The Innovation Environment Within Systems Engineering of a Defense Organization

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Abstract

Innovation may involve new design and production of a product or improvement of existing products and services of an organization. A major element for measuring organizational strength is its perception of innovation and its ability to build on and sustain such strength. While there is no shortage of research and study materials on innovation, there is shortage of thorough analysis of the intersection of innovation management and measurement of innovation within the systems engineering context of defense organizations. Moreover, while most research studies seem to adopt strictly quantitative innovation factors in determining innovation success, the qualitative side is overlooked. An objective of this research study was to address the need for exploring the innovation environment within the systems engineering context of a defense organization. In addition, the research presented a new model for exploring innovation factors using a number of data collection instruments to gather such data. The study identified significant factors that could be used to determine innovation within the specific environment. 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.

Keywords
Engineering Management, IE in the Military, Systems Engineering

1. Introduction

Innovation capability is the most important determinant of firm performance [1]. Betz thinks of innovation as new things/artifacts to increase business success and sustainability [2]. Sullivan has a more commercial viewpoint emphasizing new ways of doing activities through commercialization of technologies [3]. Finally, Freeman 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 [4]. Competitive success is dependent upon an organization’s management of the innovation process and factors exist to manage innovation. These processes and factors should be assessed to ensure effectiveness. Furthermore, 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 as explored through two main ideas:

- 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 these organizations?

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 on hand.
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.

2. Research Methodology

Responses to the research questions were answered by using the data collected from the selected organizations using different methodologies [5]. It has been postulated that the four most common methodological areas of weakness within research of this type are [6]:

(1) Quality of data;
(2) Definition of new product;
(3) Factor selection and definition; and
(4) Measurement of factors.

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 to the diagram in Figure 1.

![Figure 1: Methodology Phase Flow](image-url)
2.1 Conceptualization
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. This research explored 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 investigated and assessed 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.

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 researchers conducted a thorough and in-depth 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 21st Century.

The following research gaps that require further research and implementation were 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.

The following are the basic constructs that will guide the tone of the survey, documentations, and direct observations data collection instruments:

- 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.

2.2 Operationalization
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 [7-12]. 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. Survey is defined as the systematic assembling of information from respondents with the intention of understanding an aspect or more of a particular population.
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 further investigate questions as needed.

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. Experts in the fields of innovation and systems engineering recommended to not use these factors. Reasons such as future prediction and strong correlation among some factors were behind the recommendations to not use these factors.

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).

3. Statistical Analysis
The proposed model of this study for measuring innovation addresses the identified gaps mentioned in section 2.2. Unlike many of the examined models, the proposed model is designed to use both quantitative and qualitative measures in measuring innovation. 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.

3.1 Quantitative Factors
The model uses a number of financial measures. Financial measures are widely used to measure the success of many products. 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. They 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.

3.2 Qualitative Factors
Defense organizations/products are influenced by number of factors, some of which are technology, security, and performance. Today, strong defense systems are those that have state-of-the-art technology and security. 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.
3.3 Potential Quantitative and Qualitative Factors

Figure 2 shows the potential quantitative and qualitative factors for determining innovation in a project as assessed through this research. Detailed descriptions follow.

Figure 2: Proposed Innovation Measurement Model

1. Security: Security in defense systems is the practice of defending systems from unauthorized access, use, disclosure, disruption, modification, perusal, inspection, recording or destruction (www.answers.com). 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 (www.scholarship.org).

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.

4. 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.

6. 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 (www.wisegeek.com). 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” (www.cnx.org). 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 reduces 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).

28. 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.

The following were eliminated based on expert evaluation as defined in the research methodology section: Recognition, Project Scope, Technology, Cost Saving, Organization Structure, and Organization Management.

Factor analysis was also utilized with several steps (without including the demographic variables). The following table indicates the two most important factors FA1 and FA2 from level factor 5. FA1 has Communication, Performance, Projected ROI, Profit Growth, Organizational Leadership, Experience, Motivation, and Security. On the other hand, FA2 includes Cost, Job Creation, Design, and Project Duration.

Table 1: Rotated Factor Matrix

<table>
<thead>
<tr>
<th>Variables</th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>0.943</td>
<td></td>
</tr>
<tr>
<td>JobCreation</td>
<td>0.656</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>0.857</td>
<td>0.518</td>
</tr>
<tr>
<td>Design</td>
<td></td>
<td>0.802</td>
</tr>
<tr>
<td>Performance</td>
<td>0.861</td>
<td></td>
</tr>
<tr>
<td>ProjectedROI</td>
<td>0.843</td>
<td></td>
</tr>
<tr>
<td>ProfitGrowth</td>
<td>0.916</td>
<td></td>
</tr>
<tr>
<td>OrganizationLeadership</td>
<td>0.857</td>
<td></td>
</tr>
<tr>
<td>Experience</td>
<td>0.638</td>
<td></td>
</tr>
<tr>
<td>Motivation</td>
<td>0.858</td>
<td></td>
</tr>
<tr>
<td>Security</td>
<td>0.807</td>
<td></td>
</tr>
<tr>
<td>ProjectDuration</td>
<td></td>
<td>0.802</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Can you talk about what you called factors 1 and 2 and the implication of this grouping?

Then, backward and forward logistic regression models were built. The most important variables are indicated in Figure 3 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 [13]. In addition, the performance of logistic regression with the training and testing sets is displayed in Table 2.
4. Conclusion

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, Profit Growth, Projected ROI, Motivation, Performance, Security, Communication, Experience, and Education. 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.

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. 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.

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.

References


