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Application of Systems Engineering to Risk Management:

A Relational Review

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ABSTRACT

System engineering is an interdisciplinary field of engineering and engineering management that focuses on the design and management of the system. The system as a whole is the concern, which is followed by more technical aspects of the system, the design of everything, and the management of a complex system. Inspecting and making the system more efficient is the focus for system engineers. Additionally, risk management is being able to predict, evaluate, and solve risks that are going to happen or may happen in the future. There are three models that help system engineers with making a complex system look simpler and less frightening: the Vee, Spiral, and Waterfall models. While system thinking is a very important part of system engineering, there always has to be a collection of data to study for making decisions. As of now, there is no explanation in literature how these variables, their concepts, and models are beneficial to project management. This has created a research gap, so the study examined the most current variables, their concepts, and models in operations and project management. Furthermore, a design-science-investigate strategy was used to approve a valuable growth reveal for both reasonable and hypothetical application. As a result, an assessment model was generated to fill the research gap and to contribute to the engineering field through improved project success rates and team communication.

KEYWORDS

Risk, Risk Management, Systems, Systems Engineering

INTRODUCTION

Systems engineering has been a reliable and efficient addition to risk management. System engineers have a better understanding of making decisions for a project or company because system engineering has an understanding of other engineering fields, such as mechanical, aerospace, chemical, and project management. The engineering of a system is a discipline that develops and trades off requirement, functions, and alternative system resources to fill a cost-effective, life cycle balanced product that is based upon the needs of the stakeholders. Applying the risk management aspect with system engineering creates a more focused product that would reduce failure in more than one direction of the product. Since SE has a focus in more than one field of engineering, it would help the product to be more advanced and secure in more than one dynamic.

System Engineering (SE) has discipline and a way of thinking that is gaining popularity in many large projects. The industry's literature commonly defines a project as an "endeavor in which

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human, material, and financial resources are organized, in a novel way, to undertake a unique scope of work, of a given specification, within the constraints of cost and time, to achieve a beneficial change defined by quantitative and qualitative objectives" (Mabelo & Sunjka, 2017; Elloumi et al. 2017). Project management is defined by The Project Management Institute (PMI) as "the application of knowledge, skills, tools, and techniques to project activities to meet project requirements" (Mabelo & Sunjka, 2017; Memon, & Meyer, 2017). The key to this definition is the emphasis on "meeting project requirements" (Mabelo & Sunjka, 2017; Brown & Eisenhardt, 1995; Detert, 2000; Easton & Rosenzweig, 2012). This study compares project management to SE and shows that they are very similar, but systems engineers have more knowledge and experience working in different fields and with different forms of engineers. Thus, the primary person who would interact with management, customers, suppliers, and specialty engineers in the development of a system process is the SE.

While risk management is the identification, evaluation, and prioritization of risk, it consists of finding the risk that appears, defining it, solving it, and continuing with the project. Ensuring that uncertainty does not interfere with the project for the project to be accomplished with little to no delays is the main objective. There are two steps to project risk management on how to manage, identify, and control the risk that has come up in a project. First, project managers start with planning on how risk would be dealt with. Next, he would assign a risk officer to oversee the risk and potential project problems. While the risk officer is overseeing the risk, he would create a database for the risk with information of when it started, as well as the probability and the level of importance. Then, he would have another step, but the most important aspect would be the mitigation plan on how to deal with the risk and whether it can be avoided or fixed. These risk management steps are important to project management because the project must fulfill the satisfactory level of the client for him to enjoy the product.

Optimizing the system-engineering process by strategic models and operation research was our research objective to improve risk management in an organization. Model-based systems engineering is the use of models for analyses and document key aspects of the life cycle. SE goals with models are improving their communications with engineers, project teams, and trying to overcome any language barrier. Improving quality is an objective of SE, which is a very integral part of a project. Mostly, how well you would like it made and the allocated budget are two of the most important aspects of a project. Identifying the requirement of risk early, enhancing any design, improving specs of requirements to hardware or software, and reducing errors in the whole project were our research objectives. Also, increased productivity is a great way to improve your scheduling and to plan to save time or to reduce delays in any task of the project. Even reusing existing models on projects to support the design and technology evolution is a great way to increase productivity, as it is a well-known model to which coworkers would not have to adjust. Risk and the reduction of risk are very crucial to SE because it is one of the main concerns for the project. Overall, improve cost estimates to make them more accurate is a goal of SE, which would reduce the overspendings.

Observing current literature showed us that there was a research gap, regardless of research on the importance of these variables, their concepts, and models in operations and project management. Information about how these variables, their concepts, and models caused such a smooth progression was insufficient, which was what this study aimed to discover. The elements and applications for the most current variables, their concepts, and models within operations and project management were also assessed to find their overlaps and similarities.

This research was meant to contribute to, as well as to expand upon, literature about the effectiveness of these variables, their concepts, and models. Furthermore, this study assessed the likenesses and differences of their assessment tools. Data within this paper was derived from multiple studies that have also tested the hypotheses in this paper.

Many research perspectives were adapted in this study to find new solutions to current issues. This research's study and hypotheses were explained, as it first used a design-science-investigate approach. This study then approved a valuable growth reveal for reasonable and hypothetical application, and it then generated an assessment model for these variables, their concepts, and models. There was also an outline of development models to concentrate on evaluation instruments to respond to the examination question. The evaluation instrument was reviewed, and the outline's approach was explained. Also, there was an outline of the meetings. In conclusion, initial discoveries and suggestions were noted to categorize investigative limitations, as well as plans for future studies.

This study's substantial contribution to literature also contributed to the profession. The advantages of these variables, their concepts, and models, as well as the limitations when not considering performance and sustainability were showed in the findings. Also, this study's true-to-life examples illustrated the need to apply theories to in life, so these subjects were examined in theory and practice.

This research aimed to assess these different variables, their concepts, and models to propose a more unified framework. Future research could be compromised by the gap of not studying the relationship between these variables, so that this study will provide clarity. Many aspects of different subjects from the business world were featured in this study so that the results could apply to these subjects. By studying the relationship between these variables, there was a better understanding of their advantages and disadvantages to being used more efficiently. Furthermore, some new avenues for future research in each body of knowledge were presented in this. Also, an aim of this study was to find new ways to view these variables, their concepts, and models. These strategies can even be used by a practitioner to work more efficiently and to further understand the implications and relationship between these variables, their concepts, and models.

Additionally, this research yielded a significant contribution to the Industrial Engineering (IE) research. An engineer's work process can be expedited with the information in this study, as they can better organize and maintain the system with current technology. Also, this study showed that it can help to save time, money, materials, energy, work hours, machine time, and other resources that would otherwise hinder productivity. In this study, there were innovative ideas for the products of any business, as well as helpful ideas for practitioners. This study was easy to understand and can be read by people of all backgrounds and fields. Furthermore, the clear theoretical framework in this study provided more relevant information to serve as a reference for future research. This study can help those within the IE profession and research field to get one step ahead of the competition.

Systems engineering has contributed to engineering management, as they have made the inspection and security of the project life reduce risk. Engineering management would focus on the budget, scope, schedule, and cost, while SE focuses on the project and the company as a whole. Furthermore, the system would be focused on by SE by trying to help with all aspects, since they do have some focuses on different aspects of engineering. It is an "interdisciplinary approach and means to enable the realization of successful systems" [1]. SE would be described as a systematic process of "realizing technical systems from needs, requirements, concept, design, and the eventually realized product" (Chan, 2015; Galli & Kaviani, 2018; Labedz & Gray, 2013; Ibrahim et al., 2018). Primarily, views of the project are emphasized by SE to improve its design if some part of the project is not efficient.

LITERATURE REVIEW

The application of system engineering in risk management has a great impact on the decision-making of the system and the lifecycle of it. "The linkage between strategic organizational management and systems engineering has been observed for decades. Management theorists have compared corporate organizations to 'systems'" (Mabelo & Sunjka, 2017; Ahern et al., 2014; Galli, 2018a). Furthermore, Rice (2010) described organizational systems as follows: "A system is here defined as a set of objects together with relationships between the objects and between their attributes related to each other and their environment to form a whole." Organ & Stapleton's (2015) definition of a system was a complex grouping of human beings and machines for which there is an overall objective. Regarding systems engineering (SE), Organ & Stapleton (2015) viewed this domain as "operating in the space between research and business, assuming the attitudes of both" (Rice, 2010; Parast, 2011; Schwedes et al., 2017; Zwikael & Smyrk, 2012). The Vee, Waterfall, and Spiral models are the three models that are mostly used. There are several challenges faced by systems engineers with identifying the boundaries of the overall system and the independent constituent system within it. "These boundaries relate to both technical aspects such as interfaces, integration and testing, and management aspects such as governance and stakeholder involvement. Further challenges relate to the gaining of confidence in system operation, regarding behavioral correctness, performance qualities, and their validation. Many of these challenges are already the foci of work in the field of systems engineering" (Organ & Stapleton, 2015; Gimenez-Espin, 2013; Hartono et al., 2014). SoS engineering would not be viewed as a completely new or opposing discipline, but rather a "sub-field of systems engineering that focuses on the boundaries and interactions between independent, distributed, and evolving constituent systems and their stakeholders" (Nielsen et al., 2015; Al-Kadeem et al., 2017a; Eskerod & Blichfeldt, 2005; Galli, 2018c).

The systems are owned and operated by independent stakeholders, and there are limitations on the exchange of information about the system. Meanwhile, the system behavior is dependent on emergent phenomena that are observed at the system boundaries. "System analysis includes careful acquisition and examination of the requirements for a system with the intent of understanding them, exploring their implications, and removing inconsistencies and omissions. System design presents overall system architecture" (Nikiforova et al., 2008; Lamaakchaoui et al., 2018). Furthermore, the target system in system design is "organized into components based on both the analysis structure and the oncoming architecture. The end product of analysis and design is a system representation that corresponds to the requirements and is used for further system implementation. Testing is applied for implemented system verification and validation according to the preliminary requirements." (Nikiforova et al., 2008; Besner & Hobbs, 2012; Galli, & Hernandez – Lopez, 2018; Sharon, Weck & Dori, 2013). Thus, analyze the system as a whole is helpful with system analysis, as well as to diagnose any risk or obstacles that the system would face.

Systems Engineering

A great focus for projects and companies is systems engineering. SE was described as a "discipline based on requirements and all considerations about analyzing and managing them" (Azar, 2012; Van Gemert, 2013; Sadgui & Benchekara, 2018). Different aspects were focused on by project managers compared to systems engineers, who focus on "ensuring that the identified product requirements are documented and written in such a manner that they can be verified (built the product right) and validated (built the right product)" (Van Gemert, 2013; El Hissi et al., 2018). Furthermore, "verification ensures the product requirements are met as documented, whereas validation is the equally important aspect of meeting the end user's original intent" (Van Gemert, 2013). As one can see, there is a "big picture" focus with SE for the product to make the product more efficient, to reduce loss, and to maintain profit. A challenge for Se can be "to effectively build the skill sets of the engineers responsible for overseeing these highly complex, large-scale systems. There is often a great mantle of responsibility for engineers, which can "significantly affect the course and outcome of engineering projects" (Arnold &Wade, 2017; Lee et al., 2013; Svejvig & Andersen, 2015; Xue et al., 2016). There are many models that SE follows, such as the VEE model that helps with the development process of the product.

Systems Thinking

Systems thinking can have a different definition to many other people, as some think that it is just a collection of tools and methods. These tools are attractive to many people, such as the causal loop diagram and management flight simulator. Engineering systems thinking requires great skill, as it "enables individuals to perform systems engineering tasks successfully. To successfully perform systems engineering roles, systems engineers need a system view or a high capacity for engineering systems thinking" (Frank et al., 2011; D'Emilia et al., 2018). It is illustrated by findings that "this ability is a consistent personality trait, and that it can be used to distinguish between individual engineers" (Frank et al., 2011). Overall, these traits can analyze the client's needs, develop the concept of operation, conceptualization of a solution, lead to functional analysis and architecture synthesis, and implement the whole design. A systems engineer who is equipped with systems thinking can look at the whole project with macro thinking to aid in performing before the client can continue describing the project. "The main contribution of systems engineering to project management is integrating the technical disciplines to achieve customer's objectives (Meredith & Mantel, 2006; Zelinka & Amadei, 2019)." There are three primary objectives of systems engineering, which are bettering system performances, bettering system effectiveness, and reducing cost (Meredith & Mantel, 2006; Yun et al., 2016; Winter et al., 2006a). Thus, the systems approach requires systems thinking, and it is "very important in a complex project environment where systems approach required" (Frank et al., 2007; Sutherland, 2004; Xiong et al., 2017; Zhang et al., 2016). System, as a whole, would be defined as a group of components put together to solve or perform a task. System engineers and system thinkers are used as tools to help solve and make the system run as smoothly as possible. To project managers, system thinking is a part of the main body of knowledge that is vital to a project's success.

Risk Management

To ensure a competent product, risk management and systems engineering work hand-in-hand, especially for Systems Engineering. SE has responsibility for driving technical excellence for meeting technical standards and process. Additionally, the supplier contracts, maintenance agreements, any upgrades, and many other responsibilities must be managed by SE to ensure the project is up to date and runs efficiently.

Conventional risk involves participants individually deciding if the "risk is high enough to warrant devoting resources to risk management with the expectation of reducing risk to the desired level. However, in a SoS, interfaces can allow the inadvertent increase of risk to others. For example, persons who commit crimes in Malaysian or Singaporean waters can easily escape into Indonesian waters" (Mabelo & Sunjka, 2017; Milner, 2016; Nagel, 2015; Papke-Shields & Boyer-Wright, 2017). Without the capacity or motivation to capture these international criminals, Indonesia unintentionally increases Malaysia's and Singapore's risk of offenses in their waters. Conversely, risk in Malaysia and Singapore's waters would be reduced if Indonesian waters were no longer a refuge for offenders. Of course, it would not be intentional on Indonesia's part to increase the risk in the Straits of Malacca and Singapore, but it could be an "understandable outcome because of Indonesia's geography and current stage of development" (Bristow et al., 2012; Andersen, 2014; Galli, 2018b; Marcelino-Sádaba et al., 2014). Risk management was described in the SE as having many variables, and not aiding with the projects led to some issues. Like the Malaysia and Singapore example, they attempted to capture a criminal who escaped to Indonesia waters, which would not happen if no one was allowed in the waters. Also, Indonesia could not be capable to offer resources to catch them. Still, this is a circumstance that could have been avoided.

SE has interdisciplinary studies that were derived from some cultural, social, economic, and legal professions. With all of these professions, they still could not fully grasp the concept of risk management, as there might have been an issue on the different types of professions that might gather the risk when trying to solve one risk. "Traditionally viewed as a technical problem that must be overcome, the tendency has been to reduce the problem regarding mathematical formulae or biological parallels. The nuclear incident at the Fukushima Daiichi Nuclear Power Plant is a clear example of how risky incidents are shaped and consequences magnified from a multitude of factors (social, cultural, political and economic), which can exacerbate an already dangerous situation. Whilst the incident at Fukushima was precipitated by a natural disaster, it clearly shows how risk is equally if not more acutely produced by the coupling of different system elements" (Organ & Stapleton, 2015; Nikabadi & Hakaki, 2018). The nuclear power plant disaster at Fukushima Natural is a natural risk that should have been amended. There was a major earthquake with a 15-meter tsunami that disabled the power and cooling supply, which caused the three cores to melt. As a result, the whole plant had to be covered to contain the radiation. This risk and horrible disaster should not only have been accounted for, but it also should have been handled better. It was a disaster that put too many lives in danger, and it cost millions because of the loss of the nuclear plant.

RESEARCH METHODOLOGY

Literature Review Research Approach

There were two major steps in the literature review. Step one entailed the search for relevant information, such as input from keywords, and it was a less structured approach. Step two was the review process that utilized databases and searches strong. An additional search was done for two tables of contents from relevant journals.

Part 1: Explorative and Unstructured Literature Review

The study examined publications that reflected the keywords because this study aimed to reassess certain keywords. This yielded finding many research fields and links, as there were a total of 30 journal articles and six books. Then, the keywords were studied from the 36 publications to be used as search terms in the structured review.

Part 2: Structured Literature Review

A structured and systematic approach from other literature was used to apply methods for conducting reviews. This section contained four phases, and the first entailed preparing and scoping. The second phase entailed planning the review, and the third was the search, evaluation, and selection of literature. Finally, phase four was the evaluation of the selected literature.

For phase 1, the review scope highlighted project-relevant research on marketing and strategic planning, which was a key concept throughout the studies. As a result, the search was expected to provide sufficient evidence, as well as a representative selection of journals for this study.

Phase 2 involved connecting the keywords to other concepts for more information (i.e., the keywords, their relationship, and their interaction). Vague concepts were the success, evaluation, and impact, as their results were not practical or focused.

For phase 3, a pertinent compilation of results was generated by searching through various databases (i.e., ProQuest, Business Source Complete, Elsevier, EBSCO, ABI/Inform Global, and ScienceDirect). As a result, we compiled 14 conference papers and 28 journal-related results, which totaled 42 results.

When the search concluded, academic and practitioner-based Table of Contents were examined for relevant tier 1 and tier 2 journals. Also, it was made certain that all relevant articles were found that may not have even matched the keywords, as they would be the premier specialty journals for the keywords. In Figure 1, there were three streams to the search and selection process, which first involved the explorative and unstructured search. Secondly, the structured search was done with search strings, and then the Tables of Contents were scanned.

Pursuing the streams in Figure 1 helped to yield 45 publications for the analysis. The study collected 25 and 20 results in the selection process by focusing on the results from academic journal articles, literature reviews, conference papers and proceedings, and books. Also, the study utilized triangulation methods. In the first selection, the research concluded if the publications were linked to the keywords and project research, which was assessed with inclusion and exclusion criteria about the abstract. Some papers incorporated the entire paper, but others only contained the introduction for the criteria.

Phase 4 entailed arranging information into an inductive and deductive analysis. This was documented with a software package. The deductive analysis involved the documentation of the university and country of every author, along with suggested categories. Research genres were categorized in the following ways: empirical research, theory development, research essays, and literature reviews, or "other." Deductive coding was added by proving that the publications applied theoretical frameworks, such as with a research-based view and contingency theory. It was also noted if there was a model in the publication.

Additionally, the researched utilized a grounded theory approach for the inductive analysis to particular code publications with open and selective codes. Most of the publications were selected based on the average for the annual number of citations. This gave equilibrium for the older publications. Also, it was decided to include relevant literature reviews that signified even more relevant studies. In turn, the study then incorporated relevant, current, and significant publications for the keywords research.

Phase 4 illustrated that key themes were generated by assessing the list of open codes for collecting them into axial and selective codes. The first two parts of the literature review occurred between April 2018 and August 2018, as they were linked to related research activities. During this time, the study also did a final evaluation of relevant materials and their overlap.

Collecting these papers illustrated that the variables and concepts shared key themes from both narrative and trait perspectives. Statistically analyzing and investigating other variables/factors made our research conclusions more substantial. These key themes were addressed in Table 1, and it contained the 45 identified studies.

As the 45 studies were assessed, it was found that the literature evaluated keywords with multiple statistical methods, which were from relational and causal perspectives. Thus, our research conclusions would be more substantial. In Table 2, there was a summary of the statistical methods that the research used for the 45 studies, and Table 3 summarized the number of factors/variables that were studied in the journals.

The findings for these research methods can be found in the following, which reflected the themes or topics of later sections.

Figure 1. Research approach for literature review

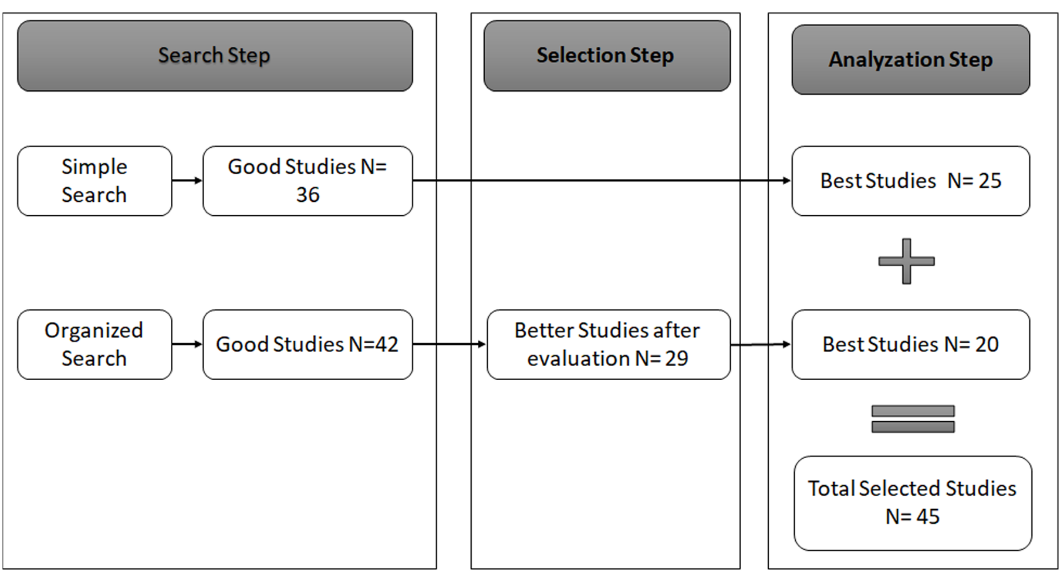


Table 1. Identified studies from research approach by theme

Theme #1	Theme #2
Ahern, Leavy, & Byrne, (2014). Andersen, (2014). Arumugam, (2016). Aslani, Akbari, & Tabasi, (2018). Bristow, Fang, & Hipel, (2012). Cova, & Salle, (2005). David, David, & David, (2017). Detert, (2000). Easton & Rosenzweig, (2012). Eskerod, & Blichfeldt, (2005). Frank, Sadeh, & Ashkenasi, (2011). Galli, (2018c). Galli & Hernandez – Lopez, (2018). Memon & Meyer, (2017). Nielsen, et al. (2015). Schwedes, Riedel, & Dziekan, (2017). Xue, Baron, & Esteban, (2016). Xue, Baron, & Esteban, (2017). Zelinka & Amadei, (2019).	Al-Kadeem, et al. (2017a). Arnold, & Wade, (2017). Besner & Hobbs, (2012). Brown & Eisenhardt, (1995). Burnes, (2014). Frank, Zwikael, & Boasson, (2007). Gimenez-Espin, (2013). Hoon Kwak & Dixon, (2008). Ibrahim, Abdallahamed, & Adam, (2018). Lamaakchaoui, Azmani, & El Jarroudi, (2018). Mabelo, & Sunjka (2017). Nikiforova, Kirikova, & Strazdiņa, (2008). Organ, & Stapleton, (2016). Rice, (2010). Sharon, Weck & Dori, (2013). Shenhar, & Levy, (2007). Sutherland, (2004). Yasui, (2011). Yun, et al. (2016).
Theme #3	**Theme #4**
Badi & Pryke. (2016). Bajaj, et al. (2017). Elloumi et al., (2017). Galli and Kaviani, (2018). Galli, et al. (2017). Gholizad et al., (2017). Omamo, Rodriguez, & Muliaro (2018). Labedz, & Gray, (2013). Lee, Lapira, Bagheri, & Kao, (2013). Medina & Medina, (2015). Milner, (2016). Nikabadi, M. S., & Hakaki, A. (2018). Parast, (2011). Parker, Parsons, & Isharyanto, (2015). Perry III, et al. (2016). Sadgui & Benchekara, (2018). Svejvig & Andersen, (2015). Todorović, et al. (2015). Usman Tariq, (2013). Von Thiele Schwarz, (2017). Young, (2010). Zhang, et al. (2016).	D'Emilia, Gaspari, & Galar, (2018). El Hissi et al., (2018). Gafi & Javadian, (2018). Galli, (2018a). Galli, (2018b). Chan, (2015). Hartono, Wijaya, & M. Arini, (2014). Loyd, (2016). Marcelino-Sádaba, Pérez-Ezcurdia, Lazcano, & Villanueva, (2014). Nabavi & Balochian, (2018). Nagel, (2015). Papke-Shields & Boyer-Wright, (2017). Parast, (2011). Peters, Doskey, & Moreland, (2017). Sharon & Dori, (2011). Van Gemert, (2013). Winter, Andersen, Elvin, & Levene, (2006a). Xiong, Zhao, Yuan, & Luo, (2017). Zwikael, & Smyrk, (2012).

FINDINGS

Models/Diagrams

Modern systems that are worked with systems engineers are becoming more complex through the use of graphs and models. However, the system can be less complicated and easier to utilize with these models. Also, the goal of having a model-based systems engineering is to create a model that can represent all of the various aspects, such as the requirements, structure, and behavior of the system. The following examples helped to show what else the system would require to work and run smoothly. Two system modeling languages are used; firstly, the Systems Modeling Language (SysML) is used for system engineering applications, supports the analysis, design, verification, and validation of a

Table 2. Systematic analysis results by statistical analysis method

Statistical Method	Number of Articles (Frequency)	Author(s)
Regression	19 (24.05% of total articles)	Arnold, & Wade, (2017). Aslani, Akbari, & Tabasi, (2018). Bajaj, et al. (2017). Cova & Salle, (2005). David, David, & David, (2017). Detert, (2000). Easton, & Rosenzweig, (2012). Frank, Sadeh, & Ashkenasi, (2011). Galli, Kaviani, Bottani, & Murino, (2017). Gimenez-Espin, (2013). Loyd, (2016). Mabelo, & Sunjka, (2017). Nielsen, Larsen, Fitzgerald, Woodcock, & Peleska (2015). Nikabadi & Hakaki, (2018). Perry III et al. (2016). Sutherland, (2004). Xue, Baron, & Esteban, (2017). Young, (2010). Zwikael & Smyrk, (2012).
ANOVA	19 (24.05% of total articles)	Ahern, Leavy, & Byrne, (2014). Brown & Eisenhardt, (1995). Chan, (2015). El Hissi et al., (2018). Frank, Zwikael, & Boasson, (2007). Galli, (2018b). Galli, (2018c). Gholizad et al., (2017). Ibrahim, Abdallahamed, & Adam, (2018). Omamo, Rodriguez, & Muliaro (2018). Memon & Meyer, (2017). Nabavi & Balochian, (2018). Nagel, (2015). Organ, & Stapleton, (2016). Papke-Shields, & Boyer-Wright, (2017). Rice, (2010). Van Gemert, (2013). Xiong, Zhao, Yuan, & Luo, (2017). Yun, Choi, Oliveira, Mulva, & Kang, (2016).
Q-Test	15 (18.99% of total articles)	Arumugam, (2016). Badi & Pryke, (2016). D'Emilia, Gaspari, & Galar, (2018). Elloumi et al., (2017). Gafi & Javadian, (2018). Hoon Kwak, & Dixon, (2008). Kawinfruangfukul, Koolmanojwong, & Kukreja, (2013). Labedz, & Gray, (2013). Lamaakchaoui, Azmani, & El Jarroudi, (2018). Nikiforova, Kirikova, & Strazdiņa, (2008). Parker, Parsons, & Isharyanto, (2015). Schwedes, Riedel, & Dziekan, (2017). Usman Tariq, (2013). Von Thiele Schwarz, (2017). Zelinka & Amadei, (2019).
t-Test	13 (16.46% of total articles)	Andersen, (2014). Besner, & Hobbs, (2012). Burnes, (2014). Eskerod, & Blichfeldt, (2005). Galli, (2018a). Winter et al. (2006a). Hartono, Wijaya, & M. Arini, (2014). Lee, Lapira, Bagheri, & Kao, (2013). Mabelo, & Sunjka, (2017). Sharon, Weck & Dori, (2013). Shenhar, & Levy, (2007). Yasui, (2011). Zhang, Bao, Wang, & Skitmore, (2016).
Chi-Square Test	13 (16.46% of total articles)	Al-Kadeem et al. (2017a). Bristow, Fang, & Hipel, (2012). Galli, and Kaviani, (2018). Galli, & Hernandez – Lopez, (2018). Marcelino-Sádaba, Pérez-Ezcurdia, Lazcano, & Villanueva, (2014). Medina, & Medina, (2015). Milner, (2016). Parast, (2011). Peters, Doskey, & Moreland, (2017). Sadgui & Benchekara, (2018). Svejvig, & Andersen, (2015). Todorović, et al. (2015). Xue, Baron, & Esteban, (2016).

Table 3. Systematic analysis results by number of variables studied

No. Factors Studied	Number of Articles (Frequency)	Author(s)
1	17 (21.52% of total articles)	Andersen (2014). Aslani, Akbari, & Tabasi, (2018). Besner, & Hobbs, (2012). Bristow, Fang, & Hipel, (2012). David, David, & David, (2017). Galli (2018b). Lee et al. (2013). Mabelo, & Sunjka, (2017). Medina, & Medina, (2015). Nagel, (2015). Nikabadi & Hakaki, (2018). Papke-Shields, & Boyer-Wright, (2017). Rice, (2010). Sutherland, (2004). Van Gemert, (2013). Von Thiele Schwarz, (2017). Yun et al. (2016).
2	12 (15.19% of total articles)	Al-Kadeem et al. (2017a). Brown, & Eisenhardt, (1995). El Hissi et al., (2018). Frank, Sadeh, & Ashkenasi, (2011). Galli, & Hernandez – Lopez, (2018). Ibrahim, Abdallahamed, & Adam, (2018). Kawinfruangfukul, Koolmanojwong, & Kukreja, (2013). Memon & Meyer, (2017). Shenhar, & Levy, (2007). Nabavi & Balochian, (2018). Xue, Baron, & Esteban, (2016). Yasui, (2011).
3	17 (21.52% of total articles)	Arumugam, (2016). Badi, & Pryke, (2016). Chan, (2015). Elloumi et al., (2017). Eskerod, & Blichfeldt, (2005). Galli, et al. (2017). Gimenez-Espin, (2013). Omamo, Rodriguez, & Muliaro (2018). Loyd (2016). Marcelino-Sádaba, et al. (2014). Perry III et al. (2016). Sadgui & Benchekara, (2018). Svejvig, & Andersen, (2015). Sharon, de Weck, & Dori, (2011). Usman Tariq, (2013). Winter et al. (2006a). Zhang et al. (2016).
4	12 (15.19% of total articles)	Ahern, Leavy, & Byrne, (2014). Detert, (2000). Easton, & Rosenzweig, (2012). Gafi & Javadian, (2018). Galli, (2018a). Hoon Kwak, & Dixon, (2008). Labedz, & Gray, (2013). Lamaakchaoui, Azmani, & El Jarroudi, (2018). Organ, & Stapleton, (2016). Parast, (2011). Todorović et al. (2015). Zwikael, & Smyrk, (2012).
5	10 (12.66% of total articles)	Burnes, (2014). Cova, & Salle, (2005). D'Emilia, Gaspari, & Galar, (2018). Frank, Zwikael, & Boasson, (2007). Galli, (2018c). Gholizad et al., (2017). Nikiforova, Kirikova, & Strazdiņa, (2008). Peters, Doskey, & Moreland, (2017). Sharon, Weck & Dori, (2013). Xue, Baron, & Esteban, (2017).
6	11 (13.92% of total articles)	Arnold, & Wade, (2017). Bajaj, et al. (2017). Galli, and Kaviani, (2018). Hartono, Wijaya, & M. Arini, (2014). Milner, (2016). Nielsen, et al. (2015). Parker, Parsons, & Isharyanto, (2015). Schwedes, Riedel, & Dziekan, (2017). Xiong et al. (2017). Young, (2010) Zelinka & Amadei, (2019).

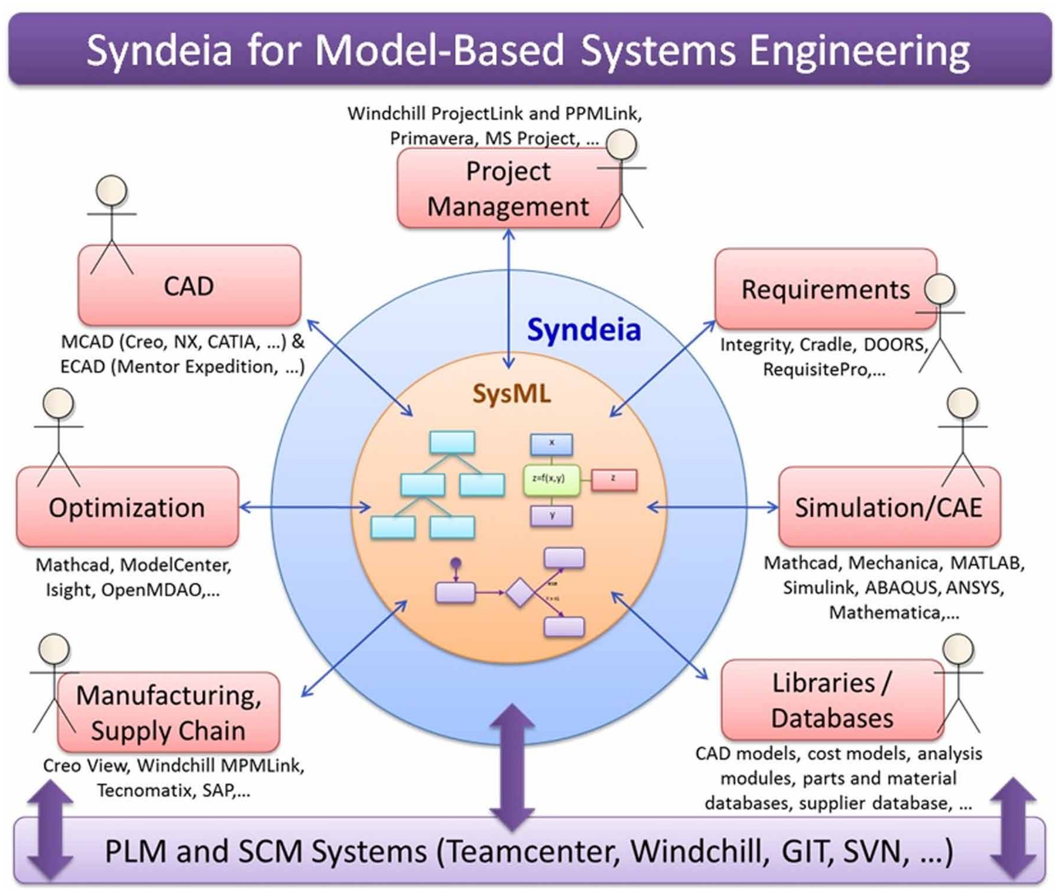
complex system. Secondly, the Lifecycle Modeling Language (LML) is an open-standard modeling language that is designed for systems engineering. A full life cycle, conceptual, utilization, support, and retirement stages are applicable with this model. Furthermore, "Syndeia is a software platform for integrated model-based engineering (MBE/MBSE) developed by Intercax with collaboration and support from leading industry organizations. In this section, the study uses Syndeia as a typical software application to demonstrate the concepts related to TSM, especially the graph-based aspects which are the theme of this paper" (Bajaj et al., 2017; Nabavi, & Balochian, 2018; Omamo, Rodriguez, & Muliaro, 2018). The Syndeia model-based systems is outlined in Figure 2.

Engineering teams can work together with Syndeia to develop and manage the total system model graph of a complex system by combining the system architecture model with other graphs and tools. Syndeia would work as configuration management of the entire collection of models, while the models are individually managed in different configuration management systems, such as PLM, ALM, and Enterprise Resource Planning systems and databases.

The Vee Model

An efficient systems engineering tool for dealing with a large-scale system is the Vee Model because it is a "hard" systems approach that is often used for systems designs for aerospace projects. Checkland's hard/soft dichotomy labels the Vee Model as "hard" because the Vee Model takes a problem-solving

Figure 2. Syndeia model-based systems (Bajaj et al., 2017)



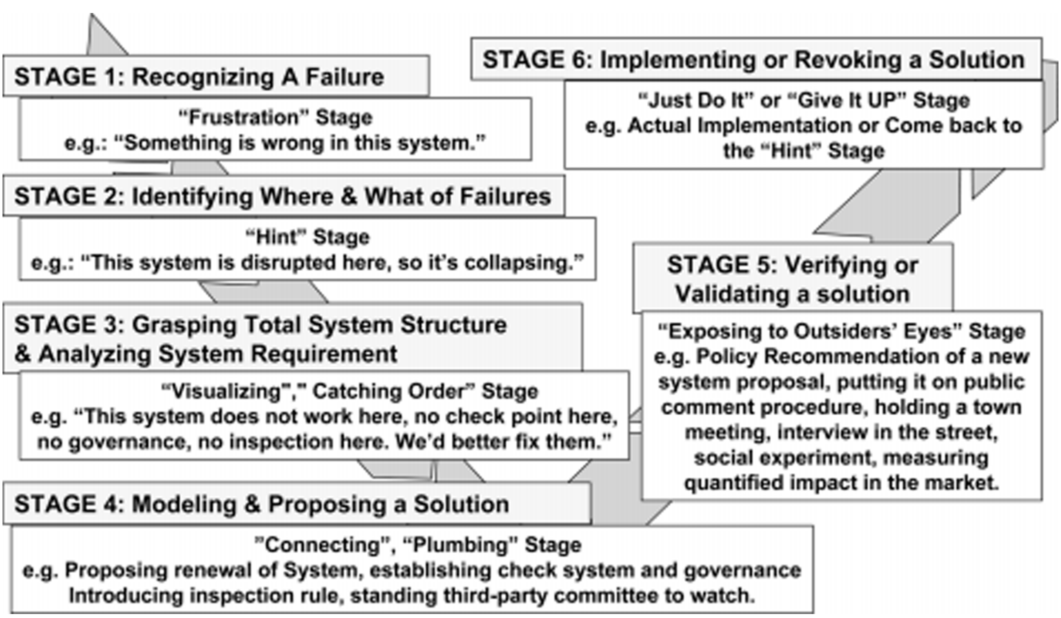
approach. Chekland and Scholes defined the dichotomy as "the 'hard' tradition taking the world to be systemic; the 'soft' tradition creates the process of inquiry as a system" (Yasui, 2011; Aslani et al., 2018). However, this traditional labeling would be distracting because "the Vee Model should be identified as a 'soft' approach" (Khan et al., 2019; Yasui, 2011). It is normally used for large scale systems, not complex systems. An aerospace project would be an example of a large-scale system because you can predict the outcome despite the variables that would have perplexed relations with the components. Furthermore, six steps to the Vee Model are commonly shared by system designers, stakeholders, and more for the system improvement: recognizing a failure, identifying the failure, grasping the total system structure and analyzing the requirement, modeling and proposal of a solution, validating the solution, and implementing the solution. The three steps of the Vee model are outlined in Figure 3.

These steps are a basic process of activities interactively made among a system designer, problem owner, and the stakeholders.

Waterfall Model

Another model that is used by systems engineers is the Waterfall Model for a one-dimensional model (when one task is completed, and then you can move on to the next task). The waterfall model would be defined as a classical software engineering that was founded by Boehm and was introduced by Royce, and government projects and many major companies use it. Planning in the early stages is shown in this model, and it would find design flaws before it is part of the project. Furthermore, intensive documentation of the project and the planning that would work well for the project would be made with this model. There must be at least seven parts to the project or the model to work smoothly. First, the system requirement would establish what the project is and what it requires. Second, a software requirement is needed. Third, the preliminary design would be the first look of the project, but not the complete version of it. Fourth, the detailed design would require all of the materials and information for the project to be implemented and to be a step closer to completion. Fifth, the coding and debugging is needed. Sixth is the integration and testing, which would finish the final steps and testing out the

Figure 3. Vee model the six steps (Yasui, 2011)

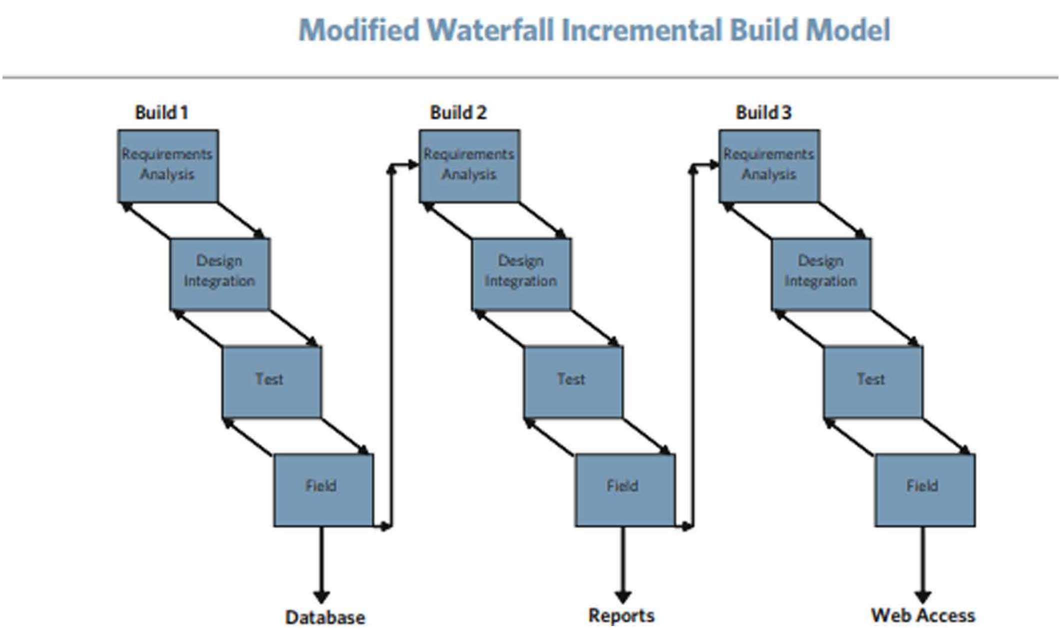


project and would ensure that it is running. Lastly, operation and maintenance would ensure that it is up and running. This step does not stop, and any problem there would be in the future should have an answer. Requirements analysis is performed based on the needs and inputs from users and engineers, logistics, and system managers. Then, the interface definition and control, overall system trade studies with sensitivity analysis, and concept definition and exploration are all accomplished. At that point, the system would start to develop into a potentially useful product, at least from a conceptual point of view. The next application of "systems engineering would be in the design and integration stage, where the project would start to resemble a real system" (Young, 2010). The Waterfall model would allow setting up the system in an easily read. This model is outlined in Figure 4.

Spiral Model

The Spiral Model was developed in the 1980s by Boehm and Papaccio. It addressed the need to shorten the period between the user's statement of requirement and the production with which the users could interact. The model aimed to solve the shortcomings in the Waterfall Model and other models, as it is meant to go in a spiral. The disadvantage of the Waterfall Model would be the advantage of the Spiral Model; thus, it is a realistic model that is used mostly in the development of large software (Young, 2010). However, the disadvantage of the Spiral Model would be that the stakeholders are more involved in the models of the project. For example, stakeholders would be notified when a step is done in the Waterfall Model. It is an "evolutionary software process model that combines the iterative nature of prototyping with the controlled and systematic aspects of the linear sequential model" (Young, 2010). This model was shown in Figure 4, and it is prevalent in OO design methodologies. Furthermore, all crucial development phases are encompassed in it: Requirements analysis, Design, Code, Test, and Maintenance. This model is marked by the use of the control and structure of the more linear, sequential waterfall process, but with a series of "evolutionary releases," it is also known as the "hybrid model." The issue of quality assurance is explicitly addressed by performing the development process in a "stepwise refinement method" (Young, 2010). This method is outlined in Figure 5.

Figure 4. Waterfall model (Young, 2010)



Each step would be deliverable, which the structure of the process embodies. Primarily, the customers or stakeholders involved during the development process are focused on by the process.

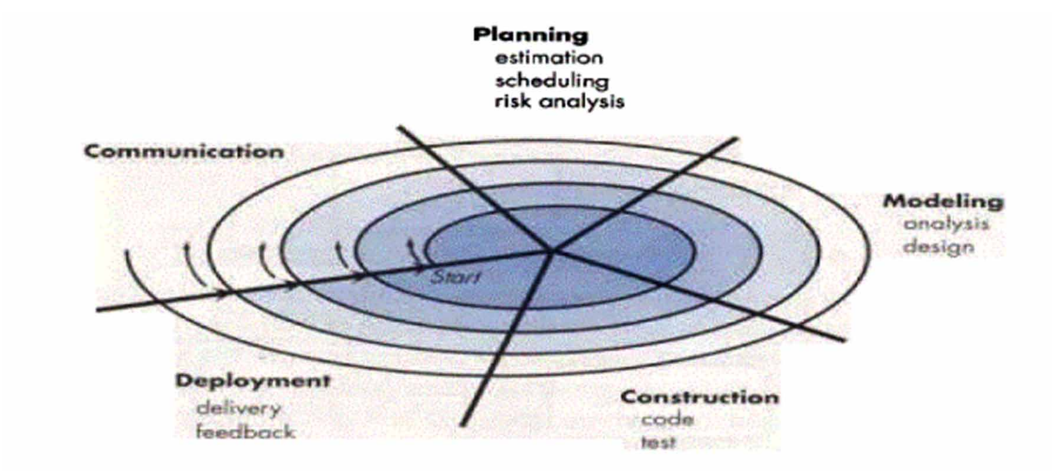
DISCUSSION

Risk management is deeply intertwined with project management, and it is important to systems engineering. Yacov Haimes discovered the similarities and differences of systems engineering and risk analysis in 2012, and he alluded to the purpose of systems engineering as a problem-solving endeavor (Young, 2010; Burnes, 2014; Cova & Salle, 2005; David et al., 2017). Young then provided a set of principles to "facilitate and improve risk assessment, management, and communication, and to align risk analysis and systems engineering to a common purpose" (Yasui, 2011; Gafi & Javadian, 2018). Perry III, Olson, Blessner, and Blackburn (2016) found that risk management had extreme risks and catastrophic system failures. Systems theory and system analysis were very useful in finding the different risks, and it was prepared to face and find solutions to the extreme risk.

Technology

Research and development have always had a dedication in further research of new technology. Technology has always made our lives less complicated, as the phones users carry every day can call a person across the globe, can send an email without using a computer, and can take a photo or video. There can be software that works with the organization's ability to manage performance, cost, and schedule. However, the job of a systems engineer would be to evaluate the available technology with the company and if it can do its job. "Inaccurate maturity assessments of a technology or product development could potentially lead to reduced or unsatisfactory technical performance and programmatic overruns. The ability to calibrate technology maturity assessments using confidence intervals would be beneficial to the systems engineering community" (Peters et al., 2016). A task for the systems engineer would be to inspect and determine if the technology is up to the task of completing the job and if it is accurate enough for it. Thus, it would be "essential for a process used to have access to a knowledge management repository with practical guidelines to facilitate and to come up the learning curve in understanding new systems engineering concepts" (Kawinfruangfukul et al., 2013). Additionally, it would be "important for the process engineers or process authors to

Figure 5. Spiral model (Abbas, Jeberson, Klinsega, 2013)



have a tool that can effectively describe the processes to the process users" (Kawinfruangfukul et al., 2013). You would need to know how to use the new technology and how to spread this knowledge to the whole staff, as it would lead to better efficiency and communication.

Environment and Sustainability

The development of using today's resources while remaining aware of the reduction of use or destruction of the resources of tomorrow is sustainability. The aim of sustainability is to reduce or maximize the use of one of our resources so that it does not run out in the future. Some examples would be solar panels and wind turbines that have reduced the use of oil as our main energy production. To have a closer look at any projects with sustainability would be having water treatment plants or water reduction use in toilets and faucets. Also, solar panels can be installed in newly constructed buildings to save resources sustainability, which has been going hand-in-hand with the green movement, as there has been such huge investment in it. There are three main concerns (economy, environment, and society) to sustainability development, and it "suggests that environmental and social criteria need to be considered along with economic criterions, which are called the 'three pillars' or the 'triple bottom line' of sustainability" (Yasui, 2011; Todorović et al., 2015; Usman Tariq, 2013; Von Thiele Schwarz, 2017). To address the sustainability in supply chain management, the decision-maker should incorporate these three pillars of sustainability simultaneously into the decision-making process. The application of the triple bottom line accounting on economic order quantity (EOQ) was shown to provide very useful insights (Arumugam, 2016). It was shown that including "environmental and social factors, in addition to economic considerations, allow the decision makers to assess their decisions from sustainability perspective" (Türkay et al., 2016; Arumugam, 2016; Badi & Pryke, 2016; Xue et al., 2017). A project that has a lot of investment, but criminal labor laws could not be considered successful. The environment and the labor force that it receives must be considered by management because it would negatively impact the project by harming its lifecycle.

Systems engineers would work with project managers, as they both have concern for the project. The project is viewed by project management from start to end and deals with every aspect and issue, systems engineers look at the project as a whole system. Meanwhile, the project is viewed by systems engineers on every aspect, such as "the project design, the planning, and scheduling ... [to] make it more efficient. As SEM is the practice that couples the SE domain and the PM domain, the successful implementation of system engineering requires not only technical, but also managerial traits" (Türkay et al., 2016; Loyd, 2016; Shenhar & Levy, 2007; Parker et al., 2015). Systems engineers are required to apply science and technology, as well as technical planning, management, and leadership activities (Frank et al., 2007; Galli et al., 2017; Medina & Medina, 2015; Hoon et al., 2008). Furthermore, systems engineering managers must "rely on a combination of technical skills and management principles that address both complex technical and managerial issues" (Sharon et al., 2011; Gholizad et al., 2017). Thus, the technical issues are related to product aspect and are generally only focused on it. However, the managerial aspect of it is in the project aspect to make the whole project run smoothly.

CONCLUSION

Organizational Implications

Researching the acquired skill and management strategies illustrated that these variables, their concepts, and models are needed to conduct business projects and project management. This approach showed that it can help businesses to find success, as it illustrated that it fosters particular skills from a team to reach their goals. Investing in technology was not as important as investing in these variables, their concepts, and models. The results demonstrated how necessary strategic planning and a top-down and bottom-up approach were to leadership, especially for elements of project management, operations management, and process improvement. The results showed the need to use these variables, their concepts, and models for leadership styles and tools, as well.

This research also illustrated that these variables, their concepts, and models affected many aspects of an organization. The leadership and management behind a business required certain training and skills to manage project management and their overall development. This research revealed that current problems in project management and operational performance were from insufficient leadership skills. Solely focusing on the bottom line or costs and profits caused problems. One can effectively supervise project management and operational performance with the proper tools and information, which will improve the overall performance, profits, and costs.

Most importantly, a finding in this study was that these variables, their concepts, and models were usually overlooked because finances were more emphasized by business leaders. This negatively affected businesses over time because finances only gave temporary solutions. For the long-term, leadership should be managing multiple business elements (i.e., operations, project management, financials, performance, strategy, and human resources). Thus, leadership should be recognizing that a business is only the sum of its parts for a more successful present and future.

Managerial and Team Implications

This study resulted in many implications. Primarily, the results examined the variables in a new way to fill a research gap about how the variables are affected by other factors, as well as each other. The effectiveness of a business depended on these concepts, so one must make the most of this information. This study could be an outline for projects and performances, as knowing how these variables relate will improve management. Better managerial constructs can be produced by leaders, so their teams and businesses can learn to recognize shortcomings that could hinder the performance and effectiveness of a project or business. Also, teams could be pinpointing their shortcomings and how they start by using the tools within this study to better meet project and business goals.

Lastly, the implications highlighted the importance of comprehensive training programs to improve performance. Most of all, project teams, project leadership, and business leaders could profit from training on assessing these factors against standard and industry accepted concepts. The project and organizational leadership can be guided on managing teams and projects to positively adjust leadership methods. Teams and leaders can become more educated on how teams and projects affect both project and team performance and effectiveness, which will benefit the entire business.

Implications and Applications to Fields of Project Management and Engineering Management

It is evident that these variables, their concepts, and models were vital aspects of projects, but the engineers and technical professions needed more attention. An engineer used to be defined as a person who uses technology and math for problem-solving. Recently, that definition would be a person who provides economically viable solutions through problem-solving with technology and math. Thus, these variables, their concepts, and models were essential to engineering decisions, as well. One must make the right decisions that will steer clear of future errors when a project is initiated. For an engineer's information to best benefit investors, engineers need to know business management and maturity models.

Management and engineering concepts are both scientific, which is why there are different management schools of thinking. Since engineering was rooted in the scientific idea of the cause and effect relationship, management and engineering are strongly connected. Thus, combining these concepts will lead to both of their improvements. The effects of management on performance and operational-related decisions in project success goes unconsidered, which is why engineering improved many projects with management. Instead of taking a business perspective, this study illustrated the need to know these methods from an engineering perspective. Also, pure engineering filed techniques were addressed, such as budgeting, equipment, and purchasing material. This study provided engineers and project managers with many decision-making methods for engineering problems, and they even screened projects for their viability.

The foundation of this research was on scholarly information about these variables, their concepts, and models. This study aimed to find the best practices for these variables, their concepts, and models to work as a future reference in the research field. The information on project management and operational performance can benefit many businesses, as well as ways to manage these concepts by using these variables, their concepts, and models. Essentially, the research highlighted literature for managing projects and for improving pre-existing management standards.

The IE/EM profession depended on project management and operational performance and the research field. Since lean thinking does not always resolve these problems, the variables, their concepts, and models were developed and managed through the best concepts for projects. As a result, they created a different environment in the IE/EM profession. However, the structural orientation of scope made players IE/EM produce the required scopes of interest for every level. A strategy can only be generated through the application of significant concentrations for every level of interest. Also, there would need to be a more tactical method for making a suitable performance to generate the same results. The implementation of these variables, their concepts, and models are caused by the given scopes.

This research contributed to industrial engineering and engineering management, but every business field needs project management. All organizations are dependent upon creating new products and services that keep them relevant. Thus, one must not ignore how these variables, their concepts, and models relate. Also, stakeholders, such as system engineers, project managers, and other experts in industrial engineering and engineering management, could find helpful information on applying maturity to project management. This study encouraged stakeholders to take advantage of the system engineering and project management roles for the success of business projects.

Organizations may utilize these variables, their concepts, and models, but they are not given enough research. As a result, this study broke new ground in the subject of how project management and operational performance development were affected by these variables, their concepts, and models. It can be profitable to use systems thinking with the objectives of new product development. It has been revealed in this study how a small company with few established processes can generate new products, as this was only the second product for the company under discussion.

Limitations

There were some limitations to the study and results. Primarily, there was a small sample size to the study that only assessed a small number of key factors. This caused some bias and validity problems with the findings and conclusions, but a larger sample size could fix this issue. Additionally, the key factors were only assessed from a project environment perspective, so the conclusions and analysis were exclusive to this environment. The findings were not applicable to other areas, either: i.e., supply chain management, operations management, or strategic management. Thus, it was difficult to say that these findings applied to industries or managerial settings.

Future Research

There were some areas for future research to explore, such as assessing these factors and their relationship from the context of other industries and managerial settings to find their strengths. Also, one can find what affects these factors and their relationship, as well as assessing them from organizational, strategic, or cultural perspectives. Thus, different perspectives of these variables, concepts, and models can be studied by future research to find how culture, strategy, human resources, and operations affect their relationship.

General Summary

In this paper, systems engineering and risk management were very important to the project and the system as a whole because they helped the system to run efficiently. The concepts and benefits of breakthrough theories for the system are understood by systems engineers, as well as what a system as a whole, would require. In other words, the system as a whole would mean that it would work with the design of the project, stakeholders, and suppliers. The Vee model, Spiral model, and the Waterfall model are used by systems engineers to help organize and inspect the system. Meanwhile, risk managers would assist system engineers to recognize the risk more easily and to know how to assess the risk to find a solution. In the end, some system engineering concepts helped with the prioritization of the framework, such as Program Model, WinBook, and Value-Based Requirements.

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