University of Tennessee, Knoxville

Trace: Tennessee Research and Creative Exchange

Doctoral Dissertations

Graduate School

5-2019

# Numerical Evaluation of Research Project Performance

Alexandr Mikhail Sokolov
*University of Tennessee*, asokolov@vols.utk.edu

# Numerical Evaluation of Research Project Performance

A Dissertation Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Alexandr Mikhail Sokolov
May 2019

# Acknowledgements

Thank you all for your help.

Abstract

When dealing with research of any kind there are no set guidelines other than general frameworks on how to measure the performance of the research. This presents a large problem for most Institutions and Principle Investigators trying to conduct research proficiently. Because there are no performance management plans on how to conduct research proficiently, Project Management techniques were implemented using an Agile system to measure the performance of research.

Using an Agile system for research allows the researcher to develop key performance indicators that shows how proficiently the research is being conducted. This will also allow the user to see any areas in the research where there are bottlenecks that will impede the research progress. This performance management system should also allow users to understand how to implement experiments steps at the same time to ensure the research gets done as promptly as possible.

Altogether this performance management system will be a highly detailed research performance plan that is not limited to types of research fields and budgetary restrictions. This performance management plan will enable researchers to conduct research as efficiently and effectively as possible with highly specialized plans.

Table of Contents

# List of Tables

List of Figures

# List of Equations

# Chapter 1

# Introduction and General Information

## *Performance Management of Research*

When dealing with performance management there are certain facets that come to mind. The first aspect is the idea that projects and processes can be managed for performance. The problem that is present is how does one measure the performance of intangible processes or projects? One intangible process that is almost impossible to measure is the performance of research, outside of seeing how often it was citied in other research. There is no set plan in place to measure research performance therefore most users tend to use measurements of publications to see how effective the research was.

The problem with this is that it does not measure the efficiency of the research this only shows the effectiveness of the research. Effectiveness can be defined as the outcome from the total input of the project or process. This is different from efficiency because this is a measure of how much resources are utilized to provide an outcome from the project or process. By this the measurement of performance of research cannot be done by only using the publications that comes from research. This only shows the effectiveness and not the efficiency. The efficiency is the equivalent to performance management of the research.

Even though efficiency is very important to capture, there currently is not a set method to capture the performance management of research. This process is very important as it can instill greater outcomes of research or allow the research to be conducted in a faster manner. Even if a project or process is completed on time and on budget it still may have not been done as efficient as possible. Creating a performance management system will allow users to not only track their efficiency with a performance management system but their effectiveness with publications that come out as a result of the research.

One of the main problems why there has not been a performance management system for research in place is because there are so many different variables present when dealing with research. Users have to consider cost of funding, types of desired outcomes whether it is publications or patents etc., then the length of the research and the categorical organization to the research. Most performance management systems that have been published only focus on a framework but not an actual system (Otley, 1999). These frameworks have been introduced because research is too variable therefore creating a system that all users can follow may prove to be too difficult.

There have been some frameworks developed to try to solve the problem of performance management in research. These frameworks took on the role of project management of research. Project management is a technique used to insure projects and processes get developed on time. The only problem with utilizing project management techniques for research is that research has too many variables. Therefore, only frameworks could have been developed to guide research projects and processes. This means there is no specific plan for research available.

By looking at Agile project management, which has been largely used in the Information Technology field, the process may be adapted for general research. The Agile project management system allows user to manage projects that are very specific.

This is important because if a performance management system was created it would have to be specific and not a framework for users. The idea behind Agile is to have a log of issues or problems that need to be addressed or fixed. From this one can take these issues or problems and then fix them. If the problem is fixed the user, then moves on to the next issues or problem. If the issue in question is not fixed, then the user cannot move on with the process.

One key characteristic that research has that is different from project management is the fact that when users use project management to make their project or process more efficient they have a very defined path forward. This is not always the case with research since research has so many variables. To address these issues an Agile project management system for research can be ever changing and developing in real time to account for changes in the architecture of the performance of the research. The Agile system will also allow user to address multiple steps in the research plan to make it as efficient as possible.

Developing a performance management system for research will rely on using a technique which addresses which step in the research plan is needed to be dispatched at what time and in what order. This plan should be specific enough for all types of research and does not have any restraints, such as cost or complexity. This will not be a framework therefore this plan can be utilized by users who want to run their research in the most optimal way.

*Why Is It Important*

When trying to define performance it is about capability and not how successful the outcome was (Yadav, 2013). This goes over the aspect that even though a project or process is on time and on budget it still may not be performing as proficient as it could be. Therefore, measuring a research publication on how many times it was citied would not be able to give the performance of the research. The measurement of how many times a research article was published only give the effectiveness of the research but not the efficiency. This means that certain aspects of the project or process can be improved to yield better results. This means that although several frameworks of performance management have been created for research there has not been an actual plan developed.

The reason why most users use frameworks is because in general they do not have specific details defined therefore they can include all types of research that have very different variables driving the research. These frameworks do not have the flexibility to address specific types of steps within research plans. These frameworks only show how efficient the research was on a macro scale but not individual on how efficient each different step in the process or project was. That means that the frameworks only may show how close to budget and time limit a certain research project or process was but not how the individual steps were performed. The performance of the individual steps is what the Agile performance management system for research will address.

Agile performance management system takes on a very open-ended performance management approach. This is important because traditional project management techniques are only meant for large scale applications. This is also the case when used for frameworks. But by introducing an Agile system for performance management there can be a more specific performance management system for research in place.

Using an Agile performance management system allows users to be specific with their research performance plan while allowing the flexibility of a framework. This also allows a user to have a very specific plan set up to help optimize their projects or processes. This Agile system will address all the required steps needed for a project or process at the beginning of an experiment therefore the users know exactly how to proceed with the experiment in the most optimal way. The Agile performance management system for research will also show any bottlenecks in the plan that will be addressed at the beginning of the experiment which will help the users understand which areas of their research need to be prioritized. This Agile performance management system will also show which steps if any can be done at the same phase to save time.

Another gained benefit of this performance management system is that if users want to track how efficient the Principal Investigator is they can check the performance management plan. This means that there can be key performance metrics in place for users who wish to use this system. This should help employers to identify how well researchers are doing their work. This is important when dealing with high budget research plans, or projects that take a long time to complete. This can also help small companies wanting to ensure their research staff is doing everything as efficient as possible. This added key performance metric can be used to measure researcher’s performance at the workplace. Employees can now track their performance for their employers. This gives the Agile performance management system an extra added benefit on top of being able to track individual performance of research.

*Summary of Work*

The methodology will go over creating an Agile performance management system for research. This will overlook at how Agile can be used for any type of research to increase its performance. By looking at the current Agile process from the information technology field, one can take the current system and creating a log of items that need attention. From this one can then organize which steps in the experiment need to be done in the order of importance. Once a list of tasks has been created from the log of items that need attention and prioritized according to importance. An Agile approach will be used to induce a process of completing the items at attention. If there are multiple items that can be started at the same time this Agile approach will identify those steps. Once all the steps have been identified then the researcher can begin to address those issues. The Agile approach will test the steps one at a time to see if the user can move forward with the project or process. If the user cannot move forward the issues are recycled back to the beginning for the researcher to continue working on that step. The Agile processes are constantly in effect, therefore if items are completed the Agile system will be updated.

To test this methodology the efficiency and the effectiveness will be calculated by understanding the relationship of output over time for efficiency, and output over input for effectiveness. Using mathematical models, the relationship will present the efficiency and effectiveness in real time. Once the efficiency and effectiveness have be calculated the Project Performance Quality (PPQ) will be identified to determine how past project can have a quality associated with the research.

When dealing with the PPQ there will be an expert judgement determined to give an observed data set for research. The multiple regression analysis based on such factors as number of publications, salaries, citations and so on, will be used to estimate the coefficients of a linear regression for the PPQ. Using the PPQ coefficients, one can calculate the predicted PPQ for a set of research. From this the Spearman Correlation and Pearson Correlation can be calculated to see the relationship between experts' PPQ's and predicted by a linear regression model. For validation of our approach we separate data in 2 subsets and use regression analysis from the first subset applied to the second one. If the Spearman Correlation of experts' PPQ and predicted ones (for the second subset) is above 0.6000 we accept the mathematical model.

# Chapter 2

# Literature Review

*General Background Information*

Taking off with the “Manifesto for Agile Software Development”, Agile has found relations to a number of applications including manufacturing, construction, and aerospace (Highsmith, 2009). The Agile movement “rests on two foundational goals: delivering valuable products to customers and creating working environments in which people look forward to coming to work each day” (Highsmith, 2009). Agile performance is measured on two triangles- scope, schedule, and budget, and value, quality, and constraints (Highsmith, 2009). Agile project management “can be applied to a wide range of product development efforts” (Highsmith, 2009).

The Agile Manifesto that accelerated the development of Agile methods and targeted them towards software development states their values as “Individuals and interactions over processes and tools, working software over comprehensive documentation, customer collaboration over contract negotiation, responding to change over following a plan” (Beck, 2001).

A chief concern of organizations considering implementing Agile practices is how Agile they can become (Sidky, 2007). The Sidky Agile measurement index (SAMI) is a scale used to determine “Agile potential (the degree to which that entity can adopt Agile practices)” (Sidky, 2007). SAMI is composed of four components: Agile levels, Agile principles, Agile practices and concepts, and indicators (Sidky, 2007). While there are issues with the "tailor ability of the measurement index", SAMI allows organizations to evaluate their Agile potential before attempting to implement Agile (Sidky, 2007).

In *Effective Project Management: Traditional, Agile, Extreme,* it notes that based on data "from over 10,000 project managers from around the world, over 70 percent of projects are best managed by processes that adapt to continual learning and discovery of the project solution" (Wysocki, 2011). By definition, Wysocki (2011) notes, that over 70 percent of all projects should have used Agile project management. Agile project management is best used on projects where there exists "high complexity and uncertainty and present the organization with a significant challenge" (Wysocki, 2011). Further he identifies in table 1 that there is a substantial difference between a Traditional Project Management project team and an Agile Project Management project team.

In "Agile project management- agilism versus traditional approaches," they analyze the effectiveness and need for Agile project management versus traditional forms of project management (Fernandez, 2008). Increased globalization has forced the necessity of project managers to implement Agile project management methods. Further they note that traditional project management simply does not have the flexibility needed in a globalized economy (Fernandez, 2008). The paper advocates the use of Agile project management due to a "new economy which is characterized by more complex and uncertain project situations" (Fernandez, 2008).

*Table 1. Traditional Project Management Team Versus Agile Project Management Team.*

| Characteristic | Traditional Project Management Project Team | Agile Project Management Project Team |
|---|---|---|
| Size | Could be very large | Usually less than 15 |
| Skill Level | All levels | Most skilled |
| Location | Co-located or distributed | Co-located |
| Experience Level | Junior to Senior | Senior |
| Position Responsibility | Requires supervision | Unsupervised |
| (Wysocki, 2011) | | |

On the other hand, some research has shown the benefits in blending traditional and Agile project management approaches. In “The Blending of Traditional and Agile Project Management”, they identify the “disciplined and deliberate planning control methods” as a strength of traditional project management tactics (Hass, 2007). However, Hass (2007) believes that combined with the Agile project management components of: “virtual control, co-located high-performing teams, test-driven development, adaptive control, collaborative development, feature-driven development, leadership and collaboration rather than command and control, move from cost to revenue, and lessons learned” that performance can be improved by project teams.

Paykina (2012) conducts research to identify the characteristics best for choosing between traditional project management and Agile project management. The study finds that the suitable characteristics for selecting the best project management style are: project complexity, communication, competencies and requirements (Paykina, 2012). Table 2 discusses the differences between these project management styles and Figure 1 shows how to use the identified characteristics to select between Agile and traditional project management (Paykina, 2012).

*Table 2. Comparison Of Traditional And Agile Project Management Approaches (Paykina, 2012).*

| Characteristics | Traditional Approach | Agile Approach |
|---|---|---|
| **General** | | |
| **Project Goal** | Highly assure project objectives & deliverables with predictability & planning | Deliver business value immediately |
| **Project Size** | All types, especially large | Small-Medium |
| **Time Required** | Pre-defined phases | Fast development |
| **Environment Stability** | Stable, predicable & low-change | Frequent changeability, uncertainty |
| **Management Processes** | | |
| **Planning** | Elaborate & document plan | Not explicit, no documentation |
| **Controlling** | Quantitative control: formal project plan & milestone driven | Qualitative control: informal reviews & pair- programming |
| **Customer Relations / communication** | As needed in early specification phase | Critical, frequent, face-to-face, customer interaction with the development team |
| **Management Style** | Command & control through milestone review | Self-managed, empowered teams |
| **Documentation** | Elaborate & complete | Neglected |
| **Technical** | | |
| **Customer requirements** | Definitive, exhaustive, functional & non-functional, predictable & determined in advance | Simple design, simple code, short increments, frequent releases |
| **Knowledge** | Explicit, documented knowledge | Tacit, high skilled team members |
| **Testing** | Documented testing plans & procedures | Iterative system testing and related defect fixing |

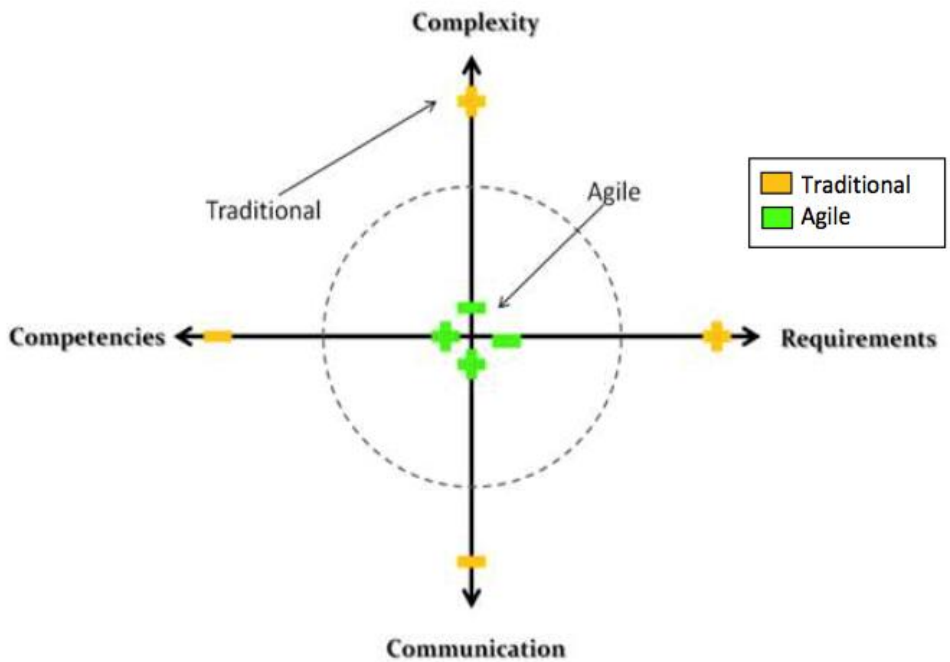


*Figure 1. Model For Method Selection (Paykina, 2012).*

Cobb (2015) identifies the misconceptions in adopting Agile from traditional management methods. Primarily "Agile and traditional project management principles and practices are treated as separate and independent domains of knowledge with little or no integration between the two and sometimes seen as in conflict with each other" (Cobb, 2015). Instead, Cobb (2015) recommends viewing Agile and traditional management styles to complement each other rather than compete with each other.

Further, in "Agile-based competence management: the relation between Agile manufacturing and time-based competence management", Van Assen (2000) notes the correlation between Agile methods and time-based competence management. His research identifies that Agile methods can be utilized efficiently from a time-based perspective.

*Agile and Scrum*

Hansenne (2011) researches the organizational challenges in adapting Agile project management. He finds that "adaptation to an environment with less structure and control is often a hard challenge, but it can be overcome with proper guidance and support of a high-level internal sponsor who champions the Agile vision top down" (Hansenne, 2011). He notes that another challenge is the development of project managers into project facilitators (Hansenne, 2011). Also, for Agile adoption to work it must be company-wide and not just a single department (Hansenne, 2011). Figure 2 shows this research's Agile adoption model (Hansenne, 2011).

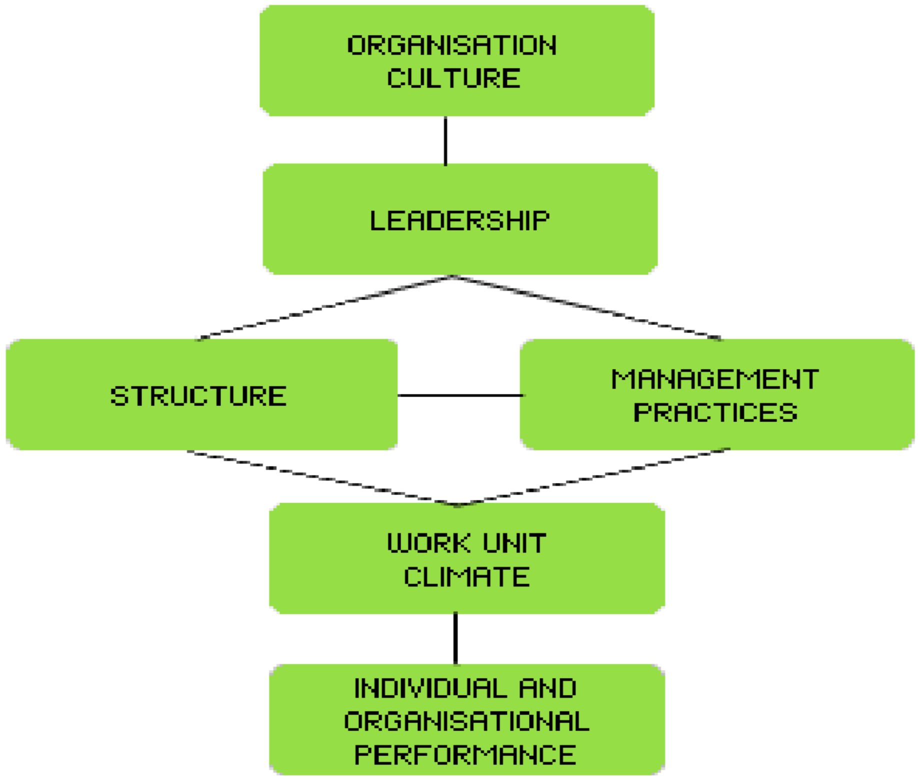


*Figure 2.* *Agile Adoption Model (Hansenne, 2011).*

There is research that finds Agile practices to be cumbersome to larger organizations and more effective in small, stand-alone projects (Boehm, 2005). Boehm (2005) has found the barriers to bringing Agile approaches to traditional organizations to be “either as problems only in terms of scope or scale, or as significant general issues needing resolution”. This has led to the identification of three areas of conflict- development process, business process, and people- that stand as the major problems with adapting agility in larger organizations (Boehm, 2005). Further, research concludes that while Agile methods may improve both informal and formal communications in project teams, in larger projects “a mismatch of adequate communication mechanisms can sometimes even hinder the communication” (Pikkarainen, 2008).

Dutoit (2007) notes the confusion and difficulty with evaluating the Agile method best for the organization. “Although there are plenty of publications on the Agile methods, the question how to combine single practices from different methods to define an organization’s specific process and when such combinations are reasonable, still remains unclear” (Dutoit, 2007). Although they have found Agile methods to help increase the productivity and efficiency of their teams, the lack of definition in Agile methodology makes the practice “unconvincing” (Dutoit, 2007).

Sidky (2009) asserts that Agile works best when it is adapted to the organization rather than following a verbatim methodology.

A case study on Agile methods focused on the overall influencing factors in Agile practices. The study found in industrial setting Agile methods “yielded above-average post-release quality and average to above-average productivity” (Layman, 2006). They identified four factors that contribute to the outcome of these industries adoption of Agile: “availability of data, tool support, cooperative personnel and project status” (Layman, 2006).

Procter (2011) notes that the emergence of Agile has been coupled with a plurality of approaches to the type of management. The overarching principle in Agile is to “enshrine iteration (rather than merely accommodating it) as the key to successful software projects (Procter, 2011).

Scrum is used with Agile project management. “Research on Agile project management with scrum method” shows that Agile project management can be more effective when used in collaboration with the Scrum method (Hu, 2009). Scrum method is an “iterative incremental process” (Hu, 2009). Scrum has three roles: the product owner, the teams, and the scrumasters (Larman, 2010). Larman (2010) also notes Scrum events: Sprint Planning, Daily Scrum, Product Backlog Refinement, Sprint Review, Spring Retrospectives, Joint Retrospectives. Larman (2010) asserts that Scrum can be applied in small or large scale, without differences; as Scrum is “an empirical process framework that within an organization can inspect and adapt to work in a group small or large”.

Cervone (2011) finds that “Agile project management using the Scrum methodology allows project teams to manage digital library projects more effectively by decreasing overhead dedicated to managing the project. Because Scrum implements a continuous review and short-term time frames, Cervone (2011) states that “the project team is better able to quickly adapt projects to rapidly evolving environments in which systems will be used". He declares that Scrum methodology is more effective in managing projects and makes them easier to complete (Cervone, 2011).

Sutherland (2001) introduces Scrum methodology to five different companies of various sizes and diverse technologies. He states that after his experiment, "SCRUM works in any environment and can scale into programming in the large. In all cases, it will radically improve communication and delivery of working code. The next challenge for SCRUM… is to provide a tight integration of the SCRUM organization pattern and XP programming techniques" (Sutherland, 2001).

*Agile Project Management with Scrum* elaborates on utilizing Agile project management with the Scrum method (Schwaber, 2004). Schwaber (2004) explains that Scrum is in fact quite difficult to transition to. Scrum takes a fine attention to detail in contrast to the flexibility of Agile. Schwaber (2004) discusses the large portion of Agile project management that involves Scrum and to beware the deceptive simplicity of the process. Cohn (2010) asserts that adapting Scrum is one of the hardest processes in adapting Agile project management because: "successful change is not entirely top-down or bottom-up, the end state is unpredictable, Scrum is pervasive, Scrum is dramatically different [from traditional methods], change is coming more quickly than ever before, and the best practices are dangerous".

Moe (2010) analyzes data from a software development company that introduced Scrum- focusing on human skills and the mechanisms of teamwork by the people involved. It is found that "problems with team orientation, team leadership and coordination in addition to highly specialized skills and corresponding division of work were important barriers for achieving team effectiveness" (Moe, 2010). Moe (2010) asserts that this can be overcome by focusing energy on the transition and reorientation of not only the team but also of management, despite the time and resources it may take.

Vlaanderen (2011) uses a case study in software product management to research the implications of adopting Scrum principles. Vlaanderen (2011) offers the "Agile requirements refinery" as an extension of Scrum to combat the difficulties in adopting Scrum. The "Agile requirements refinery" acts to enable "project managers to cope with complex requirements in an Agile development environment" (Vlaanderen, 2011).

Basahel (2014) discusses the use of SCRUM Agile project management in the management of an academic institution. He begins that SCRUM is mostly used in the information technology domain and rely on a team to control its members (Basahel, 2014). He believes this is what makes SCRUM applicable to the management of an academic institution as "staffs are highly qualified and may even be at the same and sometimes higher academic level than their managers" (Basahel, 2014). Further he believes that this is what calls for a more democratic style of management (Basahel, 2014). Basahel (2014) states that "SCRUM has a flatter management and like all Agile project management methods, tend to focus more on activities that add value directly to an organization rather that supportive activities". Figure 3 details the process of SCRUM methodology (Basahel, 2014).

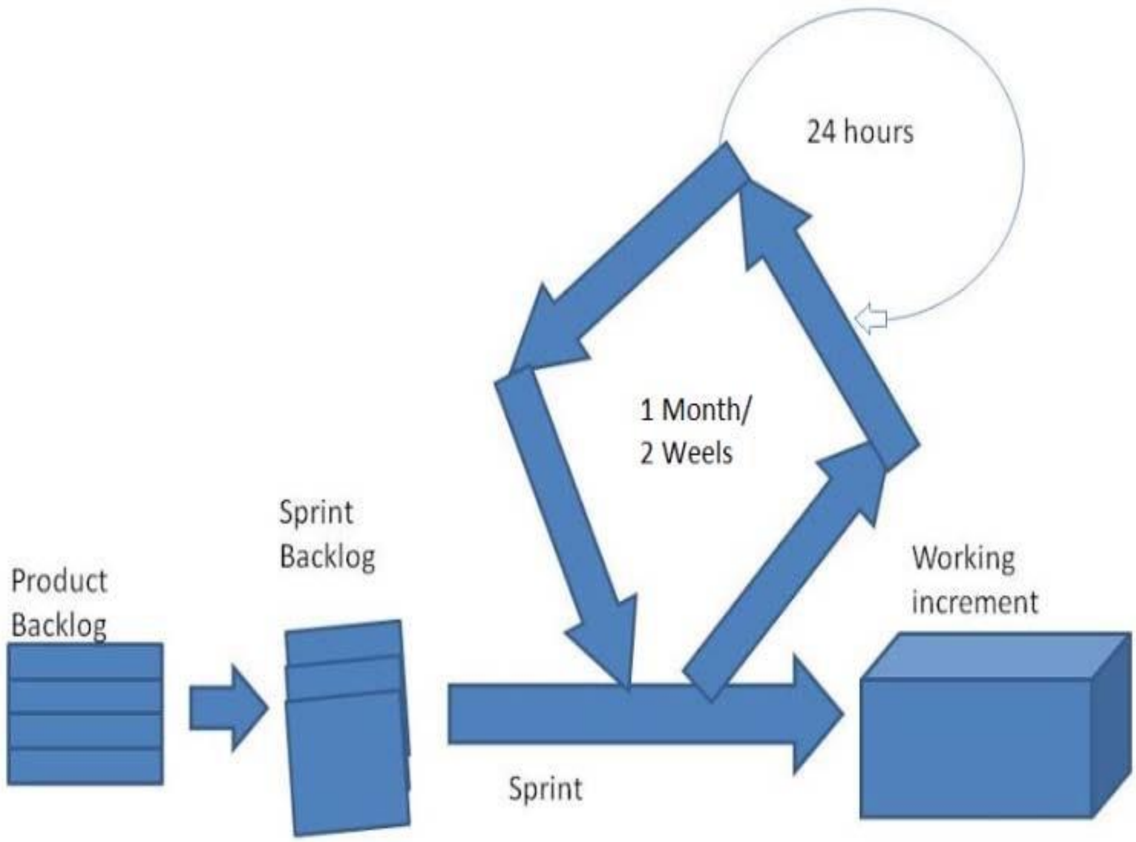


*Figure 3. Scrum Overview (Basahel, 2014).*

*Extreme Programming*

Beck (2000) notes that Extreme Programming (XP) is the most popular of Agile methods. Extreme Programming "is a lightweight methodology for small-to-medium-sized teams developing software in the face of vague or rapidly changing requirements" (Beck, 2000). XP "takes commonsense principles and practices to extreme levels": "review code all the time (pair programming)", "test all the time (unit testing)", "design… part of everybody's daily business (refactoring)", "simplest design that supports its current functionality", "integrate and test several times a day (continuous integration)", "iterations really, really short- seconds and minutes and hours… (the Planning Game)" (Beck, 2000). XP "promises that they will be able to work on things that really matter, every day…. They will make decisions that they can make best, and they won't make decisions they aren't best qualified to make" (Beck, 2000). Further "XP promises that [customers and managers] will get the most possible value out of every programming week" (Beck, 2000).

Reifer (2002) evaluates 14 firms using extreme programming and finds that early adopters "have cut costs, improved productivity and reduced time to market through the use of these methods". Further, the firms use XP "primarily to decrease time needed to bring software products/application to markets" with cutting costs as a secondary concern (Reifer, 2002). He also notes that over 90% of the projects are relatively small and all 31 are in-house projects, one-year or less in time span and low risk (Reifer, 2002).

Maurer (2002) states that extreme programming aims "to increase a software organization's responsiveness while decreasing development overhead". XP focuses on producing “executable code and automated test drivers” (Maurer, 2002). Maurer (2002) continues that “this focus on source code makes XP controversial, leading some to compare it to hacking”. This is not warranted as “XP highly values simple design, and counters hacking claims by emphasizing refactoring, strong regression testing, and continuous code inspections through pair programming” (Maurer, 2002).

Layman (2004) evaluates the success of extreme programming adoption. The case study follows two releases of the same product, one release prior to adoption XP methodology and the other after two years of using XP (Layman, 2004). Studying the two releases shows “a 50% increase in productivity, a 65% improvement in prerelease quality, and a 35% improvement in post-release quality” (Layman, 2004). Layman (2004) believes that these results indicate that “adopting the XP process can result in increased productivity and quality”.

*Agile Engineering*

Research points that traditional engineering may not fit today’s changing environment due to its “inherent rigidity” (Turner, 2007). Turner (2007) continues “as systems grow larger and more complex, new ways of dealing with abstraction, concurrency, and uncertainty need to be developed.” He postulates that Agile methods give a reasonable solution to these issues (Turner, 2007).  A key component to the success of Agile engineering is teamwork (Hazzan, 2009).

Paetsch (2003) analyzes the application of Agile management from the requirements engineering perspective. He notes that traditional engineering processes are ineffective with the changes in the economy (Paetsch, 2003). He finds the requirements engineering phases of “elicitation, analysis, and validation are present in all Agile processes” (Paetsch, 2003). He notes that an issue with Agile approaches is they are described ambiguously to give developers more liberty with enactment (Paetsch, 2003). In the end, this is why requirements engineering and Agile management work well together pursuing alike ends (Paetsch, 2003).

Eberlein (2002) notes that many programmers “welcome Agile methods as an excuse to throw overboard everything that requirements engineering has been teaching”. He notes the attractiveness of Agile methods over requirements engineering for programmers who fist want to produce code fast and second enjoy the “hands-on” aspect (Eberlein, 2002). Instead of focusing on one or the other, Eberlein (2002) offers using Agile methods and requirements engineering together as they are suited well for each other, if quality is a concern.

Cao (2008) further argues in support of requirements engineering with Agile management. He states that the “rapidly changing business environment in which most organizations operate is challenging traditional requirements-engineering approaches” (Cao, 2008). Through an empirical study of 16 software development organizations, he finds that Agile management has benefits in this setting, and can help organizations deal with the quick changes to requirements that are making them swiftly become obsolete (Cao, 2008). He elaborates that that “rapid changes in competitive threats, stakeholder preferences, development technology, and time-to-market pressures make pre-specified requirements obsolete” (Cao, 2008).

Ramesh (2010) uses data from 16 software development organizations to find two risks with Agile requirements engineering practices. One risk he finds is “problems with customer inability and a lack of concurrence among customers significantly impact Agile development” (Ramesh, 2010). Second, “risks associated with the neglecting non-functional requirements such as security and scalability are a serious concern” (Ramesh, 2010). Ramesh (2010) recommends evaluating risk factors in accordance with the project environment to determine if the benefits of Agile requirements engineering practices offset the cost.

Paige (2008) supports the Agile engineering of high-integrity software systems. Using the results of a pilot study on the utilization of Agile methods to build a high-integrity system, Paige (2008) finds the problems to be issues with communication, scalability, and system complexity; however, Paige also notes solutions to these problems. It is noted, “the flexibility and volatility problems tackled by Agile processes are exactly those experienced by high-integrity systems development; and the mechanisms through which Agile processes achieve success are difficult to combine with verification, validation, and certification requirements for high-integrity systems” (Paige, 2008). There is backing for Agile processes in the building of high-integrity systems as it highlights and minimizes the time from observation to action (Paige, 2008).

Software engineering relies on Domain-Specific Languages to “represent domain knowledge in the form of executable language” (Gunther, 2010). Gunther (2010) notes that the largest flaw with DSLs is “the high effort required to implement and use them”.

Using a case study as support, Gunther (2010) finds that Agile processes can "facilitate the successful planning and developing of internal DSLs".

Razzak (2013) notes that knowledge management is essential for success in global software development or distributed software development. Razzak (2013) writes, "to maintain effective knowledge sharing in distributed Agile projects, practitioners' need to adopt different types of knowledge sharing techniques and strategies". The study finds that "during knowledge sharing among distributed team members, practitioners faced different types of challenges, such as, language, communication, misunderstanding, visualization, cultural, technological and time zone difference" (Razzak, 2013). Razzak (2013) finds that "distributed Agile team always faces visualization problem due to temporal and geographic dispersion between teams which also leads to decrease in project productivity".

Lee (2010) also evaluates the Agile methodology in a distributed environment. She begins that "globally distributed software development is another trend [next to Agile] delivering high-quality software to global users at lower costs" (Lee, 2010). A distributed software development launch, dispersed over 3 continents, is characterized by a more than 30% increase in overall performance and satisfaction after adopting Agile methods (Lee, 2010). While Agile principles advocate face-to-face communication, many IT companies are adapting Agile to the distributed development environment (Lee, 2010). Lee (2010) identifies for distributed Agile management to be successful, there "must be a commitment from the management, product, and development teams".

Marambe (2014) evaluates the challenges of Agile software development in the offshore model. The research identifies the main challenges they face by analyzing three offshore software development companies in Sri Lanka (Marambe, 2014). The results find that “communication, tools and infrastructure, following the Agile development method, and testing had a strong relationship with the project outcome in terms of time, cost, scope, quality, and the overall project outcome” (Marambe, 2014).

Hope (2011) notes that user participation “is vital to the successful design of computer systems”. The science and technology study perspective reveals that user participation is integral to the design process of software development (Hope, 2011). Figure 4 below shows the Dynamic Systems Development Method (DSDM) of Agile project management (Hope, 2011)


*Figure 4. Visualizing The DSDM (Hope, 2011).*

Japikse (1993) says that Agile engineering has accelerated and improved the design process. He elaborates that this is an effect of Agile engineering and lean manufacturing as well as the traits that guide the management styles (Japikse, 1993). Marchese (2006) also shares how Agile engineering has impacted design. Giving examples from an art installation project called "Trigger", Agile engineering processes gave the project "flexibility that allowed for iterative adjustment" (Marchese, 2006). Further, "this style of management allowed the group to act decisively with incomplete information, thereby successfully finishing the project in time to meet a rigid deadline" (Marchese, 2006).

Johansson (2012) describes the impact that the Agile project management methodology has had on the software industry. Further he notes that Agile has evolved into different industries where the customer may need multiple tests to create improvements on a project (Johansson, 2012). More directly, Johansson (2012) notes, "the major advantages found with implementing the Agile approach is an increase in the client's involvement. The Agile approach almost forces the client to increase their participation in the project compared to the situation today". He elaborates to describe the benefits this management technique can have in the construction industry, especially in the design phase of construction projects (Johansson, 2012).

The expansion of mobile device software has led to the growth of software development for mobile platforms. These advances increase concern of quality and quantity of new applications (Rahimian, 2008). Rahimian (2008) argues that the "requirements and constraints associated with mobile systems have brought new challenges to software development for such environments, as it demands extensive improvements to traditional systems development methodologies in order to fulfill the special needs of this field". He claims Agile methods can "facilitate the application of a software engineering approach to the production of mobile software systems" (Rahimian, 2008).

In respect to Agile engineering, research has searched for the most efficient way to apply Agile management. An analysis of Agile engineering teams has shown that "in most cases Agile practices were modified with respect to the context and situational requirements" thus indicating "the need for future research on how to integrate all experiences and practices in a way to assist practitioners when setting up non-collocated Agile projects" (Jalali, 2010).

Using a comparative analysis, Abrahamsson (2003) finds that Agile methods in software engineering methods "cover certain/different phases of the software development life-cycle and most of them do not offer adequate support for project management." Further "many methods still attempt to strive for universal solutions (as opposed to situation appropriate) and the empirical evidence is still very limited" (Abrahamsson, 2003). Abrahamsson (2003) thus recommends focusing on methodological quality instead of method quantity as well as further experimentation.

Anderson (2003) claims that the issue with converting to Agile management in the software engineering sector is when teams are not ready for it. He states that converting radically to Agile can be scary and if a team is not prepared it will not be successful (Anderson, 2003). Further King (2014) notes that Agile's strength in less formal processes is also a drawback as it can “lead developers to use the Agile model as authorization to avoid any process efforts”.

Uikey (2012) claims traditional management has limitations in respect to Agile in software development. “In traditional project management, teams have to plan every single detail of the project, before they begin executing it” (Uikey, 2012). This is opposite in Agile management where there is a lot of flexibility in planning. Further, “there is a lack of collaboration between the team and the customers [in traditional project management]” (Uikey, 2012). Uikey (2012) continues “documentation in traditional project management is very extensive and detailed, consuming much of the time of development”. This makes the effort in implementing traditional management high. Uikey (2012) has outlined the effort used in implementing Agile management in software development in table 3.

In the education and training of software engineering, Rico (2009) finds Agile methods to excel. Using distributed teams of students, he discovers that “teams who struck an optimum balance of customer collaboration, use of Agile methods, and technical programming ability had better productivity and web site quality” (Rico, 2009).

*Table 3. Effort Estimation Of Various Activities In Agile Software Development.*

| No. | Activities | Effort Estimation (%) | | |
|---|---|---|---|---|
| | | Never | Sometimes | Always |
| 1 | Methodology | 23.5 | 55.25 | 21.25 |
| 2 | Requirements Management | 27 | 41 | 32 |
| 3 | Team Management | 17.23 | 59.23 | 23.54 |
| 4 | Software Testing | 27 | 44 | 29 |
| 5 | Customer Collaboration | 24.4 | 52.8 | 22.8 |
| 6 | Documentation | 6.3 | 64.29 | 29.4 |

(Uikey, 2012)

Agile methods and product line engineering work together (Carbon, 2006). Carbon (2006) notes that when used together Agile methods and product line engineering can help an organization to deliver products faster and with higher quality. His experiment seems “to indicate that design is a good area to start with balancing agility and product line engineering” because agility reduces time spent on design while product line engineering keeps changes to a minimum (Carbon, 2006). He argues for more experimentation on the topic to help “better understand when each approach is more appropriate and beneficial” (Carbon, 2006).

### *Information Technology*

Agile management in the information technology sector is more and more so prevalent. The Project Management Institute website (2016) notes that Agile project management will continue to grow and will be the largest form of project management in this field.

O’Sheedy (2012) writes, “project management methods have been developed from industry practices and international standards to ensure a higher rate of success for information technology projects”. O’Sheedy (2012) conducts research on implementing Agile in information technology projects and has found Agile to be flexible enough to solve most, but not all problems. Figure 5 shows the proposed management frameworks for the information technology field (O’Sheedy, 2012).

Research on Agile management applications in the information technology sector shows success in conjunctive utilization. In *Information Technology Project*

*Management*, Schwalbe (2015) describes Agile project management as being beneficial to information technology management in situations that are unclear and require more adaptability. She continues that, if used correctly, an Agile management method in information technology management allows for cohesive organizational efforts to quickly address changing business needs (Schwalbe, 2015). Further, as information technology is a costly and rapidly changing field, by definition Agile project management is seen as a solution (Mähring, 2008). Information technology project escalation has three phases- drift, unsuccessful increment adaption, and rationalized continuation- that can be addressed by a flexible project management approach such as Agile (Mähring, 2008).

A survey with 770 respondents from 330 organizations in India show only 14 percent of respondents have expert experience in implementing Agile management in IT, 39 percent consider themselves intermediate users, 3 percent report being beginners, and 12 percent say they had no experience (VersionOne Inc., 2014). Of these respondents, two-thirds of organizations see key benefits in the faster delivery of products, greater aptitude to manage fluctuating requirements, and improved production and quality in information technology (VersionOne Inc., 2014).

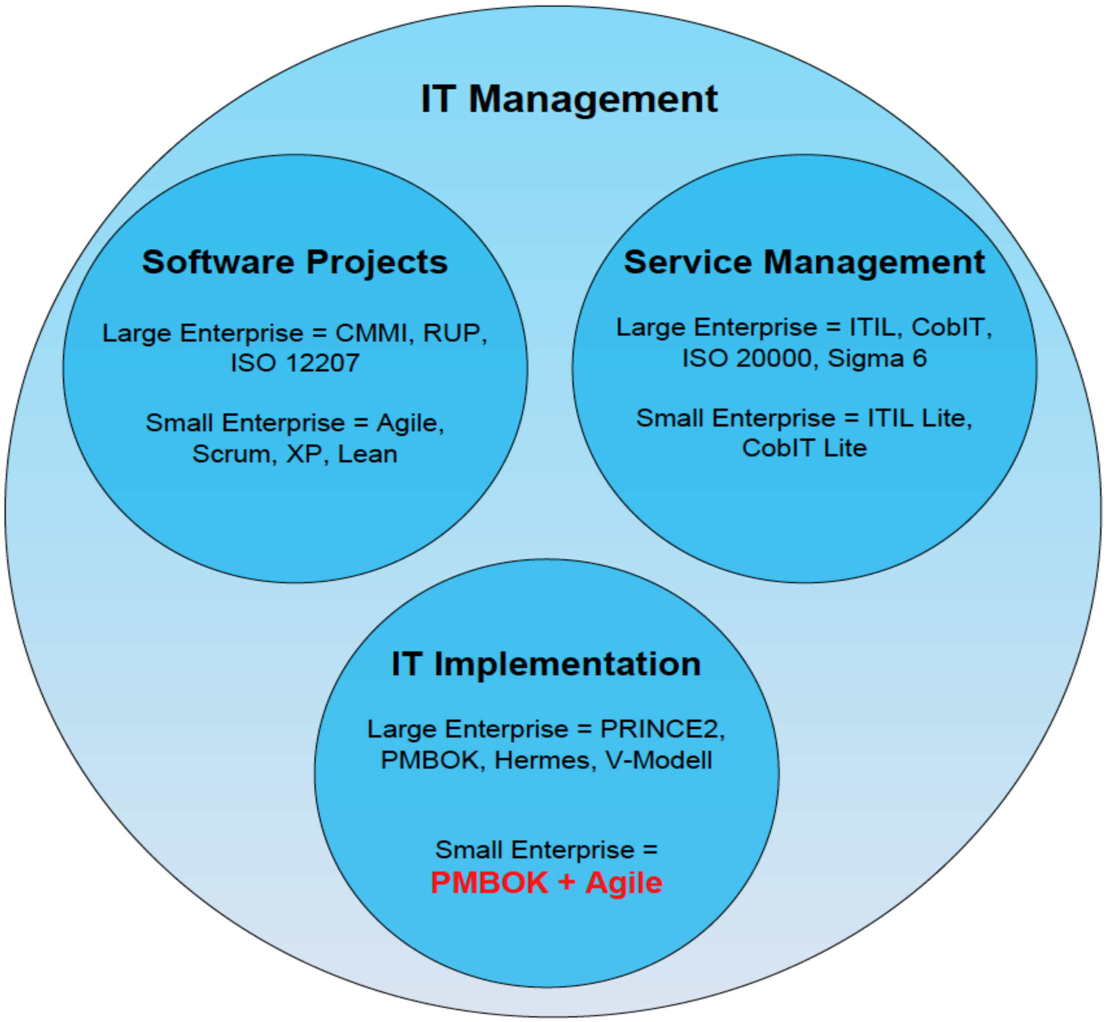


*Figure 5. IT Management Frameworks Grouped By Corresponding Management Areas (O'Sheedy 2012).*

Shen (2011) uses empirical evidence from Chinese information technology companies to discuss the implementation of Agile project management. Shen (2011) examines four organizational elements: culture, infrastructure, people and strategy. The research finds “that to adapt from traditional project management (TPM) to Agile project management, organization should make desirable cultural change and establish project operational infrastructure including processes, facilities and management practices” (Shen, 2011). Further, “regard people factor, at the individual level, Agile method also requires people to be equipped with stronger competences to ensure a smooth adaptation” (Shen, 2011). Shen (2011) notes that strategy has a large discrepancy and thus calls for further research. Lastly, the people factor was the most dominant factor, next being culture (Shen, 2011). Figure 6 shows the conceptual model for the relationships of these elements (Shen, 2011).

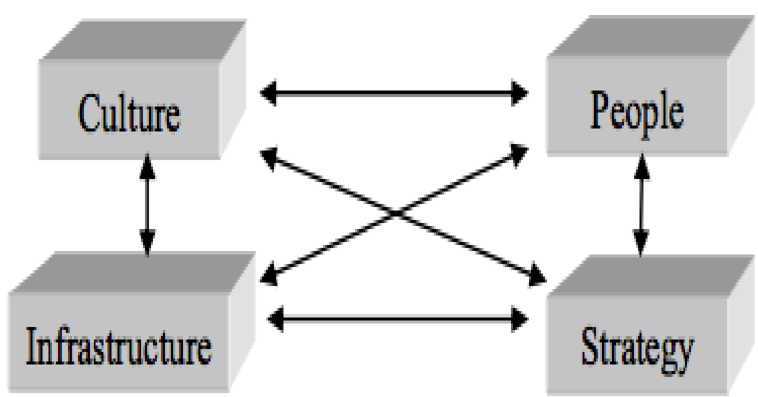


*Figure 6. Conceptual Model (Shen, 2011).*

A study analyzing the key success factors in adopting Agile management in software development practices shows factors that can be applicable to the success of adopting Agile management in information technology (Misra, 2009). This study identifies the most important success factors as: customer satisfaction, customer collaboration, customer commitment, decision time, corporate culture, control, personal characteristics, societal culture, and training and learning (Misra, 2009). Another study aims to hone in on the most critical of previous identified success factors in information technology Agile management. Data using 109 Agile projects from 25 countries show three critical success factors for Agile management with software projects: delivery strategy, Agile software engineering techniques, and team capability (Chow, 2008). Using these results, Chow and Cao (2008) recommend "choosing a high-caliber team, practicing Agile engineering techniques and following Agile-style delivery strategy."

There exist hindrances to the adaption of Agile management in information technology. The 8th Annual State of Agile Survey finds the largest obstacles to the implementation of Agile management in information technology to be the vast change in organizational culture and resistance to such a change (VersionOne Inc., 2014). Further, in *Information Technology Project Management*, Marchewka (2014) notes that organizations that implement Agile management without a complete understanding of the Agile management process will revert back to earlier styles of project management and lose time and resources.

Doherty (2010) has tested Agile project management in the e-Learning field. Doherty (2010) finds that implementing Agile project management methods has enhanced their management and tactics. He notes that two key factors impact the success of the project management: “the first is maintaining a clear educational focus in our eLearning projects whilst defining project success in terms of facilitating and/or enhancing student learning...” and “the second is ensuring that our processes mesh with the collegial nature of a university culture” (Doherty, 2010).

*Manufacturing*

Manufacturing agility is defined as “the ability to closely align manufacturing enterprise systems to changing business needs to achieve competitive performance” (Vernadat, 1999). Manufacturing agility has three main criteria- organization, technology, and human (Vernadat, 1999).

Agile manufacturing is seen as a necessary shift in methods to compete in globalized markets (Nagel, 1994). An increase in technological progress and training has made markets so dynamic that it is needed to adopt a flexible management strategy such as Agile to achieve “manufacturing excellence” (Duguay, 1997). The competitive advantage that once belonged to mass production has moved towards manufacturing management that is fast and responsive- Agile (Lee, 1999). This only became possible due to a global restructuring that disperse manufacturing networks (Lee, 1999). Further, the advances in internet technology and “Factory-on-Demand mode of electronic production” have given both producers and customers an opportunity to delve into this new market (Lee, 1999).

Agile manufacturing is the next step following craft production, mass production, and lean production (Hormozi, 2001). To successfully implement Agile manufacturing there must be change in: government regulation, business cooperation, information technology, reengineering and employee flexibility (Hormozi, 2001).

Further, “Agile manufacturing can be defined as the capability of surviving and prospering in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services” (Cho, 1996). An analysis of Korean needs and management style, Cho (1996) finds “critical to successfully accomplishing Agile manufacturing are a few enabling technologies such as the standard for the exchange of products, concurrent engineering, virtual manufacturing, component-based heterarchical shop floor control system information and communication infrastructure, etc.”

Vázquez-Bustelo (2006) uses four industrial cases in Spain to find trends in Agile manufacturing. He finds that changes in the business environment cause more and more firms to adopt the Agile manufacturing production model (Vázquez-Bustelo, 2006). The movement is characterized by focusing on “highly customized products as and when customers require them” (Vázquez-Bustelo, 2006).

Vázquez-Bustelo (2007) notes there is little empirical evidence to affirm the movement towards Agile. Researching data from Spanish manufacturers in comparison to turbulence in the business environment and Agile manufacturing practices, he is able to analyze whether the adoption of Agile manufacturing led to the success in different industries (Vázquez-Bustelo, 2007). The study results find that “in turbulent environments, the integrated use of Agile manufacturing practices promotes the manufacturing competitive strength, leading to better operational, market and financial performance" (Vázquez-Bustelo, 2007). Vázquez-Bustelo (2007) recommends managers implement Agile manufacturing "in order to develop manufacturing strength and to outperform competitors in turbulent business environments".

In "A survey on the methods and tools of concurrent new product development and Agile manufacturing", their research shows an Agile manufacturing team having strengths in "enabling technologies and physical tools" by developing a variety of products at low cost in minimal time (BüyüKözkan, 2004).

However, "Manufacturing competitiveness: different systems to achieve the same results" shows research that disagrees with the strength of adapting to Agile manufacturing (Sahin, 2000). In fact, it states that "focused factories, lean manufacturing, mass customization, and Agile manufacturing" can achieve the same results as long as companies focus on a "manufacturing strategy that stays consistent with their marketing plan" (Sahin, 2000).

A study examining the use of Agile management in the specialty chemical manufacturing industry has shown that adapting Agile management is more difficult for larger organizations yet "a small-intermediate size manufacturer can properly implement many Agile manufacturing practices" (Guisinger, 2004).

Booth (2002) argues that developments in the economy have made adopting lean methods difficult for manufacturing and production. He states the aim to reduce all costs contradicts the "original concept of adopting the best 'lean' practice and seeing costs fall"

(Booth, 2002). For this reason, he advises Agile management in the form of focusing on forgotten lean concepts and utilizing the flexibility and responsiveness of agility (Booth, 2002).

In determining influences on Agile manufacturing management, one of the strongest factors has shown to be technology. “Critical success factors in Agile supply chain management – An empirical study” analyzes results from 962 Australian manufacturing companies to identify critical success factors in Agile organizations (Power, 2001). They find technology most closely linked to the achievement of creating a more Agile organization (Power, 2001). Further, “Agile supply chain capabilities: Determinants of competitive objectives” studies 600 companies in the United Kingdom to research Agile manufacturing (Yusuf, 2004). The study finds that technology largely influences Agile management and requires organizations to have the flexibility and capabilities to respond and maintain competiveness (Yusuf, 2004).

In *Agile Manufacturing: The 21st Century Competitive Strategy,* Gunasekaran (2001) states that technology and manufacturing management evolve together. He goes into the impact technology has had on Agile manufacturing management, as technology has been rapidly changing it forces organizations to more quickly adapt and incorporate such changes (Gunasekaran, 2001). This technology has allowed for organizations to alter their production cycles, giving them great flexibility (Gunasekaran, 2001). Lastly, he asserts that since technology continues to adapt and become more expensive, it becomes more important for Agile management to “give the organization strategic direction with regard to manufacturing issues, technology included..." (Gunasekaran, 2001).

*Agile and Supply Chain*

Some research points that agility in supply management cannot be completely understood or implemented in all cases (Rigby, 2000). Rigby (2000) asserts that unless agility is seen with "an evaluation of complexity in and between organizational boundaries with a theoretical approach that gives a more robust appreciation of inter-firm ties" then all understandings of Agile interactions will be subjective. Further, these inter-firm dynamics are paramount to the success and understanding of agility (Rigby, 2000).

However, cases have shown that an Agile supply can be effective (Mason- Jones, 2000). When combined with lean production, Agile supply has allowed for changing supply chains to be properly merged with the marketplace (Mason-Jones 2000). Christopher (2000) has analyzed the differences between lean and Agile supply chain management and has found lean focuses on cost where Agile focuses on responsiveness and availability. Once again, it is found that they work best together with "lean (efficient) supply upstream and Agile (effective) supply downstream" (Christopher, 2000).

Christopher (2002) has given broad supply chain strategies that rely on various supply and demand characteristics. These strategies are defined in Figure 7.

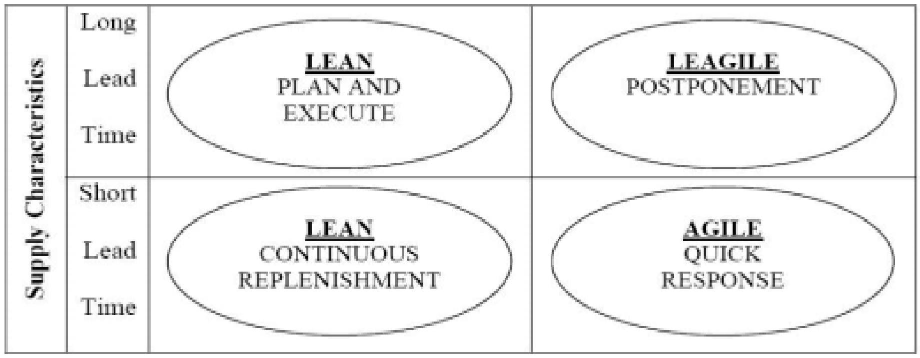


*Figure 7. Supply And Demand Characteristics (Christopher, 2002).*

Naylor (1999) would argue only looking at lean and Agile in “progression” or “isolation” is “too simplistic a view”. He believes that either method must be combined in a total supply chain strategy that is formulated in regards to current “market knowledge and positioning of the decoupling point” (Naylor, 1999). He argues for this as Agile manufacturing “is best suited to satisfying a fluctuating demand and lean manufacturing requires a level schedule” (Naylor, 1999). These arguments are supported by a supply chain case study (Naylor, 1999).

Christopher (2000) finds that the responsive component of agility is what makes the method effective in volatile markets. Further he “suggests that the key to survival in these changed conditions is through ‘agility’” (Christopher, 2000).

Ambe (2010) examines the link between Agile supply chain and competitive advantage. Ambe (2010) identifies the rise in global competition and customer demands coupled with the increased levels of turbulence in the markets as a defining business environment of the 21st century. Ambe (2010) suggests “in order to survive, companies need to respond to the ever-increasing levels of volatility in demand and focus their efforts upon achieving greater agility". Ambe (2010) finds that the "an Agile supply chain responds rapidly to changes in the business environment; align with the firm's competitive strategy to improve competitive performance, hence gain competitive advantage." Figure 8 illustrates the link between Agile supply chain and competitive strategy.

Baramichai (2007) finds that the Agile Supply Chain Transformation Matrix will aid in the implementation of a systematic approach to agility in a supply chain. The Agile Supply Chain Transformation Matrix relies on quality function deployment as well as analytic hierarchy process technique (Baramichai, 2007). Baramichai (2007) finds that "this tool can help companies create and improve their agility by relating business changes with the appropriate approaches for supplier-buyer supply chain configuration and supplier-buyer relationship establishment and determine the business processes and the infrastructures needed to support the creation of Agile capability". This finding is based off a single case study and Baramichai (2007) recommends further investigation for additional validation.

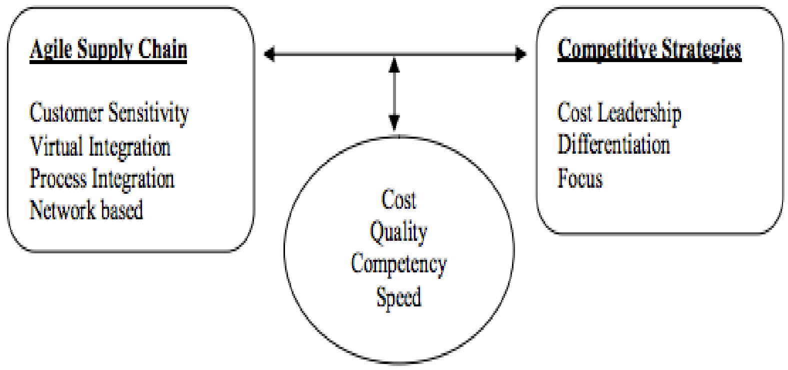


*Figure 8. Link Between Agile Supply Chain And Competitive Strategy (Ambe 2010).*

# Chapter 3

# Materials and Methods

## *Quantification of Performance Management*

### *Quantifying the Performance in Real Time*

Since there are so many unknowns when dealing with research it is important to devise a method to quantify a performance evaluation. To start the method the researcher must create a log of tasks needed to complete the research in question. This log of tasks does not need to be in depth, but the researcher must have a basic understanding of the tasks needed to complete the given research project. Once the list of tasks has been created the tasks need to be assessed by the predecessor dependency. This allows the researcher to identify the tasks that can be done simultaneously and sequentially. Once all the tasks have been organized to incorporate the predecessor dependency, the researcher must then address those tasks listed. This would imply that the researcher has identified what they are trying to do and start performing the tasks. After the researcher has addressed the task there is a point at which the researcher needs to assess if the task is completed or if the task is a failure and needs to be repeated or altered to change the parameters of the development phase to ensure the completion. If the task has been completed the researcher will then move on to the other tasks involved with the research until the entire research has been completed.

Each of the task will have an associated Sprint. The Sprint of a task is considered how the researcher goes about achieving the intended task. A typical Sprint consists of a discovery phase, design phase, development phase, and test phase in figure 9, figure 10, and figure 11.

The discovery phase consists of assessing the certain aspect dealing with the task. This could be anything from identifying what material to acquire or setting different parameters for a trial, etc. The design phase would be considered how to design a solution to the task. This design phase is very closely related to the development phase, but the design phase is more suitable for tasks requiring experiments that involve setting up experiments. The development phase deals with the aspect of taking the design that was created in the design phase and utilizing it to develop the test for the task.

In tasks that do not involve setting up experiments this phase will be very closely related to the design. One example of this would be to purchase equipment for an experiment. This can be noted as a task. The discovery phase would be considered as identification of machinery needed for the experiment. An example of the design phase might be where the researcher is planning what materials to acquire for the experiment. An example of the development phase would be where the researcher has planned out all the materials needed for the experiment and now is setting up the experiment. The final phase would be the test phase. This would be where the task in question is conducted in an experiment to completion or the results failed in a way that the researcher needs to repeat this experiment by changing certain parameters of the design or development phase. An example in a biological setting could mean that the experiment has failed for no known reason but needs to be redone to move forward. This could be to culture growth of cells in a petri dish. Sometimes cells do not grow even though the experiment


*Figure 9. Three Sequential Agile Sprints.*

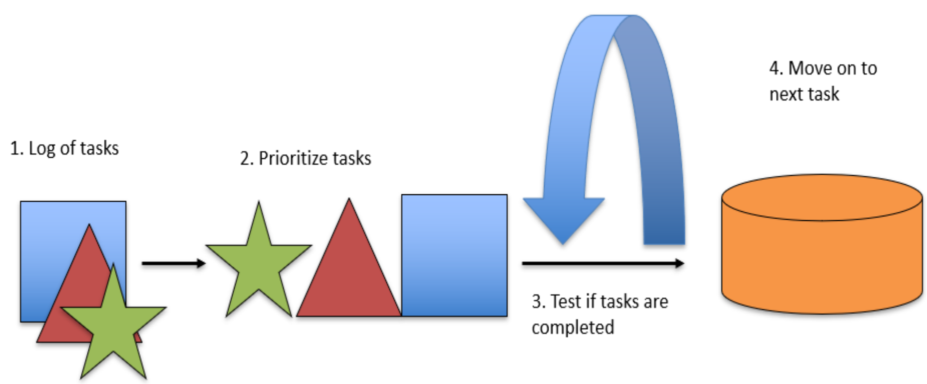


*Figure 10. Typical Agile Sequence.*

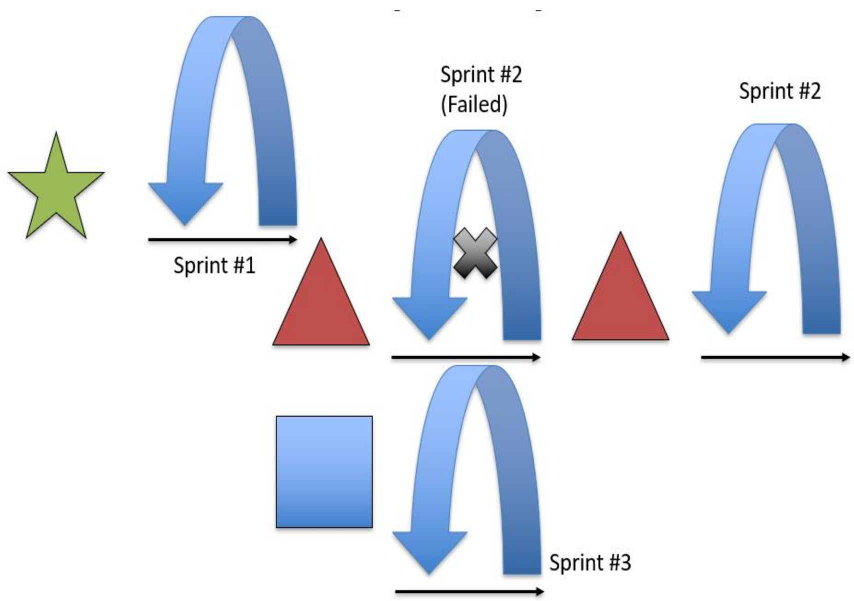


*Figure 11. Three Agile Sprints With Failed Sprint.*

was conducted properly. The only thing to do is to restart the experiment at the last saved point of work or the Sprint.

Each attempt to complete a task would be considered as a Sprint, and only a final Sprint completes the task Each task can have multiple Sprints and each Sprint has a cost associated with each run that is constant for all runs. Because of this the project manager can assign an acceptable number of Sprints needed to successfully complete the task. If the researcher completes the task using not higher than the assigned acceptable number of Sprints, the performance of the project would be considered satisfactory. If the number of Sprints for the task is higher than the assigned acceptable number of Sprints, the performance would be considered unfavorable.

Each Sprint also should carry an associated cost function for the task. This would mean that a task's Sprint that do not cost much money to complete are weighted lighter than a task that is financially burdened with a Sprint's cost. This weight will adjust the need for researcher to focus on which Sprints cost more. This would show the Project Manager and the researcher which tasks had a high failure rate and allow them to see the bottlenecks in the experiment that was conducted. By addressing the bottlenecks this allows the researchers and Project Managers to see which tasks are completed with a higher performance.

*Quantifying the Sprint Runs*

When addressing the tasks of a project the hardest part would be to understand how to successfully quantify the input data in a performance management system. The first component would be to understand how to measure efficiency and effectiveness. Efficiency quantifies how resources are utilized to provide an outcome from the project or process while effectiveness can be quantified as the outcome from the total inputs of the project or process. To quantify the results several mathematical models were created to show how to calculate the performance of the tasks and project

The mathematical model is listed in equation 1:

The example functions are listed in equation 1 are only as examples of non-increasing functions. This is due to the fact that any non-increasing function can be used in the formulation to identify and quantify the efficiency and effectiveness. The job of the

Project Manager in this situation is using the experience to pick the most appropriate shape of f-function to integrate it for the efficiency and effectiveness calculations

It is easy to see that Normalized Efficiency ($NE_y$) covers interval (0,1]. A higher NE value shows the higher efficiency of the Project Performance in equation 5.

*Equation 1. Current Efficiency At Any Given Time Point T During Performing (N+1)-Th Task.*

$$E_y(t \in (n+1)-th\ task) = \sum_{i=1}^{n} C_i t_i f\left(\frac{K_i}{V_i}\right) + C_{n+1} t_{n+1} f\left(\frac{K}{V_{n+1}}\right), 0 \le n < m$$

*where*

*f* - non-increasing function

$C_i$ - cost of one Sprint in i-th task

$t_i$ - time of one Sprint in i-th task

$V_i$ - the acceptable number of Sprints for completing the i-th task assigned by Project Manager

$K_i$ - the number of Sprint attempts to finalize i-th task

K – the number of Sprints for the task that have been unsuccessful

m – the number of all tasks.

*Possible Examples of f.*

1) $f(x) = 1\ if\ x \le 1\ and\ f(x) = \frac{1}{x}\ for\ x > 1.$

2) $f(x) = \frac{1}{\ln(2)}\ if\ 0 < x \le 1\ and\ f(x) = \frac{1}{\ln(x+1)}\ for\ x > 1.$

3) $f(x) = e^{-\lambda}\ if\ 0 < x \leq 1\ and\ f(x) = e^{-\lambda x}\ for\ x > 1$ where $\lambda$ is defined as a parameter from the Project Manager.

*Equation 2. Current Effectiveness At Any Given Point In Time During Performing (N+1)-Th Task.*

$$E_s(t \in (n+1) - th\ task) = \sum_{i=1}^{n} \frac{1}{C_i} f\left(\frac{K_i}{V_i}\right) + \frac{1}{C_{n+1}} f\left(\frac{K}{V_{n+1}}\right), 0 \leq n < m$$

*Equation 3. Current Normalized Effectiveness At Any Given Time During Performing (N+1)-Th Task.*

$$NE_s = \frac{\sum_{i=1}^{n} \frac{1}{C_i} f\left(\frac{K_i}{V_i}\right) + \frac{1}{C_{n+1}} f\left(\frac{K}{V_{n+1}}\right)}{f(1)(\sum_{i=1}^{n} \frac{1}{C_i} + \frac{1}{C_{n+1}})}, 0 \leq n < m$$

*Equation 4. Total Efficiency At End Of Project.*

$$TE_y = \sum_{i=1}^{m} C_i t_i f\left(\frac{K_i}{V_i}\right)$$

*Equation 5. Final Normalized Efficiency At End Of Project.*

$$NE_y = \frac{\sum_{i=1}^{m} C_i t_i f\left(\frac{K_i}{V_i}\right)}{f(1)(\sum_{i=1}^{m} C_i t_i)}$$

*Equation 6. Final Normalized Effectiveness At End Of Project.*

$$NE_{ss} = \frac{\sum_{i=1}^{m} \frac{1}{C_i} f\left(\frac{K_i}{V_i}\right)}{f(1) \sum_{i=1}^{m} \frac{1}{C_i}}$$

*Equation 7. Time Ratio.*

$$TR = \frac{\sum_{i=1}^{m} t_i K_i}{\sum_{i=1}^{m} t_i V_i}$$

*Equation 8. Cost Ratio.*

$$CR = \frac{\sum_{i=1}^{m} C_i K_i}{\sum_{i=1}^{m} C_i V_i}$$

All these quantitative characteristics should quantify the outcomes of performance of research in real time for any project in any field for any budget. The Time Ratio in equation 7 and Cost Ratio in equation 8 are not substitutes for a performance management system but show approximate estimate of the efficiency and effectiveness of any research project.

*Example Mini Case Study for Efficiency and Effectiveness*

To show a real-life example, this mini case study was developed to help understand how one might go about using information and data to quantify the efficiency and effectiveness of their research. For the mini case study, the research was tasked with a project of setting up a server for their future research. This task could be undertaken by multiple researchers in different fields, but the data should be shown as close to a real example as possible. The data was simulated in the most practical way. To undergo this experiment the researchers are under the assumption they have never tried to set up a server before therefore the steps to complete this project is unknown. But for this mini case study all the tasks will be listed below.

1. Get funding
2. Analysis of servers from companies
3. Connecting to company (IBM chosen as a result of step 2)
4. Calls and negotiations
5. Visit from IBM specialist
6. Choice of location

7. Safety system setup
8. Getting server from IBM
9. Installation of server
10. Testing of Server
11. Creating network for lab
12. Creating backup system
13. Network security setup
14. Creating local copies of publicly available databases

This task order shows that this mini case study has approximately 14 different tasks that need to happen sequentially for this project to be completed shown in table 4. The first task is to obtain funding to do this project. This could mean something as simple as writing proposals to get funding to complete the project. This could also mean getting approval to use internal salary funding to attempt to finish this project. The second task is to review literature and have discussion with associates about what companies are currently selling servers that would fit the project scope for the institution. The third task to start a connection to the company that has been selected that is a manufacture and customization of servers. In this example the company IBM was identified as the server that would most likely be the best option. Once it has been identified the researcher would then call to discuss options and alternatives as well as write letters and any type of first interaction with the company relating to the purchase of the server. The fourth task is the calls and negotiations with the company to find out what kind of pricing is available for this equipment. The fifth task is going to be a visit from an IBM specialist to see what

*Table 4. First Half Of The Task Required To Set Up A Server.*

| **Task** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
|---|---|---|---|---|---|---|---|
| **Ci=** | 1500 | 300 | 300 | 80 | 800 | 300 | 3000 |
| **ti=** | 5 | 3 | 2 | 2 | 2 | 3 | 10 |
| **Vi=** | 3 | 6 | 3 | 5 | 3 | 3 | 5 |
| **Geo. Dist.=** | 0.33333 3 | 0.16666 7 | 0.33333 3 | 0.2 | 0.33333 3 | 0.33333 3 | 0.2 |
| **Ki=** | 2 | 7 | 3 | 4 | 4 | 2 | 6 |

| **Task** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
|---|---|---|---|---|---|---|---|
| **Ci=** | 1500 | 2000 | 1400 | 1800 | 1200 | 800 | 900 |
| **ti=** | 7 | 10 | 10 | 5 | 4 | 3 | 4 |
| **Vi=** | 1 | 4 | 20 | 8 | 3 | 15 | 2 |
| **Geo. Dist.=** | 1 | 0.25 | 0.05 | 0.125 | 0.33333 3 | 0.06666 7 | 0.5 |
| **Ki=** | 1 | 3 | 30 | 7 | 4 | 12 | 2 |

the institution needs are. The sixth task is to pick a location to house the physical server. The seventh step is to set up the physical safety systems for the server. This could include items such as the sprinklers and the fire alarms to ensure there is adequate safety for the server. The eighth task is to get the actual server shipped to the institution’s location. The ninth task is the installation of the server. The tenth task of this project is to test the server. This could include everything from all the different tests to make sure the system is working such as activity, power, and connectivity etc. The eleventh task would be to create a network for the institution’s laboratory or work space. The twelfth task is the create a backup system for the server in case there is an emergency and the server has a malfunction. The thirteenth task would be the create a network security set up for the server, so no one with access can hack into the system and damage it. The fourteenth and last task could be to copy information from online databases to utilize on the server.

Below is a description of all the information for each task and how the project went forward.

From table 4 we can see the project has 14 different tasks. Each task has a different time and cost associated with the Sprint. From this we have also depicted what the expected number of Sprint should be from the Project Manager and the observed number of Sprints from the Researcher. The first task had a cost of $1,500 and time of completion was five days. The expected number of Sprints depicted from the Project Manager was three while the observed number of Sprints was two. The Second task had a cost of $300 and time of completion was three days. The expected number of Sprints depicted from the Project Manager was six while the observed number of Sprints was seven. The third task had a cost of $300 and time of completion was two days. The expected number of Sprints depicted from the Project Manager was three while the observed number of Sprints was three. The fourth task had a cost of $80 and time of completion was two days. The expected number of Sprints depicted from the Project Manager was five while the observed number of Sprints was four. The fifth task had a cost of $800 and time of completion was two days. The expected number of Sprints depicted from the Project Manager was two while the observed number of Sprints was three. The sixth task had a cost of $300 and time of completion was three days. The expected number of Sprints depicted from the Project Manager was three while the observed number of Sprints was two. The seventh task had a cost of $3,000 and time of completion was ten days. The expected number of Sprints depicted from the Project Manager was five while the observed number of Sprints was six. The eighth task had a cost of $1,500 and time of completion was seven days. The expected number of Sprints depicted from the Project Manager was one while the observed number of Sprints was one. The ninth task had a cost of $2,000 and time of completion was ten days. The expected number of Sprints depicted from the Project Manager was four while the observed number of Sprints was three. The first tenth had a cost of $1,400 and time of completion was ten days. The expected number of Sprints depicted from the Project Manager was 20 while the observed number of Sprints was 30. The 11th task had a cost of $1,800 and time of completion was five days. The expected number of Sprints depicted from the Project Manager was eight while the observed number of Sprints was seven. The 12th task had a cost of $1,200 and time of completion was four days. The expected number of Sprints depicted from the Project Manager was three while the observed number of Sprints was four. The 13th task had a cost of $800 and time of completion was three days. The expected number of Sprints depicted from the Project Manager was 15 while the observed number of Sprints was 12. The 14th task had a cost of $900 and time of completion was four days. The expected number of Sprints depicted from the Project Manager was four while the observed number of Sprints was two.

### *Evaluation of Finished Projects*

Once the tasks have been completely evaluated based on their real time performance the performance of the entire project can be evaluated based on different fields. The advantage of this performance management system is that it is free from the field of research essence. It converts all research details into variables without any units. Therefore, all variables do not matter as for a ranking, but they have a finite integer value. Although the variables will change the actual mathematical model will remain the same. This is because each field will have the same corresponding variables but with different values.

*Equation 9. How To Evaluate Project Performance Quality (PPQ) Of Finished Projects.*

$$PPQ = \frac{a_r \sum_{i=1}^{n} \ln(r_i) + a_t \sum_{i=1}^{K} \ln(S_i) + a_{ct} \sum_{i=1}^{n} \ln(ct_i)}{\ln(CK)} + D$$

The variables that need to be identified for each different task can be listed as:

$n$ - The number of publications

$r_1, \ldots, r_n$ - The ranks of journals where results have been published.

$K$ - The number of people involved.

$S_1, \ldots, S_K$ - The salaries provided for the project for the people involved.

$ct_1, \ldots, ct_n$ - The citations of publications.

$C$ - The funding of the project.

$D$ - The initial funding, which is independent of cost of project.

The parameters $a_r$, $a_t$, $a_{ct}$, $D$ should be estimated in this linear regression model using past projects and estimation of project performance from experts in equation 9. The salaries of people's time involved will be identified by the lead researcher or Project

Manager. The search for citations of publications is trivial and can be obtained by the researcher or Project Manager. As time moves forward the PPQ can change due to additional publication and citations.

When setting up this equation there are certain steps that need to be followed to estimate the linear coefficients and to validate the approach.

1. The first step would be to collect the data related to $M$ projects where $M$ would be greater than 10.
2. The second step would be to get experts evaluations from the scale (0,1) of the quality for each of $M$ project implementations.
3. The third step is the random partition of $M$ projects into equal two groups, each group would be listed as “Group 1” and “Group 2”.
4. Step four would be to use the data of Group 1 to estimate the regression coefficients in a linear regression model described by the formula and using the assigned evaluations.
5. The fifth step would be to use the results from step four to calculate an evaluation of projects from Group 2.
6. The last step would be to calculate Pearson and Spearman correlation coefficients between the assigned evaluations and calculated at step 5 from Group 2. If the Spearman correlation is higher than 0.6000 the validation is accepted.

# Chapter 4

# Results and Discussion

*Analysis of Real Time Simulation of Research*

The data was simulated using the following algorithm.

1. Each project is presented as three sequential tasks
2. The cost of run was picked from uniform distribution between [1,10].
3. The time for running one Sprint was picked from uniform distribution between [1,28].
4. The probability of success of Sprint run was picked form uniform distribution from [0,0.5].
5. The acceptable number of Sprint runs was the average of Sprint runs as a result of Geometric distribution.
6. The observed number of Sprint runs was a random uniform random number between [1,10].

*Efficiency Evaluation*

Taking the mathematical models and applying simulated data show results that can be validated by understanding how the project is functioning. To show this, five data sets were created with three arbitrary sequential tasks to show how a researcher and Project Manager would go about completing a research project.

*Table 5. Efficiency For f(x)=1 If x≤1 And f(x)= 1/x For x>1. Using Data Set #1 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 4 | $C_i$= | 5 |
| $t_i$= | 14 | $t_i$= | 26 | $t_i$= | 21 |
| $V_i$= | 3 | $V_i$= | 8 | $V_i$= | 5 |
| Geom. Dist.= | 0.333333 | Geom. Dist.= | 0.125 | Geom. Dist.= | 0.2 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 7 |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 84 | $C_i$*$t_i$= | 104 | $C_i$*$t_i$= | 105 |
| $K_i/V_i$= | 1.333333 | $K_i/V_i$= | 0.625 | $K_i/V_i$= | 1.4 |
| *f(x)*= | 0.75 | *f(x)*= | 1.6 | *f(x)*= | 0.714286 |
| *f(x)'*= | 0.75 | *f(x)'*= | 1 | *f(x)'*= | 0.714286 |
| $C_i$*$t_i$**f(x)*= | 63 | $C_i$*$t_i$**f(x)*= | 104 | $C_i$*$t_i$**f(x)*= | 75 |
| Sum= | 242 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 84 | $C_i$*$t_i$= | 104 | $C_i$*$t_i$= | 105 |
| $1/V_i$= | 0.333333 | $1/V_i$= | 0.125 | $1/V_i$= | 0.2 |
| *f(x)*= | 3 | *f(x)*= | 8 | *f(x)*= | 5 |
| *f(x)'*= | 1 | *f(x)'*= | 1 | *f(x)'*= | 1 |
| $C_i$*$t_i$**f(x)*= | 84 | $C_i$*$t_i$**f(x)*= | 104 | $C_i$*$t_i$**f(x)*= | 105 |
| Sum= | 293 | | | | |

| | |
|---|---|
| TR= | 0.938028 |
| CR= | 1.053333 |

| | |
|---|---|
| NEy= | 83% |

This Table 5 goes over an example of a project that requires three sequential tasks to complete. Each of the tasks have defined cost associated with each of the task. Because the task does not change the cost remains fixed once it has been determined by the Researcher or Project Manager. In this example the cost 6, 4, and 5 was used for tasks 1, 2, and 3 respectfully. This value is noted without any units because one of the benefits of using this formulation is that it converts all datum points into unitless values. From this the Project Manager also assigns the typical time required to complete each Sprint. Because this is unitless as well any positive integer can be used. For this example, days of the month was used. In the task the time depicted was 14, 26, and 2. The acceptable number of Sprints was listed from the Project Manager as 3, 8, and 5. This is important because if the Project Manager is knowledgeable in the area then acceptable number of Sprints should not be lower than the observed number of Sprints. Therefore, this could be used as almost a validation of the knowledge performance of the Project Manager.

The observed number of Sprints is listed, in the example it was 4, 5, and 7. From this the Project Manager can then select the function that is to be used. In the example listed on Table 4 the simple function was used. When subtotaling the entire project, the efficiency was calculated at roughly 83%. To check validation how close this value was being accurate the Time and Cost Ratios were listed to see the difference. The Time Ratio was 0.9380 and the Cost Ratio was 1.0533 for Table 6. This shows that the project from the observed time was slightly ahead of schedule, but the cost was slightly overbudget. By examining the other function for efficiency, we can check to see how closely related the performance of the entire project was.

*Table 6. Efficiency For f(x)=1/ln(2) If 0<x≤1 And f(x)= 1/ln(x+1) For x>1. Using Data Set #1 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 4 | $C_i$= | 5 |
| $t_i$= | 14 | $t_i$= | 26 | $t_i$= | 21 |
| $V_i$= | 3 | $V_i$= | 8 | $V_i$= | 5 |
| Geom. Dist.= | 0.333333 | Geom. Dist.= | 0.125 | Geom. Dist.= | 0.2 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 7 |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 84 | $C_i$*$t_i$= | 104 | $C_i$*$t_i$= | 105 |
| $K_i/V_i$= | 1.333333 | $K_i/V_i$= | 0.625 | $K_i/V_i$= | 1.4 |
| *f(x)*= | 1.180223 | *f(x)*= | 1.442695 | *f(x)*= | 1.142245 |
| $C_i$*$t_i$**f(x)*= | 99.13869 | $C_i$*$t_i$**f(x)*= | 150.0403 | $C_i$*$t_i$**f(x)*= | 119.9358 |
| Sum= | 369.1147 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 84 | $C_i$*$t_i$= | 104 | $C_i$*$t_i$= | 105 |
| $1/V_i$= | 0.333333 | $1/V_i$= | 0.125 | $1/V_i$= | 0.2 |
| *f(x)*= | 1.442695 | *f(x)*= | 1.442695 | *f(x)*= | 1.442695 |
| $C_i$*$t_i$**f(x)*= | 121.1864 | $C_i$*$t_i$**f(x)*= | 150.0403 | $C_i$*$t_i$**f(x)*= | 151.483 |
| Sum= | 422.7096 | | | | |

| | |
|---|---|
| TR= | 0.938028 |
| CR= | 1.053333 |

| | |
|---|---|
| NEy= | 87% |

From the example on Table 5 the second function was selected by the Project Manager. This function showed that while keeping all the data inputs constant and only changing the function produced the efficiency of 87% which is very similar to the first function of 83%. This shows that there is validation that the function and formulations are accurate because the trend of efficiency is comparable.

The lambda can be selected by the Project Manager for each of the different task depending on the demands for performance. The lambda that was selected in this data set was 0.5. From the results, all the efficiency percentages were similar to each other depicting that a Project Manager can choose any non-increasing function to evaluate the performance of the research. Then using the Time Ratio and Cost Ratio on table 6 and table 7 we can furthermore validate that the performance management system is working properly and has identified the Efficiency correctly.

To further test the validity of the Performance Management System a second data set was used. The experiment was run a second time using the three function as listed before by the Project Manager. The Cost associated with the three tasks were 10, 8, and 6 in table 8, table 9, and table 10. The expected time for completion of these task were assigned as 12, 5, and 27. The number of expected Sprints was listed as 7, 6, and 9 while the observed number of Sprints was 4, 5, and 10. When using the first function assigned by the Project Manager the efficiency was calculated as 95%. To validate this number the Time Ratio was calculated at 0.9608 being slightly ahead of schedule. While the Cost ratio was 0.8140 showing that the project was under budget.

*Table 7. Efficiency For f(x)= $e^{-\lambda}$ If 0<x≤1 And f(x)= $e^{-\lambda x}$ For x>1 Where λ Is Defined As A Parameter From The Project Manager. Using Data Set #1 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 4 | $C_i$= | 5 |
| $t_i$= | 14 | $t_i$= | 26 | $t_i$= | 21 |
| $V_i$= | 3 | $V_i$= | 8 | $V_i$= | 5 |
| Geom. Dist.= | 0.333333 | Geom. Dist.= | 0.125 | Geom. Dist.= | 0.2 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 7 |

| | | | | | |
|---|---|---|---|---|---|
| λ= | 0.5 | λ= | 0.5 | λ= | 0.5 |
| $C_i$*$t_i$= | 84 | $C_i$*$t_i$= | 104 | $C_i$*$t_i$= | 105 |
| $K_i/V_i$= | 1.333333 | $K_i/V_i$= | 0.625 | $K_i/V_i$= | 1.4 |
| *f(x)*= | 0.513417 | *f(x)*= | 0.606531 | *f(x)*= | 0.496585 |
| $C_i$*$t_i$*f(x)= | 43.12704 | $C_i$*$t_i$*f(x)= | 63.07919 | $C_i$*$t_i$*f(x)= | 52.14146 |
| Sum= | 158.3477 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 84 | $C_i$*$t_i$= | 104 | $C_i$*$t_i$= | 105 |
| $1/V_i$= | 0.333333 | $1/V_i$= | 0.125 | $1/V_i$= | 0.2 |
| *f(x)*= | 0.606531 | *f(x)*= | 0.606531 | *f(x)*= | 0.606531 |
| $C_i$*$t_i$*f(x)= | 50.94858 | $C_i$*$t_i$*f(x)= | 63.07919 | $C_i$*$t_i$*f(x)= | 63.68572 |
| Sum= | 177.7135 | | | | |

| | |
|---|---|
| TR= | 0.938028 |
| CR= | 1.053333 |

| | |
|---|---|
| NEy= | 89% |

*Table 8. Efficiency For f(x)=1 If x≤1 And f(x)= 1/x For x>1. Using Data Set #2 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 8 | $C_i$= | 6 |
| $t_i$= | 12 | $t_i$= | 5 | $t_i$= | 27 |
| $V_i$= | 7 | $V_i$= | 6 | $V_i$= | 9 |
| Geom. Dist.= | 0.142857 | Geom. Dist.= | 0.166667 | Geom. Dist.= | 0.111111 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 10 |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 120 | $C_i*t_i$= | 40 | $C_i*t_i$= | 162 |
| $K_i/V_i$= | 0.571429 | $K_i/V_i$= | 0.833333 | $K_i/V_i$= | 1.111111 |
| *f(x)*= | 1.75 | *f(x)*= | 1.2 | *f(x)*= | 0.9 |
| *f(x)'*= | 1 | *f(x)'*= | 1 | *f(x)'*= | 0.9 |
| $C_i*t_i*f(x)$= | 120 | $C_i*t_i*f(x)$= | 40 | $C_i*t_i*f(x)$= | 145.8 |
| Sum= | 305.8 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 120 | $C_i*t_i$= | 40 | $C_i*t_i$= | 162 |
| $1/V_i$= | 0.142857 | $1/V_i$= | 0.166667 | $1/V_i$= | 0.111111 |
| *f(x)*= | 7 | *f(x)*= | 6 | *f(x)*= | 9 |
| *f(x)'*= | 1 | *f(x)'*= | 1 | *f(x)'*= | 1 |
| $C_i*t_i*f(x)$= | 120 | $C_i*t_i*f(x)$= | 40 | $C_i*t_i*f(x)$= | 162 |
| Sum= | 322 | | | | |

| | |
|---|---|
| TR= | 0.960784 |
| CR= | 0.813953 |

| | |
|---|---|
| NEy= | 95% |

*Table 9. Efficiency For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1. Using Data Set #2 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 8 | $C_i$= | 6 |
| $t_i$= | 12 | $t_i$= | 5 | $t_i$= | 27 |
| $V_i$= | 7 | $V_i$= | 6 | $V_i$= | 9 |
| Geom. Dist.= | 0.142857 | Geom. Dist.= | 0.166667 | Geom. Dist.= | 0.111111 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 10 |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 120 | $C_i*t_i$= | 40 | $C_i*t_i$= | 162 |
| $K_i/V_i$= | 0.571429 | $K_i/V_i$= | 0.833333 | $K_i/V_i$= | 1.111111 |
| *f(x)*= | 1.442695 | *f(x)*= | 1.442695 | *f(x)*= | 1.338304 |
| $C_i*t_i*f(x)$= | 173.1234 | $C_i*t_i*f(x)$= | 57.7078 | $C_i*t_i*f(x)$= | 216.8052 |
| Sum= | 447.6364 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 120 | $C_i*t_i$= | 40 | $C_i*t_i$= | 162 |
| $1/V_i$= | 0.142857 | $1/V_i$= | 0.166667 | $1/V_i$= | 0.111111 |
| *f(x)*= | 1.442695 | *f(x)*= | 1.442695 | *f(x)*= | 1.442695 |
| $C_i*t_i*f(x)$= | 173.1234 | $C_i*t_i*f(x)$= | 57.7078 | $C_i*t_i*f(x)$= | 233.7166 |
| Sum= | 464.5478 | | | | |
| | | | TR= | 0.960784 | |
| NEy= | 96% | | CR= | 0.813953 | |

*Table 10. Efficiency For f(x)=1 If x≤0 And f(x)=* $e^{-\lambda x}$ *For x>0 Where λ Is Defined As A Parameter From The Project Manager. Using Data Set #2 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 8 | $C_i$= | 6 |
| $t_i$= | 12 | $t_i$= | 5 | $t_i$= | 27 |
| $V_i$= | 7 | $V_i$= | 6 | $V_i$= | 9 |
| Geom. Dist.= | 0.142857 | Geom. Dist.= | 0.166667 | Geom. Dist.= | 0.111111 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 10 |

| | | | | | |
|---|---|---|---|---|---|
| λ= | 0.5 | λ= | 0.5 | λ= | 0.5 |
| $C_i*t_i$= | 120 | $C_i*t_i$= | 40 | $C_i*t_i$= | 162 |
| $K_i/V_i$= | 0.571429 | $K_i/V_i$= | 0.833333 | $K_i/V_i$= | 1.111111 |
| *f(x)*= | 0.606531 | *f(x)*= | 0.606531 | *f(x)*= | 0.573753 |
| $C_i*t_i*f(x)$= | 72.78368 | $C_i*t_i*f(x)$= | 24.26123 | $C_i*t_i*f(x)$= | 92.94805 |
| Sum= | 189.993 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 120 | $C_i*t_i$= | 40 | $C_i*t_i$= | 162 |
| $1/V_i$= | 0.142857 | $1/V_i$= | 0.166667 | $1/V_i$= | 0.111111 |
| *f(x)*= | 0.606531 | *f(x)*= | 0.606531 | *f(x)*= | 0.606531 |
| $C_i*t_i*f(x)$= | 72.78368 | $C_i*t_i*f(x)$= | 24.26123 | $C_i*t_i*f(x)$= | 98.25797 |
| Sum= | 195.3029 | | | | |
| | | | TR= | 0.960784 | |
| NEy= | 97% | | CR= | 0.813953 | |

The second data set has confirmed the efficiency using the second function was roughly 96%. This is only one percent more than using the first function. This validates that the formulations are very closely related and can be interchange depending on the Project Managers discretion.

The efficiency for the third function is 97%. All three functions have roughly the same efficiency percentages. This shows how closely related all the efficiencies are.

The third data set has an associated Cost of 2, 2, and 3 in table 11, table 12, and table 13. The expected time for the completion of the Sprints is 17, 2, and 24. The expect number of Sprints needed to complete the tasks are 10, 9, and 7 while the observed number of Sprints were 14, 14, and 3. Using the first function the efficiency of the project was 90%. This is very similar to the Time Ratio of 0.9494 being ahead of schedule and the Cost Ratio of 1.1017 meaning that the project is slightly over budget.

When using the second function the efficiency is 93%. This is 3% higher than the first function and closer to the Time ration of 0.9494.

The third function shows that the efficiency is 94%. Using all three functions show that the efficiency is validated by the non-increasing function.

*Table 11. Efficiency For f(x)=1 If x≤1 And f(x)= 1/x For x>1. Using Data Set #3 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 2 | $C_i$= | 2 | $C_i$= | 3 |
| $t_i$= | 17 | $t_i$= | 2 | $t_i$= | 24 |
| $V_i$= | 10 | $V_i$= | 9 | $V_i$= | 7 |
| Geom. Dist.= | 0.1 | Geom. Dist.= | 0.111111 | Geom. Dist.= | 0.142857 |
| $K_i$= | 14 | $K_i$= | 14 | $K_i$= | 3 |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 34 | $C_i$*$t_i$= | 4 | $C_i$*$t_i$= | 72 |
| $K_i/V_i$= | 1.4 | $K_i/V_i$= | 1.555556 | $K_i/V_i$= | 0.428571 |
| *f(x)*= | 0.714286 | *f(x)*= | 0.642857 | *f(x)*= | 2.333333 |
| *f(x)'*= | 0.714286 | *f(x)'*= | 0.642857 | *f(x)'*= | 1 |
| $C_i$*$t_i$**f(x)*= | 24.28571 | $C_i$*$t_i$**f(x)*= | 2.571429 | $C_i$*$t_i$**f(x)*= | 72 |
| Sum= | 98.85714 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 34 | $C_i$*$t_i$= | 4 | $C_i$*$t_i$= | 72 |
| $1/V_i$= | 0.1 | $1/V_i$= | 0.111111 | $1/V_i$= | 0.142857 |
| *f(x)*= | 10 | *f(x)*= | 9 | *f(x)*= | 7 |
| *f(x)'*= | 1 | *f(x)'*= | 1 | *f(x)'*= | 1 |
| $C_i$*$t_i$**f(x)*= | 34 | $C_i$*$t_i$**f(x)*= | 4 | $C_i$*$t_i$**f(x)*= | 72 |
| Sum= | 110 | | | | |

| | |
|---|---|
| TR= | 0.949438 |
| CR= | 1.101695 |

| | |
|---|---|
| NEy= | 90% |

*Table 12. Efficiency For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1. Using Data Set #3 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 2 | $C_i$= | 2 | $C_i$= | 3 |
| $t_i$= | 17 | $t_i$= | 2 | $t_i$= | 24 |
| $V_i$= | 10 | $V_i$= | 9 | $V_i$= | 7 |
| Geom. Dist.= | 0.1 | Geom. Dist.= | 0.111111 | Geom. Dist.= | 0.142857 |
| $K_i$= | 14 | $K_i$= | 14 | $K_i$= | 3 |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 34 | $C_i*t_i$= | 4 | $C_i*t_i$= | 72 |
| $K_i/V_i$= | 1.4 | $K_i/V_i$= | 1.555556 | $K_i/V_i$= | 0.428571 |
| *f(x)*= | 1.142245 | *f(x)*= | 1.065792 | *f(x)*= | 1.442695 |
| $C_i*t_i*f(x)$= | 38.83634 | $C_i*t_i*f(x)$= | 4.263167 | $C_i*t_i*f(x)$= | 103.874 |
| Sum= | 146.9735 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 34 | $C_i*t_i$= | 4 | $C_i*t_i$= | 72 |
| $1/V_i$= | 0.1 | $1/V_i$= | 0.111111 | $1/V_i$= | 0.142857 |
| *f(x)*= | 1.442695 | *f(x)*= | 1.442695 | *f(x)*= | 1.442695 |
| $C_i*t_i*f(x)$= | 49.05163 | $C_i*t_i*f(x)$= | 5.77078 | $C_i*t_i*f(x)$= | 103.874 |
| Sum= | 158.6965 | | | | |

| | |
|---|---|
| TR= | 0.949438 |
| CR= | 1.101695 |

| | |
|---|---|
| NEy= | 93% |

*Table 13. Efficiency For f(x)=1 If x≤0 And f(x)=* $e^{-\lambda x}$ *For x>0 Where λ Is Defined As A Parameter From The Project Manager. Using Data Set #3 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 2 | $C_i$= | 2 | $C_i$= | 3 |
| $t_i$= | 17 | $t_i$= | 2 | $t_i$= | 24 |
| $V_i$= | 10 | $V_i$= | 9 | $V_i$= | 7 |
| Geom. Dist.= | 0.1 | Geom. Dist.= | 0.111111 | Geom. Dist.= | 0.142857 |
| $K_i$= | 14 | $K_i$= | 14 | $K_i$= | 3 |

| | | | | | |
|---|---|---|---|---|---|
| λ= | 0.5 | λ= | 0.5 | λ= | 0.5 |
| $C_i$*$t_i$= | 34 | $C_i$*$t_i$= | 4 | $C_i$*$t_i$= | 72 |
| $K_i/V_i$= | 1.4 | $K_i/V_i$= | 1.555556 | $K_i/V_i$= | 0.428571 |
| *f(x)*= | 0.496585 | *f(x)*= | 0.459426 | *f(x)*= | 0.606531 |
| $C_i$*$t_i$**f(x)*= | 16.8839 | $C_i$*$t_i$**f(x)*= | 1.837703 | $C_i$*$t_i$**f(x)*= | 43.67021 |
| Sum= | 62.39181 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 34 | $C_i$*$t_i$= | 4 | $C_i$*$t_i$= | 72 |
| $1/V_i$= | 0.1 | $1/V_i$= | 0.111111 | $1/V_i$= | 0.142857 |
| *f(x)*= | 0.606531 | *f(x)*= | 0.606531 | *f(x)*= | 0.606531 |
| $C_i$*$t_i$**f(x)*= | 20.62204 | $C_i$*$t_i$**f(x)*= | 2.426123 | $C_i$*$t_i$**f(x)*= | 43.67021 |
| Sum= | 66.71837 | | | | |

| | |
|---|---|
| TR= | 0.949438 |
| CR= | 1.101695 |

| | |
|---|---|
| NEy= | 94% |

The fourth data set has a Cost of 10, 6, and 7, time of 28, 28, and 19 as assigned from the Project Manager in table 14, table 15, an table 16. The expected number of Sprints for the project is 4, 16, and 30 and the observed number of Sprints is 16, 2, and 26. This is data set has a very high cost associated for task 1 and a high failure rate on observed Sprints as compared to the expected number of Sprints. This could mean that the Project Manager is not skilled enough in guessing the correct number of Sprints or that the efficiency will be drastically affected. The efficiency was calculated as 64% with a Time Ratio of 0.8832 showing that the project was ahead of schedule and a Cost Ratio of 1.0231 showing that the project is slightly over budget.

The second function on the fourth data set showed an efficiency of 73%. This is still lower than the Time Ratio and Cost Ratio.

The third function or table 16 showed an efficiency of 63%. This observation was unique that the second function had a higher efficiency. This is very important to note that the efficiency can be projected by a more skilled Project Manager by selecting a non-increasing function.

*Table 14. Efficiency For f(x)=1 If x≤1 And f(x)= 1/x For x>1. Using Data Set #4 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 6 | $C_i$= | 7 |
| $t_i$= | 28 | $t_i$= | 28 | $t_i$= | 19 |
| $V_i$= | 4 | $V_i$= | 16 | $V_i$= | 30 |
| Geom. Dist.= | 0.25 | Geom. Dist.= | 0.0625 | Geom. Dist.= | 0.033333 |
| $K_i$= | 16 | $K_i$= | 2 | $K_i$= | 26 |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 280 | $C_i$*$t_i$= | 168 | $C_i$*$t_i$= | 133 |
| $K_i/V_i$= | 4 | $K_i/V_i$= | 0.125 | $K_i/V_i$= | 0.866667 |
| *f(x)*= | 0.25 | *f(x)*= | 8 | *f(x)*= | 1.153846 |
| *f(x)'*= | 0.25 | *f(x)'*= | 1 | *f(x)'*= | 1 |
| $C_i$*$t_i$**f(x)*= | 70 | $C_i$*$t_i$**f(x)*= | 168 | $C_i$*$t_i$**f(x)*= | 133 |
| Sum= | 371 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 280 | $C_i$*$t_i$= | 168 | $C_i$*$t_i$= | 133 |
| $1/V_i$= | 0.25 | $1/V_i$= | 0.0625 | $1/V_i$= | 0.033333 |
| *f(x)*= | 4 | *f(x)*= | 16 | *f(x)*= | 30 |
| *f(x)'*= | 1 | *f(x)'*= | 1 | *f(x)'*= | 1 |
| $C_i$*$t_i$**f(x)*= | 280 | $C_i$*$t_i$**f(x)*= | 168 | $C_i$*$t_i$**f(x)*= | 133 |
| Sum= | 581 | | | | |

| | |
|---|---|
| NEy= | 64% |

| | |
|---|---|
| TR= | 0.883186 |
| CR= | 1.023121 |

*Table 15. Efficiency For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1. Using Data Set #4 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 6 | $C_i$= | 7 |
| $t_i$= | 28 | $t_i$= | 28 | $t_i$= | 19 |
| $V_i$= | 4 | $V_i$= | 16 | $V_i$= | 30 |
| Geom. Dist.= | 0.25 | Geom. Dist.= | 0.0625 | Geom. Dist.= | 0.033333 |
| $K_i$= | 16 | $K_i$= | 2 | $K_i$= | 26 |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 280 | $C_i*t_i$= | 168 | $C_i*t_i$= | 133 |
| $K_i/V_i$= | 4 | $K_i/V_i$= | 0.125 | $K_i/V_i$= | 0.866667 |
| *f(x)*= | 0.621335 | *f(x)*= | 1.442695 | *f(x)*= | 1.442695 |
| $C_i*t_i*f(x)$= | 173.9738 | $C_i*t_i*f(x)$= | 242.3728 | $C_i*t_i*f(x)$= | 191.8784 |
| Sum= | 608.225 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 280 | $C_i*t_i$= | 168 | $C_i*t_i$= | 133 |
| $1/V_i$= | 0.25 | $1/V_i$= | 0.0625 | $1/V_i$= | 0.033333 |
| *f(x)*= | 1.442695 | *f(x)*= | 1.442695 | *f(x)*= | 1.442695 |
| $C_i*t_i*f(x)$= | 403.9546 | $C_i*t_i*f(x)$= | 242.3728 | $C_i*t_i*f(x)$= | 191.8784 |
| Sum= | 838.2058 | | | | |

| | |
|---|---|
| TR= | 0.883186 |
| CR= | 1.023121 |

| | |
|---|---|
| NEy= | 73% |

*Table 16. Efficiency For f(x)=1 If x≤0 And f(x)=* $e^{-\lambda x}$ *For x>0 Where λ Is Defined As A Parameter From The Project Manager. Using Data Set #4 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 6 | $C_i$= | 7 |
| $t_i$= | 28 | $t_i$= | 28 | $t_i$= | 19 |
| $V_i$= | 4 | $V_i$= | 16 | $V_i$= | 30 |
| Geom. Dist.= | 0.25 | Geom. Dist.= | 0.0625 | Geom. Dist.= | 0.033333 |
| $K_i$= | 16 | $K_i$= | 2 | $K_i$= | 26 |

| | | | | | |
|---|---|---|---|---|---|
| λ= | 0.5 | λ= | 0.5 | λ= | 0.5 |
| $C_i$*$t_i$= | 280 | $C_i$*$t_i$= | 168 | $C_i$*$t_i$= | 133 |
| $K_i$/$V_i$= | 4 | $K_i$/$V_i$= | 0.125 | $K_i$/$V_i$= | 0.866667 |
| *f(x)*= | 0.135335 | *f(x)*= | 0.606531 | *f(x)*= | 0.606531 |
| $C_i$*$t_i$**f(x)*= | 37.89388 | $C_i$*$t_i$**f(x)*= | 101.8972 | $C_i$*$t_i$**f(x)*= | 80.66858 |
| Sum= | 220.4596 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 280 | $C_i$*$t_i$= | 168 | $C_i$*$t_i$= | 133 |
| 1/$V_i$= | 0.25 | 1/$V_i$= | 0.0625 | 1/$V_i$= | 0.033333 |
| *f(x)*= | 0.606531 | *f(x)*= | 0.606531 | *f(x)*= | 0.606531 |
| $C_i$*$t_i$**f(x)*= | 169.8286 | $C_i$*$t_i$**f(x)*= | 101.8972 | $C_i$*$t_i$**f(x)*= | 80.66858 |
| Sum= | 352.3943 | | | | |

| | |
|---|---|
| TR= | 0.883186 |
| CR= | 1.023121 |

| | |
|---|---|
| NEy= | 63% |

*Table 17. Efficiency For f(x)=1 If x≤1 And f(x)= 1/x For x>1. Using Data Set #5 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 6 | $C_i$= | 8 |
| $t_i$= | 21 | $t_i$= | 12 | $t_i$= | 14 |
| $V_i$= | 19 | $V_i$= | 12 | $V_i$= | 29 |
| Geom. Dist.= | 0.052632 | Geom. Dist.= | 0.083333 | Geom. Dist.= | 0.034483 |
| $K_i$= | 34 | $K_i$= | 27 | $K_i$= | 33 |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 126 | $C_i*t_i$= | 72 | $C_i*t_i$= | 112 |
| $K_i/V_i$= | 1.789474 | $K_i/V_i$= | 2.25 | $K_i/V_i$= | 1.137931 |
| *f(x)*= | 0.558824 | *f(x)*= | 0.444444 | *f(x)*= | 0.878788 |
| *f(x)'*= | 0.558824 | *f(x)'*= | 0.444444 | *f(x)'*= | 0.878788 |
| $C_i*t_i*f(x)$= | 70.41176 | $C_i*t_i*f(x)$= | 32 | $C_i*t_i*f(x)$= | 98.42424 |
| Sum= | 200.836 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 126 | $C_i*t_i$= | 72 | $C_i*t_i$= | 112 |
| $1/V_i$= | 0.052632 | $1/V_i$= | 0.083333 | $1/V_i$= | 0.034483 |
| *f(x)*= | 19 | *f(x)*= | 12 | *f(x)*= | 29 |
| *f(x)'*= | 1 | *f(x)'*= | 1 | *f(x)'*= | 1 |
| $C_i*t_i*f(x)$= | 126 | $C_i*t_i*f(x)$= | 72 | $C_i*t_i*f(x)$= | 112 |
| Sum= | 310 | | | | |

| | |
|---|---|
| TR= | 1.580611 |
| CR= | 1.507177 |

| | |
|---|---|
| NEy= | 65% |

The fifth data set has an associated cost from the Project Manager for the Project as 6, 6, and 8, in table 17, table 18, and table 19. The expected time for each of the Sprints was 21, 12, and 14. The expected number of Sprints assigned by the Project Manager is 19, 12, and 29. While the observed number of Sprints is 34, 27, and 33. This project had every observed Sprint go over the expected number of Sprints. This means that the efficiency should not be high at the observed 65%. This is on par with the Time Ratio of 1.5806 and Cost Ratio of 1.5072. This clearly shows that this project was not efficiently completed.

The second function shows an efficiency of 74% which is slightly higher than the first function used.

When using the third function the efficiency calculation is 74% as the same in the second function. This also shows that project that are not very efficient can have relatively the same function integrated in the mathematical models.

*Effectiveness Evaluation*

When dealing effectiveness, the same five data sets were used when trying to quantify the efficiency. Therefore, one could compare the efficiency and effectiveness at the same time. The effectiveness still using the same three functions as stated before, but the mathematical formulation of effectiveness is different from efficiency.

*Table 18. Efficiency For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1. Using Data Set #5 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 6 | $C_i$= | 8 |
| $t_i$= | 21 | $t_i$= | 12 | $t_i$= | 14 |
| $V_i$= | 19 | $V_i$= | 12 | $V_i$= | 29 |
| Geom. Dist.= | 0.052632 | Geom. Dist.= | 0.083333 | Geom. Dist.= | 0.034483 |
| $K_i$= | 34 | $K_i$= | 27 | $K_i$= | 33 |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 126 | $C_i*t_i$= | 72 | $C_i*t_i$= | 112 |
| $K_i/V_i$= | 1.789474 | $K_i/V_i$= | 2.25 | $K_i/V_i$= | 1.137931 |
| *f(x)*= | 0.974799 | *f(x)*= | 0.848425 | *f(x)*= | 1.316069 |
| $C_i*t_i*f(x)$= | 122.8246 | $C_i*t_i*f(x)$= | 61.08658 | $C_i*t_i*f(x)$= | 147.3997 |
| Sum= | 331.3109 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i*t_i$= | 126 | $C_i*t_i$= | 72 | $C_i*t_i$= | 112 |
| $1/V_i$= | 0.052632 | $1/V_i$= | 0.083333 | $1/V_i$= | 0.034483 |
| *f(x)*= | 1.442695 | *f(x)*= | 1.442695 | *f(x)*= | 1.442695 |
| $C_i*t_i*f(x)$= | 181.7796 | $C_i*t_i*f(x)$= | 103.874 | $C_i*t_i*f(x)$= | 161.5818 |
| Sum= | 447.2355 | | | | |

| | |
|---|---|
| TR= | 1.580611 |
| CR= | 1.507177 |

| | |
|---|---|
| NEy= | 74% |

*Table 19. Efficiency For f(x)=1 If x≤0 And f(x)=* $e^{-\lambda x}$ *For x>0 Where λ Is Defined As A Parameter From The Project Manager. Using Data Set #5 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 6 | $C_i$= | 8 |
| $t_i$= | 21 | $t_i$= | 12 | $t_i$= | 14 |
| $V_i$= | 19 | $V_i$= | 12 | $V_i$= | 29 |
| Geom. Dist.= | 0.052632 | Geom. Dist.= | 0.083333 | Geom. Dist.= | 0.034483 |
| $K_i$= | 34 | $K_i$= | 27 | $K_i$= | 33 |

| | | | | | |
|---|---|---|---|---|---|
| λ= | 0.5 | λ= | 0.5 | λ= | 0.5 |
| $C_i$*$t_i$= | 126 | $C_i$*$t_i$= | 72 | $C_i$*$t_i$= | 112 |
| $K_i/V_i$= | 1.789474 | $K_i/V_i$= | 2.25 | $K_i/V_i$= | 1.137931 |
| *f(x)*= | 0.408715 | *f(x)*= | 0.324652 | *f(x)*= | 0.566111 |
| $C_i$*$t_i$**f(x)*= | 51.49811 | $C_i$*$t_i$**f(x)*= | 23.37498 | $C_i$*$t_i$**f(x)*= | 63.40441 |
| Sum= | 138.2775 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $C_i$*$t_i$= | 126 | $C_i$*$t_i$= | 72 | $C_i$*$t_i$= | 112 |
| $1/V_i$= | 0.052632 | $1/V_i$= | 0.083333 | $1/V_i$= | 0.034483 |
| *f(x)*= | 0.606531 | *f(x)*= | 0.606531 | *f(x)*= | 0.606531 |
| $C_i$*$t_i$**f(x)*= | 76.42286 | $C_i$*$t_i$**f(x)*= | 43.67021 | $C_i$*$t_i$**f(x)*= | 67.93143 |
| Sum= | 188.0245 | | | | |

| | | | |
|---|---|---|---|
| | | TR= | 1.580611 |
| NEy= | 74% | CR= | 1.507177 |

The effectiveness for the first data set was 84%. This is lower than the Cost Ratio that was calculated for the data set #1 in table 20. Therefore, if the cost of the project was used to calculate the effectiveness of the research it would should that the project is performing poorly because the project is over budget. By quantifying the effectiveness, the performance of the work has shifted to 84%. The efficiency of the first data set was 83% showing the close relationship between the two performance indicators.

Using the second function on the effectiveness is calculated to be 88% which is slightly higher than the first function in table 21. The effectiveness is still closely related to each other showing that it is still up to the Project Manager to pick the best associated non-increasing function. The efficiency for this function was 87% which falls in line with the calculated effectiveness.

This third function on the first data set gives an effectiveness of 90% in table 22. This is important because this still shows that the project is being conducted well even though it is above the set budget. The Project Manager can change the lambda according to the desired effect of the performance. The efficiency of this data set was 89%. Therefore, this performance management system gives a more clear and precise way to find out how performance is measured in the field of research without having to rely on budget or time as a measure of performance.

The second data set for the first function of effectiveness yielded 96%in table 23. This was slightly higher than the efficiency of the data set that was 95% efficient. The Cost Ratio for this data set was roughly 0.8140 which is slightly lower than the effectiveness that was calculated.

*Table 20. Effectiveness For f(x)=1 If x≤1 And f(x)= 1/x For x>1. Using Data Set #1 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 4 | $C_i$= | 5 |
| $V_i$= | 3 | $V_i$= | 8 | $V_i$= | 5 |
| Geom. Dist.= | 0.333333 | Geom. Dist.= | 0.125 | Geom. Dist.= | 0.2 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 7 |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.25 | $1/C_i$= | 0.2 |
| $K_i/V_i$= | 1.333333 | $K_i/V_i$= | 0.625 | $K_i/V_i$= | 1.4 |
| *f(x)*= | 0.75 | *f(x)*= | 1.6 | *f(x)*= | 0.714286 |
| *f(x)'*= | 0.75 | *f(x)'*= | 1 | *f(x)'*= | 0.714286 |
| $1/C_i$**f(x)*= | 0.125 | $1/C_i$**f(x)*= | 0.25 | $1/C_i$**f(x)*= | 0.142857 |
| sum= | 0.517857 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.25 | $1/C_i$= | 0.2 |
| *f*/$C_i$= | 0.166667 | *f*/$C_i$= | 0.25 | *f*/$C_i$= | 0.2 |
| sum= | 0.616667 | | | | |

| | | | |
|---|---|---|---|
| NEs= | 84% | CR= | 1.053333 |

*Table 21. Effectiveness For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1. Using Data Set #1 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 4 | $C_i$= | 5 |
| $V_i$= | 3 | $V_i$= | 8 | $V_i$= | 5 |
| Geom. Dist.= | 0.333333 | Geom. Dist.= | 0.125 | Geom. Dist.= | 0.2 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 7 |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.25 | $1/C_i$= | 0.2 |
| $K_i/V_i$= | 1.333333 | $K_i/V_i$= | 0.625 | $K_i/V_i$= | 1.4 |
| *f(x)*= | 1.180223 | *f(x)*= | 1.442695 | *f(x)*= | 1.142245 |
| $1/C_i$**f(x)*= | 0.196704 | $1/C_i$**f(x)*= | 0.360674 | $1/C_i$**f(x)*= | 0.228449 |
| sum= | 0.785827 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.25 | $1/C_i$= | 0.2 |
| sum= | 0.616667 | | | | |
| *f(x)*= | 0.889662 | | CR= | 1.053333 | |

| | |
|---|---|
| NEs= | 88% |

*Table 22. Effectiveness For f(x)=1 If x≤0 And f(x)=* $e^{-\lambda x}$ *For x>0 Where λ Is Defined As A Parameter From The Project Manager. Using Data Set #1 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 4 | $C_i$= | 5 |
| $V_i$= | 3 | $V_i$= | 8 | $V_i$= | 5 |
| Geom. Dist.= | 0.333333 | Geom. Dist.= | 0.125 | Geom. Dist.= | 0.2 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 7 |

| | | | | | |
|---|---|---|---|---|---|
| λ= | 0.5 | λ= | 0.5 | λ= | 0.5 |
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.25 | $1/C_i$= | 0.2 |
| $K_i/V_i$= | 1.333333 | $K_i/V_i$= | 0.625 | $K_i/V_i$= | 1.4 |
| *f(x)*= | 0.513417 | *f(x)*= | 0.606531 | *f(x)*= | 0.496585 |
| $1/C_i$**f(x)*= | 0.08557 | $1/C_i$**f(x)*= | 0.151633 | $1/C_i$**f(x)*= | 0.099317 |
| sum= | 0.336519 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.25 | $1/C_i$= | 0.2 |
| sum= | 0.616667 | | | | |
| *f(x)*= | 0.374027 | | CR= | 1.053333 | |

| | |
|---|---|
| NEs= | 90% |

*Table 23. Effectiveness For f(x)=1 If x≤1 And f(x)= 1/x For x>1. Using Data Set #2 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 8 | $C_i$= | 6 |
| $V_i$= | 7 | $V_i$= | 6 | $V_i$= | 9 |
| Geom. Dist.= | 0.142857 | Geom. Dist.= | 0.166667 | Geom. Dist.= | 0.111111 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 10 |
| | | | | | |
| $1/C_i$= | 0.1 | $1/C_i$= | 0.125 | $1/C_i$= | 0.166667 |
| $K_i/V_i$= | 0.571429 | $K_i/V_i$= | 0.833333 | $K_i/V_i$= | 1.111111 |
| *f(x)*= | 1.75 | *f(x)*= | 1.2 | *f(x)*= | 0.9 |
| *f(x)'*= | 1 | *f(x)'*= | 1 | *f(x)'*= | 0.9 |
| $1/C_i$**f(x)*= | 0.1 | $1/C_i$**f(x)*= | 0.125 | $1/C_i$**f(x)*= | 0.15 |
| sum= | 0.375 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.1 | $1/C_i$= | 0.125 | $1/C_i$= | 0.166667 |
| $f/C_i$= | 0.1 | $f/C_i$= | 0.125 | $f/C_i$= | 0.166667 |
| sum= | 0.391667 | | | | |

| | | | |
|---|---|---|---|
| NEs= | 96% | CR= | 0.813953 |

The second function of the second data set has an effectiveness of 97% which is higher than the efficiency of the second set of 96% in table 24 and table 25. This effectiveness is still higher than the first function but only had a difference of 1% validating that the function selected by the Project Manager is not an important as the actual mathematical formulation of effectiveness.

The third function shows that there is an effectiveness of roughly 98%. The efficiency of this function was 97%. The Cost Ratio was 0.8134 in table 26.

The third data set had an effectiveness rate of 76% on the first function while the Cost Ratio was 0.8134 in table 27. This effectiveness could be attributed to the observed number of Sprints being higher than expected for task 1 and 2. The efficiency of this function in the third data set is 90%. This change validates that even though the efficiency can be very high the effectiveness can still be low.

The effectiveness for the second function was slightly higher than the first function at 82% in table 28. The efficiency for the third data set on the second function was 93%.

The third function has an effectiveness of 84% as compared to an efficiency of 94%. These values are all still below the Cost Ratio of 1.1017 in table 29.

*Table 24. Effectiveness For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1. Using Data Set #2 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 8 | $C_i$= | 6 |
| $V_i$= | 7 | $V_i$= | 6 | $V_i$= | 9 |
| Geom. Dist.= | 0.142857 | Geom. Dist.= | 0.166667 | Geom. Dist.= | 0.111111 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 10 |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.1 | $1/C_i$= | 0.125 | $1/C_i$= | 0.166667 |
| $K_i/V_i$= | 0.571429 | $K_i/V_i$= | 0.833333 | $K_i/V_i$= | 1.111111 |
| *f(x)*= | 1.442695 | *f(x)*= | 1.442695 | *f(x)*= | 1.338304 |
| $1/C_i$**f(x)*= | 0.14427 | $1/C_i$**f(x)*= | 0.180337 | $1/C_i$**f(x)*= | 0.223051 |
| sum= | 0.547657 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.1 | $1/C_i$= | 0.125 | $1/C_i$= | 0.166667 |
| sum= | 0.391667 | | | | |
| *f(x)*= | 0.565056 | | CR= | 0.813953 | |

| | |
|---|---|
| NEs= | 97% |

*Table 25. Effectiveness For f(x)=1 If x≤0 And f(x)=* $e^{-\lambda x}$ *For x>0 Where λ Is Defined As A Parameter From The Project Manager. Using Data Set #2 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 8 | $C_i$= | 6 |
| $V_i$= | 7 | $V_i$= | 6 | $V_i$= | 9 |
| Geom. Dist.= | 0.142857 | Geom. Dist.= | 0.166667 | Geom. Dist.= | 0.111111 |
| $K_i$= | 4 | $K_i$= | 5 | $K_i$= | 10 |

| | | | | | |
|---|---|---|---|---|---|
| λ= | 0.5 | λ= | 0.5 | λ= | 0.5 |
| $1/C_i$= | 0.1 | $1/C_i$= | 0.125 | $1/C_i$= | 0.166667 |
| $K_i/V_i$= | 0.571429 | $K_i/V_i$= | 0.833333 | $K_i/V_i$= | 1.111111 |
| *f(x)*= | 0.606531 | *f(x)*= | 0.606531 | *f(x)*= | 0.573753 |
| $1/C_i$**f(x)*= | 0.060653 | $1/C_i$**f(x)*= | 0.075816 | $1/C_i$**f(x)*= | 0.095626 |
| sum= | 0.232095 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.1 | $1/C_i$= | 0.125 | $1/C_i$= | 0.166667 |
| sum= | 0.391667 | | | | |
| *f(x)*= | 0.237558 | | CR= | 0.813953 | |

| | |
|---|---|
| NEs= | 98% |

*Table 26. Effectiveness For f(x)=1 If x≤1 And f(x)= 1/x For x>1. Using Data Set #3 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 2 | $C_i$= | 2 | $C_i$= | 3 |
| $V_i$= | 10 | $V_i$= | 9 | $V_i$= | 7 |
| Geom. Dist.= | 0.1 | Geom. Dist.= | 0.111111 | Geom. Dist.= | 0.142857 |
| $K_i$= | 14 | $K_i$= | 14 | $K_i$= | 3 |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.5 | $1/C_i$= | 0.5 | $1/C_i$= | 0.333333 |
| $K_i/V_i$= | 1.4 | $K_i/V_i$= | 1.555556 | $K_i/V_i$= | 0.428571 |
| *f(x)*= | 0.714286 | *f(x)*= | 0.642857 | *f(x)*= | 2.333333 |
| *f(x)'*= | 0.714286 | *f(x)'*= | 0.642857 | *f(x)'*= | 1 |
| $1/C_i$**f(x)*= | 0.357143 | $1/C_i$**f(x)*= | 0.321429 | $1/C_i$**f(x)*= | 0.333333 |
| sum= | 1.011905 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.5 | $1/C_i$= | 0.5 | $1/C_i$= | 0.333333 |
| $f/C_i$= | 0.5 | $f/C_i$= | 0.5 | $f/C_i$= | 0.333333 |
| sum= | 1.333333 | | | | |
| | | | CR= | 1.101695 | |
| NEs= | 76% | | | | |

*Table 27. Effectiveness For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1. Using Data Set #3 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 2 | $C_i$= | 2 | $C_i$= | 3 |
| $V_i$= | 10 | $V_i$= | 9 | $V_i$= | 7 |
| Geom. Dist.= | 0.1 | Geom. Dist.= | 0.111111 | Geom. Dist.= | 0.142857 |
| $K_i$= | 14 | $K_i$= | 14 | $K_i$= | 3 |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.5 | $1/C_i$= | 0.5 | $1/C_i$= | 0.333333 |
| $K_i/V_i$= | 1.4 | $K_i/V_i$= | 1.555556 | $K_i/V_i$= | 0.428571 |
| *f(x)*= | 1.142245 | *f(x)*= | 1.065792 | *f(x)*= | 1.442695 |
| $1/C_i$**f(x)*= | 0.571123 | $1/C_i$**f(x)*= | 0.532896 | $1/C_i$**f(x)*= | 0.480898 |
| sum= | 1.584917 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.5 | $1/C_i$= | 0.5 | $1/C_i$= | 0.333333 |
| sum= | 1.333333 | | | | |
| *f(x)*= | 1.923593 | | CR= | 1.101695 | |

| | |
|---|---|
| NEs= | 82% |

*Table 28. Effectiveness For f(x)=1 If x≤0 And f(x)=* $e^{-\lambda x}$ *For x>0 Where λ Is Defined As A Parameter From The Project Manager. Using Data Set #3 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 2 | $C_i$= | 2 | $C_i$= | 3 |
| $V_i$= | 10 | $V_i$= | 9 | $V_i$= | 7 |
| Geom. Dist.= | 0.1 | Geom. Dist.= | 0.111111 | Geom. Dist.= | 0.142857 |
| $K_i$= | 14 | $K_i$= | 14 | $K_i$= | 3 |

| | | | | | |
|---|---|---|---|---|---|
| λ= | 0.5 | λ= | 0.5 | λ= | 0.5 |
| $1/C_i$= | 0.5 | $1/C_i$= | 0.5 | $1/C_i$= | 0.333333 |
| $K_i/V_i$= | 1.4 | $K_i/V_i$= | 1.555556 | $K_i/V_i$= | 0.428571 |
| *f(x)*= | 0.496585 | *f(x)*= | 0.459426 | *f(x)*= | 0.606531 |
| $1/C_i$**f(x)*= | 0.248293 | $1/C_i$**f(x)*= | 0.229713 | $1/C_i$**f(x)*= | 0.202177 |
| sum= | 0.680182 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.5 | $1/C_i$= | 0.5 | $1/C_i$= | 0.333333 |
| sum= | 1.333333 | | | | |
| *f(x)*= | 0.808708 | | CR= | 1.101695 | |

| | |
|---|---|
| NEs= | 84% |

*Table 29. Effectiveness For f(x)=1 If x≤1 And f(x)= 1/x For x>1. Using Data Set #4 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 6 | $C_i$= | 7 |
| $V_i$= | 4 | $V_i$= | 16 | $V_i$= | 30 |
| Geom. Dist.= | 0.25 | Geom. Dist.= | 0.0625 | Geom. Dist.= | 0.033333 |
| $K_i$= | 16 | $K_i$= | 2 | $K_i$= | 26 |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.1 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.142857 |
| $K_i/V_i$= | 4 | $K_i/V_i$= | 0.125 | $K_i/V_i$= | 0.866667 |
| $f(x)$= | 0.25 | $f(x)$= | 8 | $f(x)$= | 1.153846 |
| $f(x)'$= | 0.25 | $f(x)'$= | 1 | $f(x)'$= | 1 |
| $1/C_i*f(x)$= | 0.025 | $1/C_i*f(x)$= | 0.166667 | $1/C_i*f(x)$= | 0.142857 |
| sum= | 0.334524 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.1 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.142857 |
| $f/C_i$= | 0.1 | $f/C_i$= | 0.166667 | $f/C_i$= | 0.142857 |
| sum= | 0.409524 | | | | |
| | | | CR= | 1.023121 | |
| NEs= | 82% | | | | |

The fourth data set showed an effectiveness of 82% with a corresponding efficiency of 64% given the first function in table 30. This was lower than the Cost Ratio of 1.0231.

When using the second function for the fourth data set the effectiveness was 86%. The efficiency of the second function on the fourth data set was 73% in table 31.

The third function for the fourth data set presented an effectiveness of 81%. The efficiency of this function was 63%. All these values are under the Cost Ratio of 1.0231 in table 32, table 33, and table 34.

*Table 30. Effectiveness For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1. Using Data Set #4 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 6 | $C_i$= | 7 |
| $V_i$= | 4 | $V_i$= | 16 | $V_i$= | 30 |
| Geom. Dist.= | 0.25 | Geom. Dist.= | 0.0625 | Geom. Dist.= | 0.033333 |
| $K_i$= | 16 | $K_i$= | 2 | $K_i$= | 26 |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.1 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.142857 |
| $K_i/V_i$= | 4 | $K_i/V_i$= | 0.125 | $K_i/V_i$= | 0.866667 |
| *f(x)*= | 0.621335 | *f(x)*= | 1.442695 | *f(x)*= | 1.442695 |
| $1/C_i$**f(x)*= | 0.062133 | $1/C_i$**f(x)*= | 0.240449 | $1/C_i$**f(x)*= | 0.206099 |
| sum= | 0.508682 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.1 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.142857 |
| sum= | 0.409524 | | | | |
| *f(x)*= | 0.590818 | CR= | 1.023121 | | |

| | |
|---|---|
| NEs= | 86% |

*Table 31. Effectiveness For f(x)=1 If x≤0 And f(x)=* $e^{-\lambda x}$ *For x>0 Where λ Is Defined As A Parameter From The Project Manager. Using Data Set #4 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 10 | $C_i$= | 6 | $C_i$= | 7 |
| $V_i$= | 4 | $V_i$= | 16 | $V_i$= | 30 |
| Geom. Dist.= | 0.25 | Geom. Dist.= | 0.0625 | Geom. Dist.= | 0.033333 |
| $K_i$= | 16 | $K_i$= | 2 | $K_i$= | 26 |

| | | | | | |
|---|---|---|---|---|---|
| λ= | 0.5 | λ= | 0.5 | λ= | 0.5 |
| $1/C_i$= | 0.1 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.142857 |
| $K_i/V_i$= | 4 | $K_i/V_i$= | 0.125 | $K_i/V_i$= | 0.866667 |
| *f(x)*= | 0.135335 | *f(x)*= | 0.606531 | *f(x)*= | 0.606531 |
| $1/C_i$**f(x)*= | 0.013534 | $1/C_i$**f(x)*= | 0.101088 | $1/C_i$**f(x)*= | 0.086647 |
| sum= | 0.201269 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.1 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.142857 |
| sum= | 0.409524 | | | | |
| *f(x)*= | 0.248389 | | CR= | 1.023121 | |

| | |
|---|---|
| NEs= | 81% |

*Table 32. Effectiveness For f(x)=1 If x≤1 And f(x)= 1/x For x>1. Using Data Set #5 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 6 | $C_i$= | 8 |
| $V_i$= | 19 | $V_i$= | 12 | $V_i$= | 29 |
| Geom. Dist.= | 0.052632 | Geom. Dist.= | 0.083333 | Geom. Dist.= | 0.034483 |
| $K_i$= | 34 | $K_i$= | 27 | $K_i$= | 33 |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.125 |
| $K_i/V_i$= | 1.789474 | $K_i/V_i$= | 2.25 | $K_i/V_i$= | 1.137931 |
| *f(x)*= | 0.558824 | *f(x)*= | 0.444444 | *f(x)*= | 0.878788 |
| *f(x)'*= | 0.558824 | *f(x)'*= | 0.444444 | *f(x)'*= | 0.878788 |
| $1/C_i$**f(x)*= | 0.093137 | $1/C_i$**f(x)*= | 0.074074 | $1/C_i$**f(x)*= | 0.109848 |
| sum= | 0.27706 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.125 |
| $f/C_i$= | 0.166667 | $f/C_i$= | 0.166667 | $f/C_i$= | 0.125 |
| sum= | 0.458333 | | | | |
| | | CR= | 1.507177 | | |
| NEs= | 60% | | | | |

*Table 33. Effectiveness For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1. Using Data Set #5 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 6 | $C_i$= | 8 |
| $V_i$= | 19 | $V_i$= | 12 | $V_i$= | 29 |
| Geom. Dist.= | 0.052632 | Geom. Dist.= | 0.083333 | Geom. Dist.= | 0.034483 |
| $K_i$= | 34 | $K_i$= | 27 | $K_i$= | 33 |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.125 |
| $K_i/V_i$= | 1.789474 | $K_i/V_i$= | 2.25 | $K_i/V_i$= | 1.137931 |
| *f(x)*= | 0.974799 | *f(x)*= | 0.848425 | *f(x)*= | 1.316069 |
| $1/C_i$**f(x)*= | 0.162466 | $1/C_i$**f(x)*= | 0.141404 | $1/C_i$**f(x)*= | 0.164509 |
| sum= | 0.468379 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.125 |
| sum= | 0.458333 | | | | |
| *f(x)*= | 0.661235 | | CR= | 1.507177 | |

| | |
|---|---|
| NEs= | 71% |

*Table 34. Effectiveness For f(x)=1 If x≤0 And f(x)=* $e^{-\lambda x}$ *For x>0 Where λ Is Defined As A Parameter From The Project Manager. Using Data Set #5 With 3 Sequential Tasks.*

| Task 1 | | Task 2 | | Task 3 | |
|---|---|---|---|---|---|
| $C_i$= | 6 | $C_i$= | 6 | $C_i$= | 8 |
| $V_i$= | 19 | $V_i$= | 12 | $V_i$= | 29 |
| Geom. Dist.= | 0.052632 | Geom. Dist.= | 0.083333 | Geom. Dist.= | 0.034483 |
| $K_i$= | 34 | $K_i$= | 27 | $K_i$= | 33 |

| | | | | | |
|---|---|---|---|---|---|
| λ= | 0.5 | λ= | 0.5 | λ= | 0.5 |
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.125 |
| $K_i/V_i$= | 1.789474 | $K_i/V_i$= | 2.25 | $K_i/V_i$= | 1.137931 |
| *f(x)*= | 0.408715 | *f(x)*= | 0.324652 | *f(x)*= | 0.566111 |
| $1/C_i$**f(x)*= | 0.068119 | $1/C_i$**f(x)*= | 0.054109 | $1/C_i$**f(x)*= | 0.070764 |
| sum= | 0.192992 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $1/C_i$= | 0.166667 | $1/C_i$= | 0.166667 | $1/C_i$= | 0.125 |
| sum= | 0.458333 | | | | |
| *f(x)*= | 0.277993 | | CR= | 1.507177 | |

| | |
|---|---|
| NEs= | 69% |

*Sensitivity Analysis*

When dealing with the efficiency and effectiveness a sensitivity analysis can be conducted to see how different values will affect the overall performance of these mathematical models. When looking at the first function when all the values are listed as ten for the cost, time, expected and observed Sprints then the efficiency and effectiveness is 100%. This is due to the fact that you have completed the research project on time and on budget. If you decrease any of the observed Sprints to a number that is lower than the expected Sprints the efficiency and effectiveness still stays the same because of the range of the function being used. At the same time if the expected Sprints increase then the efficiency and effectiveness will stay the same. But if the expected number of sprints decreases then the efficiency and effectiveness will decrease. Changing the values of the cost and time will not have any effect on the efficiency and effectiveness because the values will get normalized in the end.

For the second function when listing the values for cost, time, expected and observed Sprints to ten the efficiency and effectiveness is still 100%. When increasing the observed number of Sprints, the efficiency and effectiveness decreases yet not as drastic if using the first function. This could be attributed to the slope of the function.

The third function is the most unique of all the functions as the Project Manager can establish a weight to subject the efficiency and effectiveness. If all the other values of cost, time, expected and observed Sprints are ten the same effect happens with the increasing and decreasing of the efficiency and the effectiveness. With the ability to change the lambda the effect of the performance can change as well. For the efficiency if the lambda increases the impact to the efficiency is larger. In the same sense if the lambda is smaller the effect on the efficiency is smaller. The lambda has a similar effect when dealing with the effectiveness.

*Analysis of Mini Case Study*

When looking at the results of the mini case study we can see the same thing happens as the three tasks stated for the validation of Efficiency and Effectiveness. The table of the tasks for the mini case study is listed in the Appendix.

From this graph we can see that the efficiency for all the different non-increasing function are relatively the same among the entire project time span. We can see that as the number of tasks increases the efficiency changes depending on the difference in the expected and observed number of Sprints for each task.

The second graph cost vs. efficiency depicts the total running cost in time for the tasks as well as the efficiency to give a sense of idea of how the cost ratio will affect the efficiency and why the cost ratio cannot be used as an efficiency measure.

Time vs efficiency graph represents how the time of the tasks or time ratio is related to the efficiency of the project. From this we can see that even though the time spent on the project is increasing it does not give a good assessment for efficiency.

The effectiveness of tasks graph shows the different effectiveness for the project given all three non-increasing functions.

Figure 12, figure 13, figure 14, figure 15, and figure 16 shows the relationship between the cost of the project and the effectiveness. This is important because it shows the cost ratio and how it relates to effectiveness. From this we can see although the cost ratio is slowly going to one the effectiveness does not change drastically. The effectiveness also does not change due to the fact of the slow cash spending at the start of the project.

*Analysis of Project Performance Quality*

When dealing with past projects the quality of the project can be assessed in two different methods. The first method would be to have a panel of experts assess the quality of the publication or past projects. From this each expert would rank the project according to how good the quality was. This would be on a scale of 0.00 being the lowest quality to 1.00 being the highest quality of a project. The Project Performance Quality or PPQ can be assigned by one expert if there are limited number or people. From this the multiple linear regression would show the coefficients for the formulation to find the Predicted PPQ, as the second method of analyzing performance of past projects. This can also show how different the expert evaluation was as compared to a predicted PPQ. From the predicted PPQ and the expert PPQ the Spearman Correlation can be calculated to address if the validation between the two number is correct. This would happen if the Spearman Correlation is greater than 0.6000. The reason why the Spearman Correlation is used and not the Pearson Correlation is because the Pearson Correlation can only validate linear dependence while the Spearman Correlation will validate a non-linear monotonic relation.

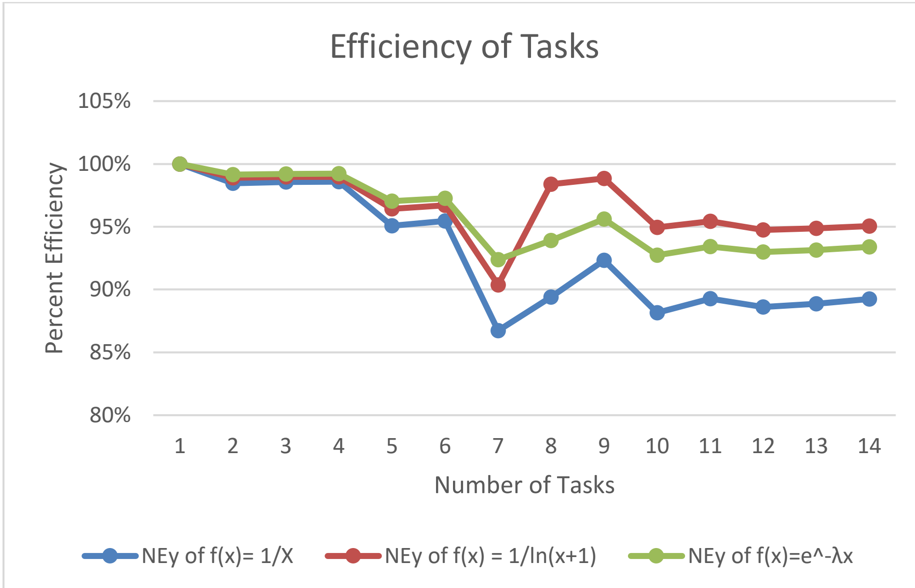


*Figure 12. Efficiency Of Tasks From Mini Case Study.*

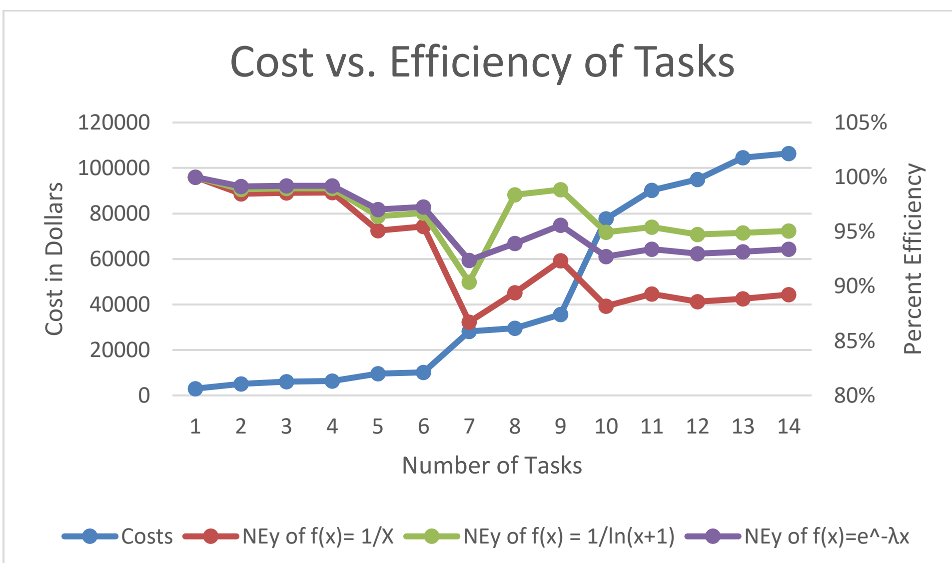


*Figure 13. Cost Vs. Efficiency From Mini Case Study.*

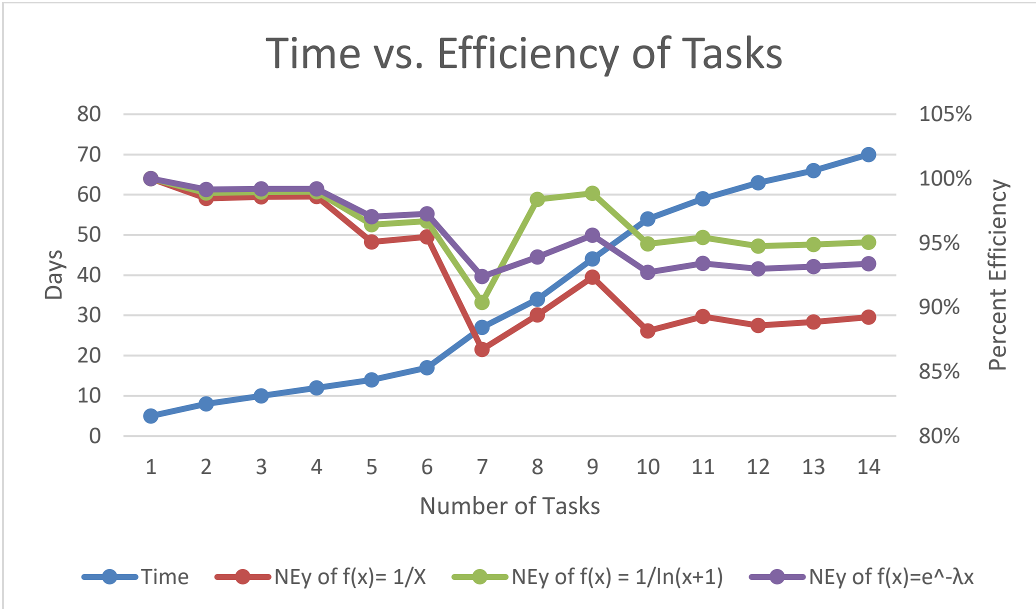


*Figure 14. Time Vs. Efficiency Of Tasks From Mini Case Study.*

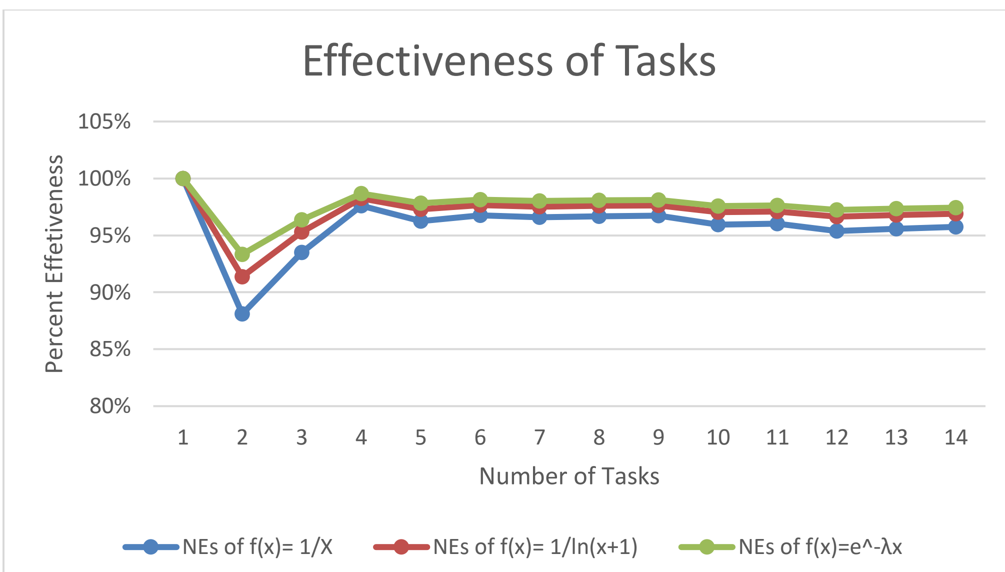


*Figure 15. Effectiveness Of Tasks From Mini Case Study.*

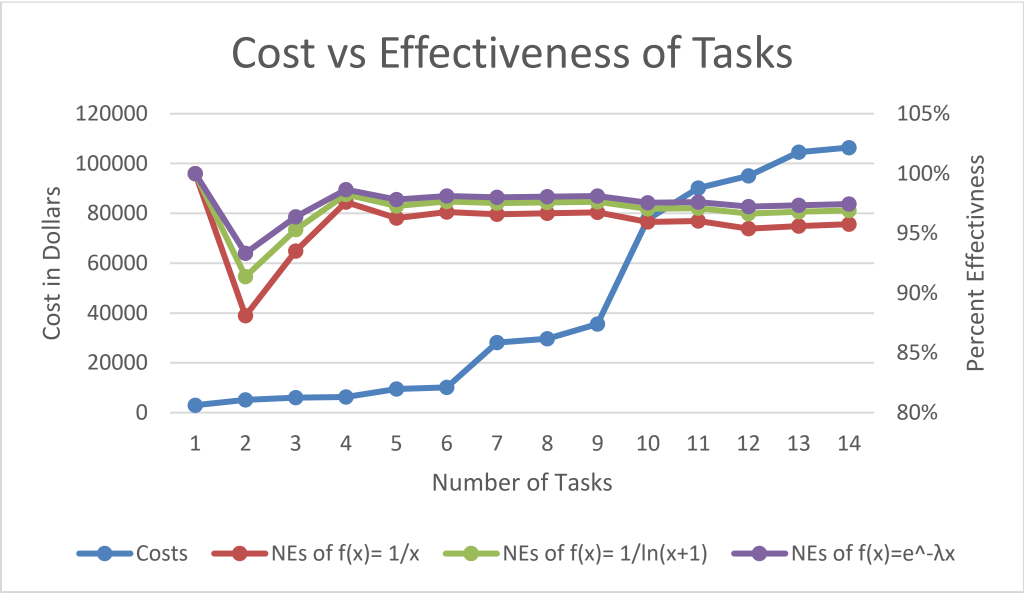


*Figure 16. Cost Vs. Effectiveness Of Task From Mini Case Study.*

*Project Performance Quality*

All the data from the PPQ was simulated and shown in the Appendix with the corresponding Table number. Each Table number depicts a different data set. The first column is showing expert judgment to evaluate the PPQ for each of the rows that stand for a research project that has been completed. From this we can see how differently expert rank and judge the quality of the research project given the total funding of the project in the second column listed as C. The number of people involved is listed as K, and the salaries associated with each researcher or team member is listed as S. Each member could have a different salary based on the funding of the project. The funding and salaries are not given any units because the results are unitless. This means the currency can be converted to match the country that is conducting their experiment. The number of publication and the ranking of each journal is listed as well as the number of citations. For the simulated data the funding was within a range of 75,000 and 500,000. The number of people involved was between 1 and 10. The Salaries were divided by the funding given. From this the number of publications was simulated between 1 and 10 and the ranking associated for those publication was between 1 and 50 where the lower the number the better the publication is. The citations for the journals was simulated as an integer from 1 to 70 based on the ranking of the journal where the higher the amount of citations the better the research was.

From the Multiple Regression Statistics, we can see that the Multiple R was 0.8416. Which is high, and the $a_r$, $a_t$, $a_{ct}$, $D$ coefficients were calculated as -0.3178, -0.0278, 0.9741, and 0.5268 in table 35.

Table 36 shows that the Spearman Correlation between the predicted and expert PPQ was 0.8147.

From the Multiple Regression Statistics in table 37, we can see that the Multiple R was 0.8293. Which is high, and the $a_r$, $a_t$, $a_{ct}$, $D$ coefficients were calculated as -0.2651, -0.0210, 1.0069, and 0.4857.

Table 38 shows that the Spearman Correlation between the predicted and expert PPQ was 0.7705.

From the Multiple Regression Statistics in table 39, we can see that the Multiple R was 0.8088. Which is high, and the $a_r$, $a_t$, $a_{ct}$, $D$ coefficients were calculated as -0.1432, -0.0398, 0.8859, and 0.4934.

Table 40 shows that the Spearman Correlation between the predicted and expert PPQ was 0.7700.

From the Multiple Regression Statistics, we can see that the Multiple R was 0.9033 in table 39. Which is high, and the $a_r$, $a_t$, $a_{ct}$, $D$ coefficients were calculated as -0.0561, -0.0914, 0.9674, and 0.6735 in table 40 and table 41.

Table 42 shows that the Spearman Correlation between the predicted and expert PPQ was 0.8406.

*Table 35. Regression Statistics For Data Set #1 With Expert PPQ.*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.8418 |
| R Square | 0.7086 |
| Adjusted R Square | 0.6539 |
| Standard Error | 0.1241 |
| Observations | 20 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.5994 | 0.1998 | 12.9665 | 0.0001 |
| Residual | 16 | 0.2466 | 0.0154 | | |
| Total | 19 | 0.8460 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.5268 | 0.1081 | 4.8737 | 0.0002 | 0.2976 | 0.7559 | 0.2976 | 0.7559 |
| X Variable 1 | -0.3178 | 0.2082 | -1.5268 | 0.1463 | -0.7591 | 0.1235 | -0.7591 | 0.1235 |
| X Variable 2 | -0.0278 | 0.0394 | -0.7042 | 0.4914 | -0.1113 | 0.0558 | -0.1113 | 0.0558 |
| X Variable 3 | 0.9741 | 0.1918 | 5.0783 | 0.0001 | 0.5675 | 1.3807 | 0.5675 | 1.3807 |

*Table 36. Spearman Correlation For All Research With Expert PPQ In Data Set #1.*

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.40 | 0.3896 | 8 | 11 | 0.8147 | 0.8418 |
| 0.35 | 0.1940 | 11 | 20 | | |
| 0.60 | 0.5679 | 5 | 4 | | |
| 0.10 | 0.2228 | 20 | 19 | | |
| 0.20 | 0.2669 | 19 | 18 | | |
| 0.90 | 0.7920 | 1 | 2 | | |
| 0.45 | 0.3374 | 7 | 14 | | |
| 0.85 | 0.5658 | 2 | 5 | | |
| 0.35 | 0.4345 | 11 | 8 | | |
| 0.70 | 0.6179 | 3 | 3 | | |
| 0.35 | 0.3127 | 11 | 15 | | |
| 0.40 | 0.4283 | 8 | 9 | | |
| 0.30 | 0.2696 | 15 | 17 | | |
| 0.65 | 0.8645 | 4 | 1 | | |
| 0.25 | 0.3468 | 18 | 13 | | |
| 0.26 | 0.2959 | 17 | 16 | | |
| 0.31 | 0.3986 | 14 | 10 | | |
| 0.30 | 0.3781 | 15 | 12 | | |
| 0.50 | 0.4544 | 6 | 7 | | |
| 0.40 | 0.4822 | 8 | 6 | | |

*Table 37. Regression Statistics For Data Set #2 With Expert PPQ.*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.8293 |
| R Square | 0.6878 |
| Adjusted R Square | 0.6292 |
| Standard Error | 0.1357 |
| Observations | 20 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.6488 | 0.2163 | 11.7488 | 0.0003 |
| Residual | 16 | 0.2945 | 0.0184 | | |
| Total | 19 | 0.9433 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.4857 | 0.0994 | 4.8865 | 0.0002 | 0.2750 | 0.6964 | 0.2750 | 0.6964 |
| X Variable 1 | -0.2651 | 0.2001 | -1.3251 | 0.2037 | -0.6892 | 0.1590 | -0.6892 | 0.1590 |
| X Variable 2 | -0.0210 | 0.0530 | -0.3966 | 0.6969 | -0.1335 | 0.0914 | -0.1335 | 0.0914 |
| X Variable 3 | 1.0069 | 0.1749 | 5.7587 | 0.0000 | 0.6363 | 1.3776 | 0.6363 | 1.3776 |

*Table 38. Spearman Correlation For All Research With Expert PPQ In Data Set #2.*

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.25 | 0.2860 | 16 | 19 | 0.7705 | 0.8293 |
| 0.20 | 0.2710 | 18 | 20 | | |
| 0.85 | 0.7712 | 1 | 2 | | |
| 0.20 | 0.2986 | 18 | 18 | | |
| 0.24 | 0.3557 | 17 | 15 | | |
| 0.78 | 0.7185 | 2 | 3 | | |
| 0.65 | 0.4513 | 6 | 8 | | |
| 0.50 | 0.4565 | 9 | 7 | | |
| 0.75 | 0.8997 | 3 | 1 | | |
| 0.15 | 0.4864 | 20 | 6 | | |
| 0.70 | 0.6912 | 5 | 5 | | |
| 0.55 | 0.4446 | 8 | 9 | | |
| 0.75 | 0.7163 | 3 | 4 | | |
| 0.30 | 0.3927 | 14 | 11 | | |
| 0.32 | 0.3029 | 13 | 17 | | |
| 0.40 | 0.3793 | 12 | 14 | | |
| 0.30 | 0.3037 | 14 | 16 | | |
| 0.44 | 0.4257 | 11 | 10 | | |
| 0.50 | 0.3877 | 9 | 13 | | |
| 0.60 | 0.3912 | 7 | 12 | | |

*Table 39. Regression Statistics Of Data Set #3 With Expert PPQ.*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.8088 |
| R Square | 0.6542 |
| Adjusted R Square | 0.5894 |
| Standard Error | 0.0988 |
| Observations | 20 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.2953 | 0.0984 | 10.0909 | 0.0006 |
| Residual | 16 | 0.1561 | 0.0098 | | |
| Total | 19 | 0.4514 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.4934 | 0.0737 | 6.6970 | 0.0000 | 0.3372 | 0.6496 | 0.3372 | 0.6496 |
| X Variable 1 | -0.1432 | 0.1432 | -1.0001 | 0.3321 | -0.4467 | 0.1603 | -0.4467 | 0.1603 |
| X Variable 2 | -0.0398 | 0.0402 | -0.9895 | 0.3372 | -0.1250 | 0.0454 | -0.1250 | 0.0454 |
| X Variable 3 | 0.8859 | 0.1686 | 5.2547 | 0.0001 | 0.5285 | 1.2433 | 0.5285 | 1.2433 |

*Table 40. Spearman Correlation For All Research With Expert PPQ In Data Set #3.*

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.35 | 0.4844 | 16 | 13 | 0.7700 | 0.8088 |
| 0.55 | 0.6619 | 10 | 4 | | |
| 0.60 | 0.6630 | 6 | 3 | | |
| 0.60 | 0.4918 | 6 | 12 | | |
| 0.85 | 0.8605 | 1 | 1 | | |
| 0.55 | 0.5784 | 10 | 6 | | |
| 0.35 | 0.3538 | 16 | 19 | | |
| 0.50 | 0.5541 | 14 | 8 | | |
| 0.55 | 0.4758 | 10 | 15 | | |
| 0.30 | 0.4055 | 18 | 17 | | |
| 0.60 | 0.5145 | 6 | 11 | | |
| 0.70 | 0.6970 | 2 | 2 | | |
| 0.60 | 0.5384 | 6 | 9 | | |
| 0.30 | 0.3995 | 18 | 18 | | |
| 0.65 | 0.5351 | 4 | 10 | | |
| 0.55 | 0.4820 | 10 | 14 | | |
| 0.65 | 0.5974 | 4 | 5 | | |
| 0.70 | 0.5614 | 2 | 7 | | |
| 0.40 | 0.3383 | 15 | 20 | | |
| 0.30 | 0.4572 | 18 | 16 | | |

*Table 41. Regression Statistics For Data Set #4 With Expert PPQ.*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.9033 |
| R Square | 0.8159 |
| Adjusted R Square | 0.7814 |
| Standard Error | 0.0722 |
| Observations | 20 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.3698 | 0.1233 | 23.6423 | 0.0000 |
| Residual | 16 | 0.0834 | 0.0052 | | |
| Total | 19 | 0.4532 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.6735 | 0.0616 | 10.9290 | 0.0000 | 0.5428 | 0.8041 | 0.5428 | 0.8041 |
| X Variable 1 | -0.0561 | 0.1236 | -0.4541 | 0.6558 | -0.3182 | 0.2060 | -0.3182 | 0.2060 |
| X Variable 2 | -0.0914 | 0.0441 | -2.0725 | 0.0547 | -0.1848 | 0.0021 | -0.1848 | 0.0021 |
| X Variable 3 | 0.9674 | 0.1301 | 7.4338 | 0.0000 | 0.6915 | 1.2433 | 0.6915 | 1.2433 |

*Table 42. Spearman Correlation For All Research With Expert PPQ In Data Set #4.*

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.51 | 0.6245 | 16 | 7 | 0.8406 | 0.9033 |
| 0.57 | 0.5973 | 10 | 10 | | |
| 0.66 | 0.7219 | 7 | 5 | | |
| 0.42 | 0.4804 | 19 | 18 | | |
| 0.52 | 0.4833 | 15 | 17 | | |
| 0.41 | 0.5623 | 20 | 12 | | |
| 0.55 | 0.5470 | 14 | 13 | | |
| 0.56 | 0.5307 | 13 | 16 | | |
| 0.51 | 0.4154 | 17 | 20 | | |
| 0.70 | 0.6996 | 6 | 6 | | |
| 0.45 | 0.4766 | 18 | 19 | | |
| 0.86 | 0.8537 | 3 | 3 | | |
| 0.75 | 0.6232 | 5 | 8 | | |
| 0.91 | 0.9122 | 2 | 1 | | |
| 0.61 | 0.5634 | 8 | 11 | | |
| 0.58 | 0.6138 | 9 | 9 | | |
| 0.57 | 0.5416 | 12 | 15 | | |
| 0.81 | 0.7428 | 4 | 4 | | |
| 0.57 | 0.5448 | 11 | 14 | | |
| 0.91 | 0.8753 | 1 | 2 | | |

From the Multiple Regression Statistics, we can see that the Multiple R was 0.9261. Which is high, and the $a_r$, $a_t$, $a_{ct}$, $D$ coefficients were calculated as -0.0189, -0.1764, -0.1764, 1.2747, and 0.6467 in table 43.

Table 44 shows that the Spearman Correlation between the predicted and expert PPQ was 0.9293.

*Spearman Correlation Validation*

All five data sets were divided into two equal project groups. From this the Regression Coefficients were calculated and used to find the predicted PPQ for the second group. This was then validated by the Spearman Correlation.

For the validation we see that the Multiple Regression Statistics shows that the Multiple R was 0.9287. Which is high, and the $ar$, $at$, $act$, $D$ coefficients were calculated as -0.1287, -0.1177, 1.3643, and 0.6751 in table 45. From this we can calculate the predicted PPQ and use it to find the Spearman Correlation for each group. Group 1 had a Spearman Correlation of 0.9201 and Group 2 had a Spearman Correlation of 0.6865 in table 46.

For the validation we see that the Multiple Regression Statistics shows that the Multiple R was 0.8534. Which is high, and the $ar$, $at$, $act$, $D$ coefficients were calculated as -0.3240, -0.0636, -0.0636, 1.1318, and 0.5450 in able 47. From this we can calculate the predicted PPQ and use it to find the Spearman Correlation for each group. Group 1 had a Spearman Correlation of 0.6424 and Group 2 had a Spearman Correlation of 0.7658 in table 48.

*Table 43. Regression Statistics For Data Set #5 With Expert PPQ.*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.9261 |
| R Square | 0.8576 |
| Adjusted R Square | 0.8309 |
| Standard Error | 0.0823 |
| Observations | 20 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.6531 | 0.2177 | 32.1208 | 0.0000 |
| Residual | 16 | 0.1084 | 0.0068 | | |
| Total | 19 | 0.7615 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.6467 | 0.0587 | 11.0107 | 0.0000 | 0.5222 | 0.7712 | 0.5222 | 0.7712 |
| X Variable 1 | -0.0189 | 0.1378 | -0.1373 | 0.8925 | -0.3110 | 0.2731 | -0.3110 | 0.2731 |
| X Variable 2 | -0.1764 | 0.0517 | -3.4089 | 0.0036 | -0.2861 | -0.0667 | -0.2861 | -0.0667 |
| X Variable 3 | 1.2747 | 0.1754 | 7.2687 | 0.0000 | 0.9029 | 1.6464 | 0.9029 | 1.6464 |

*Table 44. Spearman Correlation For All Research With Expert PPQ In Data Set #5.*

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.45 | 0.5416 | 12 | 9 | 0.9293 | 0.9261 |
| 0.30 | 0.3982 | 17 | 15 | | |
| 0.26 | 0.3277 | 19 | 17 | | |
| 0.57 | 0.4943 | 8 | 12 | | |
| 0.73 | 0.7171 | 4 | 2 | | |
| 0.33 | 0.2535 | 16 | 19 | | |
| 0.50 | 0.5669 | 10 | 8 | | |
| 0.43 | 0.4391 | 13 | 13 | | |
| 0.46 | 0.5193 | 11 | 11 | | |
| 0.63 | 0.7100 | 6 | 4 | | |
| 0.19 | 0.1225 | 20 | 20 | | |
| 0.38 | 0.4327 | 14 | 14 | | |
| 0.29 | 0.2854 | 18 | 18 | | |
| 0.90 | 0.8804 | 1 | 1 | | |
| 0.74 | 0.6562 | 3 | 5 | | |
| 0.69 | 0.5295 | 5 | 10 | | |
| 0.62 | 0.5898 | 7 | 7 | | |
| 0.34 | 0.3637 | 15 | 16 | | |
| 0.54 | 0.6265 | 9 | 6 | | |
| 0.82 | 0.7156 | 2 | 3 | | |

*Table 45. Regression Statistics For Validation Of Spearman Correlation For Group 1 Of Data Set #1.*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.9287 |
| R Square | 0.8625 |
| Adjusted R Square | 0.7937 |
| Standard Error | 0.1210 |
| Observations | 10 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.5511 | 0.1837 | 12.5433 | 0.0054 |
| Residual | 6 | 0.0879 | 0.0146 | | |
| Total | 9 | 0.6390 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.6751 | 0.1467 | 4.6029 | 0.0037 | 0.3162 | 1.0340 | 0.3162 | 1.0340 |
| X Variable 1 | -0.1287 | 0.3198 | -0.4025 | 0.7013 | -0.9113 | 0.6538 | -0.9113 | 0.6538 |
| X Variable 2 | -0.1177 | 0.0614 | -1.9170 | 0.1037 | -0.2679 | 0.0325 | -0.2679 | 0.0325 |
| X Variable 3 | 1.3643 | 0.2613 | 5.2214 | 0.0020 | 0.7249 | 2.0036 | 0.7249 | 2.0036 |

*Table 46. Validation Of PPQ By Spearman Correlation For Data Set #1.*

Group 1

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.40 | 0.4593 | 6 | 6 | 0.9201 | 0.9287 |
| 0.35 | 0.2220 | 7 | 8 | | |
| 0.60 | 0.7188 | 4 | 3 | | |
| 0.10 | 0.1851 | 10 | 9 | | |
| 0.20 | 0.1798 | 9 | 10 | | |
| 0.90 | 0.8664 | 1 | 1 | | |
| 0.45 | 0.3830 | 5 | 7 | | |
| 0.85 | 0.7231 | 2 | 2 | | |
| 0.35 | 0.5016 | 7 | 5 | | |
| 0.70 | 0.6609 | 3 | 4 | | |

Group 2

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.35 | 0.2978 | 5 | 10 | 0.6865 | 0.8654 |
| 0.40 | 0.5029 | 3 | 5 | | |
| 0.30 | 0.4317 | 7 | 7 | | |
| 0.65 | 1.0673 | 1 | 1 | | |
| 0.25 | 0.4583 | 10 | 6 | | |
| 0.26 | 0.3902 | 9 | 9 | | |
| 0.31 | 0.5310 | 6 | 4 | | |
| 0.30 | 0.4259 | 7 | 8 | | |
| 0.50 | 0.5909 | 2 | 3 | | |
| 0.40 | 0.6215 | 3 | 2 | | |

*Table 47. Regression Statistics For Validation Of Spearman Correlation For Group 1 Of Data Set #2.*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.8534 |
| R Square | 0.7283 |
| Adjusted R Square | 0.5924 |
| Standard Error | 0.1780 |
| Observations | 10 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.5098 | 0.1699 | 5.3606 | 0.0391 |
| Residual | 6 | 0.1902 | 0.0317 | | |
| Total | 9 | 0.7000 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.5450 | 0.2366 | 2.3030 | 0.0608 | -0.0340 | 1.1240 | -0.0340 | 1.1240 |
| X Variable 1 | -0.3240 | 0.5824 | -0.5563 | 0.5981 | -1.7492 | 1.1012 | -1.7492 | 1.1012 |
| X Variable 2 | -0.0636 | 0.2288 | -0.2782 | 0.7902 | -0.6234 | 0.4961 | -0.6234 | 0.4961 |
| X Variable 3 | 1.1318 | 0.3373 | 3.3553 | 0.0153 | 0.3064 | 1.9572 | 0.3064 | 1.9572 |

*Table 48. Validation Of PPQ By Spearman Correlation For Data Set #2.*

Group 1

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.25 | 0.2336 | 6 | 9 | 0.6424 | 0.8534 |
| 0.20 | 0.1822 | 8 | 10 | | |
| 0.85 | 0.7145 | 1 | 2 | | |
| 0.20 | 0.2485 | 8 | 8 | | |
| 0.24 | 0.2727 | 7 | 7 | | |
| 0.78 | 0.6873 | 2 | 3 | | |
| 0.65 | 0.4591 | 4 | 5 | | |
| 0.50 | 0.4214 | 5 | 6 | | |
| 0.75 | 0.8885 | 3 | 1 | | |
| 0.15 | 0.4622 | 10 | 4 | | |

Group 2

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.70 | 0.6174 | 2 | 2 | 0.7658 | 0.8625 |
| 0.55 | 0.3097 | 4 | 7 | | |
| 0.75 | 0.6521 | 1 | 1 | | |
| 0.30 | 0.2997 | 9 | 8 | | |
| 0.32 | 0.1595 | 8 | 10 | | |
| 0.40 | 0.3770 | 7 | 4 | | |
| 0.30 | 0.1599 | 9 | 9 | | |
| 0.44 | 0.3865 | 6 | 3 | | |
| 0.50 | 0.3219 | 5 | 6 | | |
| 0.60 | 0.3534 | 3 | 5 | | |

For the validation we see that the Multiple Regression Statistics shows that the Multiple R was 0.9027. Which is high, and the $ar$, $at$, $act$, $D$ coefficients were calculated as -0.0422, -0.0256, 0.8635, and 0.3601 in table 49. From this we can calculate the predicted PPQ and use it to find the Spearman Correlation for each group. Group 1 had a Spearman Correlation of 0.8409 and Group 2 had a Spearman Correlation of 0.7468 in table 50.

For the validation we see that the Multiple Regression Statistics shows that the Multiple R was 0.7265. Which is high, and the $ar$, $at$, $act$, $D$ coefficients were calculated as 0.0192, -0.0871, 0.3993, and 0.6936 in table 51. From this we can calculate the predicted PPQ and use it to find the Spearman Correlation for each group. Group 1 had a Spearman Correlation of 0.6000 and Group 2 had a Spearman Correlation of 0.9273 in table 52.

For the validation we see that the Multiple Regression Statistics shows that the Multiple R was 0.9237 table 53. Which is high, and the $ar$, $at$, $act$, $D$ coefficients were calculated as -0.0042, -0.1155, 1.1326, and 0.5083 table 54. From this we can calculate the predicted PPQ and use it to find the Spearman Correlation for each group. Group 1 had a Spearman Correlation of 0.9394 and Group 2 had a Spearman Correlation of 0.9152.

*Table 49. Regression Statistics For Validation Of Spearman Correlation For Group 1 Of Data Set #3.*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.9027 |
| R Square | 0.8148 |
| Adjusted R Square | 0.7222 |
| Standard Error | 0.0844 |
| Observations | 10 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.1882 | 0.0627 | 8.7983 | 0.0129 |
| Residual | 6 | 0.0428 | 0.0071 | | |
| Total | 9 | 0.2310 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.3601 | 0.0843 | 4.2694 | 0.0053 | 0.1537 | 0.5665 | 0.1537 | 0.5665 |
| X Variable 1 | -0.0422 | 0.2052 | -0.2055 | 0.8440 | -0.5442 | 0.4598 | -0.5442 | 0.4598 |
| X Variable 2 | -0.0256 | 0.0658 | -0.3896 | 0.7103 | -0.1867 | 0.1354 | -0.1867 | 0.1354 |
| X Variable 3 | 0.8635 | 0.1797 | 4.8041 | 0.0030 | 0.4237 | 1.3033 | 0.4237 | 1.3033 |

*Table 50. Validation Of PPQ By Spearman Correlation For Data Set #3.*

Group 1

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.35 | 0.4517 | 8 | 7 | 0.8409 | 0.9027 |
| 0.55 | 0.6314 | 4 | 3 | | |
| 0.60 | 0.6602 | 2 | 2 | | |
| 0.60 | 0.5314 | 2 | 5 | | |
| 0.85 | 0.7792 | 1 | 1 | | |
| 0.55 | 0.5651 | 4 | 4 | | |
| 0.35 | 0.3326 | 8 | 9 | | |
| 0.50 | 0.4843 | 7 | 6 | | |
| 0.55 | 0.4437 | 4 | 8 | | |
| 0.30 | 0.3203 | 10 | 10 | | |

Group 2

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.60 | 0.4501 | 5 | 8 | 0.7468 | 0.6640 |
| 0.70 | 0.6964 | 1 | 1 | | |
| 0.60 | 0.5603 | 5 | 2 | | |
| 0.30 | 0.4211 | 9 | 9 | | |
| 0.65 | 0.4738 | 3 | 5 | | |
| 0.55 | 0.4514 | 7 | 7 | | |
| 0.65 | 0.5508 | 3 | 3 | | |
| 0.70 | 0.5441 | 1 | 4 | | |
| 0.40 | 0.2896 | 8 | 10 | | |
| 0.30 | 0.4616 | 9 | 6 | | |

*Table 51. Regression Statistics For Validation Of Spearman Correlation For Group 1 Of Data Set #4.*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.7265 |
| R Square | 0.5278 |
| Adjusted R Square | 0.2917 |
| Standard Error | 0.0781 |
| Observations | 10 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.0409 | 0.0136 | 2.2355 | 0.1847 |
| Residual | 6 | 0.0366 | 0.0061 | | |
| Total | 9 | 0.0776 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.6936 | 0.1244 | 5.5748 | 0.0014 | 0.3892 | 0.9981 | 0.3892 | 0.9981 |
| X Variable 1 | 0.0192 | 0.1560 | 0.1231 | 0.9061 | -0.3625 | 0.4009 | -0.3625 | 0.4009 |
| X Variable 2 | -0.0871 | 0.0583 | -1.4952 | 0.1855 | -0.2296 | 0.0554 | -0.2296 | 0.0554 |
| X Variable 3 | 0.3993 | 0.4563 | 0.8750 | 0.4152 | -0.7172 | 1.5157 | -0.7172 | 1.5157 |

*Table 52. Validation Of PPQ By Spearman Correlation For Data Set #4.*

Group 1

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.51 | 0.5947 | 7 | 3 | 0.6000 | 0.7265 |
| 0.57 | 0.5279 | 3 | 5 | | |
| 0.66 | 0.6550 | 2 | 1 | | |
| 0.42 | 0.4709 | 9 | 8 | | |
| 0.52 | 0.4698 | 6 | 10 | | |
| 0.41 | 0.5277 | 10 | 6 | | |
| 0.55 | 0.5368 | 5 | 4 | | |
| 0.56 | 0.5133 | 4 | 7 | | |
| 0.51 | 0.4699 | 8 | 9 | | |
| 0.70 | 0.6353 | 1 | 2 | | |

Group 2

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.45 | 0.4677 | 10 | 10 | 0.9273 | 0.8883 |
| 0.86 | 0.6467 | 3 | 4 | | |
| 0.75 | 0.5480 | 5 | 7 | | |
| 0.91 | 0.6948 | 2 | 1 | | |
| 0.61 | 0.6129 | 6 | 5 | | |
| 0.58 | 0.5727 | 7 | 6 | | |
| 0.57 | 0.5450 | 9 | 8 | | |
| 0.81 | 0.6508 | 4 | 3 | | |
| 0.57 | 0.5201 | 8 | 9 | | |
| 0.91 | 0.6701 | 1 | 2 | | |

*Table 53. Regression Statistics For Validation Of Spearman Correlation For Group 1 Of Data Set #5.*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.9237 |
| R Square | 0.8533 |
| Adjusted R Square | 0.7799 |
| Standard Error | 0.0697 |
| Observations | 10 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 3 | 0.1692 | 0.0564 | 11.6286 | 0.0065 |
| Residual | 6 | 0.0291 | 0.0049 | | |
| Total | 9 | 0.1983 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.5083 | 0.0854 | 5.9500 | 0.0010 | 0.2993 | 0.7173 | 0.2993 | 0.7173 |
| X Variable 1 | -0.0042 | 0.1425 | -0.0296 | 0.9774 | -0.3528 | 0.3444 | -0.3528 | 0.3444 |
| X Variable 2 | -0.1155 | 0.0580 | -1.9923 | 0.0934 | -0.2575 | 0.0264 | -0.2575 | 0.0264 |
| X Variable 3 | 1.1326 | 0.2030 | 5.5794 | 0.0014 | 0.6359 | 1.6293 | 0.6359 | 1.6293 |

*Table 54. Validation Of PPQ By Spearman Correlation For Data Set #5.*

Group 1

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.45 | 0.4597 | 6 | 6 | 0.9394 | 0.9237 |
| 0.30 | 0.3643 | 9 | 8 | | |
| 0.26 | 0.3019 | 10 | 9 | | |
| 0.57 | 0.4807 | 3 | 4 | | |
| 0.73 | 0.6487 | 1 | 2 | | |
| 0.33 | 0.2724 | 8 | 10 | | |
| 0.50 | 0.5164 | 4 | 3 | | |
| 0.43 | 0.4363 | 7 | 7 | | |
| 0.46 | 0.4781 | 5 | 5 | | |
| 0.63 | 0.7053 | 2 | 1 | | |

Group 2

| Expert PPQ | Predicted PPQ | Rank of Expert PPQ | Rank of Predicted PPQ | Spearman Correlation | Pearson Correlation |
|---|---|---|---|---|---|
| 0.19 | 0.1877 | 10 | 10 | 0.9152 | 0.8961 |
| 0.38 | 0.4611 | 7 | 7 | | |
| 0.29 | 0.3317 | 9 | 9 | | |
| 0.90 | 0.8820 | 1 | 1 | | |
| 0.74 | 0.6272 | 3 | 4 | | |
| 0.69 | 0.4834 | 4 | 6 | | |
| 0.62 | 0.5024 | 5 | 5 | | |
| 0.34 | 0.4010 | 8 | 8 | | |
| 0.54 | 0.6324 | 6 | 3 | | |
| 0.82 | 0.6473 | 2 | 2 | | |

# Chapter 5

## Conclusions and Recommendations

The approach used to measure efficiency and effectiveness for research projects in real time has been validated by the methodology. The methodology has also validated that the efficiency and effectiveness are not dependent on budget and the field of research.

Measuring past Project Performance Quality has also been validated by the methodology. The methodology has confirmed that the past Project Performance Quality is independent of budget and the field of research.

Using these mathematical models stated in the methodology together can establish a working Performance Management System for institutions to measure their research performance. To name this Performance Management System the terminology will be referred to as the Sokolov Performance Management System or (SPMS). Institutions that conduct research can now implement the SPMS into their Key Performance Management Systems to track how their researchers are conducting their work.

The future recommendations for this research are to test the SPMS with real data to show that the concept will work in the real world. The second recommendation of future work for this research would be cluster all scientific fields into subgroups that would share the similar functions and regression models for evaluation of efficiency and effectiveness. The third recommendation for future work of this research would be to identify more parameters that can be integrated within either the PPQ formulations or efficiency and effectiveness models. The fourth recommendation for future work on this research would be to test different number of research projects within the Groups for the validation of PPQ. Therefore, instead of dividing the Groups in to equal parts, use an integer such 8 research projects for the first Group and 12 research projects for the second Group. This will test if the PPQ coefficients will still be accurate with lower data sets.

Altogether the SPMS should be used by institutions who want to measure their performance of research no matter what their budget may be or what research field they are in. This will allow institutions to be more productive and waste less resources to track performance.

# List of References

Abrahamsson, P., Warsta, J., Siponen, M. T., & Ronkainen, J. (2003, May). New directions on Agile methods: a comparative analysis. In Software Engineering, 2003. Proceedings. 25th International Conference on (pp. 244-254). IEEE.

Ambe, I. M. (2010). Agile supply chain: strategy for competitive advantage. Journal of Global Strategic Management, 7, 5-17.

Anderson, D. J. (2003). Agile management for software engineering: Applying the theory of constraints for business results. Prentice Hall Professional.

Baramichai, M., Zimmers Jr, E. W., & Marangos, C. A. (2007). Agile supply chain transformation matrix: an integrated tool for creating an Agile enterprise. Supply Chain Management: An International Journal, 12(5), 334-348.

Basahel, A. (2014). Adopting SCRUM Agile Project Management for Managing Academic Institutions. Our Major Indexing at International Level, 4852, 795.

Beck, K. (2000). Extreme programming explained: embrace change. addison-wesley professional.

Beck, K., Beedle, M., Van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., ... & Kern, J. (2001). Manifesto for Agile software development.

Boehm, B., & Turner, R. (2005). Management challenges to implementing Agile processes in traditional development organizations. IEEE software, 22(5), 30-39.

Booth, R. (1996). Agile manufacturing [management]. Engineering Management Journal, 6(2), 105-112.

BüyüKözkan, G., Derelİ, T., & Baykasoğlu, A. (2004). A survey on the methods and tools of concurrent new product development and Agile manufacturing. Journal of Intelligent Manufacturing, 15(6), 731-751.

Cao, L., & Ramesh, B. (2008). Agile requirements engineering practices: An empirical study. IEEE software, 25(1), 60-67.

Carbon, R., Lindvall, M., Muthig, D., & Costa, P. (2006, August). Integrating product line engineering and Agile methods: flexible design up-front vs. incremental design. In Workshop on Agile Product Line Engineering.

Cervone, H. F. (2011). Understanding Agile project management methods using Scrum. OCLC Systems & Services: International digital library perspectives, 27(1), 18-22.

Cho, H., Jung, M., & Kim, M. (1996). Enabling technologies of Agile manufacturing and its related activities in Korea. Computers & Industrial Engineering, 30(3), 323-334.

Chow, T., & Cao, D. B. (2008). A survey study of critical success factors in Agile software projects. Journal of Systems and Software, 81(6), 961-971.

Christopher, M. (2000). The Agile supply chain: competing in volatile markets. Industrial marketing management, 29(1), 37-44.

Christopher, M., & Towill, D. R. (2000). Supply chain migration from lean and functional to Agile and customized. Supply Chain Management: An International Journal, 5(4), 206-213.

Christopher, M., & Towill, D. R. (2002). Developing market specific supply chain strategies. The international journal of logistics management, 13(1), 1-14.

Cobb, C. G. (2015). The Project Manager's Guide to Mastering Agile: Principles and Practices for an Adaptive Approach. John Wiley & Sons.

Cohn, M. (2010). Succeeding with Agile: software development using Scrum. Saddle River: Pearson Education.

Doherty, I. (2010). Agile project management for e-learning developments. Journal of Distance Education (Online), 24(1), 91.

Duguay, C. R., Landry, S., & Pasin, F. (1997). From mass production to flexible/Agile production. International Journal of Operations & Production Management, 17(12), 1183-1195.

Dutoit, A. H., McCall, R., Mistrík, I., & Paech, B. (Eds.). (2007). Rationale management in software engineering. Springer Science & Business Media.

Eberlein, A., & Leite, J. C. S. P. (2002, September). Agile requirements definition: A view from requirements engineering. In Proceedings of the International Workshop on Time-Constrained Requirements Engineering (TCRE'02) (pp. 4-8).

Fernandez, D. J., & Fernandez, J. D. (2008). Agile project management—agilism versus traditional approaches. Journal of Computer Information Systems, 49(2), 10-17.

Guisinger, A., & Ghorashi, B. (2004). Agile manufacturing practices in the specialty chemical industry: An overview of the trends and results of a specific case study. International Journal of Operations & Production Management, 24(6), 625-635.

Gunasekaran, A. (2001). Agile Manufacturing: The 21st Century Competitive Strategy: The 21st Century Competitive Strategy. Amsterdam: Elsevier. pp. 1-20

Gunther, S., Haupt, M., & Splieth, M. (2010, August). Agile engineering of internal domain-specific languages with dynamic programming languages. In Software Engineering Advances (ICSEA), 2010 Fifth International Conference on (pp. 162-168). IEEE.

Hansenne, R., & Hibner, A. (2011). Overcoming Organizational Challenges related to Agile Project Management Adoption.

Hass, K. B. (2007). The blending of traditional and Agile project management. PM world today, 9(5), 1-8.

Hazzan, O., & Dubinsky, Y. (2009). Agile software engineering. Springer Science & Business Media.

Highsmith, J. (2009). Agile project management: creating innovative products. Saddle River: Pearson Education.

Hope, K. L., & Amdahl, E. (2011). Configuring designers? Using one Agile project management methodology to achieve user participation. New Technology, Work and Employment, 26(1), 54-67.

Hormozi, A. M. (2001). Agile manufacturing: the next logical step. Benchmarking: An International Journal, 8(2), 132-143.

Hu, Z. G., Yuan, Q., & Zhang, X. (2009, July). Research on Agile project management with scrum method. IITA International Conference on Services Science, Management and Engineering, 2009. SSME'09, pp. 26-29.

Jalali, S., & Wohlin, C. (2010). Agile practices in global software engineering-A systematic map. In 2010 5th IEEE International Conference on Global Software Engineering (pp. 45-54). IEEE.

Japikse, D., & Olsofka, F. A. (1993). Agile engineering accelerates design. Mechanical engineering, 115(11), 60.

Johansson, G. (2012). Agile project management in the construction industry-An inquiry of the opportunities in construction projects. Department of Real Estate and Construction Management, KTH Architecture and the Built Environment.

King, G. R. (2014). Using the Agile development methodology and applying best practice project management processes. NAVAL POSTGRADUATE SCHOOL MONTEREY CA.

Larman, C., & Vodde, B. (2010). Practices for scaling lean & Agile development: large, multisite, and offshore product development with large-scale scrum. Pearson Education.

Layman, L., Williams, L., & Cunningham, L. (2004, June). Exploring extreme programming in context: an industrial case study. In Agile Development Conference, 2004 (pp. 32-41). IEEE.

Layman, L., Williams, L., & Cunningham, L. (2006). Motivations and measurements in an Agile case study. Journal of Systems Architecture, 52(11), 654-667.

Lee, S., & Yong, H. S. (2010). Distributed Agile: project management in a global environment. Empirical Software Engineering, 15(2), 204-217.

Lee, W. B., & Lau, H. C. W. (1999). Factory on demand: the shaping of an Agile production network. International Journal of Agile Management Systems, 1(2), 83-87.

Mähring, M., & Keil, M. (2008). Information technology project escalation: A process model. Decision Sciences, 39(2), 239-272.

Marambe, A. (2014). The Challenges of Offshore Agile Software Development in Sri Lanka and Effects on the Project Outcome.

Marchese, F. T. (2006, July). The Making of Trigger and the Agile Engineering of Artist-Scientist Collaboration. In Tenth International Conference on Information Visualization (IV'06) (pp. 839-844). IEEE.

Marchewka, J. T. (2014). Information technology project management. Hoboken: John Wiley & Sons. pp. 42-46.

Mason-Jones, R., Naylor, B., & Towill, D. R. (2000). Engineering the Agile supply chain. International Journal of Agile Management Systems, 2(1), 54-61.

Maurer, F., & Martel, S. (2002). Extreme programming: Rapid development for web-based applications. IEEE Internet computing, 6(1), 86.

Misra, S. C., Kumar, V., & Kumar, U. (2009). Identifying some important success factors in adopting Agile software development practices. Journal of Systems and Software, 82(11), 1869-1890.

Moe, N. B., Dingsøyr, T., & Dybå, T. (2010). A teamwork model for understanding an Agile team: A case study of a Scrum project. Information and Software Technology, 52(5), 480-491.

Nagel, R. N., & Bhargava, P. (1994). Agility: the ultimate requirement for world-class manufacturing performance. National Productivity Review, 13(3), 331-340.

Naylor, J. B., Naim, M. M., & Berry, D. (1999). Leagility: integrating the lean and Agile manufacturing paradigms in the total supply chain. International Journal of production economics, 62(1), 107-118.

O'Sheedy, D. G. (2012). A study of Agile project management methods used for IT implementation projects in small and medium-sized enterprises.

Otley, D. (1999). Performance management: a framework for management control systems research. Management accounting research, 10(4), 363-382.

Paetsch, F., Eberlein, A., & Maurer, F. (2003, June). Requirements Engineering and Agile Software Development. In WETICE (Vol. 3, p. 308).

Paige, R. F., Charalambous, R., Ge, X., & Brooke, P. J. (2008, September). Towards Agile engineering of high-integrity systems. In International Conference on Computer Safety, Reliability, and Security (pp. 30-43). Springer Berlin Heidelberg.

Paykina, E., & Zhou, L. (2012). What characteristics are suited to help choosing traditional or Agile project management methods for software development projects?

Pikkarainen, M., Haikara, J., Salo, O., Abrahamsson, P., & Still, J. (2008). The impact of Agile practices on communication in software development. Empirical Software Engineering, 13(3), 303-337.

Power, D. J., Sohal, A. S., & Rahman, S. U. (2001). Critical success factors in Agile supply chain management-An empirical study. International journal of physical distribution & logistics management, 31(4), 247-265.

Procter, R., Rouncefield, M., Poschen, M., Lin, Y., & Voss, A. (2011). Agile project management: A case study of a virtual research environment development project. Computer Supported Cooperative Work (CSCW), 20(3), 197-225.

Rahimian, V., & Ramsin, R. (2008, June). Designing an Agile methodology for mobile software development: A hybrid method engineering approach. In 2008 Second International Conference on Research Challenges in Information Science (pp. 337-342). IEEE.

Ramesh, B., Cao, L., & Baskerville, R. (2010). Agile requirements engineering practices and challenges: an empirical study. Information Systems Journal, 20(5), 449-480.

Razzak, M. A., & Ahmed, R. (2013, August). Spatial knowledge creation and sharing activities in a distributed Agile project. In 2013 IEEE 8th International Conference on Global Software Engineering Workshops (pp. 24-30). IEEE.

Reifer, D. J. (2002, August). How to get the most out of extreme programming/Agile methods. In Conference on Extreme Programming and Agile Methods (pp. 185-196). Springer Berlin Heidelberg.

Rico, D. F., & Sayani, H. H. (2009, August). Use of Agile methods in software engineering education. In Agile Conference, 2009. AGILE'09. (pp. 174-179). IEEE.

Rigby, C., Day, M., Forrester, P., & Burnett, J. (2000). Agile supply: rethinking systems thinking, systems practice. International Journal of Agile Management Systems, 2(3), 178-186.

Sahin, F. (2000). Manufacturing competitiveness: Different systems to achieve the same results. Production and Inventory Management Journal, 41(1), 56.

Schwaber, K. (2004). Agile project management with Scrum. Microsoft press.

Schwalbe, K. (2015). Information technology project management. Boston: Cengage Learning. pp. 87-127.

Shen, H. L., & Zhang, Y. (2011). An Exploratory Study of Organizational Adaptation to Agile Project Management: An Investigation of IT Industry in China.

Sidky, A., & Smith, G. (2009). Becoming Agile in an imperfect World.

Sidky, A., Arthur, J., & Bohner, S. (2007). A disciplined approach to adopting Agile practices: the Agile adoption framework. Innovations in systems and software engineering, 3(3), 203-216.

Sutherland, J. (2001). Agile can scale: Inventing and reinventing scrum in five companies. Cutter IT journal, 14(12), 5-11.

The Project Management Institute, PMI Agile Certified Practitioner (PMI-ACP) (Accessed: May 24, 2016).

Turner, R. (2007). Toward Agile systems engineering processes. CrossTalk, 20(4), 11-15.

Uikey, N., & Suman, U. (2012, September). An empirical study to design an effective Agile project management framework. In Proceedings of the CUBE International Information Technology Conference (pp. 385-390). ACM.

Van Assen, M. F. (2000). Agile-based competence management: the relation between Agile manufacturing and time-based competence management. International Journal of Agile Management Systems, 2(2), 142-155.

Vázquez-Bustelo, D., & Avella, L. (2006). Agile manufacturing: Industrial case studies in Spain. Technovation, 26(10), 1147-1161.

Vazquez-Bustelo, D., Avella, L., & Fernández, E. (2007). Agility drivers, enablers and outcomes: empirical test of an integrated Agile manufacturing model. International Journal of Operations & Production Management,27(12), 1303-1332.

Vernadat, F. B. (1999). Research agenda for Agile manufacturing. International Journal of Agile Management Systems, 1(1), 37-40.

Version One Inc., “8th Annual State of Agile Survey,” VersionOne.com (2014).

Vlaanderen, K., Jansen, S., Brinkkemper, S., & Jaspers, E. (2011). The Agile requirements refinery: Applying SCRUM principles to software product management. Information and software technology, 53(1), 58-70.

Wysocki, R. K. (2011). Effective project management: traditional, Agile, extreme. Hoboken: John Wiley & Sons.

Yadav, N., & Sagar, M. (2013). Performance measurement and management frameworks. Business Process Management Journal, 19(6), 947–971. doi:10.1108/bpmj-01-2013-0003.

Yusuf, Y. Y., Gunasekaran, A., Adeleye, E. O., & Sivayoganathan, K. (2004). Agile supply chain capabilities: Determinants of competitive objectives. European Journal of Operational Research, 159(2), 379-392.

# Appendix

*Table 55. Efficiency Data For Mini Case Study For f(x)=1 If x≤1 And f(x)= 1/x For x>1.*

| **Task** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ci=** | 1500 | 300 | 300 | 80 | 800 | 300 | 3000 | 1500 | 2000 | 1400 | 1800 | 1200 | 800 | 900 |
| **ti=** | 5 | 3 | 2 | 2 | 2 | 3 | 10 | 7 | 10 | 10 | 5 | 4 | 3 | 4 |
| **Vi=** | 3 | 6 | 3 | 5 | 3 | 3 | 5 | 1 | 4 | 20 | 8 | 3 | 15 | 2 |
| **Geom. Dist. =** | 0.333333 | 0.166667 | 0.333333 | 0.2 | 0.333333 | 0.333333 | 0.2 | 1 | 0.25 | 0.05 | 0.125 | 0.333333 | 0.066667 | 0.5 |
| **Ki=** | 2 | 7 | 3 | 4 | 4 | 2 | 6 | 1 | 3 | 30 | 7 | 4 | 12 | 2 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ci*ti =** | 7500 | 900 | 600 | 160 | 1600 | 900 | 30000 | 10500 | 20000 | 14000 | 9000 | 4800 | 2400 | 3600 |
| **Ki/Vi =** | 0.666667 | 1.166667 | 1 | 0.8 | 1.333333 | 0.666667 | 1.2 | 1 | 0.75 | 1.5 | 0.875 | 1.333333 | 0.8 | 1 |
| **f(x)=** | 1.5 | 0.857143 | 1 | 1.25 | 0.75 | 1.5 | 0.833333 | 1 | 1.333333 | 0.666667 | 1.142857 | 0.75 | 1.25 | 1 |
| **adj f(x)=** | 1 | 0.857143 | 1 | 1 | 0.75 | 1 | 0.833333 | 1 | 1 | 0.666667 | 1 | 0.75 | 1 | 1 |
| **Ci*ti *f(x) =** | 7500 | 771.4286 | 600 | 160 | 1200 | 900 | 25000 | 10500 | 20000 | 9333.333 | 9000 | 3600 | 2400 | 3600 |
| **Sum =** | 7500 | 8271.429 | 8871.429 | 9031.429 | 10231.43 | 11131.43 | 36131.43 | 46631.43 | 66631.43 | 75964.76 | 84964.76 | 88564.76 | 90964.76 | 94564.76 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ci*ti =** | 7500 | 900 | 600 | 160 | 1600 | 900 | 30000 | 10500 | 20000 | 14000 | 9000 | 4800 | 2400 | 3600 |
| **1/Vi=** | 0.333333 | 0.166667 | 0.333333 | 0.2 | 0.333333 | 0.333333 | 0.2 | 1 | 0.25 | 0.05 | 0.125 | 0.333333 | 0.066667 | 0.5 |
| **f(x)=** | 3 | 6 | 3 | 5 | 3 | 3 | 5 | 1 | 4 | 20 | 8 | 3 | 15 | 2 |
| **adj f(x)=** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

*Table 55. Continued.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ci*ti*f(x)=** | 7500 | 900 | 600 | 160 | 1600 | 900 | 30000 | 10500 | 20000 | 14000 | 9000 | 4800 | 2400 | 3600 |
| **Sum=** | 7500 | 8400 | 9000 | 9160 | 10760 | 11660 | 41660 | 52160 | 72160 | 86160 | 95160 | 99960 | 102360 | 105960 |
| **NEy=** | 100% | 98% | 99% | 99% | 95% | 95% | 87% | 89% | 92% | 88% | 89% | 89% | 89% | 89% |
| **Costs** | 3000 | 5100 | 6000 | 6320 | 9520 | 10120 | 28120 | 29620 | 35620 | 77620 | 90220 | 95020 | 104620 | 106420 |
| **Time** | 5 | 8 | 10 | 12 | 14 | 17 | 27 | 34 | 44 | 54 | 59 | 63 | 66 | 70 |

*Table 56. Efficiency Data For Mini Case Study For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ci=** | 1500 | 300 | 300 | 80 | 800 | 300 | 3000 | 1500 | 2000 | 1400 | 1800 | 1200 | 800 | 900 |
| **ti=** | 5 | 3 | 2 | 2 | 2 | 3 | 10 | 7 | 10 | 10 | 5 | 4 | 3 | 4 |
| **Vi=** | 3 | 6 | 3 | 5 | 3 | 3 | 5 | 1 | 4 | 20 | 8 | 3 | 15 | 2 |
| **Geo. Dist.=** | 0.333333 | 0.166667 | 0.333333 | 0.2 | 0.333333 | 0.333333 | 0.2 | 1 | 0.25 | 0.05 | 0.125 | 0.333333 | 0.066667 | 0.5 |
| **Ki=** | 2 | 7 | 3 | 4 | 4 | 2 | 6 | 1 | 3 | 30 | 7 | 4 | 12 | 2 |
| **Ci*ti=** | 7500 | 900 | 600 | 160 | 1600 | 900 | 30000 | 10500 | 20000 | 14000 | 9000 | 4800 | 2400 | 3600 |
| **Ki/Vi=** | 0.666667 | 1.166667 | 1 | 0.8 | 1.333333 | 0.666667 | 1.2 | 1 | 0.75 | 1.5 | 0.875 | 1.333333 | 0.8 | 1 |
| **f(x)=** | 1.442695 | 1.293343 | 1.442695 | 1.442695 | 1.180223 | 1.442695 | 1.268299 | 1.442695 | 1.442695 | 1.091357 | 1.442695 | 1.180223 | 1.442695 | 1.442695 |

*Table 56. Continued.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ci*ti*f(x)= | 10820.21 | 1164.009 | 865.617 | 230.8312 | 1888.356 | 1298.426 | 38048.98 | 15148.3 | 28853.9 | 15278.99 | 12984.26 | 5665.068 | 3462.468 | 5193.702 |
| Sum= | 10820.21 | 11984.22 | 12849.84 | 13080.67 | 14969.03 | 16267.45 | 54316.43 | 69464.73 | 98318.63 | 113597.6 | 126581.9 | 132246.9 | 135709.4 | 140903.1 |

*Table 57. Efficiency Data For Mini Case Study For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1.*

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ci*ti= | 7500 | 900 | 600 | 160 | 1600 | 900 | 30000 | 10500 | 20000 | 14000 | 9000 | 4800 | 2400 | 3600 |
| 1/Vi= | 0.333333 | 0.166667 | 0.333333 | 0.2 | 0.333333 | 0.333333 | 0.2 | 1 | 0.25 | 0.05 | 0.125 | 0.333333 | 0.066667 | 0.5 |
| f(x)= | 1.442695 | 1.442695 | 1.442695 | 1.442695 | 1.442695 | 1.442695 | 1.442695 | 1 | 1.442695 | 1.442695 | 1.442695 | 1.442695 | 1.442695 | 1.442695 |
| Ci*ti*f(x)= | 10820.21 | 1298.426 | 865.617 | 230.8312 | 2308.312 | 1298.426 | 43280.85 | 10500 | 28853.9 | 20197.73 | 12984.26 | 6924.936 | 3462.468 | 5193.702 |
| Sum= | 10820.21 | 12118.64 | 12984.26 | 13215.09 | 15523.4 | 16821.82 | 60102.68 | 70602.68 | 99456.58 | 119654.3 | 132638.6 | 139563.5 | 143026 | 148219.7 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NEy= | 100% | 99% | 99% | 99% | 96% | 97% | 90% | 98% | 99% | 95% | 95% | 95% | 95% | 95% |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Costs | 3000 | 5100 | 6000 | 6320 | 9520 | 10120 | 28120 | 29620 | 35620 | 77620 | 90220 | 95020 | 104620 | 106420 |
| Time | 5 | 8 | 10 | 12 | 14 | 17 | 27 | 34 | 44 | 54 | 59 | 63 | 66 | 70 |

*Table 58. Efficiency Data For Mini Case Study For f(x)=1 If x≤0 And f(x)=* $e^{-\lambda x}$ *For x>0 Where λ Is Defined As A Parameter From The Project Manager.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ci= | 1500 | 300 | 300 | 80 | 800 | 300 | 3000 | 1500 | 2000 | 1400 | 1800 | 1200 | 800 | 900 |
| ti= | 5 | 3 | 2 | 2 | 2 | 3 | 10 | 7 | 10 | 10 | 5 | 4 | 3 | 4 |
| Vi= | 3 | 6 | 3 | 5 | 3 | 3 | 5 | 1 | 4 | 20 | 8 | 3 | 15 | 2 |
| Geo. Dist. = | 0.333333 | 0.166667 | 0.333333 | 0.2 | 0.333333 | 0.333333 | 0.2 | 1 | 0.25 | 0.05 | 0.125 | 0.333333 | 0.066667 | 0.5 |
| Ki= | 2 | 7 | 3 | 4 | 4 | 2 | 6 | 1 | 3 | 30 | 7 | 4 | 12 | 2 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| λ= | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Ci*ti= | 7500 | 900 | 600 | 160 | 1600 | 900 | 30000 | 10500 | 20000 | 14000 | 9000 | 4800 | 2400 | 3600 |
| Ki/Vi= | 0.666667 | 1.166667 | 1 | 0.8 | 1.333333 | 0.666667 | 1.2 | 1 | 0.75 | 1.5 | 0.875 | 1.333333 | 0.8 | 1 |
| f(x) = | 0.606531 | 0.558035 | 0.606531 | 0.606531 | 0.513417 | 0.606531 | 0.548812 | 0.606531 | 0.606531 | 0.472367 | 0.606531 | 0.513417 | 0.606531 | 0.60653066 |
| Ci*ti*f(x)= | 4548.98 | 502.2316 | 363.9184 | 97.04491 | 821.4674 | 545.8776 | 16464.35 | 6368.572 | 12130.61 | 6613.132 | 5458.776 | 2464.402 | 1455.674 | 2183.510375 |
| Sum = | 4548.98 | 5051.212 | 5415.13 | 5512.175 | 6333.642 | 6879.52 | 23343.87 | 29712.44 | 41843.05 | 48456.19 | 53914.96 | 56379.36 | 57835.04 | 60018.54787 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ci*ti= | 7500 | 900 | 600 | 160 | 1600 | 900 | 30000 | 10500 | 20000 | 14000 | 9000 | 4800 | 2400 | 3600 |
| 1/Vi = | 0.333333 | 0.166667 | 0.333333 | 0.2 | 0.333333 | 0.333333 | 0.2 | 1 | 0.25 | 0.05 | 0.125 | 0.333333 | 0.066667 | 0.5 |
| f(x) = | 0.606531 | 0.606531 | 0.606531 | 0.606531 | 0.606531 | 0.606531 | 0.606531 | 0.606531 | 0.606531 | 0.606531 | 0.606531 | 0.606531 | 0.606531 | 0.60653066 |
| Ci*ti*f(x)= | 4548.98 | 545.8776 | 363.9184 | 97.04491 | 970.4491 | 545.8776 | 18195.92 | 6368.572 | 12130.61 | 8491.429 | 5458.776 | 2911.347 | 1455.674 | 2183.510375 |

*Table 58. Continued.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sum= | 4548.98 | 5094.858 | 5458.776 | 5555.821 | 6526.27 | 7072.147 | 25268.07 | 31636.64 | 43767.25 | 52258.68 | 57717.46 | 60628.8 | 62084.48 | 64267.9887 |
| NEy= | 100% | 99% | 99% | 99% | 97% | 97% | 92% | 94% | 96% | 93% | 93% | 93% | 93% | 93% |
| **Costs** | 3000 | 5100 | 6000 | 6320 | 9520 | 10120 | 28120 | 29620 | 35620 | 77620 | 90220 | 95020 | 104620 | 106420 |
| **Time** | 5 | 8 | 10 | 12 | 14 | 17 | 27 | 34 | 44 | 54 | 59 | 63 | 66 | 70 |

*Table 59. Effectiveness Data For Mini Case Study For f(x)=1 If x≤1 And f(x)= 1/x For x>1.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ci= | 1500 | 300 | 300 | 80 | 800 | 300 | 3000 | 1500 | 2000 | 1400 | 1800 | 1200 | 800 | 900 |
| Vi= | 3 | 6 | 3 | 5 | 3 | 3 | 5 | 1 | 4 | 20 | 8 | 3 | 15 | 2 |
| Geo. Dist. = | 0.333333 | 0.166667 | 0.333333 | 0.2 | 0.333333 | 0.333333 | 0.2 | 1 | 0.25 | 0.05 | 0.125 | 0.333333 | 0.066667 | 0.5 |
| Ki= | 2 | 7 | 3 | 4 | 4 | 2 | 6 | 1 | 3 | 30 | 7 | 4 | 12 | 2 |
| 1/Ci = | 0.000667 | 0.003333 | 0.003333 | 0.0125 | 0.00125 | 0.003333 | 0.000333 | 0.000667 | 0.0005 | 0.000714 | 0.000556 | 0.000833 | 0.00125 | 0.001111 |
| Ki/Vi= | 0.666667 | 1.166667 | 1 | 0.8 | 1.333333 | 0.666667 | 1.2 | 1 | 0.75 | 1.5 | 0.875 | 1.333333 | 0.8 | 1 |
| f(x) = | 1.5 | 0.857143 | 1 | 1.25 | 0.75 | 1.5 | 0.833333 | 1 | 1.333333 | 0.666667 | 1.142857 | 0.75 | 1.25 | 1 |

*Table 59. Continued.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| adj f(x) = | 1 | 0.857143 | 1 | 1 | 0.75 | 1 | 0.833333 | 1 | 1 | 0.666667 | 1 | 0.75 | 1 | 1 |
| 1/Ci *f(x )= | 0.000667 | 0.002857 | 0.003333 | 0.00125 | 0.000938 | 0.003333 | 0.000278 | 0.000667 | 0.0005 | 0.000476 | 0.000556 | 0.000625 | 0.00125 | 0.001111 |
| sum = | 0.000667 | 0.003524 | 0.006857 | 0.019357 | 0.020295 | 0.023628 | 0.023906 | 0.024572 | 0.025072 | 0.025549 | 0.026104 | 0.026729 | 0.027979 | 0.02909 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/Ci = | 0.000667 | 0.003333 | 0.003333 | 0.00125 | 0.00125 | 0.003333 | 0.000333 | 0.000667 | 0.0005 | 0.000714 | 0.000556 | 0.000833 | 0.00125 | 0.001111 |
| f/Ci = | 0.000667 | 0.003333 | 0.003333 | 0.00125 | 0.00125 | 0.003333 | 0.000333 | 0.000667 | 0.0005 | 0.000714 | 0.000556 | 0.000833 | 0.00125 | 0.001111 |
| sum = | 0.000667 | 0.004 | 0.007333 | 0.019833 | 0.021083 | 0.024417 | 0.02475 | 0.025417 | 0.025917 | 0.026631 | 0.027187 | 0.02802 | 0.02927 | 0.030381 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NEs = | 100% | 88% | 94% | 98% | 96% | 97% | 97% | 97% | 97% | 96% | 96% | 95% | 96% | 96% |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Costs | 3000 | 5100 | 6000 | 6320 | 9520 | 10120 | 28120 | 29620 | 35620 | 77620 | 90220 | 95020 | 104620 | 106420 |

*Table 60. Effectiveness Data For f(x)=1 If x≤1 And f(x)= 1/ln(x+1) For x>1 From Mini Case Study.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ci= | 1500 | 300 | 300 | 80 | 800 | 300 | 3000 | 1500 | 2000 | 1400 | 1800 | 1200 | 800 | 900 |
| Vi= | 3 | 6 | 3 | 5 | 3 | 3 | 5 | 1 | 4 | 20 | 8 | 3 | 15 | 2 |
| Geo. Dist. = | 0.333333 | 0.166667 | 0.333333 | 0.2 | 0.333333 | 0.333333 | 0.2 | 1 | 0.25 | 0.05 | 0.125 | 0.333333 | 0.066667 | 0.5 |
| Ki= | 2 | 7 | 3 | 4 | 4 | 2 | 6 | 1 | 3 | 30 | 7 | 4 | 12 | 2 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/Ci = | 0.000667 | 0.003333 | 0.003333 | 0.0125 | 0.00125 | 0.003333 | 0.000333 | 0.000667 | 0.0005 | 0.000714 | 0.000556 | 0.000833 | 0.00125 | 0.001111 |
| Ki/ Vi= | 0.666667 | 1.166667 | 1 | 0.8 | 1.333333 | 0.666667 | 1.2 | 1 | 0.75 | 1.5 | 0.875 | 1.333333 | 0.8 | 1 |
| f(x) = | 1.442695 | 1.293343 | 1.442695 | 1.442695 | 1.180223 | 1.442695 | 1.268299 | 1.442695 | 1.442695 | 1.091357 | 1.442695 | 1.180223 | 1.442695 | 1.442695 |
| 1/Ci *f(x )= | 0.000962 | 0.004311 | 0.004809 | 0.018034 | 0.001475 | 0.004809 | 0.000423 | 0.000962 | 0.000721 | 0.00078 | 0.000801 | 0.000984 | 0.001803 | 0.001603 |
| sum = | 0.000962 | 0.005273 | 0.010082 | 0.028116 | 0.029591 | 0.0344 | 0.034823 | 0.035784 | 0.036506 | 0.037285 | 0.038087 | 0.03907 | 0.040874 | 0.042477 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/Ci = | 0.000667 | 0.003333 | 0.003333 | 0.0125 | 0.00125 | 0.003333 | 0.000333 | 0.000667 | 0.0005 | 0.000714 | 0.000556 | 0.000833 | 0.00125 | 0.001111 |
| sum = | 0.000667 | 0.004 | 0.007333 | 0.019833 | 0.021083 | 0.024417 | 0.02475 | 0.025417 | 0.025917 | 0.026631 | 0.027187 | 0.02802 | 0.02927 | 0.030381 |
| f(x) = | 0.000962 | 0.005771 | 0.01058 | 0.028613 | 0.030417 | 0.035226 | 0.035707 | 0.036668 | 0.03739 | 0.03842 | 0.039222 | 0.040424 | 0.042227 | 0.04383 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NEs = | 100% | 91% | 95% | 98% | 97% | 98% | 98% | 98% | 98% | 97% | 97% | 97% | 97% | 97% |

*Table 60. Continued.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Costs | 3000 | 5100 | 6000 | 6320 | 9520 | 10120 | 28120 | 29620 | 35620 | 77620 | 90220 | 95020 | 104620 | 106420 |

*Table 61. Effectiveness Data For f(x)=1 If x≤0 And f(x)= $e^{-\lambda x}$ For x>0 Where λ Is Defined As A Parameter From The Project Manager From Mini Case Study.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ci= | 1500 | 300 | 300 | 80 | 800 | 300 | 3000 | 1500 | 2000 | 1400 | 1800 | 1200 | 800 | 900 |
| Vi= | 3 | 6 | 3 | 5 | 3 | 3 | 5 | 1 | 4 | 20 | 8 | 3 | 15 | 2 |
| Geo. Dist. = | 0.333333 | 0.166667 | 0.333333 | 0.2 | 0.333333 | 0.333333 | 0.2 | 1 | 0.25 | 0.05 | 0.125 | 0.333333 | 0.066667 | 0.5 |
| Ki= | 2 | 7 | 3 | 4 | 4 | 2 | 6 | 1 | 3 | 30 | 7 | 4 | 12 | 2 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| λ= | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 1/Ci = | 0.000667 | 0.003333 | 0.003333 | 0.0125 | 0.00125 | 0.003333 | 0.000333 | 0.000667 | 0.0005 | 0.000714 | 0.000556 | 0.000833 | 0.00125 | 0.001111 |
| Ki/ Vi= | 0.666667 | 1.166667 | 1 | 0.8 | 1.333333 | 0.666667 | 1.2 | 1 | 0.75 | 1.5 | 0.875 | 1.333333 | 0.8 | 1 |
| f(x) = | 0.606531 | 0.558035 | 0.606531 | 0.606531 | 0.513417 | 0.606531 | 0.548812 | 0.606531 | 0.606531 | 0.472367 | 0.606531 | 0.513417 | 0.606531 | 0.606531 |
| 1/Ci *f(x )= | 0.000404 | 0.00186 | 0.002022 | 0.007582 | 0.000642 | 0.002022 | 0.000183 | 0.000404 | 0.000303 | 0.000337 | 0.000337 | 0.000428 | 0.000758 | 0.000674 |
| sum = | 0.000404 | 0.002264 | 0.004286 | 0.011868 | 0.01251 | 0.014531 | 0.014714 | 0.015119 | 0.015422 | 0.015759 | 0.016096 | 0.016524 | 0.017282 | 0.017956 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/Ci = | 0.000667 | 0.003333 | 0.003333 | 0.0125 | 0.00125 | 0.003333 | 0.000333 | 0.000667 | 0.0005 | 0.000714 | 0.000556 | 0.000833 | 0.00125 | 0.001111 |

*Table 61. Continued.*

| Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| sum = | 0.000667 | 0.004 | 0.007333 | 0.019833 | 0.021083 | 0.024417 | 0.02475 | 0.025417 | 0.025917 | 0.026631 | 0.027187 | 0.02802 | 0.02927 | 0.030381 |
| f(x) = | 0.000404 | 0.002426 | 0.004448 | 0.01203 | 0.012788 | 0.014809 | 0.015012 | 0.015416 | 0.015719 | 0.016152 | 0.016489 | 0.016995 | 0.017753 | 0.018427 |
| NEs = | 100% | 93% | 96% | 99% | 98% | 98% | 98% | 98% | 98% | 98% | 98% | 97% | 97% | 97% |
| Costs | 3000 | 5100 | 6000 | 6320 | 9520 | 10120 | 28120 | 29620 | 35620 | 77620 | 90220 | 95020 | 104620 | 106420 |

*Table 62. PPQ For Data Set #1.*

| PPQ | C | K | Savg | S | S | S | S | S | S | | n | r | r | r | r | r | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.4 | 190261 | 4 | 47565.25 | 52321.78 | 57078.3 | 42808.73 | 38052.2 | | | | 3 | 48 | 20 | 17 | | | 1 | 3 | 4 | | |
| 0.35 | 329334 | 5 | 65866.8 | 72453.48 | 79040.16 | 59280.12 | 52693.44 | 65866.8 | | | 4 | 30 | 50 | 41 | 29 | | 2 | 1 | 1 | 2 | |
| 0.6 | 322340 | 4 | 80585 | 88643.5 | 96702 | 72526.5 | 64468 | | | | 4 | 19 | 45 | 2 | 24 | | 3 | 1 | 35 | 2 | |
| 0.1 | 378414 | 5 | 75682.8 | 83251.08 | 90819.36 | 68114.52 | 60546.24 | 75682.8 | | | 3 | 40 | 32 | 49 | | | 1 | 2 | 1 | | |
| 0.2 | 393362 | 6 | 65560.33 | 72116.37 | 78672.4 | 59004.3 | 52448.27 | 85228.43 | 45892.23 | | 3 | 41 | 35 | 24 | | | 1 | 2 | 2 | | |

*Table 62. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | S | | n | r | r | r | r | r | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.9 | 495798 | 7 | 70828.29 | 77911.11 | 84993.94 | 63745.46 | 56662.63 | 92076.77 | 49579.8 | 70828.29 | 5 | 30 | 3 | 1 | 20 | 29 | 2 | 23 | 70 | 3 | 2 |
| 0.45 | 269878 | 4 | 67469.5 | 74216.45 | 80963.4 | 60722.55 | 53975.6 | | | | 3 | 38 | 11 | 47 | | | 1 | 6 | 1 | | |
| 0.85 | 77606 | 1 | 77606 | 77606 | | | | | | | 1 | 13 | | | | | 5 | | | | |
| 0.35 | 202760 | 3 | 67586.67 | 74345.33 | 60828 | 67586.67 | | | | | 2 | 18 | 35 | | | | 3 | 2 | | | |
| 0.7 | 451550 | 6 | 75258.33 | 82784.17 | 90310 | 67732.5 | 60206.67 | 97835.83 | 52680.83 | | 4 | 9 | 13 | 21 | 10 | | 7 | 5 | 3 | 7 | |

*Table 62. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | S | | n | r | r | r | r | r | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.35 | 325483 | 5 | 65096.6 | 71606.26 | 78115.92 | 58586.94 | 52077.28 | 65096.6 | | | 3 | 31 | 22 | 43 | | | 2 | 3 | 1 | | |
| 0.4 | 154326 | 3 | 51442 | 56586.2 | 46297.8 | 51442 | | | | | 2 | 23 | 35 | | | | 3 | 2 | | | |
| 0.3 | 256085 | 2 | 128042.5 | 140846.8 | 115238.3 | | | | | | 3 | 43 | 26 | 40 | | | 1 | 2 | 1 | | |
| 0.65 | 412170 | 4 | 103042.5 | 113346.8 | 123651 | 92738.25 | 82434 | | | | 4 | 1 | 28 | 10 | 9 | | 70 | 2 | 7 | 7 | |
| 0.25 | 366815 | 3 | 122271.7 | 134498.8 | 110044.5 | 122271.7 | | | | | 3 | 23 | 34 | 38 | | | 3 | 2 | 1 | | |

*Table 62. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | S | | n | r | r | r | r | r | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.26 | 335637 | 3 | 111879 | 123066.9 | 100691.1 | 111879 | | | | | 3 | 18 | 45 | 39 | | | 3 | 1 | 1 | | |
| 0.31 | 296456 | 3 | 98818.67 | 108700.5 | 88936.8 | 98818.67 | | | | | 3 | 21 | 35 | 34 | | | 3 | 2 | 2 | | |
| 0.3 | 118519 | 2 | 59259.5 | 65185.45 | 53333.55 | | | | | | 1 | 48 | | | | | 1 | | | | |
| 0.5 | 193947 | 2 | 96973.5 | 106670.9 | 87276.15 | | | | | | 2 | 34 | 18 | | | | 2 | 3 | | | |
| 0.4 | 230992 | 2 | 115496 | 127045.6 | 103946.4 | | | | | | 2 | 28 | 17 | | | | 2 | 4 | | | |

*Table 63. PPQ For Data Set #2.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | r | r | ct | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.25 | 123306 | 2 | 61653 | 67818.3 | 55487.7 | | | | 2 | 50 | 40 | | | | | 1 | 1 | | | | |
| 0.2 | 277630 | 3 | 92543.33 | 101797.7 | 83289 | 92543.33 | | | 3 | 44 | 35 | 37 | | | | 1 | 2 | 1 | | | |
| 0.85 | 379437 | 4 | 94859.25 | 104345.2 | 85373.33 | 75887.4 | 113831.1 | | 5 | 32 | 14 | 2 | 45 | 6 | | 2 | 5 | 35 | 1 | 11 | |
| 0.2 | 261105 | 2 | 130552.5 | 143607.8 | 117497.3 | | | | 2 | 38 | 44 | | | | | 1 | 1 | | | | |
| 0.24 | 299843 | 3 | 99947.67 | 109942.4 | 89952.9 | 99947.67 | | | 4 | 49 | 20 | 16 | 43 | | | 1 | 3 | 4 | 1 | | |

*Table 63. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | r | r | ct | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.78 | 294654 | 3 | 98218 | 108039.8 | 88396.2 | 98218 | | | 4 | 39 | 3 | 5 | 31 | | | 1 | 23 | 14 | 2 | | |
| 0.65 | 111628 | 1 | 111628 | 111628 | | | | | 1 | 25 | | | | | | 2 | | | | | |
| 0.5 | 195419 | 2 | 97709.5 | 107480.5 | 87938.55 | | | | 3 | 47 | 32 | 10 | | | | 1 | 2 | 7 | | | |
| 0.75 | 327120 | 3 | 109040 | 119944 | 98136 | 109040 | | | 5 | 2 | 35 | 9 | 3 | 36 | | 35 | 2 | 7 | 23 | 1 | |
| 0.15 | 162761 | 2 | 81380.5 | 89518.55 | 73242.45 | | | | 2 | 16 | 27 | | | | | 4 | 2 | | | | |

*Table 63. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | r | r | ct | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.7 | 456922 | 4 | 114230.5 | 125653.6 | 102807.5 | 91384.4 | 137076.6 | | 6 | 28 | 7 | 32 | 27 | 24 | 3 | 2 | 10 | 2 | 2 | 2 | 23 |
| 0.55 | 469019 | 5 | 93803.8 | 103184.2 | 84423.42 | 75043.04 | 112564.6 | 93803.8 | 6 | 20 | 46 | 26 | 26 | 10 | 22 | 3 | 1 | 2 | 2 | 7 | 3 |
| 0.75 | 440970 | 4 | 110242.5 | 121266.8 | 99218.25 | 88194 | 132291 | | 5 | 12 | 4 | 16 | 25 | 18 | | 5 | 17 | 4 | 2 | 3 | |
| 0.3 | 387063 | 4 | 96765.75 | 106442.3 | 87089.18 | 77412.6 | 116118.9 | | 2 | 47 | 16 | | | | | 1 | 4 | | | | |
| 0.32 | 499775 | 5 | 99955 | 109950.5 | 89959.5 | 79964 | 119946 | 99955 | 4 | 31 | 41 | 38 | 15 | | | 2 | 1 | 1 | 4 | | |

*Table 63. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | r | r | ct | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.4 | 87531 | 1 | 87531 | 87531 | | | | | 1 | 39 | | | | | | 1 | | | | | |
| 0.3 | 473300 | 5 | 94660 | 104126 | 85194 | 75728 | 113592 | 94660 | 4 | 21 | 48 | 22 | 48 | | | 3 | 1 | 3 | 1 | | |
| 0.44 | 238612 | 2 | 119306 | 131236.6 | 107375.4 | | | | 3 | 45 | 12 | 35 | | | | 1 | 5 | 2 | | | |
| 0.5 | 247280 | 3 | 82426.67 | 90669.33 | 74184 | 82426.67 | | | 2 | 36 | 18 | | | | | 1 | 3 | | | | |
| 0.6 | 141029 | 2 | 70514.5 | 77565.95 | 63463.05 | | | | 2 | 22 | 44 | | | | | 3 | 1 | | | | |

*Table 64. PPQ For Data Set #3.*

| PPQ | C | K | Savg | S | S | S | S | S | S | n | r | r | r | r | r | r | ct | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.35 | 239206 | 3 | 79735.33 | 87708.87 | 71761.8 | 79735.33 | | | | 3 | 22 | 27 | 19 | | | | 3 | 2 | 3 | | | |
| 0.55 | 256858 | 3 | 85619.33 | 94181.27 | 77057.4 | 85619.33 | | | | 4 | 5 | 41 | 49 | 3 | | | 14 | 1 | 1 | 23 | | |
| 0.6 | 351124 | 4 | 87781 | 96559.1 | 79002.9 | 70224.8 | 105337.2 | | | 5 | 13 | 16 | 18 | 47 | 4 | | 5 | 4 | 3 | 1 | 17 | |
| 0.6 | 452678 | 5 | 90535.6 | 99589.16 | 81482.04 | 72428.48 | 108642.7 | 90535.6 | | 6 | 47 | 6 | 26 | 45 | 6 | 44 | 1 | 11 | 2 | 1 | 11 | 1 |
| 0.85 | 240214 | 2 | 120107 | 132117.7 | 108096.3 | | | | | 3 | 9 | 1 | 18 | | | | 7 | 70 | 3 | | | |

*Table 64. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | S | n | r | r | r | r | r | r | ct | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.55 | 371411 | 5 | 74282.2 | 81710.42 | 66853.98 | 59425.76 | 89138.64 | 74282.2 | | 4 | 24 | 16 | 25 | 4 | | | 2 | 4 | 2 | 17 | | |
| 0.35 | 271562 | 3 | 90520.67 | 99572.73 | 81468.6 | 90520.67 | | | | 3 | 23 | 41 | 41 | | | | 3 | 1 | 1 | | | |
| 0.5 | 171181 | 2 | 85590.5 | 94149.55 | 77031.45 | | | | | 2 | 8 | 29 | | | | | 8 | 2 | | | | |
| 0.55 | 242320 | 3 | 80773.33 | 88850.67 | 72696 | 80773.33 | | | | 3 | 46 | 8 | 33 | | | | 1 | 8 | 2 | | | |
| 0.3 | 83197 | 1 | 83197 | 83197 | | | | | | 1 | 45 | | | | | | 1 | | | | | |

*Table 64. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | S | n | r | r | r | r | r | r | ct | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.6 | 176124 | 2 | 88062 | 96868.2 | 79255.8 | | | | | 2 | 35 | 12 | | | | | 2 | 5 | | | | |
| 0.7 | 405497 | 5 | 81099.4 | 89209.34 | 72989.46 | 64879.52 | 97319.28 | 81099.4 | | 5 | 11 | 7 | 31 | 8 | 22 | | 6 | 10 | 2 | 8 | 3 | |
| 0.6 | 406759 | 6 | 67793.17 | 74572.48 | 61013.85 | 54234.53 | 81351.8 | 57624.19 | 77962.14 | 5 | 15 | 9 | 30 | 35 | 16 | | 4 | 7 | 2 | 2 | 4 | |
| 0.3 | 420819 | 4 | 105204.8 | 115725.2 | 94684.28 | 84163.8 | 126245.7 | | | 5 | 36 | 44 | 11 | 15 | 43 | | 1 | 1 | 6 | 4 | 1 | |
| 0.65 | 188896 | 3 | 62965.33 | 69261.87 | 56668.8 | 62965.33 | | | | 2 | 34 | 7 | | | | | 2 | 10 | | | | |

*Table 64. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | S | n | r | r | r | r | r | r | ct | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.55 | 229715 | 3 | 76571.67 | 84228.83 | 68914.5 | 76571.67 | | | | 3 | 21 | 21 | 33 | | | | 3 | 3 | 2 | | | |
| 0.65 | 292869 | 3 | 97623 | 107385.3 | 87860.7 | 97623 | | | | 3 | 18 | 5 | 30 | | | | 3 | 14 | 2 | | | |
| 0.7 | 390077 | 4 | 97519.25 | 107271.2 | 87767.33 | 78015.4 | 117023.1 | | | 4 | 30 | 44 | 2 | 24 | | | 2 | 1 | 35 | 2 | | |
| 0.4 | 160225 | 2 | 80112.5 | 88123.75 | 72101.25 | | | | | 2 | 46 | 38 | | | | | 1 | 1 | | | | |
| 0.3 | 498713 | 6 | 83118.83 | 91430.72 | 74806.95 | 66495.07 | 99742.6 | 70651.01 | 95586.66 | 4 | 9 | 6 | 50 | 49 | | | 7 | 11 | 1 | 1 | | |

*Table 65. PPQ For Data Set #4.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | r | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.51 | 125263 | 2 | 62631.5 | 68894.65 | 56368.35 | | | | 1 | 14 | | | | | 5 | | | | |
| 0.57 | 384460 | 4 | 96115 | 105726.5 | 86503.5 | 76892 | 115338 | | 3 | 13 | 8 | 38 | | | 5 | 8 | 1 | | |
| 0.66 | 193525 | 2 | 96762.5 | 106438.8 | 87086.25 | | | | 3 | 30 | 26 | 10 | | | 2 | 2 | 7 | | |
| 0.42 | 463750 | 5 | 92750 | 102025 | 83475 | 74200 | 111300 | 92750 | 5 | 28 | 17 | 50 | 34 | 34 | 2 | 4 | 1 | 2 | 2 |
| 0.52 | 466509 | 5 | 93301.8 | 102632 | 83971.62 | 74641.44 | 111962.2 | 93301.8 | 5 | 15 | 36 | 47 | 33 | 15 | 4 | 1 | 1 | 2 | 4 |

*Table 65. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | r | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.41 | 400202 | 4 | 100050.5 | 110055.6 | 90045.45 | 80040.4 | 120060.6 | | 4 | 31 | 16 | 35 | 29 | | 2 | 4 | 2 | 2 | |
| 0.55 | 238609 | 3 | 79536.33 | 87489.97 | 71582.7 | 79536.33 | | | 2 | 43 | 11 | | | | 1 | 6 | | | |
| 0.56 | 427457 | 4 | 106864.3 | 117550.7 | 96177.83 | 85491.4 | 128237.1 | | 4 | 40 | 12 | 32 | 24 | | 1 | 5 | 2 | 2 | |
| 0.51 | 469081 | 4 | 117270.3 | 128997.3 | 105543.2 | 93816.2 | 140724.3 | | 4 | 50 | 27 | 47 | 28 | | 1 | 2 | 1 | 2 | |
| 0.70 | 143495 | 2 | 71747.5 | 78922.25 | 64572.75 | | | | 2 | 15 | 17 | | | | 4 | 4 | | | |

*Table 65. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | r | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.45 | 494700 | 5 | 98940 | 108834 | 89046 | 79152 | 118728 | 98940 | 5 | 35 | 12 | 48 | 50 | 18 | 2 | 5 | 1 | 1 | 3 |
| 0.86 | 397462 | 4 | 99365.5 | 109302.1 | 89428.95 | 79492.4 | 119238.6 | | 5 | 42 | 13 | 12 | 17 | 3 | 1 | 5 | 5 | 4 | 23 |
| 0.75 | 380031 | 4 | 95007.75 | 104508.5 | 85506.98 | 76006.2 | 114009.3 | | 4 | 44 | 41 | 2 | 25 | | 1 | 1 | 35 | 2 | |
| 0.91 | 378822 | 3 | 126274 | 138901.4 | 113646.6 | 126274 | | | 4 | 42 | 1 | 10 | 20 | | 1 | 70 | 7 | 3 | |
| 0.61 | 91690 | 1 | 91690 | 91690 | | | | | 1 | 45 | | | | | 1 | | | | |

*Table 65. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | r | ct | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.58 | 358553 | 3 | 119517.7 | 131469.4 | 107565.9 | 119517.7 | | | 3 | 34 | 25 | 13 | | | 2 | 2 | 5 | | |
| 0.57 | 282694 | 3 | 94231.33 | 103654.5 | 84808.2 | 94231.33 | | | 3 | 37 | 49 | 9 | | | 1 | 1 | 7 | | |
| 0.81 | 163310 | 2 | 81655 | 89820.5 | 73489.5 | | | | 2 | 28 | 5 | | | | 2 | 14 | | | |
| 0.57 | 375161 | 4 | 93790.25 | 103169.3 | 84411.23 | 75032.2 | 112548.3 | | 4 | 20 | 39 | 16 | 32 | | 3 | 1 | 4 | 2 | |
| 0.91 | 359895 | 3 | 119965 | 131961.5 | 107968.5 | 119965 | | | 3 | 50 | 1 | 7 | | | 1 | 70 | 10 | | |

*Table 66. PPQ For Data Set #5.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.45 | 100626 | 1 | 100626 | 100626 | | | | | 1 | 27 | | | | 2 | | | |
| 0.30 | 140111 | 2 | 70055.5 | 77061.05 | 63049.95 | | | | 1 | 33 | | | | 2 | | | |
| 0.26 | 114382 | 2 | 57191 | 62910.1 | 51471.9 | | | | 1 | 49 | | | | 1 | | | |
| 0.57 | 233356 | 3 | 77785.33 | 85563.87 | 70006.8 | 77785.33 | | | 2 | 3 | 38 | | | 23 | 1 | | |
| 0.73 | 170397 | 2 | 85198.5 | 93718.35 | 76678.65 | | | | 2 | 7 | 14 | | | 10 | 5 | | |

*Table 66. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.33 | 260587 | 3 | 86862.33 | 95548.57 | 78176.1 | 86862.33 | | | 3 | 42 | 39 | 28 | | 1 | 1 | 2 | |
| 0.50 | 224345 | 2 | 112172.5 | 123389.8 | 100955.3 | | | | 2 | 18 | 15 | | | 3 | 4 | | |
| 0.43 | 327394 | 3 | 109131.3 | 120044.5 | 98218.2 | 109131.3 | | | 3 | 14 | 43 | 22 | | 5 | 1 | 3 | |
| 0.46 | 250176 | 2 | 125088 | 137596.8 | 112579.2 | | | | 3 | 26 | 36 | 17 | | 2 | 1 | 4 | |
| 0.63 | 446392 | 4 | 111598 | 122757.8 | 100438.2 | 89278.4 | 133917.6 | | 4 | 4 | 13 | 41 | 4 | 17 | 5 | 1 | 17 |

*Table 66. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.19 | 370706 | 4 | 92676.5 | 101944.2 | 83408.85 | 74141.2 | 111211.8 | | 4 | 27 | 44 | 40 | 36 | 2 | 1 | 1 | 1 |
| 0.38 | 350656 | 4 | 87664 | 96430.4 | 78897.6 | 70131.2 | 105196.8 | | 4 | 11 | 12 | 30 | 39 | 6 | 5 | 2 | 1 |
| 0.29 | 354661 | 4 | 88665.25 | 97531.78 | 79798.73 | 70932.2 | 106398.3 | | 4 | 27 | 29 | 23 | 40 | 2 | 2 | 3 | 1 |
| 0.90 | 488771 | 5 | 97754.2 | 107529.6 | 87978.78 | 78203.36 | 117305 | 97754.2 | 4 | 6 | 2 | 4 | 10 | 11 | 35 | 17 | 7 |
| 0.74 | 266628 | 3 | 88876 | 97763.6 | 79988.4 | 88876 | | | 3 | 14 | 5 | 26 | | 5 | 14 | 2 | |

*Table 66. Continued.*

| PPQ | C | K | Savg | S | S | S | S | S | n | r | r | r | r | ct | ct | ct | ct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.69 | 192620 | 2 | 96310 | 105941 | 86679 | | | | 2 | 44 | 8 | | | 1 | 8 | | |
| 0.62 | 75830 | 1 | 75830 | 75830 | | | | | 1 | 21 | | | | 3 | | | |
| 0.34 | 417616 | 4 | 104404 | 114844.4 | 93963.6 | 83523.2 | 125284.8 | | 4 | 32 | 21 | 14 | 47 | 2 | 3 | 5 | 1 |
| 0.54 | 424089 | 4 | 106022.3 | 116624.5 | 95420.03 | 84817.8 | 127226.7 | | 4 | 17 | 34 | 35 | 2 | 4 | 2 | 2 | 35 |
| 0.82 | 138981 | 2 | 69490.5 | 76439.55 | 62541.45 | | | | 2 | 30 | 3 | | | 2 | 23 | | |

# Vita

Alexandr M. Sokolov was born on March 27, 1988 in Moscow, Russia but immigrated to the United States in 1993. He grew up in Oak Ridge, TN and graduated from Oak Ridge High School in 2006, The University of Tennessee in 2011 with a B.S. in Biological Sciences, Microbiology, and again in 2013 with a M.B.A. in Finance from Lincoln Memorial University. He matriculated at the University of Tennessee for his Doctor of Philosophy (Ph.D.) in Industrial Engineering with a concentration of Engineering Management in 2014. His academic ambition is to provide the research community with advanced performance management techniques.