logistic regression and neural networks models) of the system engineering initiative under consideration. This process will assist the organization's executive personnel in identifying and prioritizing their organization's projects according to innovation probabilities predicted by the framework, with the ultimate goal of

concentrating their limited resources on only those projects with the highest innovation potential.

4. It is important to see that the security factor resulted as one of higher importance in the environment of innovation in these defense organizations. Unfortunately, security means potential of high innovation but the restrictive policies of security clearance and ITAR regulations can be hampering and being an obstacle to the development of new ventures, new commercial products, and other potential financial benefits from these innovations.

5. Another interesting indicator was experience. Experience in high technology projects has been considered as an important factor for success. Therefore, it is not a surprise that experience is also an indicator of an innovative project in the defense industry.

#### 5.4 Contributions to the Body of Knowledge

This research studies for the first time the innovation environment from the systems engineering viewpoint within the defense industry. It was important to include qualitative and quantitative factors that targeted specifically the actual practices.

In addition, this preliminary framework developed in this research, represents the first attempt ever to build a decision support system using a combination of logistic regression, neural networks, and classification/regression trees to see the tendency of an initiative to be innovative in the defense industry.

133

The framework simplifies the monitoring and assessment process for innovation in the project environment of the defense industry taking into consideration the systems engineering core. This framework and indicators can help policy makers, the project management office (PMO) and executives such as the chief technological officers (CTOs) in identifying and prioritizing those projects with the potential for the best allocation of the limited available resources, and the pursuit of innovation.

The statistical proof of indicators such as security, organization leadership, and communication to be very important factors is just something new in this environment. These indicators are unique to this study.

#### 5.5 Case Study (Recipe)

This is a case study to demonstrate how to use the developed framework. Therefore, the final significant and critical factors of innovation and the models were put into an actual project. This is a real time simulation project (the name of the company is not disclosed due to confidentiality issues). The proposed project is to replace existing tethered weapons with tether-less weapons. Current weapons connected with cables to the main host computer to transfer data and to other components in the systems to provide pressured air for the weapons magazine charging and coiling. The cables may hamper the movement of the user and decrease the quality of the simulation of the life like experience. The proposed solution suggests the elimination of the cables.

Table 5-1 shows the significant innovation factors data collected from the tether-less weapons innovation project, Q refers to the question number in the survey appendix.

Table 5-1: Recipe Innovation Project Data.			
Innovation Factors	Response		
Organization Leadership (survey question # 20)	Very Involved		
Profit Growth (survey question # 18)	High		
Projected ROI (survey question # 17)	Excellent		
Motivation (survey question # 23)	High		
Performance (survey question # 16)	Very High		
Security (survey question # 2)	Very High		
Communication (survey question # 9)	Very Good		
Education (survey question # 21)	Master Degree		
Supply Chain Management (survey question # 11)	Good		
Logistics (survey question # 10)	Yes		
Experience (survey question # 22)	16 – 20 Years		
Project Nature (survey question # 8)	Software and Hardware		
Well Defined Requirements (survey question # 13)	Yes		
Competition (survey question # 3)	No		
Organizational Management (survey question # 12)	Very good		
Quality (survey question # 14)	Good		

Table 5-1:	Recipe	Innovation	Pro	iect	Data.
				,	

#### 5.5.1 Agent: The Innovator Assessor

The innovator assessor will take the values of these factors and he/she will use the models developed by us (in particular the ones that can generate probabilities such as logistics regression and neural networks).

- The output of the neural networks is 0.997. The indication is of a strong innovative project.
- The output of the logistic regression is 1.00. The indication of the probability of success (innovation) is good enough to be considered a strong innovative project.
- The output of the classification/regression tree (based on CART) is 1 (BLUE) Please see
   Figure 4-12. The indication is of a project classified as innovative.

Now, the innovation assessor can relay this information to the respective decision makers and the financial organisms and/or corporate incubators to see potential spinoffs from this initiative.

### 5.5.2 Agent: Project Review Board (PRB)

The function of the Project Review Board (PRB) in project-based organizations such as the defense corporations is to manage the organization's projects collectively as a portfolio. That means PRB select and prioritize projects according to their relative importance and contributions to the organizational goals. Therefore, the PRB can use our framework in order to monitor projects through the gating process. PRB usually uses information on website-posted project dashboards that show each project innovation indicator (most important factors) and the likelihood of being innovative. The PRB will make decisions in the Go-No Go of this real-time simulation project and compare it with the other projects of the portfolio.

### 5.5.3 Agent: The Chief Technological Officer (CTO)

This is important information for the CTO and the project will rise to his/her level due to innovative potential for further projects or discussions of ventures and development of spinoffs. This information can be communicated to the corporate incubator and start the negotiations with the respective stakeholders. A very good point of this real-time simulation project is the high motivation of the system engineers and that could also be a good measure that keeping innovative projects are also good motivators of people.

#### 5.6 Future Research

This study was conducted within the systems engineering (engineered systems/product innovations) context within the defense industry. The findings are restricted to the examined environment, and may vary from one innovation category to another.

Another important study is the one from the customer side. The US Government is the customer of the US Defense Industry. It is a priority for them to analyze their policies and see the potential on how to increase innovation and help increase the impact of the defense sector on the overall economy of the country.

In addition, it will be good to study the impact of the general economy in the innovation environment and priorities of the defense industry. The effect of globalization and the inclusion of other customers such as the Saudi Arabian Government and the South Korean Government are very important issues. Are those projects more innovative?

This research study focused on the engineered system/product innovation side. It will be very interesting to expand the study to other types of innovations such as operational innovation, process innovation, and markets/suppliers innovation (e.g., Will it be good to have Chinese companies to supply Defense Contractors?).

# **APPENDIX A: SURVEY QUESTIONS**

# SURVEY QUESTIONS

**Research Goal:** The goal of this research is to explore the key factors of measuring innovation within the systems engineering context of a defense company; and test the validity of a quantitative and qualitative model proposed by the researcher.

**Innovation Definition:** Innovation may involve the introduction of ideas for designing or producing new products, or introducing improvements to products, processes, services or any other aspect of an organization to the market place.

1. Was your project successful from the innovation view point (innovative processes, or/and products, or/and services):

Yes	
No	

- 2. What was the level of security in your project?
  - a. Very low
  - b. Low
  - c. Neutral
  - d. High
  - e. Very high
- 3. Was your project part of a competition with other projector/s within your organization and/or with external organization/s?

Yes	
No	

# 4. What was the duration (in months) of your project?

- a. 1-12
- b. 13 24
- c. 25 36
- d. 37 48
- e. Greater than 48

# 5. What was the cost (in million) of your project?

- a. Cost < 10
- b.  $10 \le \cos t < 30$
- c.  $30 \le \cos t < 50$
- d. 50 ≤ cost <80
- e. Cost ≥ 80

## 6. How many jobs did you project create?

- a. 0-3
- b. 4-8
- c. 9 12
- d. 13 15
- e. Greater than 15

7. What was the level of procurement for your project?

- a. Low
- b. Medium
- c. High

### 8. What was your project nature?

- a. Software
- b. Hardware
- c. Software and Hardware

# 9. What was the level of communication within your project?

- a. No communication at all
- b. Poor
- c. Good
- d. Very good
- e. Excellent

### 10. Were there any logistics requirements in your project?

Ye	
No	

11. How efficient was the supply chain management in your project?

- a. Poor
- b. Good
- c. Very good
- d. Excellent

### 12. How efficient was the operational management in your project?

- a. Poor
- b. Good
- c. Very good
- d. Excellent

### 13. Was your project requirements well defined?

Yes	
No	

### 14. How you consider the quality of your project?

- a. Poor
- b. Good
- c. Very good
- d. Excellent

### 15. Which of the following design levels best describe your project?

- a. Very simple
- b. Simple
- c. Medium
- d. Complex
- e. Very complex

### 16. What was the level of performance for your project?

- a. Very low
- b. Low
- c. Medium
- d. High
- e. Very high

# 17. What you consider the projected ROI from your project?

- a. Very poor
- b. Poor
- c. Good
- d. Very good
- e. Excellent

### 18. How was the profit growth in your project?

- a. Very low
- b. Low
- c. Medium
- d. High
- e. Very high

19. What is the organization size (people) in your project?

- a. 1-19
- b. 20 39
- c. 40 59
- d. 60 99
- e. Greater than 99

### 20. How involved was organization leadership in your project?

- a. Not involved
- b. Slightly involved
- c. Somewhat involved
- d. Involved
- e. Very involved

# 21. What was the average education level of engineering team in your project?

- a. Associate degree
- b. Bachelor degree
- c. Master degree
- d. PhD degree

## 22. What was the average years of experience for the engineering team in your project?

- a. 0-5
- b. 6-10
- c. 11 15
- d. 16 20
- e. Greater than 20

### 23. What was the level of motivation for the members on your project?

- a. Very low
- b. Low
- c. Neutral
- d. High
- e. Very high

# **APPENDIX B: IRB HUMAN SUBJECTS PERMISSION LETTER**



University of Central Florida Institutional Review Board Office of Research & Commercialization 12201 Research Parkway, Suite 501 Orlando, Florida 32826-3246 Telephone: 407-823-2901 or 407-882-2276 www.research.ucf.edu/compliance/irb.html

# **Approval of Exempt Human Research**

From:	UCF Institutional Review Board #1
	FWA00000351, IRB00001138

To: Khaled S. Odeh

Date: April 29, 2013

Dear Researcher:

On 4/29/2013, the IRB approved the following activity as human participant research that is exempt from regulation:

Type of Review:	Exempt Determination
Project Title:	A FRAMEWORK OF MEASURING INNOVATION WITHIN
	THE SYSTEMS ENGINEERING CONTEXT OF A DEFENSE
	ORGANIZATION
Investigator:	Khaled S. Odeh
IRB Number:	SBE-13-09335
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 04/29/2013 10:05:05 AM EDT

Joanne muratori

**IRB** Coordinator

# APPENDIX C: SURVEY QUESTIONS CODED TO BE USED IN THE DATA ANALYSIS

1. Was your project successful from the innovation view point (innovative processes, or/and products, or/and services):

Yes	1
No	0

- 2. What was the level of security in your project?
  - a. Very low 1
  - b. Low 2
  - c. Neutral 3
  - d. High 4
  - e. Very high 5
- 3. Was your project part of a competition with other projector/s within your organization and/or with external organization/s?
  - Yes 
    1
    No
    0

### 4. What was the duration (in months) of your project?

- a. 1-12 1
- b. 13 24 2
- c. 25 36 3
- d. 37 48 4
- e. More than 48 5

### 5. What was the cost (in million) of your project?

- a. Cost < 10 1
- b. 10 ≤ cost < 30 2
- c.  $30 \le \cos t < 50$  3
- d.  $50 \le \cos t < 80$  4
- e. Cost ≥ 80 5

### 6. How many jobs did you project create?

- a. 0-3 1
- b. 4-8 2
- c. 9–12 3
- d. 13–15 4
- e. Greater than 15 5

### 7. What was the level of procurement for your project?

- d. Low 1
- e. Medium 2
- f. High 3

### 8. What was your project nature?

- d. Software 1
- e. Hardware 2
- f. Software and Hardware 3

# 9. What was the level of communication within your project?

- f. No communication at all 1
- g. Poor 2
- h. Good 3
- i. Very good 4
- j. Excellent 5

## 10. Were there any logistics requirements in your project?

1

2

1

2



### 11. How efficient was the supply chain management in your project?

- e. Poor
- f. Good
- g. Very good 3
- h. Excellent 4

# 12. How efficient was the operational management in your project?

- e. Poor
- f. Good
- g. Very good 3
- h. Excellent 4

### 13. Was your project requirements well defined?



# 14. How you consider the quality of your project? 1

- e. Poor
- f. Good 2
- g. Very good 3
- h. Excellent 4

### 15. Which of the following design levels best describe your project?

- f. Very simple 1
- 2 g. Simple
- h. Medium 3
- i. Complex 4
- j. Very complex 5

### 16. What was the level of performance for your project?

- f. Very low 1
- g. Low 2
- h. Medium 3
- i. High 4
- j. Very high 5

### 17. What you consider the ROI from your project?

- f. Very poor 1
- g. Poor 2
- 3 h. Good
- i. Very good 4
- j. Excellent 5

### 18. How was the profit growth in your project?

- a. Very low 1
- b. Low 2
- c. Medium 3
- d. High 4
- e. Very high 5

### 19. What is the organization size (people) in your project?

- a. 1-19 1
- b. 20 39 2
- c. 40 59 3
- d. 60–99 4
- e. Greater than 99 5

### 20. How involved was organization leadership in your project?

- a. Not involved 1
- b. Slightly involved 2
- c. Somewhat involved 3
- d. Involved 4
- e. Very involved 5

### 21. What was the average education level of engineering team in your project?

- a. Associate degree 1
- b. Bachelor degree 2
- c. Master degree 3
- d. PhD degree 4

2

### 22. What was the average years of experience for the engineering team in your project?

- a. 0-5 1
- b. 6-10
- c. 11 15 3
- d. 16 20 4
- e. Greater than 20 5

### 23. What was the level of motivation for the members on your project?

- a. Very low 1
- b. Low 2
- c. Neutral 3
- d. High 4
- e. Very high 5

# **APPENDIX D: COLLECTED SURVEY DATA**

The entire data collection file is part of this research and it is submitted as a separate Excel file under this dissertation. Please refer to it for more details on the collected data.

### LIST OF REFERENCES

- Acs, Z. and Audretsch, D. (1990). Innovation and Small Firms. Cambridge, MA: MIT Press.
- Adams R., Bessant, J. and Phelps, R. (2006) International Journal of Management Reviews Volume 8 Issue 1 pp. 21–47.
- AL-Ali. How to build an innovation management system is explained step-by-step in the book: Comprehensive Intellectual Capital Management: 2003.
- Balachandra, R. and Friar, J. (1997). 'Factors for success in R&D projects and new product innovation: a contextual framework'. IEEE Transactions on Engineering Management, 44, 276–87.
- 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=tr ue&db=nlebk&AN=71426&site=eds-live&scope=site
- Breiman, L., Friedman, J., Olshen, R. and Stone, P. (1984). Classification and Regression Trees.The Wadsworth Statistics/Probability Series, Wadsworth and Brooks, 1984.
- **Brooks, L.** (1988), spectral decomposition in noise and vibration, and empirical modal analysis in structural dynamics.
- Camison-Zornoza, C., Lapiedra-Alcami, R., Segarra-Cipres, M. and Boronat-Navarro, M. (2004).
   'A meta-analysis of innovation and organizational size'. Organization Studies, 25, 331–61.
- Chen G. and Muller, A. (2010) How Do you Measure Innovation. http://news.idg.no/cw/art.cfm?id=D157C168-1A64-67EA-E41E0831244C4B90

CIDEM. G U I D E. (2002) For Managing Innovation Part I: Diagnosis

- **Cooper, R.** (1979a). The dimensions of industrial new product success and failure. Journal of Marketing, 43, 93–103.
- **Covin, J. and Slevin, D.** (1989). Strategic management of small firms in hostile and benign environments. Strategic Management Journal, 10, 75–87.
- **CRA, Charles River Associates**. (2010). Innovation in Aerospace and Defense. CRA Project No. M13385-05.
- **Creswell, J.** (2002). Research Design: Qualitative, Quantitative and Mixed Method Approaches, SAGE Publications Ltd.
- **Creswell, J.** (2007). Qualitative Inquiry and Research Design: Choosing Among Five Traditions, London: Sage.
- Dalkey, N. (1972). The Delphi method: An experimental study of group opinion. In N. C. Dalkey,
   D. L. Rourke, R. Lewis, & D. Snyder (Eds.). Studies in the quality of life: Delphi and
   decision-making (pp. 13-54). Lexington, MA: Lexington Books.
- **Dalkey, N., and Helmer, O.** (1963). An experimental application of the Delphi method to the use of experts. Management Science, 9 (3), 458-467.
- DAU. (2010) "Defense Acquisition Guidebook." Defense Acquisition University. February 19, 2010. https://dag.dau.mil/ (accessed March 5, 2010).
- **Davis, M.** (1998). Knowledge management. Information Strategy: The Executive's Journal, 15, 11–22.
- **De Brentani, U.** (1991). Success factors in developing new business services. European Journal of Marketing, 25, 33–60.

Dean H. and Philips, J. (2005). Innovation Roles, The People You need for Successful Innovation.

- **Delbecq, A.** (1975) Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes, Scott Foresman, IL.
- **Delbecq, A., Van de Ven, A. , and Gustafson, D.** (1975). Group techniques for program planning. Glenview, IL: Scott, Foresman, and Co.
- **Dess, G. and Picken, J.** (2000). 'Changing roles: leadership in the 21st century'. Organizational Dynamics, 28, 18–34.
- **Di Benedetto, C.** (1996). Identifying the key success factors in new product launch. Journal of Product Innovation Management, 16, 530–544.
- **Douglas, D.** (1983). A comparative study of the effectiveness of decision making processes which utilize the Delphi and leaderless group methodologies. Unpublished doctoral dissertation, The Ohio State University, Columbus.
- Druckman D., Singer, J. and Van Cott, H. (1997) enhancing organizational performance, from http://books.nap.edu/catalog.php?record\_id=5128
- Duncan, R. (1976). 'The Ambidextrous Organization: Designing Dual Structures for Innovation'.
   In: R. H. Kilmann, L. R. Pondy and D. P. Slevin (eds), The Management of Organizational
   Design: Strategy Implementation, 1, pp. 167–188. North-Holland, New York.
- **Dvir, D. and Tishler, A**. (2000). The Changing Role of the Defense Industry in Israel's Industrial and Technological Development. Forthcoming in Defense Analysis.
- **Dyer, B. and Song, X.M.** (1998). Innovation strategy and sanctioned conflict: a new edge in innovation? Journal of Product Innovation Management, 15, 505–519.

- Eckman, C. (1983). Development of an instrument to evaluate intercollegiate athletic coaches:A modified Delphi study. Unpublished doctoral dissertation, West Virginia University,Morgantown.
- **Ed, R.** (2008). Overview of the System Engineering Process, North Dakota Department of Transportation (NDDOT).
- **Eisenhardt, K.** (1989) "Building Theories from Case Study Research", Academy of Management Review, (4:4), 532-550.
- **Ernst, H.** (2002). Success factors of new product development: a review of the empirical literature. International Journal of Management Reviews, 4, 1–40.
- **Esposito, J.** (2002). Interactive, multiple-method questionnaire evaluation research: A case study. Paper presented at the International Conference in Questionnaire Development, Evaluation, and Testing (QDET) Methods. Charleston, SC.
- **Forsgren, R.** (1989) "Increasing mail survey response rates: Methods for small business researchers." Journal of Small Business Management 27(4): 61-66.
- Frawley, W., Piatetsky-Shapiro, G. and Matheus, C. (1992). "Knowledge Discovery in Databases: An Overview". Al Magazine: pp. 213–228.
- **Freeman, C.** (1982). Economics of Industrial Innovation. Economics of Industrial Innovation, 2nd. methods. New York: John Wiley & Sons.
- **Frenkel, A., Maital, S. and Grupp, H.** (2000). Measuring dynamic technical change: a technometric approach. International Journal of Technology Management, 20, 429–441.
- Gallivan, M. (1997) "Value in Triangulation: A Comparison of Two Approaches for Combining Qualitative and Quantitative Methods", in A. Lee, J. Leibenau and J. De Gross (Eds), Qualitative Methods in Information Systems, New York: Chapman & Hall, (1997) 83-107.

- **Gonzalez, L.** (2010). "The Similarity between the Square of the Coeficient of Variation and the Gini Index of a General Random Variable". Journal of Quantitative Methods for Economics and Business Administration 10: 5–18. ISSN 1886-516X.
- Green, P. (1982). The content of a college-level outdoor leadership course. Paper presented at the Conference of the Northwest District Association for the American Alliance for Health, Physical Education, Recreation, and Dance, Spokane, WA.
- **Griffin, A.** (1997). PDMA research on new product development practices: updating trends and benchmarking best practices. Journal of Product Innovation Management, 14, 429–458.
- **Grunfeld L., Jakobsen E., Kaloudis A., Skogli E., and Olsen D.** (2011). Key innovation indicators, Nordic Innovation Publication, ISBN 978-82-8277-005-7.
- Hage, J. and Aiken, M. (1970). Social Change in Complex Organizations. Random House, New York.
- Hansen, S. and Wakonen, J. (1997). 'Innovation, a winning solution?'. International Journal of Technology Management, 13, 345–58.
- Hasson, F., Keeney, S., and McKenna, H. (2000). Research guidelines for the Delphi survey technique. Journal of Advanced Nursing, 32 (4), 1008-1015.

Henerson, M., Morris L. (1987). How to measure attitudes, Newbury Park, CA: Sage.

- **Hill, K., and Fowles, J.** (1975). The methodological worth of the Delphi forecasting technique. Technological Forecasting and Social Change, 7, 179-192.
- **Hobday, M.** (2005). 'Firm-level innovation models: perspectives on research in developed and developing countries'. Technology Analysis and Strategic Management, 17, 121–46.
- Hobday, M. and Davies, D. (2005) The Business of Projects: Managing Innovation in Complex Products and Systems, Cambridge, Cambridge University Press.

- Holland, M. (1997). 'Diffusion of innovation theories and their relevance to understanding the role of librarians when introducing users to networked information'. Electronic Library, 15, 389–94.
- Jacobs, J. (1996). Essential assessment criteria for physical education teacher education programs: A Delphi study. Unpublished doctoral dissertation, West Virginia University, Morgantown.
- Jick, T. (1997) "Mixing Qualitative and Quantitative Methods: Triangulation in Action", Administrative Science Quarterly, (24), (1979) 602-611.
- **Kaplan, L. M.** (1971). The use of the Delphi method in organizational communication: A case study. Unpublished master's thesis, The Ohio State University, Columbus.
- Klein, K. and Knight, A. (2005). 'Innovation implementation overcoming the challenge'.Current Directions in Psychological Science, 14, 243–6.
- Klein, K. and Sorra, J. (1996). 'The Challenge of Innovation Implementation', Academy of Management Review, 21, pp. 1055–1080.
- Langdon, M. (2008) Innovation Metrics. The Innovation Process and How to Measure It. Innovation Labs LCC.
- Lansisalmi, H., Kivimaki, M., Aalto, P. and Ruoranen, R. (2006). 'Innovation in healthcare: a systematic review of recent research'. Nursing Science Quarterly, 19, 66–72.
- **Louscher, J., Cook, A. and Barto, V**. (1998) The Emerging Competitive Position of US Defense Firms in the International Market, Defense Analysis, 14, 2, 1998, 115-134.
- Ludlow, J. (1975). Delphi inquiries and knowledge utilization. In H. A. Linstone, & M. Turoff (Eds.). The Delphi method: Techniques and applications (pp. 102-123). Reading, MA: Addison-Wesley Publishing Company.

- Ludwig, B. G. (1994). Internationalizing Extension: An exploration of the characteristics evident in a state university Extension system that achieves internationalization. Unpublished doctoral dissertation, The Ohio State University, Columbus.
- McAdam E, Moffett S, Hazlett S, and Shevlin, M. (2010) Developing a model of innovation implementation for UK SME: A path analysis and explanatory case analysis. International Small Business Journal 28(3) 195-214.
- Menard, S. (2002). Applied Logistic Regression Analysis (2nd edn). Thousand Oaks, CA: Sage Publications. Series: Quantitative Applications in the Social Sciences, No. 106 (1st edn), 1995.
- Meyer, A. and Goes, J. (1988). 'Organizational Assimilation of Innovation: A Multilevel Contextual Analysis', Academy of Management Journal, 31, pp. 897–923.

Microsoft. (2007) Innovation Process Management.

- **Milbergs, E.** (2006). Innovation Metrics: Measurement to Insight, Center for International Science and Technology Policy George Washington University.
- Miles, M. and Huberman, A. (1994)Qualitative Data Analysis, An Expanded Source Book, Beverly Hills, CA: Sage.
- Miles, R. and Snow, C. (1978). Organization Strategy, Structure and Process. New York: McGraw-Hill.
- Miller, L. (2006, October). Determining what could/should be: The Delphi technique and its application. Paper presented at the meeting of the 2006 annual meeting of the Mid-Western Educational Research Association, Columbus, Ohio.
- Mintzberg, H. (1978). Patterns in strategy formation. Management Science, 24, 934–948.

- Mone, M., McKinley, W. and Barker, V. (1998). 'Organizational decline and innovation: a contingency framework'. Academy of Management Review, 23, 115–32.
- Moody, J. (1994). "The Effective Number of Parameters: An Analysis of Generalization and Regularization in Nonlinear Learning Systems," Advances in Neural Information Processing System 4, Edited by J. Moody, S. Hanson, and R. Lippmann, Morgan Kaufman Publishers, Inc., 683-690, 1994.
- Murray, W. F., and Jarman, B. O. (1987). Predicting future trends in adult fitness using the Delphi approach. Research Quarterly for Exercise and Sport, 58 (2), 124-131.
- Narvekar, R. S., and Jain, K. (2006). A new framework to understand the technological innovation process. Journal of Intellectual Capital, 7(2), 174–186.

Nielsen, J. (1994) Heuristic evaluation. In: Nielsen, J. and Mack, R.L. (eds). Usability inspection.

- **O'Connell, A.** (2005). Logistic Regression Models for Ordinal Response Variables. Thousand Oaks, CA: Sage Publications. Quantitative applications in the social sciences, Volume 146.
- O'Reilly, C. and Tushman, L. (1997). Using culture for strategic advantage: promoting innovation through social control. In Tushman, M.L. and Anderson, P. (eds), Managing Strategic Innovation and Change: A Collection of Readings. New York: Oxford University Press, pp. 200–216.
- **Oates, Briony J.** (2006) Researching Information Systems and Computing, London: Sage. of Theoretical and Applied Information Technology.

- **Onkham W., Rabelo, L., and** Yazici, H. (2013). "A Systematic Architecture of Operational Innovation," Proceedings of the 2013 Industrial and Systems Engineering Research Conference, San Juan, Puerto Rico, 2013, (CD-ROM), ISBN: 978-0-9837624-2-3.
- P. Trott, (1998) Innovation Management and New Product Development (Essex, UK, Prentice Hall).
- Pampel, C. (2000). Logistic Regression: A Primer . Sage quantitative applications in the Social Sciences Series #132. Thousand Oaks, CA: Sage Publications.
- Patter, M. (1990) Qualitative evaluation and research, Newbury Park, CA: Sage.
- Patton, M. (1999) "Enhancing the Quality and Credibility of Qualitative Analysis", Health Services Research, (34:5), part2, December, 1189-1208.
- **Pierce, J. L. and A. L. Delbecq** (1977). 'Organization Structure, Individual Attitudes and Innovation', Academy of Management Review, 2, pp. 27–37.
- Pittaway, L., Robertson, M., Munir, K., Denyer, D. and Neely, A. (2004). 'Networking and innovation: a systematic review of the evidence'. International Journal of Management Reviews, 5/6, 137–68.
- Plate, T. P. Band, J. Bert and Grace, J. (1997) "A comparison between neural networks and other statistical techniques for modeling the relationship between tobacco and alcohol and cancer," Advances in Neural Information Processing System 9, Edited by M. Mozer, M. Jordan, and t. Petsche, The MIT Press, 967-973.
- Rahal, A. (2005) Assessment framework for the evaluation and prioritization of university technologies for licensing and commercialization . Ph.D. Dissertation, Advisor Dr. Luis Rabelo, University of Central Florida.

- Richard, O., McMillan, A., Chadwick, K. and Dwyer, S. (2003). Employing an innovation strategy in racially diverse workforces – effects on firm performance. Group & Organization Management, 28, 107–126.
- Rogers, E. M. (1995). Diffusion of Innovations. Free Press, New York.
- Rothwell, R. (1992). Successful industrial innovation: critical factors for the 1990s. R&D Management, 22, 221–239.
- Rumelhart, D. J. McClelland and the PDP Research Group. (1989) Parallel Distributed Processing: explorations in the microstructure of cognition, Vol. 1: Foundations, Cambridge, MIT Press/Bradford Books.
- Sawyer, S. (2001) "Analysis by Long Walk: Some Approaches to the Synthesis of Multiple Sources of Evidence", in E.M. Trauth (Ed.) Qualitative Research in IS: Issues and Trends, Hershey, PA: Idea Group Publishing, (2001) 163-191.
- Scheibe, M., Skutsch, M., and Schofer, J. (1975). Experiments in Delphi methodology. In H. A.
   Linstone, & M. Turoff (Eds.). The Delphi method: Techniques and applications (pp. 262-287). Reading, MA: Addison-Wesley Publishing Company.

Schein EH (1985). Organizational Culture and Leadership [Book]. - San Fransisco : Josey-Bass.

Sekaran, U. (2000). Research Methods for Business: A Skill-Building Approach. New York, John Wilew and Sons, Inc.

**SIEMENS** (2001). Systems Engineering for the Aerospace and Defense Industry, 2001.

Singh, Y. and Chauhan, S. (2009). Neural Networks in Data Mining. Journal

Stake, E. (1995). The Art of Case Study Research, Thousand Oaks: Sage.

- Steinberg, D. and Colla, P. (1995). CART: Tree-Structured Non-Parametric Data Analysis. San Diego, CA: Salford Systems.
- Stone, S. and C. Harris. (1984). Crus Guide: Basic Social Research Techniques. Sheffield, University of Sheffield.
- **Strano, M. and Colosimo, B.** (2006). "Logistic regression analysis for experimental determination of forming limit diagrams". International Journal of Machine Tools and Manufacture 46 (6).
- Sullivan, M. (1990). The Competitive Advantage of Nations. Magill's Book Reviews, 1–1.
- Teper, N. (2010). Exploring the use of Model-Based Systems Engineering (MBSE) to develop Systems Architecture in Naval Ship Design .Massachusetts Institute of Technology MS Thesis.
- Turban, E., Sharda, R.; Dursun D. and King, D. (2011). Business Intelligence; A Managerial Approach.
- **Tushman, M. and O'Reilly, C.**(1996). 'Ambidextrous organizations: managing evolutionary and revolutionary change'. California Management Review, 38, 8–30.
- **Ulschak, F.** (1983). Human resource development: The theory and practice of need assessment. Reston, VA: Reston Publishing Company, Inc.
- Werbos, P. (1994). The Roots of Backpropagation, John Wiley & Sons.

Whitten, J. and Bentley, D. (1994). Systems analysis and design methods, Burr Ridge, Ill: Irwin.

Wilson, N. and Stokes, D. (2006). Managing creativity and innovation. Journal of Small Business and Enterprise Development 12: 366-378.

- Witkin, B. (1984). Assessing needs in educational and social programs. San Francisco, CA: Jossey-Bass Publishers.
- Witkin, B. and Altschuld, J. (1995). Planning and conducting needs assessment: A practical guide. Thousand Oaks, CA: Sage Publications, Inc.
- Witten, I. and Frank E. (2005), Data Mining: Practical Machine Learning Tools and Techniques (Second Edition), Morgan Kaufmann Publishers.
- Wolf J and Pett, T. (2006). Small-firm performance: modelling the role of product and process improvements. Journal of Small Business Management 44: 268-284.
- Yin, R. (1994). Case Study Research, Design and Method, (2nd edition), Beverly Hills, CA: Sage, 1994.
- Yin, R. (2008). "Enhancing the Quality of Case Studies in Health Services Research", Health Services Research, (34:5), Supplement Part 2, December (2008) 1209-1224.
- Zahra, S. and George, G. (2002). Absorptive capacity: a review, reconceptualization, and extension. Academy of Management Review, 27, 185.
- Zaltman, G., Duncan, R. and Holbek, J. (1973). Innovations and Organizations. New York: John Wiley.
- Ziglio, E. (1996). The Delphi method and its contribution to decision making. Gazing into the oracle: The Delphi method and its application to social policy and public health. E. Adler & E Ziglio. Bristol, PA, Jessica Kingsley Publishers: (1996) 3-33.
- **Zmud, R.** (1982). 'Diffusion of Modern Software Practices: Influence of Centralization and Formalization', Management Science, 28, pp. 1421–1431.