TECHNICAL PROJECT MANAGEMENT: UNION OF SYSTEMS ENGINEERING PROCESSES WITH PROJECT MANAGEMENT PROCESSES

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TECHNICAL PROJECT MANAGEMENT: UNION OF SYSTEMS ENGINEERING PROCESSES WITH PROJECT MANAGEMENT PROCESSES

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Deyaaldeen Abusal

ABSTRACT

Today, most projects in technical fields utilize project management to complete projects as planned, and some of the projects utilize system engineering to cover the project in both technically and commercially. This thesis investigates the relationship between Project Management (PM) and Systems Engineering (SE) to determine if a suitably professional level of management and level of quality can be achieved. When studying PM and SE separately and make a comparison between both, there is much overlap between these two mature fields. The project could be planned and completed solely by either process. This study combines both fields of Project Management and Systems Engineering to get the best cost, time and quality. The Project Manager and the System Engineer both cover technical and managerial aspects of a project, and their collaboration is essential and leads to greater efficiency and effectiveness, as well as leading to project optimization and efficiency in cost, time and quality. This thesis integrates PM and SE processes and discusses the possibility of creating new steps for PM and SE to achieve more efficient results in the life cycle of a project from the initial study phase to the optimization, completion, and close of a project. This paper study the efficiency and effectiveness for both system engineering and project management then integrates PM and SE processes and get a complete process that covers the two aspects technical and managerial with the maximum efficiency (time and cost) and maximum effectiveness (risk and performance) as well. This paper after study and determine the efficiency and effectiveness for PM and SE will propose and create new steps that cover PM and SE without any redundant processes or additional processes that will increase the cost without giving the project any advantages. These new steps called the hybrid processes between PM and SE and these processes will be in steps cover the whole project technically and managerially these steps called Technical Project Management.

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CHAPTER 1: INTRODUCTION AND OVERVIEW OF PROJECT MANAGEMENT (PM) AND SYSTEMS ENGINEERING (SE)

1.1 Introduction

This thesis discusses the integration and overlap between Project Management (PM) and System Engineering (SE), with the objective of creating a complete process for the technical and managerial fields. System Engineering has been successfully utilized for developing and documenting a solution, product or service. Project Management has tools, skills, and techniques used to complete the project as planned and meet customer requirements. PM and SE can be integrated for increased process performance; for example, more accurate and correct price estimates are obtainable and lead to more reliable profit. Similarly, the combination of PM and SE facilitates better schedule estimates, on which depend the quality of process execution, making required profits more achievable. The significant overlap between PM and SE will not be in one process, as there are several overlaps in different processes and stages. Mainly, the SE Life Cycle focuses on the processes of studying, defining and managing to solve a problem, and developing or establishing a product or service. The PM Life Cycle is more focused on starting, organizing, preparing, and executing, as well as carrying out and closing, projects to meet the requirements. [INCOSE: International Council on Systems Engineering SE Handbook v4, 2015. Monzón, Antonio, Bi-directional Mapping between CMMI and INCOSE SE Handbook, 2012. PMI: Project Management Institute, PMBOK: Project Management Book of Knowledge Guide (PMI 2013). AACE International, Skills and Knowledge of Cost Engineering, 6th edition, 2015.

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Programs, 2012. Online Learning Center - www.mhhe.com/doane4e - 'Applied Statistics in Business and Economics' – Chapter 7 - Continuous Probability Distributions David P. Doane, Oakland University, Lori E. Seward, University of Colorado, 2010. SEI: Software Engineering Institute, CMMI: Capability Maturity Model Integration, 2011. Swanson, S. A. All things considered. PM Network, (2011). Swanson, S. A. Boosting the bottom line. PM Network, (2011). Swanson, S. A. Disaster averted. PM Network, (2014).]

Most projects start when authorization is obtained, that is, when an owner decides to begin, with the completion of a Project Charter. The project owner sends the requirements and the functions of the project to the specifier or designer to start designing to meet the functional requirements and specifications as per the owner's requirements. The specifier will issue the project tender, including a tender drawing, tender specification and bill of quantity, and then send those documents back to the owner. Then the project tender goes to the market, and the contractors will start competing to study and quote the project, to be awarded the project. The project award depends on several factors, including the lowest price, shortest time to execute the project, and quality optimization, as judged by the history of the contractor's previous projects. The diagram below is an Organization Chart, along which there is a corresponding procedure flow.

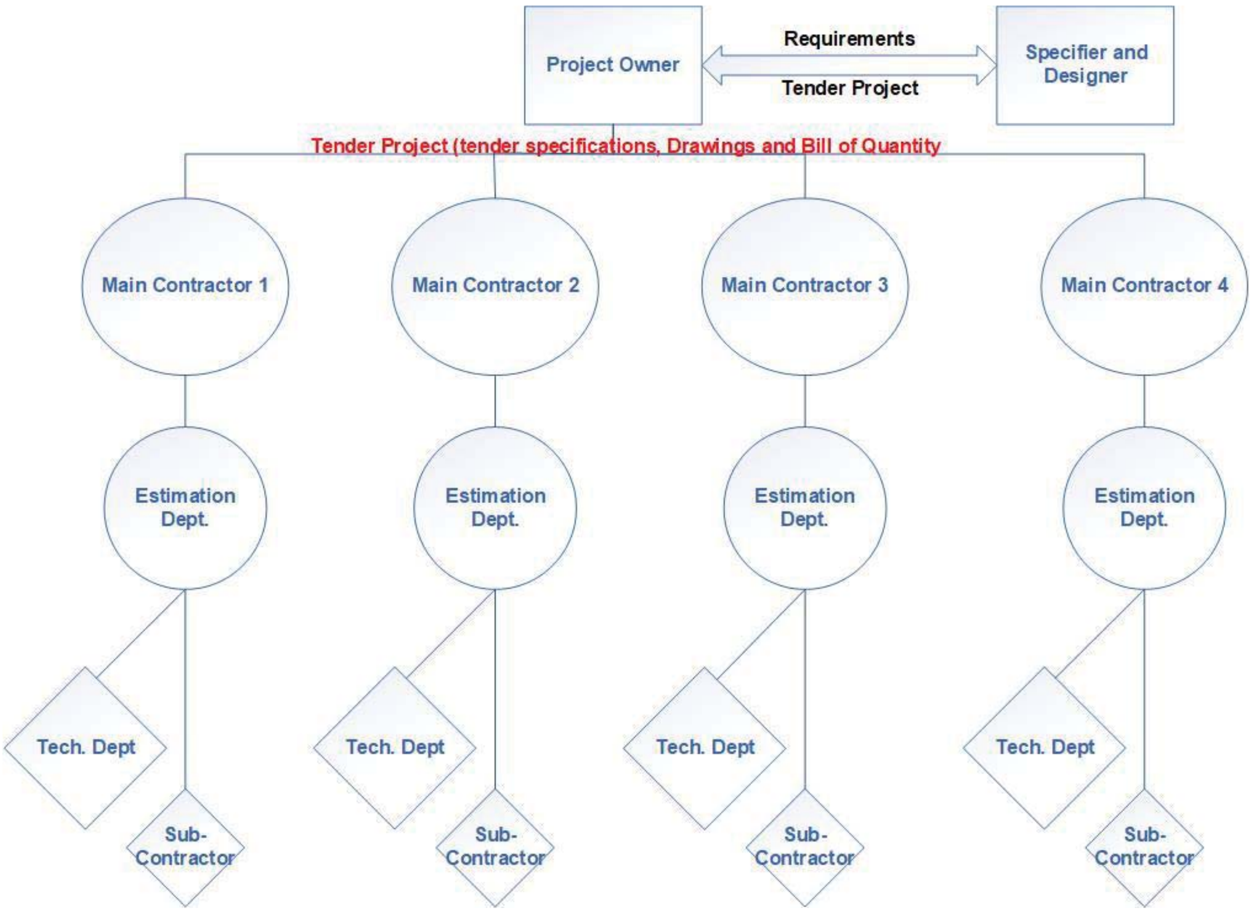

Figure 1-1: Tender Project Competition Among Contractors

The above diagram explains the procedure flow in the market when the tender project is emitted. Any project can have significant problems that need quick action and solutions. One of these problems is mistaken pricing from the estimation department, with the reason for this mistake being a misunderstanding of the tender specifications and inadequate coordination with subcontractors, or other quality and quantity reasons. In each project, especially construction projects, the project has a Bill of Quantity for all materials in the project, as shown in the following table of a Bill of Quantity:

Table 1-1: Bill of Quantity

Item	Quantity	Price	Description
Steel Structure	10,000 m2		
Roofing System	5,000 m2		
Glazing System	3,000 m2		
Cladding	7,000 m2		
Aluminum Doors	30 Pcs		
Wooden Doors	20 Pcs		

The estimation department will study the project and put a unit price on each item, but most projects, especially government projects, ask the contractor to make a Firm Fixed Price (FFP) for the project, so the contractor should study the project very well to create an FFP offer, This estimation process might be mistaken, because the estimation process depends on the experience of hired estimators, who may not have the necessary expertise.

This thesis research introduces the holistic measures of Efficiency and Effectiveness for Project Management and System Engineering and then proposes a Hybrid Processes of PM and SE combined. Combined PM and SE steps can find the accurate cost for each item and the execution time for each process. Based on this and from here the team can make the price for each item with a known margin from the beginning of the project to handover.

Now more than ever, companies want to deliver products and services better, faster, and cheaper. At the same time, in the high-technology environment of the twenty-first century, nearly all organizations have found themselves building increasingly sophisticated products and services. CMMI® for Development (CMMI-DEV) provides an opportunity to avoid or eliminate these stovepipes and barriers. CMMI for Development consists of best practices that address development activities applied to products and services. CMMI-DEV contains five steps are development specific process areas.

1.1.1 Technical Processes

Technical processes are distributing along the project procedure from the initial step to close and handover the project. Most of these processes are from System Engineering using methods and from Project Management as well but using skills and techniques. Systems Engineering focuses on technical processes more than Project Management, but the skills and techniques used in Project Management will integrate and support the methods used in System Engineering to get the optimization of the project. Depending on the PM triangle and SE constraints, the optimization will be in the functionality of the system, time & schedule, cost, risk, and quality. So, we are looking to reduce the risk and get high quality with the lowest cost and best time for the functionality. For Example, the Work Breakdown Structure (WBS) process is used in both SE and PM; in SE, the WBS process divides the project into pieces to accomplish the technical procedures, especially integration, verification, validation, and testing. But in PM, the WBS process splits the project into manageable parts to manage the project efficiently. [INCOSE: International Council on Systems Engineering SE Handbook v4, 2015. Monzón, Antonio, Bi-directional Mapping between CMMI and INCOSE SE Handbook, 2012. PMI: Project Management Institute, PMBOK: Project Management Book of Knowledge Guide (PMI 2013). AACE International, Skills and Knowledge of Cost Engineering, 6th edition, 2015.

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1.1.2 Project Processes

Project processes, mainly focusing in the management field, control the quality and control the changes. Most of these processes are techniques and skills from Project Management but may also utilize technical methods from System Engineering.

For example, the Perform Integrated Change Control process, also called Change Management, controls changes by establishing system baselines, controlling the design, as well as documenting and communicate changes and approvals. Change is inevitable, and even small changes, if not controlled, may cause major system effects.

Changes happen for different reasons, like errors in system specifications, external factors, upgrades or improved solutions proposed by the technical team. Corrected solutions by the technical team can largely be avoided if SE is followed, with the remainder of most change requests being triggered by advances in technology and upgrades.

Project processes also include monitoring and control processes to keep the project as planned, and to control the actual cost to the budgeted cost, because the changes also affect the actual cost as well as the time. Figure (1-2) shows the difference between the budget cost and the actual cost in most construction projects because of variation orders, changes, delays in materials delivery, and activity sequences. [INCOSE: International Council on Systems Engineering SE Handbook v4, 2015. Monzón, Antonio, Bi-directional Mapping between CMMI and INCOSE SE Handbook, 2012. PMI: Project Management Institute, PMBOK: Project Management Book of Knowledge Guide (PMI 2013).]

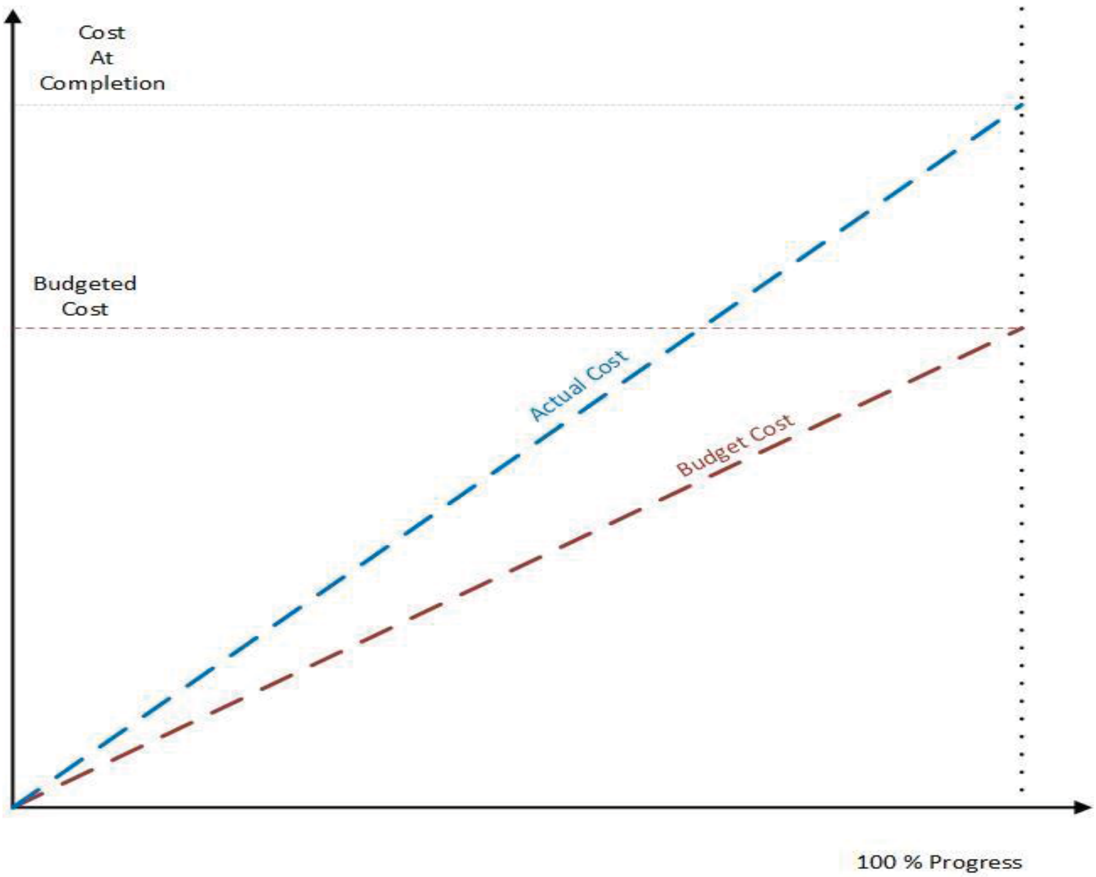

Figure 1-2: Actual Cost and Budget Cost

1.1.3 Enterprise & Agreement Processes

Enterprise and Agreement Processes combine technical and management processes, especially Human Resource Management, Training Management and System Life Cycle.

1.2 System Life Cycle

Project Management, as well as System Engineering, should divide the project into phases to get the best management control and get the optimization, throughout the project life cycle. Project Management phases are generally sequential. In Project Management, costs are lower at the start and final phases, and the maximum cost level will be in the intermediate phase.

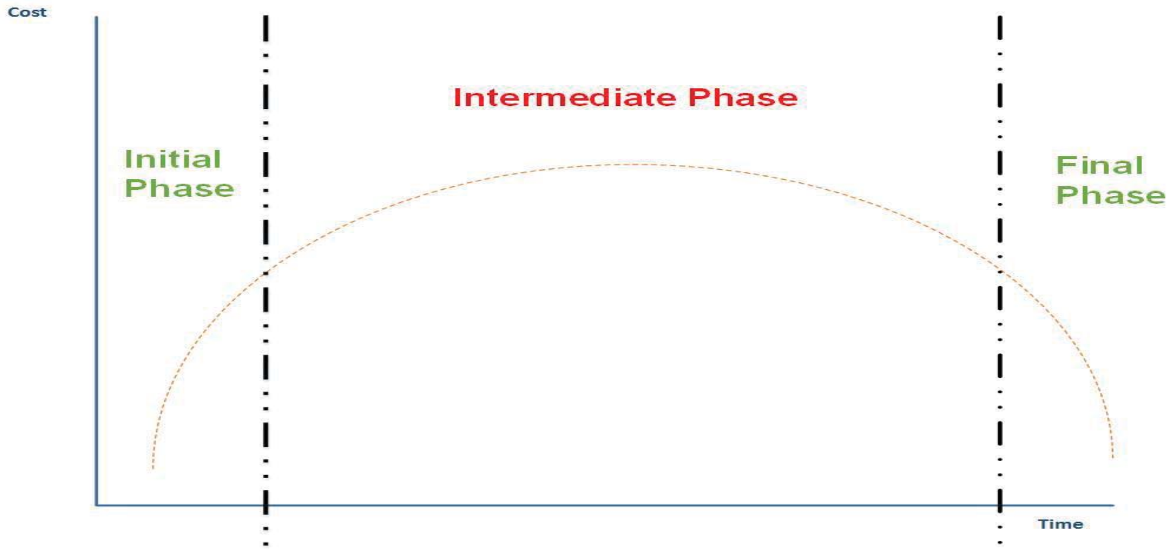

Figure 1-3: Cost Over Time for Initial, Intermediate, and Final Phase

Because risk exists in business and projects, there is a Risk Management process in project management and system engineering. Risk and changes connected together, so change management and control keeps changes under control, and keeps risk at a low level that does not affect the project in time, cost and quality.

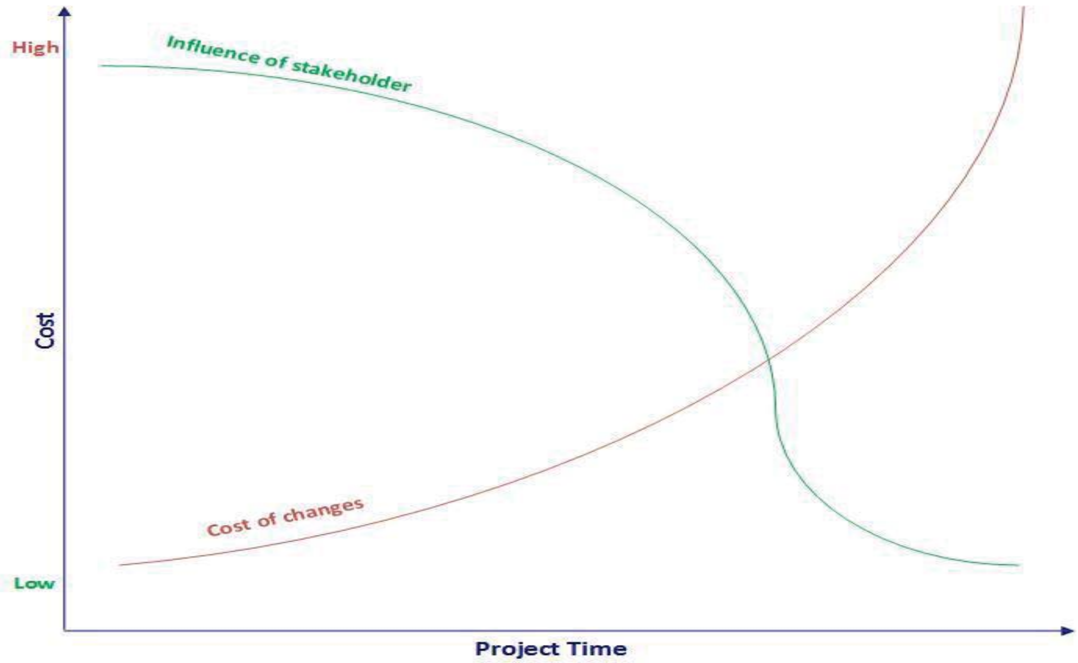

Figure 1-4: Cost over Time for Influence of Stakeholder and Cost of Changes

1.3 Project Stakeholders

In Project Management and System Engineering, project stakeholders are individuals and organization that actively involved in the project. The Project Management team and System Engineering team should gather and study stakeholder requirements, determine their requirements and manage their effectiveness to the requirements to get successful project and to be sure that we achieve the optimization.

1.4 Process and Knowledge Areas

The Project Management includes 49 processes and these processes are needed to identify, combine, unify and coordinate the processes.

Systems Engineering contains 31 process areas and these areas focus on the activities of developers and organizations, focusing on practices specific to development: addressing requirements development, technical solution, product integration, verification, and validation.

1.5 Organizational Influences and Process Improvement

Project Management is application of knowledge, skills, tool and technique of project activities to meet the project requirements. Project Management has five process stages to meet the project requirements: Initiating, Planning, Executing, Monitoring & Controlling, and Closing.

SE focuses on three critical dimensions that organizations typically focus on: people, procedures & methods, and tools & equipment. [INCOSE: International Council on Systems Engineering SE Handbook v4, 2015. Monzón, Antonio, Bi-directional Mapping between CMMI and INCOSE SE Handbook, 2012. PMI: Project Management Institute, PMBOK: Project Management Book of Knowledge Guide (PMI 2013). AACE International, Skills and Knowledge of Cost Engineering, 6th edition, 2015.

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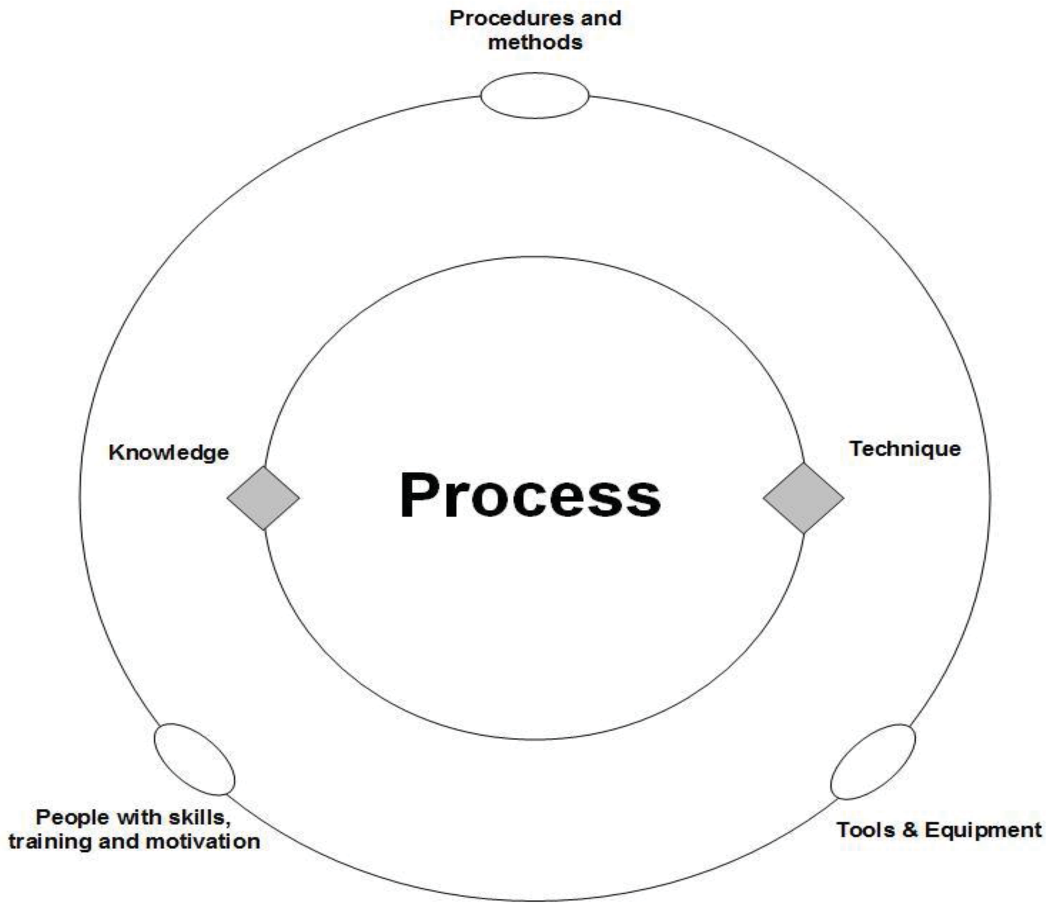

Figure 1-5: A Hybridization of Se Handbook 2015 And PmBok 2013

The functional organization show in the figure below is a hierarchy where the processes flow in the company, especially construction or industrial companies. Shown is the process flow for system engineering and project management. System engineering covers all project management procedures, but there is some difference, because system engineering should start before project management, and the system engineering includes methods to achieve technical optimization, and project management includes skills and techniques for project success.

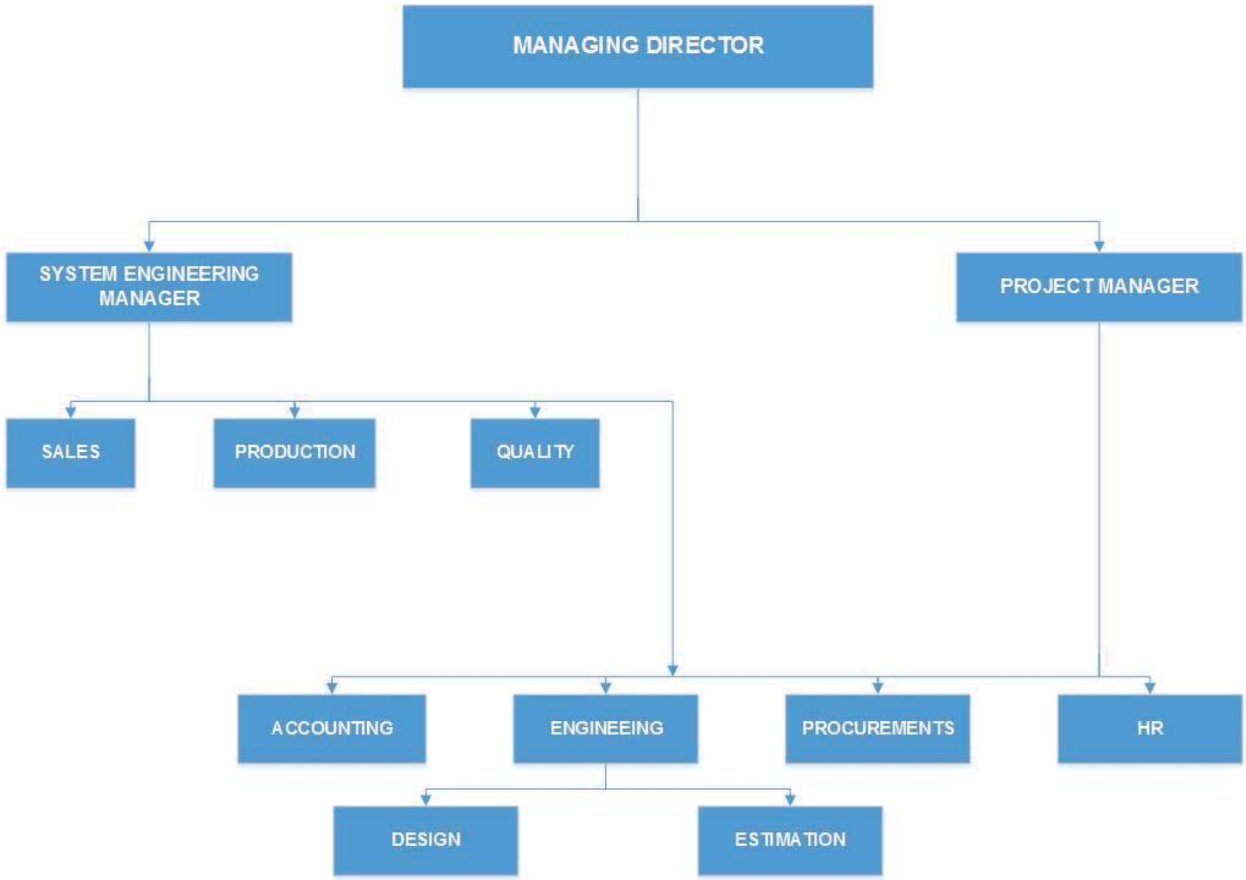

Figure 1-6: Work Breakdown Structure for PM and SE

Now in the market, some companies use Project Management and some use System Engineering, while few companies use both; this means that companies often apply system engineering from A to Z to get the technical optimization, and after getting this optimization, implement project management to successfully deploy the project or product. Now, we are going to study efficiency and effectiveness for both PM & SE then, depends on the results we going to make steps from A to Z that covered system engineering and project management, and the company will apply the hybrid process only one time to succeed in the project, product or service and at the same time get the optimization in quality, profit and time. The figure below shows how procedure flows depending on organizational structure.

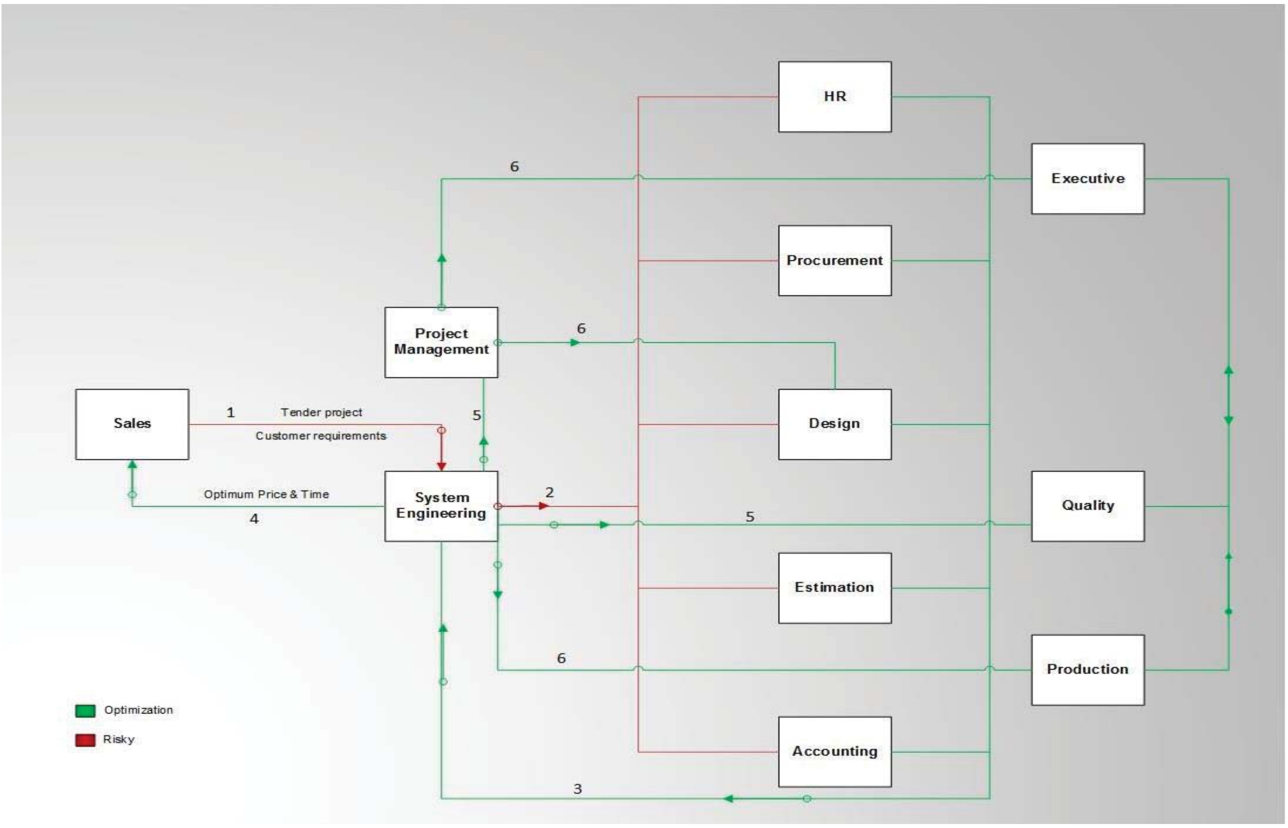

Figure 1-7: Procedure Flow Between Departments

CHAPTER 2: LITERATURE REVIEW

2.1 Case Study 00: Self Experience

Actually, in this case study, I will talk about my experience in project management and system engineering. During my experience for more than eight years in construction field and especially in steel structure, aluminum and metal roofing system I had a lot of problems during the project some of these problems were in misunderstanding stakeholder requirements and some in planning, design, variation order in some items to cut the cost and some was in estimation that mean mistake in pricing the item then the contractor looking to change this item by cheaper item to reduce the cost and save the money. I used to work in 14 projects for eight years, and in these all project even estimates very well and follow a lot of project management techniques and skills but never any project finished by how to plan from the beginning and never any project got the same profit that planned and estimated. So, from this point and depends on personal experience in several projects and after study system engineering in my master's program, I got the idea that synergized Project Management and System Engineering.

I found that megaprojects do not stick to the original plan; the budget increases and scope changes, and schedules get pushed sometimes by years; however, the final success-measure is the customer's satisfaction, so all that cannot be considered a failure as long as the customer is satisfied. In many projects, the budget and scope are not what controls how the project goes, but schedule on the other side is the main bottleneck in many projects, so we might find the designers working parallel with the construction and civil works, meaning that the construction begins before the final design gets approved.

2.2 Case Study 01: Arar International Airport in Saudi Arabia

This project I used to work on during 2016. I was Managing Director for a Steel Structure and Roofing System Subcontractor. When I started to work on the project, get award and sign the contract, the project was on hold for two years because of different reasons one of these reasons was steel structure. The main contractor was don't know how to move in this item, and the owner also used to ask them to reduce the steel weight to cut the cost, they put the project on hold for two years spend time and money without doing anything. When I started in the project, I looked at the architecture design and the general specifications I found a lot of information dis-match and does not make sense only related to my scope of work (steel structure and metal roofing system), and I'm sure in the other items also a lot of mistakes. When I met the owner (Civil Aviation of Saudi Arabia) and discussed with them about some points they all know very well how to manage the project, but nobody know how to figure out the specifications and what we can do to get the optimization in the project as well as run the project quickly and move it from in hold statue. When I discussed with them about the specification and architectural design, they said it makes sense! Then I talked with them to reset the specification (Stakeholder Requirements) to let me redesign the project and reduce the cost, but on the same way, I want to know precisely the specifications or requirements to don't waste any more time. I redesign the steel structure in the project from A-Z with my friend working as a freelancer he is an expert designer. After redesigning the project structure way, not architecture, so we didn't change any functionality in the project, we reduced the weight of steel by almost 1000 ton so that's mean reduce the cost in this item more than 1M. then, got the approval and the project run to materials, procurements, delivery, installations, etc. during all these processes it was a lot of problems and most of the reasons that cause these problem communication between parties, changes, delay, some they are expert technical but they don't know how to manage and some they are expert on management but they are not familiar with technical as much as they should be.

2.3 Case Study 02: Mohammed Bin Abd Al Aziz International Airport, Al-Madinah, KSA

In that project, the scope was changing too often, because the design of the steel connections started before the main designer gets the approval on the steel sections from the consultant, and that was based on the request of our client, the main contractor.

It was hard to say No to our client, especially that the money was not an issue for them, so they were very clear, they will compensate any changes or additional efforts through money, especially that the design cost is the lowest among the other departments; because everything is still on papers.

Additionally, my company didn't have that culture that supports the idea that sometimes it is necessary to say No to the client, so they would accept anything that they are being asked to, even though that the client in these projects can be very tough and even rude to our top management. The stress used to end up at the bottom of the chain where the design team is, and that was very stressful, which made two designers out of eight quit their job because of all the redo that we had to do, which resulted in more stress on the rest of the team members.

I find all of what was mentioned above to be part of the soft skills that all project managers should have, and also I believe that the project managers should always be supported by numbers and hard data. They should also move away from the subjectivity and move forward to the objectivity of the issue, and try as much possible to be polite, even when they say No, and try to stick to what is in the original contract.

What I noticed while working on that project is that there were a lot of communications gaps, and there was no clear communication plan, so we had many project emergency-traveling to Egypt where the consultant was, we didn't prepare for our meeting well; the main contractor who was our customer was the reason for all that confusion; they were overwhelmed and behind schedule and that pressure was getting to all the subcontractors, and we were part of that loop. Another issue was with the status reports that we used to get from the main contractor, and in those, it was too detailed, and it would take us more than an hour to analyze it and try to get a good understanding for what was going on. We used to distribute a copy to all the key players on the project, and after they go through the report, we would set in the meeting room to make sure that we all got the same understanding for the report which had too many information, and that made all of us feel overwhelmed and wasted our time as well.

2.4 Case Study 03: King Abdul-Aziz International Airport, Jeddah, KSA

This project had an ending date of November 2013, but the design itself, took almost 18 months to be done, without getting the approval from the consultant. The construction work started before the approval, and all of that was under the responsibility of the main contractor, because they were pushing the schedule as much as they could, so when the project was completed in 2014, the consultant started working on the approval process of the design; they didn't stick to the schedule, and the budget also increased by almost 23%, and the scope of our work kept increasing, because other subcontractors failed to do their work. With all of that the final customer, or the project sponsor, the Saudi government was glad about the results, and we were rewarded another contract.

We were responsible for the main steel design, and we were a subcontractor for the main contractor which was a company from Holland, the consultant was Dar, a Lebanese company, on the top of that the construction department and the steel factory were between KSA and UAE. What was very challenging in that complex project is that the main contractor did not have a communication plan for all parties involved, their focus was the schedule and the cost, but they didn't give attention to things like the communication, and that was reflected on the performance of the design department and caused a lot of a work redo. Finally, my company started to focus on the communication tools and ways and ask about those at a very early phase of the projects that were assigned to us later.

2.5 Case Study 04: Project Management vs. Systems Engineering Management by Amira Sharon, Olivier L. de Weck, and Dov Dori, 2010

The article discussed the systems engineering within an academic environment instead of industrial environment that represents a real large-scale project. The article discussed the system engineering and showed its relation to Project Management. Systems Engineering Management is based on some project management framework concepts, such as Work Breakdown Structure, task organization, and project planning, which makes Systems Engineering and Project Management tightly overlapped domains. Additionally, it was indicated that when no specific product is concerned, the systems engineers inter-correlated the project with the project, under the influence of practicing environment. As a result, not only there is no separation of domains, but also the domains emerge to become significant, of course in the context of a specific project/product.

2.6 Case Study 05: Managing Complex Technology Projects by Simon P. Philbin, 2008

The article discussed the complex nature of the technology and engineering projects from a technical as well as management perspective, knowing that the failure of such complex projects is linked to technical and social causes. A strong tool had to be found to overcome these failures and to facilitate the design, and management of the new programs and this is how the System engineering was introduced to the market, knowing that this new tool is not limited to engineering projects, in fact it is being nowadays to biological, financial, and social system/applications.

The article also introduced one approach of SE that does not replace PM, but works with PM via systematic methodologies in order to manage technical and organizational complexity; this is described in the four-frames system. The four-frames system view is simply a conceptual framework that was designed to be tool for managing complex technological projects, and what makes it so different than other approaches is the fact that it provides a road map for project managers to help reduce the technical as well as managerial risk for such complex projects.

2.7 Case Study 06: Keeping Score by Bowles, May 2011

The article "Keeping Score" discussed one aspect of change management, project metrics. Through creating the right project management metrics, organization can measure up; it is easy to judge if a project is ineffective or not by its direct contribution to the bottom line. However, that is not always right, new project metrics has risen to take place beside ROI, such as customer satisfaction and risk management.

Customer satisfaction metrics have become the top priority for many organizations, because these metrics give a way for an organization to improve its culture and maturity. Many companies also focus on internal employees' satisfaction; some of them would set employee satisfaction and retention metrics at the beginning of each year and adjust that later based on the market conditions. Nowadays, risk management metrics are also very important, and in those, organizations track how often the risk assessment is completed, as well as the number of risks rated low initially, however, they become bigger issues later. They also track how often the risk assessments are being reviewed, and the percentage of actual risks which were identified at the early stages.

The project managers should develop solid metrics which relate to key performance indicators; because this type of metrics helps the top management to know where the projects stand. And that is why the metrics should be informative, predictive, objective, and automated. Finally, leaders should consider how much time will be spent tracking these metrics, because simply, it might not be worth it. When constructing the metric, project managers should also keep in mind the following; metrics are often backward-looking, and they can't measure everything, also metrics should not be used to evaluate the project team members, knowing that not all metrics are worth the effort.

Some of the lessons learned from this article are that we cannot manage what we cannot control, and we cannot control what you cannot measure. Project managers need to think of the justification for having the project portfolio, because it will tell them what they should be measuring. Additionally, metrics change over time, so organizations should collect feedback on those metrics, and this feedback can be used to make the right adjustments, and then communicating these adjustments to the project team and the other stakeholders.

2.8 Case Study 07: In Times of Change by Gale, June 2012

The article "In Times of Change" keeps the discussion open about change management. It talked about the role of strong leadership in change management where fast is becoming the new norm of the current business world, and that leaves no choices for organizations but to adjust and change, and therefore companies have to be on the lookout for change drivers in order to rapidly recalibrate the project portfolio as a response.

Many project managers tend to focus on processes, but not the culture, and that is wrong because part of change management is managing human resistance, and a key thing to do so is being open to new ideas and empowering people to make the right decisions; after all it is all about communication. Change is about processes, people and technology, but the focus should be on the people, and to win the people (end users) trust, leaders should discuss what is relevant to them.

Leaders need to assess what their teams can handle and when they will accept it, otherwise, they can implement an excellent change, but it will be ignored. Change does not just happen; it must be well-planned and communicated for people to embrace the change.

One of the techniques mentioned in the article is to complete a one-page brief by project leaders that outlines the value of the project to the organization, as well as projected outcomes and how these outcomes align with the strategic business goals; that helps the top management to accurately evaluate all kinds of projects. According to the article, there can be some ingredients that help companies in having a successful change; alignment between change and strategic business goals, a business case that defines the benefits expected from the change, strong leadership backing, a targeted communications plan, and defined success metrics.

And finally, to effectively manage any change process, companies need to ensure that when the change occurs on a project, the end result should align with the financial performance and the other business measures as it is originally planned.

2.9 Case Study 08: Merge with Caution by Alderton, November 2013

The article "Merge with Caution" discussed the merge process and the challenges that managers face during the mergers and what factors need to be considered in order to ensure a successful merge. Organizations need to take a deep look into the portfolio, trying to understand if the new firm has the right mixes of projects; a project that may have been aligned to the strategic vision at one of the companies may be found way out of the new organization's goals.

The article also suggested four tips to ensure a successful organizational merge. First, establishing centralized leadership; organizations need to consider forming an enterprise PMO to lead and control the integration process, where this PMO direct the two companies to which projects to continue, postpone or cancel. However, it is crucial to have representation from both firms of the merger to treat all lines of business in objective way. Second, defining strategic priorities; the top management has to establish a new strategic objective, and only then they can pick the projects that will help the merge achieve those strategic goals.

Sometimes project teams can get off track, and so they need to be reminded that this top-down process is placed to build one new organization, and not improve the old organizations. Third, take inventory; the inventory does simply list all projects underway and the resources deployed as soon as the strategic priorities are set; however, the new organization have to take a deeper dive to make the right decision on what projects should continue, or being canceled. Among the important decision points at this phase are the strategic alignment, project type, project timeline, project status.

Finally, reallocating resources; the human resources need to be assessed in the new strategic priorities, so those practitioners should be there in the post-merger integration as early as possible to be able to answer important questions like; Are there project resources to fill our gaps?

Who are the key-staff we want to retain? etc. Additionally, both sides of the merge have to be involved in integration planning and execution, in order to get a real feel for project management capabilities and skill sets, knowing that there has to be time to assess and monitor the process as people go through that change.

Some of the lessons learned from this article are in order to survive a merge, the top management has to make sure to embrace change, to be flexible, and of course to be part of the deal. Project managers are also recommended to be very open and very honest with their team members regarding the projects during and after the merge; they need to make decisions and communicate them clearly to everyone. Finally, projects that doing well need to be looked at to ensure that they can still be aligned given the integration work by guarding these projects all the way to the finish line.

Personally, I was involved of a merge process in 2017 between two companies that sell phone accessories, and both are located in Columbus Ohio. However, the merge did not survive; the two companies had so much difference when it comes to the organizational culture, both had no flexibility, and so it was hard to see them work as a team. Merging is a very challenging process to have, and it could be the hardest process out there to be successfully implemented. However, the two companies agreed to another solution, one of the companies became the main supplier for the other company, and a coordination office was opened at the main supplier's warehouse to organize the transaction between the two firms; many would consider that a strategic alliance. Both companies kept their old management and decided to improve their internal processes and asking each other for advice, and it has been working well for the companies for the past year.

2.10 Case Study 09: Tech Trek by Hendershot, November 2013

The article "Tech Trek" discussed a new aspect of the complexity that project manager face in the current market. It talked about how project managers act when they hear about breakthrough tech by answering a very basic question "At what point do we jump-in, and to what level?" Project managers must evaluate each technology in terms of its potential impact, difficulty and its cost of implementation, and what type of effect on processes already in place it will have.

When a new technology comes out, the early adopters benefit a lot by being first in the market, and if the new technologies become an industry standard, those can stay ahead of the competition. On the other hand, organizations that follow a wait-and-see approach benefit from the early adopter's mistakes, learning from their struggles. Project managers must understand that it is not a choice between those two approaches, it is more of doing both at once; the project manager must understand the degree of chaos this new technology can introduce to a project's scope and timeline, and they need to balance their needs accordingly. However, there is always more risk involved; if the company has never worked with the new technology, they have to account for additional risk into their project timeline.

The article also discussed the twelve disruptive technologies that going to transform business and the economy of the whole world; Mobile internet, Automation of knowledge work, Internet of things, Cloud, Advanced robotics, Autonomous vehicles, Next-generation genomics, Energy storage, 3-D printing, Advanced materials, Advanced oil and gas exploration and discovery, Renewable energy.

Some of the lesson learned from this article are that some clients do not know what they really want and they cannot define their need especially when the technology is very new, and the best solution to that problem is the rapid prototyping, knowing that part of the project managers' job is to be able to sell the vision to the stakeholders, and keeping in mind that developing a smart strategy for implementing them can help the organizations as well as project managers to respond effectively to the market innovation.

2.11 Case Study 10: Sustained Momentum by Burba, May 2014

The article "Sustained Momentum" is discussing another aspect of the change management; sustaining the change. The long-term benefits of a change strategic initiative are what truly determine its business value, so to measure the success of these initiatives, organizations need to do well in taking the long view, because all the wins in any project mean nothing if the change itself is abandoned few months after the project is completed. Project leaders must have mechanisms to measure the long-term organizational impact of the change initiatives, and each transformation project has to have tools to provide the needed support after the project is completed.

The article discussed also three-steps approach that can help sustaining change; First is (Measure for Measure); the project leader have to determine what impact the initiatives are intended to have and over what period of time; evaluating the impact and the outcomes can be seen in Customer satisfaction, Employee morale or retention, Sales or profits, Product or process innovation, Cost reduction, etc. knowing that the impact can be differently presented in different parts of the same organization. Project leaders are recommended to establish a system for communicating the metrics to the relevant stakeholders because gathering data is only valuable if the team is willing to investigate then adapt based on the information gathered.

Second is (Intangible Made Tangible); project leader should have another long-term mechanism, but this one is to capture the transformative effect on the organizational culture, because many times even when the adoption rates of a new process are adequate, many employees find it inefficient. One of the tools mentioned in the article is establishing the online portal, where employees ask questions about changes and a senior leader providing answers; that can be a very rich source of feedback. Third is (Continued Support); project leaders should provide a compelling case of change that will make the stakeholders focus on the resulting benefits, and not on the change project, because project leaders must support affected members by the change. In addition to that, project leaders should maintain support from above, because getting executive engagement makes a huge difference in sustaining changes.

Some of lessons learned from this article are that there are some factors that help organizations to be successful at change management; having an active support by senior management, stakeholder involvement in the initiative, creating effective communication plans, properly executing the communication plans, effective identification, measurement and communication of the intended benefits of the change, having the culture of the organization embraces change, and finally, having an effective management of people throughout the change.

2.12 Case Study 11: Securing Support by Merrick, May 2014

The article "Securing Support" discussed change and change management, it talked about how to get stakeholders to start embracing change and stop resisting it, because the more that stakeholders support strategic initiatives, the more likely those changing initiatives will succeed, so their involvement makes an organization highly effective at change management. Unfortunately, it is found that poor stakeholder management is among the top three reasons that change strategic initiatives fail; however, when they engage in the change process, they can recognize how their performance helps the firm achieve the expected benefits, and that can be a game changer.

A strong communication plan makes an organization highly effective in change management, that is why project managers need to identify the stakeholders' challenges that might impede the change and methodically build a communication plan to address all of them. Another tool project manager needs to use is the Two-Way Feedback, change creates resistance, but for an organization that devotes the resources to securing employees buy-in, it leads to substantial benefits, that is why the project manager needs to keep the feedback channels open during and after the change is implemented. Project managers need to keep in mind that Terminology is akin to culture; it can change from one site to another, even within the same company. The choice of words can be a source of tension, so it is crucial to give extra attention to the terminology chosen. There are four main key communication models that can be used (Steady messaging, Cyclical messaging, Feedback messaging, Situational messaging), knowing that the most effective communication plans take advantage of not only one of the messaging approaches; it should be using a combination of them, depending on needs of the strategic change initiative and its stakeholders.

Some of the lessons learned from this article are that sometimes people can be too busy and don't have enough space in their day to embrace the change, so project managers should understand and built that space in their plan. Additionally, even if a stakeholder is willing to change, sometimes he/she lacks the knowledge and skills to do so, and that is another thing to be considered by the project manager. Finally, the project managers need to help their employees to become more comfortable with the change, keeping in mind that lasting change takes time as change must be deep-rooted.

2.13 Case Study 12: At the Ready by Alderton, May 2014

The article "The Elements of Change: At the Ready" discussed many interesting points; change management and how to successfully implement it within the organization, taking into consideration the human element in the process. In order to have a successful strategic initiative within an organization, you must be supported by a change-ready culture, which is basically a culture that embraces change. Change management aims to close the gap between what is intended and what is realized; however, many project managers don't believe change is their job, and that is why to solve that issue, the influence has to be coming from strategic level, and also reporting to top management.

A change management program is in fact a cultural change, not only an implementation, so that is why you need a mature organization that views change as opportunity. In order to develop such a culture, executives must create a compelling vision for the staff to buy-in and to accept the new ways of doing things. Executives technically own the organizational culture, and it can change largely as a result of their own personal changes in thinking that is why they play a key role in implementing change; they have tremendous influence on employees' attitudes, so they can make or break any strategic initiative.

According to the article, change readiness assessment includes the following factors; The historical experience in dealing with change, Policies, Processes and decision-making norms, Accountability hierarchy, change agenda, Resources that are applied to change management, Leadership's capability of sponsoring change. The article also discussed a new term "Change fatigue" which is basically the number-one-reason change initiatives fail; it happens when employees are asked to follow too many changes at once. Besides that, change Initiatives fail due to the insufficient communication and Lack of leadership.

Some of the lessons learned from this article are that project managers need to keep in mind that it is crucial to understand what behaviors your current culture have and what the behaviors you need the new culture to have and is important to have the change readiness embed within your vision and strategy. Additionally, project managers have to make the benefits of change clear to the people, because people resist change that they don't understand, and that can be achieved through frequent and transparent communication.

2.14 Case Study 13: Disaster Averted by Swanson, July 2014 May 2014

The article "Disaster Averted" discussed very important aspects of the complex projects, which is the human factor and team morale when applying the change. To have a successful project, we must have a strong and confident team who believes in its ability of change for better. Project success stands for continuously identifying plus avoiding the risks that may lead the project to its failure, and managing the human factor effectively helps the project manager in achieving project success.

The article discussed several examples for project success. One of the projects was facing unclear communications, ambiguous structure plus scope creep. The project manager in that project solved the three problems through a project reporting that is more consistent and transparent with a new format and status report process. He also established a clear organizational structure where roles and responsibilities were communicated to the whole team and stakeholders. Finally, to control the scope creep, he made sure that any changes to the scope would be determined in a controlled manner through a committee vetting change requests.

Another project was discussed in the article where the communication with the client's team was very coarse, especially when tasks were not completed. To solve that communicating problem, the project manager had to learn the client team members' motivations and personalities, and he found out that the problem was not about having enough communication, but it is all about having an effective one. After understating that, he started asking much more specific and situational questions which triggered different responses than previously and that had more transparency in the overall conversation. As a result, the project had a significant progress.

The last project discussed was facing an internal resistance, where the top management was applying a pressure to reduce costs; however, that pressure was not translating to the team members who were developing, implementing the project. The project manager who understands that external motivation, even if it comes from the top management, it is less effective than self-motivation, he broke the project up into much smaller sub-projects and gave the team members responsibility for executing them, and that give them a great sense of responsibility and a sense of achievement, and that was translated into a huge progress within that project.

Some of the lessons learned from this article are that to help foster a very strong team culture, the project manager needs to build trust, by providing a platform to listen and respond and by celebrating significant milestones though out the project. It is also very helpful to have a reward and recognition program for the team members. The project manager also needs to have a positive attitude since he will be viewed as a role model that team members tend to follow.

2.15 Case Study 14: Boosting the Bottom Line, By Swanson, August 2011

The article "Boosting the Bottom Line" discussed another set of good practices when it comes to project management, taking into consideration the behavior of many organizations that are trying to remain profits through cutting underperforming projects. The article discussed the innovation projects which most of the time have more profits, but in the same time they carry more risk, and here comes the role of the project manager who should build a strong business case to convince decision-makers that the benefits outweigh the risks; however, project managers should keep in mind that top managers who force the creation of a business case before the real scope and level of effort are known end-up with misleading and meaningless numbers. When it comes to creating a business case, the project manager should make sure that business case Clear and Concise where the project scope plus approach should be in simple terms that are familiar to the audience. Additionally, it must be Correct and Compelling by building on reliable facts and data, and that will make the ROI speak for itself.

It is also discussed that portfolio will not remain static, so it must be modified when changes occur; sometimes organization stop some projects to focus on other projects that are more aligned with the organization strategy. After completing a project, project managers are reallocated to other projects and so, no one is left to be driving the benefits; the leadership team should continue to monitor results, including post-implementation because sometimes it takes long time to determine whether a project was profitable or not. Monitoring projects from concept to cash is not only a project management best practice, but also that establishes a culture of accountability within the organization.

The project management offices that had a big role in increasing profits stick to the following processes; 1, Developing business cases to get project approval by including a benefits realization baseline, 2, Making a stage-gate decision of how to proceed with a project, 3, Tracking benefits after implementation and reporting it to executives, and finally, 4, Connecting bonus compensation to the realization of the project benefits.

Some of the lessons learned from this article are that, in many situations, project managers and financial managers view the world differently, Project managers think of a project as a task with a start date and end date, while financial departments tend to think of projects as a cycle, with annual budgets and reporting. And that is why project managers should know how to speak with the financial department's language, and they must engage with the financial staff to understand what information they need, and when they need it.

2.16 Case Study 15: All Things Considered, By Swanson, February 2011

The article "All Things Considered" discusses portfolio management practices. The article talks about the challenges that executives face in managing portfolios when they try to answer the following question: What projects should be selected?, How to rank projects within the company's portfolio?, and How to align portfolios with the organization's strategic objectives? Because answering those questions takes great responsibility, many executives unfortunately focus on low-risk projects that are aimed solely at sustaining the business, basically to avoid losing their jobs when they fail to manage those portfolios.

One of the biggest dilemmas that companies face when prioritizing projects is that active project priorities change frequently, which leads to resource churn, and that is why organizations try to establish a documented assessment process across the company, because having a standardized methodology helps the company to have the flexibility needed to overcome those changes, and to align resources with the organization strategic goals. Additionally, in portfolio management it is very important that the levels of formality and complexity of process to be matching the maturity of the organization, taking into consideration the company's culture to make sure that it is adopted for real in practice.

Some of the lesson learned from this article are that project decisions should not be only based on the bottom line; project managers should understand the benefits that the firm will realize from such project; besides the bottom line, the firm could be aiming to improve working conditions, work force satisfaction, improving corporate morale, improving quality, or even ensure business continuity. So, the ROI is not everything; to look beyond it, many companies consider multi-criteria decision analysis, following the four basic steps; alternatives definition, criteria definition, comparisons, computation of the projects' ranking.

CHAPTER 3: METHODS

3.1 Project Management and System Engineering Efficiency and Effectiveness

Efficiency and Effectiveness are essential criteria for assessing SE and PM performance. Efficiency combines Cost and Time. Effectiveness combines Risk and Performance.

In this thesis, the empirical assessment of Efficiency and Effectiveness occurred for the case studies listed below, based on personal observations and expert assessments via the Delphi Method. Some of these case studies were introduced in Chapter 2. The case studies utilized are the following:

- CS 01: Arar International Airport. Arar, Saudi Arabia, 2014-2017
- CS 02: Prince Mohammed Bin Abd Al Aziz International Airport in Al-Medina in KSA, Kingdom of Saudi Arabia. Al Medina, Saudi Arabia 2011-2015
- CS 03: King Abdul-Aziz International Airport in Jeddah, Saudi Arabia, 2013-2018
- CS 04: Queen Alia International Airport. Amman, Jordan, 2014
- CS 05: Saad AlDeen Mega Sweet Factory. Riyadh, Saudi Arabia, 2016-2017
- CS 06: Terminal 2 Cairo International Airport renovations. Cairo, Egypt, 2012-2016
- CS 07: Doha International Airport. Doha, Qatar, 2010-2014

Depending on the Project Management and System Engineering targets, both Efficiency and Effectiveness are interested in time and resources, because both take care of planning, schedule, design, and stakeholder requirements analysis. This means that the time factor is significant. In the same way, both identify, study and analyze the costs for everything, including even the cost of processes to achieve the profit sought, and that means resource costs are also significant factors as well. Both time and resources indicate efficiency.

Also, the target of both Project Management and System Engineering is to finish, complete and handover the project successfully without any changes in the functionality that the stakeholders required from the beginning, and this will happen using several processes and factors. The most important is Risk Management, to get high performance.

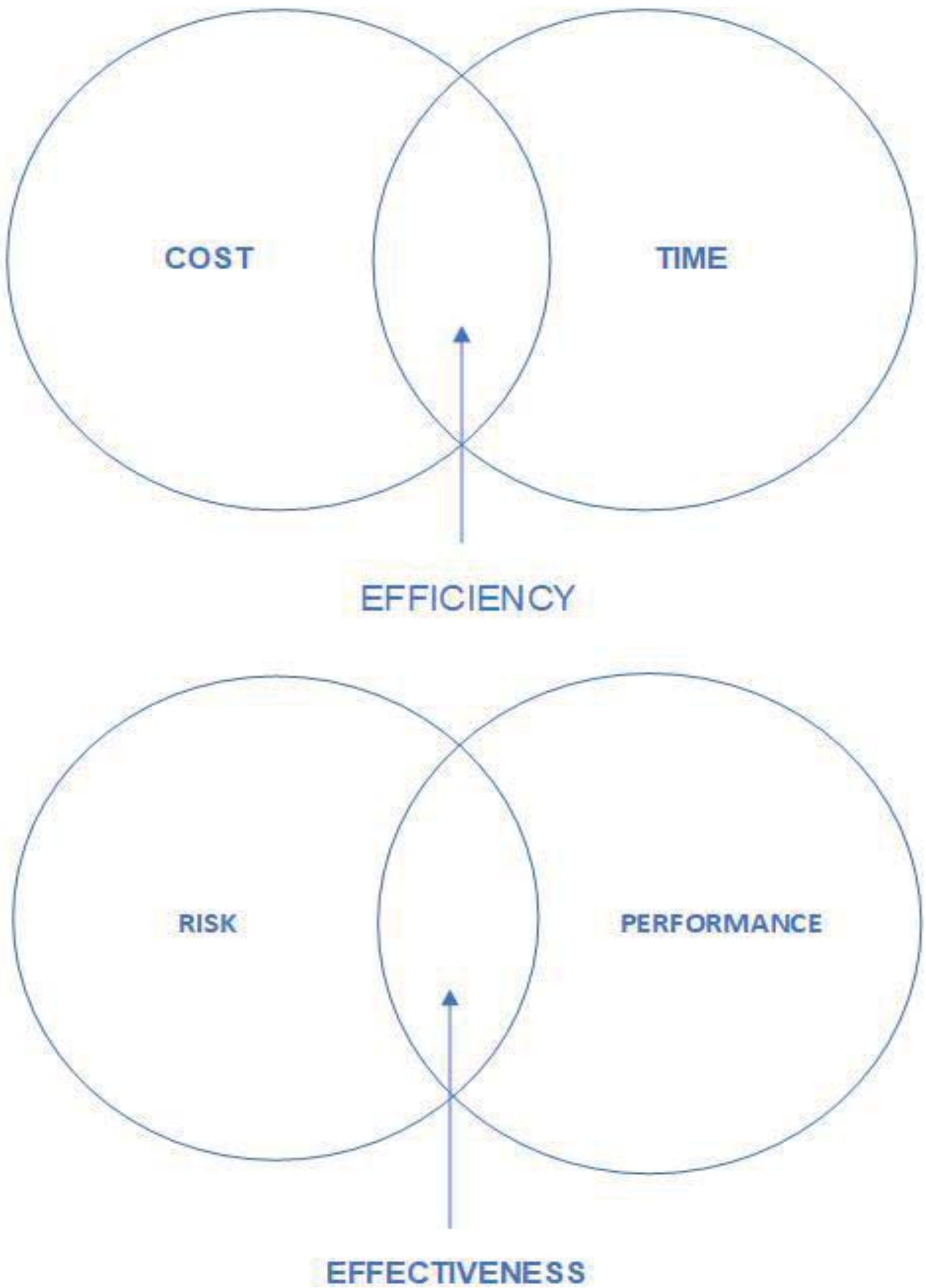

Figure 3-1: Efficiency Vs. Effectiveness

To study Efficiency and Effectiveness, this thesis depends on personal observations, which will be tabulated in a matrix for all case studies introduced.

First, the importance of each process in Project Management and each process in System Engineering is assessed and classified as from 0% to 100% on a scale from 1 -10, with each scale meaning a rate of 10%. For example, 1 indicates 0%-10%, 2 indicates 10%-20% … etc. Thus, the first step in this method is to figure out the weight of each process in System Engineering and the weight of each process in Project Management.

3.2 Delphi Method

The Delphi Method will facilitate the survey of experts involved in the case studies and will allow the estimation of the weight of each SE and PM process on a scale from 1-10, with 1 meaning a range from 0%-10%, etc.

The Delphi Method is used for business forecasting and has advantages over other structured forecasting approaches. The Delphi Method uses experts and has the experts answer questionnaires in two or more rounds. The Delphi Method is not only for business, but it also used in many fields of engineering. The foundational concept of the Delphi method is the use of experts to answer questions to evaluate processes or even projects. For example, if there is a problem to solve using the Delphi Method, the experts meet and talk about the problem. Then each expert evaluates and explains for factors separately and individually. After the first round, the same experts meet another time and talk about the problem again, as well as what each one answered; then the expert hold another round to answer again, until the experts get answers that are close in concept, evaluation and scale.

The table below lists the participant experts in PM and SE who used the Delphi Method for this research.

Table 3-1: Delphi Method Participants

Participant	*Educational Level*	*Position Level*	*Location*
1	**B.S. Civil Engineering, MBA PM**	**Projects Manager**	**Ohio, US**
2	**B.S. Civil Engineering**	**Project Manager**	**Paraguay**
3	**B.S. Mechanical Engineering**	**System Engineer**	**Dubai, UAE**
4	**B.S. Civil Engineering**	**Project Manager**	**Riyadh, KSA**
5	**PhD Business Administration**	**Managing Director**	**Jeddah, KSA**
6	**B.S. Civil Engineering, MBA**	**PM & Estimation**	**Jordan**
7	**PhD Sustainable Logistics**	**Professor Assistant**	**Sweden**
8	**M.S. Industrial Engineering & SE**	**Managing Director**	**Texas, US**

The Delphi Method rules hold that there should be a face-to-face meeting, but in this case, because of different countries and different time zones, the meeting was on Skype. The results and analyses will be introduced in Chapter 4.

Table 3-2: System Engineering Processes Weight

	1 (0%-10%)	2 (10%-20%)	3 (20%-30%)	4 (30%-40%)	5 (40%-50%)	6 (50%-60%)	7 (60%-70%)	8 (70%-80%)	9 (80%-90%)	10 (90%-100%)
TECHNICAL PROCESS AREAS										
SE1 Business or Mission Analysis										
SE2 Stakeholder Needs or Requirements Definition Process										
SE3 System Requirements Definition Process										
SE4 Architecture Definition Process										
SE5 Design Definition Process										
SE6 System Analysis Process										
SE7 Implementation Process										
SE8 Integration Process										
SE9 Verification Process										
SE10 Transition Process										
SE11 Validation Process										
SE12 Operations Process										
SE13 Maintenance Process										
SE14 Disposal Process										
TECHNICAL MANAGEMENT PROCESS AREAS										
SE15 Project Planning Process										
SE16 Project Assessment and Control Process										
SE17 Decision Management Process										
SE18 Risk Management Process										
SE19 Configuration Management Process										
SE20 Information Management Process										
SE21 Measurement Process										
SE22 Quality Assurance Process										
AGREEMENT PROCESS AREAS										
SE23 Acquisition Process										
SE24 Supply Process										
ORGANIZATIONAL PROJECT-ENABLING PROCESS AREAS										
SE25 Life-Cycle Model Management Process										
SE26 Infrastructure Management Process										
SE27 Portfolio Management Process										
SE28 Human Resource Management Process										
SE29 Quality Management Process										
SE30 Knowledge Management Process										
TAILORING PROCESS AREAS										
SE31 Tailoring Process										

Table 3-3: Project Management Processes Weight

	1 (0%-10%)	2 (10%-20%)	3 (20%-30%)	4 (30%- 40%)	5 (40%-50%)	6 (50%-60%)	7 (60%-70%)	8 (70%-80%)	9 (80%-90%)	10 (90%-100%)
Project Integration Management										
PM1 Develop Project Charter										
PM2 Develop Project Management Plan										
PM3 Direct and Manage Project Work										
PM4 Manage Project Knowledge										
PM5 Monitor and Control Project Work										
PM6 Perform Integrated Change Control										
PM7 Close Project or Phase										
Project Scope Management										
PM8 Plan Scope Management										
PM9 Collect Requirements										
PM10 Define Scope										
PM11 Create WBS										
PM12 Validate Scope										
PM13 Control Scope										
Project Schedule Management										
PM14 Plan Schedule Management										
PM15 Define Activities										
PM16 Sequence Activities										
PM17 Estimate Activity Durations										
PM18 Develop Schedule										
PM19 Control Schedule										
Project Cost Management										
PM20 Plan Cost Management										
PM21 Estimate Costs										
PM22 Determine Budget										
PM23 Control Costs										
Project Quality Management										
PM24 Plan Quality Management										
PM25 Manage Quality										
PM26 Control Quality										
Project ResourceManagement										
PM27 Plan Resource Management										
PM28 Estimate Activity Resources										
PM29 Acquired Resources										
PM30 Develop Team										
PM31 Manage Team										
PM32 Control Resources										
Project Communications Management										
PM33 Plan Communications Management										
PM34 Manage Communications										
PM35 Monitor Communications										
Project Risk Management										
PM36 Plan Risk Management										
PM37 Identify Risks										
PM38 Perform Qualitative Risk Analysis										
PM39 Perform Quantitative Risk Analysis										
PM40 Plan Risk Responses										
PM41 Implement Risk Responses										
PM42 MonitorRisks										
Project Procurement Management										
Pm43 Plan Procurement Management										
Pm44 Conduct Procurements										
Pm45 Control Procurements										
Project Stakeholder Management										
PM46 Identify Stakeholders										
PM47 Plan Stakeholder Engagement										
PM48 Manage Stakeholder Engagement										
PM49 Monitor Stakeholder Engagement										

3.3 Numerical Analysis Method

The next step in the method used in this research is to analyze the case studies used in Chapter 3 and see the rank of each process used in both Project Management and System Engineering.
The scale used in this analysis is ten scales degree from 1-10, which 1 is the lowest scale and 10 is the highest scale. This type of scale came from engineering and finance scale; it is from 0% to 100% (each 10% is scale).

For Efficiency, when any company wants to estimate any project and quote it, the estimation department should analyze the project with co-operate with finance and Human Resource Department because it is not only estimate and study from engineering vision, projects should also be studied from an overhead view. That's meaning to figure out the profit and margin percentage in the project the company should review the project from all corners related in the project. Depends on personal experience most of the projects have a margin percent for the profit between 25%-35% and this as the average because there are some projects especially the projects have a lot of competitors the margin goes down. From this margin studied 15%-18% is overhead, and the overhead means salaries, fixed cost, variable cost, direct cost, and indirect cost. For example, if there is a project has a margin of 30%, and the overhead from the margin percent is 15%. So, 50% of the profit is cost. If the company lost 50% from the margin, the company would cover salaries and the cost of the company, but it will not get any profit. So, we can start the scale for Efficiency from 50% as a zero but let's see the Effectiveness in the next paragraph.

For Effectiveness, sometimes the project has very low Effectiveness, but the project owner or stakeholder be happy, and they could give the contractor another project, so the 50% for Effectiveness does not mean that the project is not good like Efficiency.

That's why the scale used in this research from 1-10 that's mean 1 is a range between 0%-10% and 2 is a range from 11%-20% etc.…

The next two tables introduce the picture of the method, and the results will be got in the next chapter.

The first table will explain the processes in Project Management with the case studies used. And the second table will introduce the processes in System Engineering with the same case studies.

Table 3-4: Project Management Processes Performance for Each Case Study

	CS01	CS02	CS03	CS04	CS05	CS06	CS07
Project Integration Management							
PM1 Develop Project Charter							
PM2 Develop Project Management Plan							
PM3 Direct and Manage Project Work							
PM4 Manage Project Knowledge							
PM5 Monitor and Control Project Work							
PM6 Perform Integrated Change Control							
PM7 Close Project or Phase							
Project Scope Management							
PM8 Plan Scope Management							
PM9 Collect Requirements							
PM10 Define Scope							
PM11 Create WBS							
PM12 Validate Scope							
PM13 Control Scope							
Project Schedule Management							
PM14 Plan Schedule Management							
PM15 Define Activities							
PM16 Sequence Activities							
PM17 Estimate Activity Durations							
PM18 Develop Schedule							
PM19 Control Schedule							
Project Cost Management							
PM20 Plan Cost Management							
PM21 Estimate Costs							
PM22 Determine Budget							
PM23 Control Costs							
Project Quality Management							
PM24 Plan Quality Management							
PM25 Manage Quality							
PM26 Control Quality							
Project ResourceManagement							
PM27 Plan Resource Management							
PM28 Estimate Activity Resources							
PM29 Acquired Resources							
PM30 Develop Team							
PM31 Manage Team							
PM32 Control Resources							
Project Communications Management							
PM33 Plan Communications Management							
PM34 Manage Communications							
PM35 Monitor Communications							
Project Risk Management							
PM36 Plan Risk Management							
PM37 Identify Risks							
PM38 Perform Qualitative Risk Analysis							
PM39 Perform Quantitative Risk Analysis							
PM40 Plan Risk Responses							
PM41 Implement Risk Responses							
PM42 MonitorRisks							
Project Procurement Management							
Pm43 Plan Procurement Management							
Pm44 Conduct Procurements							
Pm45 Control Procurements							
Project Stakeholder Management							
PM46 Identify Stakeholders							
PM47 Plan Stakeholder Engagement							
PM48 Manage Stakeholder Engagement							
PM49 Monitor Stakeholder Engagement							

Table 3-5: System Engineering Processes Performance for Each Case Study

	CS01	CS02	CS03	CS04	CS05	CS06	CS07
TECHNICAL PROCESS AREAS							
SE1 Business or Mission Analysis							
SE2 Stakeholder Needs or Requirements Definition Process							
SE3 System Requirements Definition Process							
SE4 Architecture Definition Process							
SE5 Design Definition Process							
SE6 System Analysis Process							
SE7 Implementation Process							
SE8 Integration Process							
SE9 Verification Process							
SE10 Transition Process							
SE11 Validation Process							
SE12 Operations Process							
SE13 Maintenance Process							
SE14 Disposal Process							
TECHNICAL MANAGEMENT PROCESS AREAS							
SE15 Project Planning Process							
SE16 Project Assessment and Control Process							
SE17 Decision Management Process							
SE18 Risk Management Process							
SE19 Configuration Management Process							
SE20 Information Management Process							
SE21 Measurement Process							
SE22 Quality Assurance Process							
AGREEMENT PROCESS AREAS							
SE23 Acquisition Process							
SE24 Supply Process							
ORGANIZATIONAL PROJECT-ENABLING PROCESS AREAS							
SE25 Life-Cycle Model Management Process							
SE26 Infrastructure Management Process							
SE27 Portfolio Management Process							
SE28 Human Resource Management Process							
SE29 Quality Management Process							
SE30 Knowledge Management Process							
TAILORING PROCESS AREAS							
SE31 Tailoring Process							

The method will calculate the total score for Project Management and System Engineering for each case study by sum the score for each process in the case study. Then, figure out the score out of the max score that it will calculate using the following equation:

Total Score = scale * number of processes

For example, the total score for scale 10 that is from 90%-100% it will be

Total score = 10 * 49 (for Project Management) = 490

So, the maximum score for PM is 490.

And the total score for System Engineering:

Total score = 10 * 31 = 310

So, the maximum score for SE is 310

The next step in this method is to analyze the processes in both Project Management and System Engineering from two corners Efficiency and Effectiveness. That's mean each process affect efficiency or effectiveness or both and how much it affects using the score from 1-10. Then calculate the final score of Project Management Efficiency and Effectiveness, and System Engineering Efficiency and Effectiveness. The next two tables introduce how to use this part of the method, and the analysis and results will get it on Chapter 4.

Table 3-6: PM Processes Classification between Efficiency or/and Effectiveness

	EFCY	EFTV
Project Integration Management		
PM1 Develop Project Charter		
PM2 Develop Project Management Plan		
PM3 Direct and Manage Project Work		
PM4 Manage Project Knowledge		
PM5 Monitor and Control Project Work		
PM6 Perform Integrated Change Control		
PM7 Close Project or Phase		
Project Scope Management		
PM8 Plan Scope Management		
PM9 Collect Requirements		
PM10 Define Scope		
PM11 Create WBS		
PM12 Validate Scope		
PM13 Control Scope		
Project Schedule Management		
PM14 Plan Schedule Management		
PM15 Define Activities		
PM16 Sequence Activities		
PM17 Estimate Activity Durations		
PM18 Develop Schedule		
PM19 Control Schedule		
Project Cost Management		
PM20 Plan Cost Management		
PM21 Estimate Costs		
PM22 Determine Budget		
PM23 Control Costs		
Project Quality Management		
PM24 Plan Quality Management		
PM25 Manage Quality		
PM26 Control Quality		
Project ResourceManagement		
PM27 Plan Resource Management		
PM28 Estimate Activity Resources		
PM29 Acquired Resources		
PM30 Develop Team		
PM31 Manage Team		
PM32 Control Resources		
Project Communications Management		
PM33 Plan Communications Management		
PM34 Manage Communications		
PM35 Monitor Communications		
Project Risk Management		
PM36 Plan Risk Management		
PM37 Identify Risks		
PM38 Perform Qualitative Risk Analysis		
PM39 Perform Quantitative Risk Analysis		
PM40 Plan Risk Responses		
PM41 Implement Risk Responses		
PM42 MonitorRisks		
Project Procurement Management		
Pm43 Plan Procurement Management		
Pm44 Conduct Procurements		
Pm45 Control Procurements		
Project Stakeholder Management		
PM46 Identify Stakeholders		
PM47 Plan Stakeholder Engagement		
PM48 Manage Stakeholder Engagement		
PM49 Monitor Stakeholder Engagement		

Table 3-7: SE Processes Classification between Efficiency or/and Effectiveness

	EFCY	EFTV
TECHNICAL PROCESS AREAS		
SE1 Business or Mission Analysis		
SE2 Stakeholder Needs or Requirements Definition Process		
SE3 System Requirements Definition Process		
SE4 Architecture Definition Process		
SE5 Design Definition Process		
SE6 System Analysis Process		
SE7 Implementation Process		
SE8 Integration Process		
SE9 Verification Process		
SE10 Transition Process		
SE11 Validation Process		
SE12 Operations Process		
SE13 Maintenance Process		
SE14 Disposal Process		
TECHNICAL MANAGEMENT PROCESS AREAS		
SE15 Project Planning Process		
SE16 Project Assessment and Control Process		
SE17 Decision Management Process		
SE18 Risk Management Process		
SE19 Configuration Management Process		
SE20 Information Management Process		
SE21 Measurement Process		
SE22 Quality Assurance Process		
AGREEMENT PROCESS AREAS		
SE23 Acquisition Process		
SE24 Supply Process		
ORGANIZATIONAL PROJECT-ENABLING PROCESS AREAS		
SE25 Life-Cycle Model Management Process		
SE26 Infrastructure Management Process		
SE27 Portfolio Management Process		
SE28 Human Resource Management Process		
SE29 Quality Management Process		
SE30 Knowledge Management Process		
TAILORING PROCESS AREAS		
SE31 Tailoring Process		

The next step of this method is to calculate the weight of each process mathematically and compare these results with the weight got from the Delphi Method to know the weight of each process used. On the same way the results will be obtained to illustrate the processes need to propose Hybrid Processes for Project Management and System Engineering synergized and get Technical Project Management.

This step will calculate all processes together 31 Systems Engineering processes and 49 Projects Management processes once for Efficiency and once for Effectiveness, these two equations will apply for each case study.

In Efficiency & Effectiveness for Project Management and System Engineering, the table below introduces the number of processes for Efficiency and Effectiveness.

The following equation form will use in this method:

$$\sum_{i=1}^{37} Wi * CSi \rightarrow \text{For Efficiency.}$$

$$\sum_{i=1}^{54} Wi * CSi \rightarrow \text{For Effectiveness.}$$

Table 3-8: Efficiency Group Processes

	CS1	CS2	CS3	CS4	CS5	CS6	CS7
PM2 Develop Project Management Plan							
PM3 Direct and Manage Project Work							
PM5 Monitor and Control Project Work							
PM6 Perform Integrated Change Control							
PM9 Collect Requirements							
PM10 Define Scope							
PM11 Create WBS							
PM13 Control Scope							
PM16 Sequence Activities							
PM17 Estimate Activity Durations							
PM20 Plan Cost Management							
PM21 Estimate Costs							
PM22 Determine Budget							
PM23 Control Costs							
PM24 Plan Quality Management							
PM25 Manage Quality							
PM26 Control Quality							
PM28 Estimate Activity Resources							
PM29 Acquired Resources							
PM32 Control Resources							
PM36 Plan Risk Management							
PM41 Implement Risk Responses							
SE1 Business or Mission Analysis							
SE2 Stakeholder Needs or Requirements Definition Process							
SE3 System Requirements Definition Process							
SE5 Design Definition Process							
SE6 System Analysis Process							
SE13 Maintenance Process							
SE14 Disposal Process							
SE15 Project Planning Process							
SE16 Project Assessment and Control Process							
SE19 Configuration Management Process							
SE23 Acquisition Process							
SE25 Life-Cycle Model Management Process							
SE28 Human Resource Management Process							
SE29 Quality Management Process							
SE31 Tailoring Process							

Table 3-9: Effectiveness Group Processes

	CS1	CS2	CS3	CS4	CS5	CS6	CS7
PM1 Develop Project Charter							
PM2 Develop Project Management Plan							
PM3 Direct and Manage Project Work							
PM4 Manage Project Knowledge							
PM5 Monitor and Control Project Work							
PM7 Close Project or Phase							
PM8 Plan Scope Management							
PM9 Collect Requirements							
PM12 Validate Scope							
PM14 Plan Schedule Management							
PM15 Define Activities							
PM16 Sequence Activities							
PM17 Estimate Activity Durations							
PM18 Develop Schedule							
PM19 Control Schedule							
PM24 Plan Quality Management							
PM25 Manage Quality							
PM27 Plan Resource Management							
PM30 Develop Team							
PM31 Manage Team							
PM33 Plan Communications Management							
PM34 Manage Communications							
PM35 Monitor Communications							
PM36 Plan Risk Management							
PM37 Identify Risks							
PM38 Perform Qualitative Risk Analysis							
PM39 Perform Quantitative Risk Analysis							
PM40 Plan Risk Responses							
PM41 Implement Risk Responses							
PM42 MonitorRisks							
SE1 Business or Mission Analysis							
SE2 Stakeholder Needs or Requirements Definition Process							
SE4 Architecture Definition Process							
SE5 Design Definition Process							
SE7 Implementation Process							
SE8 Integration Process							
SE9 Verification Process							
SE10 Transition Process							
SE11 Validation Process							
SE12 Operations Process							
SE15 Project Planning Process							
SE16 Project Assessment and Control Process							
SE17 Decision Management Process							
SE18 Risk Management Process							
SE19 Configuration Management Process							
SE20 Information Management Process							
SE21 Measurement Process							
SE22 Quality Assurance Process							
SE24 Supply Process							
SE26 Infrastructure Management Process							
SE27 Portfolio Management Process							
SE28 Human Resource Management Process							
SE30 Knowledge Management Process							
SE31 Tailoring Process							

The equations obtained are the following:

For Efficiency for CS1:

$$\sum_{i=1}^{37} \boldsymbol{Wi * CS1} = \textbf{Cost + Time}$$

$$= \frac{\textit{Expected Cost}}{\textit{Actual Cost}} + \frac{\textit{Expected Time}}{\textit{Actual Time}}$$

For Effectiveness for CS1:

$$\sum_{i=1}^{54} \boldsymbol{Wi * CS1} = \textbf{Performance + Risk}$$

Performance percentage evaluation got it for each case study project from the project manager for each project.

Risk percentage calculation is using Three Points Estimates and Triangle Distribution Method. This method uses an assumption for the cost of the risk in three classification levels: low, most likely and high, and then gets two triangle distributions as in the figure below:

Figure 3-2: Triangle Distribution

(AACE International, Skills and Knowledge of Cost Engineering, 6th edition)

Using triangle distribution there are two values for risk percentage, under run and over run that's mean the most likely point is the based, the triangle after this point is the over run and the triangle before this point is under run.

Triangle distribution: Calculate the area of both triangle as the following proof:

Low (a)

Most Likely (b)

High (c)

A2 = 1/2 * (b - a) * 2/(c - a)

A2 = (b - a)/(c - a)

And

A1 = 1/2 * (c - b) * 2/(c - a)

A1 = (c - b)/(c - a)

A2 is the actual probability of Most Likely risk.

3.4 Limitations of this Study

This thesis has a limited number of case studies for analyses which depend on personal experience in construction projects. In order to increase the accuracy of the data and the percentage evaluation of each factor, the Triangular Distribution and Delphi Methods were utilized.

The case studies and data used in this paper are introduced in the first chapter and consist of seven projects in the Middle East, some of which are completed.

The Triangular Distribution helped to calculate the risk percentage for each project. Then this percentage was added to the performance percentage (already obtained from the Delphi Method) to figure out the effectiveness value of each project.

3.5 Literature Review Case Studies

Literature review case studies in Chapter 2 are some academic articles introduce some PM and SE processes to success the project and get the optimization. It is difficult to put these case studies in the analysis method because each case study (academic article) talk about some processes by 100% and doesn't talk about others, so it is difficult to evaluate the processes in these case studies.

However, the results will be got from Chapter 4 will compare with the processes focused and introduces by the case studies used in Chapter 2.

CHAPTER 4: RESULTS

4.1 Delphi Method

As introduced in Chapter 3 about Delphi Method, here are the results of process weight in both field Project Management and System Engineering.

Table 4-1: Results of Delphi Method for System Engineering Processes Weight

	1 (0%-10%)	2 (10%-20%)	3 (20%-30%)	4 (30%- 40%)	5 (40%-50%)	6 (50%-60%)	7 (60%-70%)	8 (70%-80%)	9 (80%-90%)	10 (90%-100%)
TECHNICAL PROCESS AREAS										
SE1 Business or Mission Analysis	■									
SE2 Stakeholder Needs or Requirements Definition Process									■	
SE3 System Requirements Definition Process		■								
SE4 Architecture Definition Process			■							
SE5 Design Definition Process					■					
SE6 System Analysis Process				■						
SE7 Implementation Process						■				
SE8 Integration Process						■				
SE9 Verification Process							■			
SE10 Transition Process				■						
SE11 Validation Process							■			
SE12 Operations Process							■			
SE13 Maintenance Process		■								
SE14 Disposal Process	■									
TECHNICAL MANAGEMENT PROCESS AREAS										
SE15 Project Planning Process										■
SE16 Project Assessment and Control Process								■		
SE17 Decision Management Process		■								
SE18 Risk Management Process										■
SE19 Configuration Management Process			■							
SE20 Information Management Process	■									
SE21 Measurement Process				■						
SE22 Quality Assurance Process				■						
AGREEMENT PROCESS AREAS										
SE23 Acquisition Process				■						
SE24 Supply Process				■						
ORGANIZATIONAL PROJECT-ENABLING PROCESS AREAS										
SE25 Life-Cycle Model Management Process					■					
SE26 Infrastructure Management Process		■								
SE27 Portfolio Management Process		■								
SE28 Human Resource Management Process						■				
SE29 Quality Management Process									■	
SE30 Knowledge Management Process	■									
TAILORING PROCESS AREAS										
SE31 Tailoring Process								■		

Table 4-2: Results of Delphi Method for Project Management Processes Weight

	1 (0%-10%)	2 (10%-20%)	3 (20%-30%)	4 (30%- 40%)	5 (40%-50%)	6 (50%-60%)	7 (60%-70%)	8 (70%-80%)	9 (80%-90%)	10 (90%-100%)
Project Integration Management										
PM1 Develop Project Charter	■									
PM2 Develop Project Management Plan	■									
PM3 Direct and Manage Project Work						■				
PM4 Manage Project Knowledge	■									
PM5 Monitor and Control Project Work						■				
PM6 Perform Integrated Change Control			■							
PM7 Close Project or Phase									■	
Project Scope Management										
PM8 Plan Scope Management				■						
PM9 Collect Requirements					■					
PM10 Define Scope			■							
PM11 Create WBS								■		
PM12 Validate Scope						■				
PM13 Control Scope					■					
Project Schedule Management										
PM14 Plan Schedule Management								■		
PM15 Define Activities				■						
PM16 Sequence Activities							■			
PM17 Estimate Activity Durations					■					
PM18 Develop Schedule	■									
PM19 Control Schedule				■						
Project Cost Management										
PM20 Plan Cost Management									■	
PM21 Estimate Costs								■		
PM22 Determine Budget				■						
PM23 Control Costs							■			
Project Quality Management										
PM24 Plan Quality Management								■		
PM25 Manage Quality				■						
PM26 Control Quality									■	
Project ResourceManagement										
PM27 Plan Resource Management					■					
PM28 Estimate Activity Resources					■					
PM29 Acquired Resources				■						
PM30 Develop Team		■								
PM31 Manage Team										■
PM32 Control Resources					■					
Project Communications Management										
PM33 Plan Communications Management					■					
PM34 Manage Communications	■									
PM35 Monitor Communications							■			
Project Risk Management										
PM36 Plan Risk Management					■					
PM37 Identify Risks				■						
PM38 Perform Qualitative Risk Analysis			■							
PM39 Perform Quantitative Risk Analysis			■							
PM40 Plan Risk Responses		■								
PM41 Implement Risk Responses							■			
PM42 MonitorRisks							■			
Project Procurement Management										
Pm43 Plan Procurement Management					■					
Pm44 Conduct Procurements	■									
Pm45 Control Procurements							■			
Project Stakeholder Management										
PM46 Identify Stakeholders							■			
PM47 Plan Stakeholder Engagement			■							
PM48 Manage Stakeholder Engagement								■		
PM49 Monitor Stakeholder Engagement								■		

4.2 Numerical Analysis Method

4.2.1 Method Introduction

In this chapter, we are going to calculate and analyze the weight of each process and compare it with the weight got from Delphi Method.

Calculate the weight using mathematical analysis and method so once we are going to calculate it using math, we will have 80 unknowns from both Project Management and System Engineering, 49 unknowns from PM and 31 unknowns from SE.

So, if we want to find 80 unknown, we should have 80 equation to get matrix 80*80 then we can solve this matrix using MATLAB software or Microsoft Excel program.

The first step is to determine the Efficiency equation and Effectiveness equation.

For Efficiency:

$$\sum_{i=1}^{44} Wi * CS1 = \text{Cost} + \text{Time}$$

For Effectiveness:

$$\sum_{i=1}^{55} Wi * CS1 = \text{Performance} + \text{Risk}$$

The first step to figuring out the two equations is to classify the processes between the efficiency process and the effectiveness process that mean what this process achieves more efficiency or effectiveness? The tables below classify the processes between EFCY & EFTV for both PM & SE.

From this step, we can know how many processes will use for efficiency equation and how many processes will use for effectiveness equation.

Table 4-3: PM Processes Classification between Efficiency or Effectiveness

	EFCY	EFTV
Project Integration Management		
PM1 Develop Project Charter	0	1
PM2 Develop Project Management Plan	1	1
PM3 Direct and Manage Project Work	1	1
PM4 Manage Project Knowledge	0	1
PM5 Monitor and Control Project Work	1	1
PM6 Perform Integrated Change Control	1	0
PM7 Close Project or Phase	0	1
Project Scope Management		
PM8 Plan Scope Management	0	1
PM9 Collect Requirements	1	1
PM10 Define Scope	1	0
PM11 Create WBS	1	0
PM12 Validate Scope	0	1
PM13 Control Scope	1	0
Project Schedule Management		
PM14 Plan Schedule Management	0	1
PM15 Define Activities	0	1
PM16 Sequence Activities	1	1
PM17 Estimate Activity Durations	1	1
PM18 Develop Schedule	0	1
PM19 Control Schedule	0	1
Project Cost Management		
PM20 Plan Cost Management	1	0
PM21 Estimate Costs	1	0
PM22 Determine Budget	1	0
PM23 Control Costs	1	0
Project Quality Management		
PM24 Plan Quality Management	1	1
PM25 Manage Quality	1	1
PM26 Control Quality	1	0
Project ResourceManagement		
PM27 Plan Resource Management	0	1
PM28 Estimate Activity Resources	1	0
PM29 Acquired Resources	1	0
PM30 Develop Team	0	1
PM31 Manage Team	0	1
PM32 Control Resources	1	0
Project Communications Management		
PM33 Plan Communications Management	0	1
PM34 Manage Communications	0	1
PM35 Monitor Communications	0	1
Project Risk Management		
PM36 Plan Risk Management	1	1
PM37 Identify Risks	0	1
PM38 Perform Qualitative Risk Analysis	0	1
PM39 Perform Quantitative Risk Analysis	0	1
PM40 Plan Risk Responses	0	1
PM41 Implement Risk Responses	1	1
PM42 MonitorRisks	0	1
Project Procurement Management		
Pm43 Plan Procurement Management	1	0
Pm44 Conduct Procurements	1	0
Pm45 Control Procurements	1	0
Project Stakeholder Management		
PM46 Identify Stakeholders	1	0
PM47 Plan Stakeholder Engagement	1	0
PM48 Manage Stakeholder Engagement	1	1
PM49 Monitor Stakeholder Engagement	1	0

Table 4-4: SE Processes Classification between Efficiency or Effectiveness

	EFCY	EFTV
TECHNICAL PROCESS AREAS		
SE1 Business or Mission Analysis	1	1
SE2 Stakeholder Needs or Requirements Definition Process	1	1
SE3 System Requirements Definition Process	1	0
SE4 Architecture Definition Process	0	1
SE5 Design Definition Process	1	1
SE6 System Analysis Process	1	0
SE7 Implementation Process	0	1
SE8 Integration Process	0	1
SE9 Verification Process	0	1
SE10 Transition Process	0	1
SE11 Validation Process	0	1
SE12 Operations Process	0	1
SE13 Maintenance Process	1	0
SE14 Disposal Process	1	0
TECHNICAL MANAGEMENT PROCESS AREAS		
SE15 Project Planning Process	1	1
SE16 Project Assessment and Control Process	1	1
SE17 Decision Management Process	0	1
SE18 Risk Management Process	0	1
SE19 Configuration Management Process	1	1
SE20 Information Management Process	0	1
SE21 Measurement Process	0	1
SE22 Quality Assurance Process	0	1
AGREEMENT PROCESS AREAS		
SE23 Acquisition Process	1	0
SE24 Supply Process	0	1
ORGANIZATIONAL PROJECT-ENABLING PROCESS AREAS		
SE25 Life-Cycle Model Management Process	1	0
SE26 Infrastructure Management Process	0	1
SE27 Portfolio Management Process	0	1
SE28 Human Resource Management Process	1	1
SE29 Quality Management Process	1	0
SE30 Knowledge Management Process	0	1
TAILORING PROCESS AREAS		
SE31 Tailoring Process	1	1

4.2.2 Processes Score

Now, the number of efficiency processes are known, it is 44 processes, and the number of effectiveness processes is 55 processes. Then, the next step is to find the actual score for each process that applied in our seven case studies introduced at the beginning of Chapter 3 as in the tables below.

Table 4-5: System Engineering Processes Performance for Each Case Study

	CS01	CS02	CS03	CS04	CS05	CS06	CS07
TECHNICAL PROCESS AREAS							
SE1 Business or Mission Analysis	5	5	6	6	7	5	8
SE2 Stakeholder Needs or Requirements Definition Process	6	5	5	6	5	6	7
SE3 System Requirements Definition Process	4	5	5	6	6	5	6
SE4 Architecture Definition Process	4	3	4	4	5	4	6
SE5 Design Definition Process	5	6	5	7	6	6	7
SE6 System Analysis Process	5	6	6	6	6	4	6
SE7 Implementation Process	6	5	4	5	6	5	7
SE8 Integration Process	3	5	5	4	5	5	6
SE9 Verification Process	4	6	5	5	6	6	7
SE10 Transition Process	3	5	4	4	5	5	6
SE11 Validation Process	4	6	6	6	6	6	7
SE12 Operations Process	5	6	6	6	5	5	8
SE13 Maintenance Process	5	4	5	5	6	5	8
SE14 Disposal Process	5	4	5	5	6	4	6
TECHNICAL MANAGEMENT PROCESS AREAS							
SE15 Project Planning Process	7	6	7	6	6	6	8
SE16 Project Assessment and Control Process	6	6	6	6	5	5	8
SE17 Decision Management Process	6	5	5	6	6	6	7
SE18 Risk Management Process	3	3	3	5	6	5	6
SE19 Configuration Management Process	5	4	6	3	5	4	7
SE20 Information Management Process	4	2	3	4	5	5	6
SE21 Measurement Process	4	5	4	3	4	5	6
SE22 Quality Assurance Process	3	4	4	4	5	5	6
AGREEMENT PROCESS AREAS							
SE23 Acquisition Process	5	4	5	4	5	5	7
SE24 Supply Process	5	5	6	5	5	5	7
ORGANIZATIONAL PROJECT-ENABLING PROCESS AREAS							
SE25 Life-Cycle Model Management Process	3	6	5	5	5	5	6
SE26 Infrastructure Management Process	4	5	5	4	6	6	7
SE27 Portfolio Management Process	4	5	4	5	6	5	7
SE28 Human Resource Management Process	5	6	5	6	7	5	8
SE29 Quality Management Process	5	7	4	6	5	4	8
SE30 Knowledge Management Process	4	4	5	6	6	5	8
TAILORING PROCESS AREAS							
SE31 Tailoring Process	3	3	4	5	4	3	6
TOTAL	**140**	**151**	**152**	**158**	**171**	**155**	**213**

Table 4-6: Project Management Processes Performance for Each Case Study

	CS01	CS02	CS03	CS04	CS05	CS06	CS07
Project Integration Management							
PM1 Develop Project Charter	3	5	6	5	6	4	7
PM2 Develop Project Management Plan	5	6	6	5	7	5	7
PM3 Direct and Manage Project Work	8	5	6	6	6	5	8
PM4 Manage Project Knowledge	7	6	4	7	8	6	8
PM5 Monitor and Control Project Work	8	6	4	6	7	7	8
PM6 Perform Integrated Change Control	4	7	5	4	6	6	7
PM7 Close Project or Phase	7	8	6	9	9	7	9
Project Scope Management							
PM8 Plan Scope Management	5	6	6	7	8	6	7
PM9 Collect Requirements	8	8	7	8	8	8	8
PM10 Define Scope	6	5	7	7	7	7	7
PM11 Create WBS	6	4	4	6	7	5	7
PM12 Validate Scope	6	7	7	7	7	6	7
PM13 Control Scope	6	8	7	8	8	7	8
Project Schedule Management							
PM14 Plan Schedule Management	8	5	5	6	7	7	7
PM15 Define Activities	8	5	6	7	7	6	8
PM16 Sequence Activities	3	7	8	8	8	7	8
PM17 Estimate Activity Durations	5	7	8	5	8	6	8
PM18 Develop Schedule	2	5	6	4	7	5	7
PM19 Control Schedule	6	8	6	6	8	6	6
Project Cost Management							
PM20 Plan Cost Management	7	5	5	8	8	6	8
PM21 Estimate Costs	8	4	6	8	7	7	8
PM22 Determine Budget	7	5	5	8	8	6	7
PM23 Control Costs	5	6	6	7	8	7	7
Project Quality Management							
PM24 Plan Quality Management	5	5	5	9	8	7	9
PM25 Manage Quality	4	8	8	8	8	7	8
PM26 Control Quality	2	8	8	9	8	8	8
Project ResourceManagement							
PM27 Plan Resource Management	8	6	6	8	7	7	6
PM28 Estimate Activity Resources	7	6	6	7	7	7	6
PM29 Acquired Resources	7	8	8	8	8	8	8
PM30 Develop Team	6	7	8	8	8	7	8
PM31 Manage Team	5	6	8	8	8	7	9
PM32 Control Resources	6	6	6	6	7	6	7
Project Communications Management							
PM33 Plan Communications Management	8	5	5	8	8	7	9
PM34 Manage Communications	7	6	6	7	8	6	8
PM35 Monitor Communications	3	4	4	9	8	8	7
Project Risk Management							
PM36 Plan Risk Management	5	3	3	6	7	5	7
PM37 Identify Risks	3	4	4	5	5	5	7
PM38 Perform Qualitative Risk Analysis	5	2	2	5	6	4	6
PM39 Perform Quantitative Risk Analysis	5	2	2	6	6	4	6
PM40 Plan Risk Responses	4	2	2	6	6	5	5
PM41 Implement Risk Responses	5	4	4	6	7	5	5
PM42 MonitorRisks	3	2	2	3	5	3	4
Project Procurement Management							
Pm43 Plan Procurement Management	7	8	7	8	7	6	7
Pm44 Conduct Procurements	8	7	7	8	6	6	7
Pm45 Control Procurements	8	8	7	8	8	8	8
Project Stakeholder Management							
PM46 Identify Stakeholders	7	7	8	8	7	7	8
PM47 Plan Stakeholder Engagement	6	7	6	7	8	7	7
PM48 Manage Stakeholder Engagement	7	8	7	7	8	8	7
PM49 Monitor Stakeholder Engagement	7	7	7	8	8	7	8
TOTAL	**286**	**284**	**282**	**338**	**357**	**307**	**357**

4.2.3 Effectiveness and Efficiency Processes Score

Now, just arrange the 44 efficiency processes in a table and the 55 effectiveness processes in another table to figure out the equations smoothly as the following tables.

Table 4-7: Efficiency Group Processes

	CS1	CS2	CS3	CS4	CS5	CS6	CS7
PM2 Develop Project Management Plan	3	6	6	5	7	5	7
PM3 Direct and Manage Project Work	8	5	6	6	6	5	8
PM5 Monitor and Control Project Work	8	6	4	6	7	7	8
PM6 Perform Integrated Change Control	4	7	5	4	6	6	7
PM9 Collect Requirements	8	8	7	8	8	8	8
PM10 Define Scope	6	5	7	7	7	7	7
PM11 Create WBS	6	4	4	6	7	5	7
PM13 Control Scope	6	8	7	8	8	7	8
PM16 Sequence Activities	3	7	8	8	8	7	8
PM17 Estimate Activity Durations	5	7	8	5	8	6	8
PM20 Plan Cost Management	7	5	5	8	8	6	8
PM21 Estimate Costs	8	4	6	8	7	7	8
PM22 Determine Budget	7	5	5	8	8	6	7
PM23 Control Costs	5	6	6	7	8	7	7
PM24 Plan Quality Management	5	5	5	9	8	7	9
PM25 Manage Quality	4	8	8	8	8	7	8
PM26 Control Quality	2	8	8	9	8	8	8
PM28 Estimate Activity Resources	7	6	6	7	7	7	6
PM29 Acquired Resources	7	8	8	8	8	8	8
PM32 Control Resources	6	6	6	6	7	6	7
PM36 Plan Risk Management	5	3	3	6	7	5	7
PM41 Implement Risk Responses	5	4	4	6	7	5	5
Pm43 Plan Procurement Management	7	8	7	8	7	6	7
Pm44 Conduct Procurements	8	7	7	8	6	6	7
Pm45 Control Procurements	8	8	7	8	8	8	8
PM46 Identify Stakeholders	7	7	8	8	7	7	8
PM47 Plan Stakeholder Engagement	6	7	6	7	8	7	7
PM48 Manage Stakeholder Engagement	7	8	7	7	8	8	7
PM49 Monitor Stakeholder Engagement	7	7	7	8	8	7	8
SE1 Business or Mission Analysis	5	5	6	6	7	5	8
SE2 Stakeholder Needs or Requirements Definition Process	6	5	5	6	5	6	7
SE3 System Requirements Definition Process	4	5	5	6	6	5	6
SE5 Design Definition Process	5	6	5	7	6	6	7
SE6 System Analysis Process	5	6	6	6	6	4	6
SE13 Maintenance Process	5	4	5	5	6	5	8
SE14 Disposal Process	5	4	5	5	6	4	6
SE15 Project Planning Process	7	6	7	6	6	6	8
SE16 Project Assessment and Control Process	6	6	6	6	5	5	8
SE19 Configuration Management Process	5	4	6	3	5	4	7
SE23 Acquisition Process	5	4	5	4	5	5	7
SE25 Life-Cycle Model Management Process	3	6	5	5	5	5	6
SE28 Human Resource Management Process	5	6	5	6	7	5	8
SE29 Quality Management Process	5	7	4	6	5	4	8
SE31 Tailoring Process	3	3	4	5	4	3	6

Table 4-8: Effectiveness Group Processes

	CS1	CS2	CS3	CS4	CS5	CS6	CS7
PM1 Develop Project Charter	3	5	6	5	6	4	7
PM2 Develop Project Management Plan	5	6	6	5	7	5	7
PM3 Direct and Manage Project Work	8	5	6	6	6	5	8
PM4 Manage Project Knowledge	7	6	4	7	8	6	8
PM5 Monitor and Control Project Work	8	6	4	6	7	7	8
PM7 Close Project or Phase	7	8	6	9	9	7	9
PM8 Plan Scope Management	5	6	6	7	8	6	7
PM9 Collect Requirements	8	8	7	8	8	8	8
PM12 Validate Scope	6	7	7	7	7	6	7
PM14 Plan Schedule Management	8	5	5	6	7	7	7
PM15 Define Activities	8	5	6	7	7	6	8
PM16 Sequence Activities	3	7	8	8	8	7	8
PM17 Estimate Activity Durations	5	7	8	5	8	6	8
PM18 Develop Schedule	2	5	6	4	7	5	7
PM19 Control Schedule	6	8	6	6	8	6	6
PM24 Plan Quality Management	5	5	5	9	8	7	9
PM25 Manage Quality	4	8	8	8	8	7	8
PM27 Plan Resource Management	8	6	6	8	7	7	6
PM30 Develop Team	6	7	8	8	8	7	8
PM31 Manage Team	5	6	8	8	8	7	9
PM33 Plan Communications Management	8	5	5	8	8	7	9
PM34 Manage Communications	7	6	6	7	8	6	8
PM35 Monitor Communications	3	4	4	9	8	8	7
PM36 Plan Risk Management	5	3	3	6	7	5	7
PM37 Identify Risks	3	4	4	5	5	5	7
PM38 Perform Qualitative Risk Analysis	5	2	2	5	6	4	6
PM39 Perform Quantitative Risk Analysis	5	2	2	6	6	4	6
PM40 Plan Risk Responses	4	2	2	6	6	5	5
PM41 Implement Risk Responses	5	4	4	6	7	5	5
PM42 MonitorRisks	3	2	2	3	5	3	4
PM49 Monitor Stakeholder Engagement	7	7	7	8	8	7	8
SE1 Business or Mission Analysis	5	5	6	6	7	5	8
SE2 Stakeholder Needs or Requirements Definition Process	6	5	5	6	5	6	7
SE4 Architecture Definition Process	4	3	4	4	5	4	6
SE5 Design Definition Process	5	6	5	7	6	6	7
SE7 Implementation Process	6	5	4	5	6	5	7
SE8 Integration Process	3	5	5	4	5	5	6
SE9 Verification Process	4	6	5	5	6	6	7
SE10 Transition Process	3	5	4	4	5	5	6
SE11 Validation Process	4	6	6	6	6	6	7
SE12 Operations Process	5	6	6	6	5	5	8
SE15 Project Planning Process	7	6	7	6	6	6	8
SE16 Project Assessment and Control Process	6	6	6	6	5	5	8
SE17 Decision Management Process	6	5	5	6	6	6	7
SE18 Risk Management Process	3	3	3	5	6	5	6
SE19 Configuration Management Process	5	4	6	3	5	4	7
SE20 Information Management Process	4	2	3	4	5	5	6
SE21 Measurement Process	4	5	4	3	4	5	6
SE22 Quality Assurance Process	3	4	4	4	5	5	6
SE24 Supply Process	5	5	6	5	5	5	7
SE26 Infrastructure Management Process	4	5	5	4	6	6	7
SE27 Portfolio Management Process	4	5	4	5	6	5	7
SE28 Human Resource Management Process	5	6	5	6	7	5	8
SE30 Knowledge Management Process	4	4	5	6	6	5	8
SE31 Tailoring Process	3	3	4	5	4	3	6

4.2.4 Efficiency and Effectiveness Factors

In Efficiency equation in the left side, there are two factors the first one Wi is the weight of each efficiency process and the second one is CSi is the score of each process applied in the case study using 1-10 score from 0%-100% as shown in the table (4-7). The right side also has two factors cost and time, and these two factors will be defined and how to calculate it in this section.

In Effectiveness, the left side is the same in the efficiency equation, but the right side also has two factors performance and risk also will define.

4.2.4.1 Cost and Time

This method will define the cost as the ratio between the expected cost and the actual cost and determine the time as the ratio between the expected time and the actual time, as the following formula:

$$Cost\ Ratio = \frac{Expected\ Cost}{Actual\ Cost}$$

$$Time\ Ratio = \frac{Expected\ Time}{Actual\ Time}$$

The actual cost, expected cost and the actual time, expected time provided by authorized source in each project as the table below:

Table 4-9: Cost and Time Ratio for Each Case Study

	Expected Cost	Actual Cost	Expected Time	Actual Time	Cost Ratio	Time Ratio	Total Ratio
CS_1	327 M	386 M	1,825 D	2,555 D	0.85	0.71	1.56
CS_2	405 M	443 M	1,277.5 D	1,460 D	0.91	0.88	1.79
CS_3	490 M	560 M	1460 D	2,190 D	0.88	0.60	1.54
CS_4	261 M	297 M	2098 D	2,737 D	0.87	0.77	1.65
CS_5	79 M	93 M	365 D	5,47.5 D	0.85	0.60	1.51
CS_6	170 M	209 M	912.5 D	1,460 D	0.81	0.50	1.85
CS_7	459 M	483 M	1460 D	1,642 D	0.95	0.80	1.84

*The cost value by AED currency

*The time by Days

4.2.4.2 Performance

Performance percentage also got from authorized source from the project as the table below.

Table 4-10: Case Studies Performance (Results from Delphi Method)

	Performance %
CS_1	40%
CS_2	45%
CS_3	50%
CS_4	55%
CS_5	45%
CS_6	65%
CS_7	60%

4.2.4.3 Risk

The risk percentage for the whole project is difficult to calculate, the team could classify the risks in the project and make it low, Mid and high but the percentage of risk is difficult to find it 100%. Here to calculate the risk percentage we use two methods together Three Points Estimates Method and Triangle Distribution Method as we introduced in Chapter 3, Risk percentage calculation is using Three Points Estimates and Triangle Distribution Method. This method is an assumption for the cost of the risk in three classification level low, most likely and high then got two triangle distributions as in the figure below:

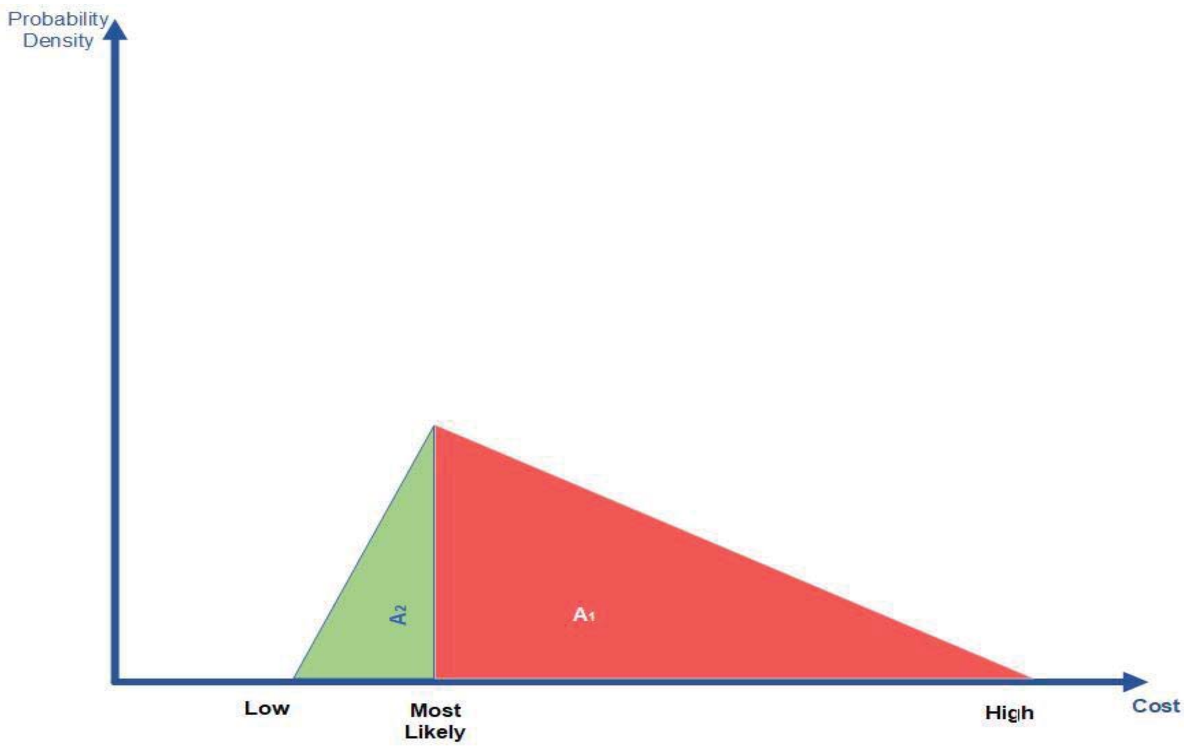

Figure 4-1: Triangle Distribution

(AACE International, Skills and Knowledge of Cost Engineering, 6th edition)

Using triangle distribution, there are two values for risk percentage, underrun and overrun that's mean the most likely point is the base. The triangle after this point is the overrun and the triangle before this point is underrun.

Triangle distribution: Calculate the area of both triangles as the following proof:

Low (a)

Most Likely (b)

High (c)

A2 = 1/2 * (b - a) * 2/(c - a)

A2 = (b - a)/(c - a)

And

A1 = 1/2 * (c - b) * 2/(c - a)

A1 = (c - b)/(c - a)

A2 is the actual probability of Most Likely risk.

The results for over run risk and under run risk in the following table:

Under run risk is most likely one and this risk percentage will be in our calculation.

Table 4-11: Three Points Estimate and Risk Percentage for Each Case Study

	Low	Most Likely	High	Average	A1 OverRun Risk	A2 UnderRun Risk	Performance	Effectiveness
CS1	10,000.00	17,000.00	22,000.00	16,333.33	0.42	0.58	0.4	0.98
CS2	10,000.00	18,000.00	20,000.00	16,000.00	0.20	0.80	0.45	1.25
CS3	15,000.00	21,000.00	25,000.00	20,333.33	0.40	0.60	0.5	1.10
CS4	13,000.00	13,300.00	14,100.00	13,466.67	0.73	0.27	0.55	0.82
CS5	20,000.00	22,500.00	28,000.00	23,500.00	0.69	0.31	0.45	0.76
CS6	20,000.00	27,000.00	30,000.00	25,666.67	0.30	0.70	0.65	1.35
CS7	18,000.00	24,000.00	26,000.00	22,666.67	0.25	0.75	0.6	1.35

4.2.5 Method Equations

Now that we can figure out the left and the right sides in both equations Efficiency and Effectiveness.

The following equations are related to Case Study 1 for both EFCY & EFTV then will complete the whole cases in a table Matrix.

For Efficiency for CS1:

$$\sum_{i=1}^{44} Wi * CS1 = \text{EFCY\%} = \text{Cost\%} + \text{Time\%}$$

And for the all cases studies it will be as the following Matrix

$$\mathbf{A} = \begin{bmatrix} w_1 * P_{1Cs1} & \dots & w_{44} * P_{44Cs1} \\ w_1 * P_{1Cs2} & \dots & w_{44} * P_{44Cs2} \\ w_1 * P_{1Cs3} & \dots & w_{44} * P_{44Cs3} \\ w_1 * P_{1Cs4} & \dots & w_{44} * P_{44Cs4} \\ w_1 * P_{1Cs5} & \dots & w_{44} * P_{44Cs5} \\ w_1 * P_{1Cs6} & \dots & w_{44} * P_{44Cs6} \\ w_1 * P_{1Cs7} & \cdots & w_{44} * P_{44Cs7} \end{bmatrix} \qquad \mathbf{B} = \begin{bmatrix} EFCYCs1 \\ EFCYCs2 \\ EFCYCs3 \\ EFCYCs4 \\ EFCYCs5 \\ EFCYCs6 \\ EFCYCs7 \end{bmatrix}$$

For example:

The equation for case study 1 as the following

$(W_{pm2}*5) + (W_{pm3}*8) + (W_{pm5}*8) + (W_{pm6}*4) + (W_{pm9}*8) + (W_{pm10}*6) + (W_{pm11}*6) + (W_{pm13}*6) + (W_{pm16}*3) + (W_{pm17}*5) + (W_{pm20}*7) + (W_{pm21}*8) + (W_{pm22}*7) + (W_{pm23}*5) + (W_{pm24}*5) + (W_{pm25}*4) + (W_{pm26}*2) + (W_{pm28}*7) + (W_{pm29}*7) + (W_{pm32}*6) + (W_{pm36}*5) + (W_{pm41}*5) + (W_{se1}*5) + (W_{se2}*6) + (W_{se3}*4) + (W_{se5}*5) + (W_{se6}*5) + (W_{se13}*5) + (W_{se14}*5) + (W_{se15}*7) + (W_{se16}*6) + (W_{se19}*5) + (W_{se23}*5) + (W_{se25}*3) + (W_{se28}*5) + (W_{se29}*5) + (W_{se31}*3) = 0.85 + 0.71 = 1.56$

These are the values for Efficiency processes and in this equation any process not related to efficiency will be zero.

For Effectiveness for CS1:

$$\sum_{i=1}^{55} Wi * CS1 = \text{EFTV\%} = \text{Performance\%} + \text{Risk\%}$$

And for the all cases studies it will be as the following Matrix

$$A = \begin{bmatrix} w1 * P1Cs1 & \dots & w55 * P55Cs1 \\ w1 * P1Cs2 & \dots & w55 * P55Cs2 \\ w1 * P1Cs3 & \dots & w55 * P55Cs3 \\ w1 * P1Cs4 & \dots & w55 * P55Cs4 \\ w1 * P1Cs5 & \dots & w55 * P55Cs5 \\ w1 * P1Cs6 & \dots & w55 * P55Cs6 \\ w1 * P1Cs7 & \cdots & w55 * P55Cs7 \end{bmatrix} \qquad B = \begin{bmatrix} EFTVCs1 \\ EFTVCs2 \\ EFTVCs3 \\ EFTVCs4 \\ EFTVCs5 \\ EFTVCs6 \\ EFTVCs7 \end{bmatrix}$$

For example:

The equation for case study 1 as the following:

$(W_{pm1}*3) + (W_{pm2}*5) + (W_{pm3}*8) + (W_{pm4}*7) + (W_{pm5}*8) + (W_{pm7}*7) + (W_{pm8}*5) + (W_{pm9}*8) + (W_{pm12}*6) + (W_{pm14}*8) + (W_{pm15}*8) + (W_{pm16}*3) + (W_{pm17}*5) + (W_{pm18}*2) + (W_{pm19}*6) + (W_{pm24}*5) + (W_{pm25}*4) + (W_{pm27}*8) + (W_{pm30}*6) + (W_{pm31}*5) + (W_{pm33}*8) + (W_{pm34}*7) + (W_{pm35}*3) + (W_{pm36}*5) + (W_{pm37}*3) + (W_{pm38}*5) + (W_{pm39}*5)$

+ (W_{pm40}*4) + (W_{pm41}*5) + (W_{pm42}*3) + (W_{se1}*5) + (W_{se2}*6) + (W_{se4}*4) + (W_{se5}*5) + (W_{se7}*6) + (W_{se8}*3) + (W_{se9}*4) + (W_{se10}*3) + (W_{se11}*4) + (W_{se12}*5) + (W_{se16}*6) + (W_{se17}*6) + (W_{se18}*3) + (W_{se19}*5) + (W_{se20}*4) + (W_{se21}*4) + (W_{se22}*3) + (W_{se24}*5) + (W_{se26}*4) + (W_{se27}*4) + (W_{se28}*5) + (W_{se30}*4) + (W_{se31}*3) = 0.4 + 0.58 = 0.98

These are the values for Effectiveness processes, and in this equation, any process not related to Effectiveness will be zero.

Now, we have 14 equations with 80 unknowns, so we need more equation to solve the 80 unknowns.

From System Engineering processes score for each case study will get 7 more equations and from Project Management will also get 7 more equations as the following equations and Matrices as the following formulas and the data collected from table 4-12 and table 4-13:

For System Engineering:

$$\sum_{i=1}^{31} Wi * CS1 = \frac{310}{140}$$

$$A = \begin{bmatrix} w1 * P1_{Cs1} & \dots & w31 * P31_{Cs1} \\ w1 * P1_{Cs2} & \dots & w31 * P31_{Cs2} \\ w1 * P1_{Cs3} & \dots & w31 * P31_{Cs3} \\ w1 * P1_{Cs4} & \dots & w31 * P31_{Cs4} \\ w1 * P1_{Cs5} & \dots & w31 * P31_{Cs5} \\ w1 * P1_{Cs6} & \dots & w31 * P31_{Cs6} \\ w1 * P1_{Cs7} & \cdots & w31 * P31_{Cs7} \end{bmatrix} \qquad B = \begin{bmatrix} 2.21 \\ 2.05 \\ 2.04 \\ 1.96 \\ 1.81 \\ 2 \\ 1.46 \end{bmatrix}$$

For Project Management:

$$\sum_{i=1}^{49} Wi * CS1 = \frac{490}{286}$$

$$\mathbf{A} \quad = \begin{bmatrix} w_1 * P_{1Cs1} & \dots & w_{49} * P_{49Cs1} \\ w_1 * P_{1Cs2} & \dots & w_{49} * P_{49Cs2} \\ w_1 * P_{1Cs3} & \dots & w_{49} * P_{49Cs3} \\ w_1 * P_{1Cs4} & \dots & w_{49} * P_{49Cs4} \\ w_1 * P_{1Cs5} & \dots & w_{49} * P_{49Cs5} \\ w_1 * P_{1Cs6} & \dots & w_{49} * P_{49Cs6} \\ w_1 * P_{1Cs7} & \cdots & w_{49} * P_{49Cs7} \end{bmatrix} \qquad \mathbf{B} \quad = \begin{bmatrix} 1.71 \\ 1.73 \\ 1.74 \\ 1.45 \\ 1.37 \\ 1.60 \\ 1.37 \end{bmatrix}$$

Table 4-12: Project Management Processes Case Studies Score

	CS01	CS02	CS03	CS04	CS05	CS06	CS07
Project Integration Management							
PM1 Develop Project Charter	3	5	6	5	6	4	7
PM2 Develop Project Management Plan	5	6	6	5	7	5	7
PM3 Direct and Manage Project Work	8	5	6	6	6	5	8
PM4 Manage Project Knowledge	7	6	4	7	8	6	8
PM5 Monitor and Control Project Work	8	6	4	6	7	7	8
PM6 Perform Integrated Change Control	4	7	5	4	6	6	7
PM7 Close Project or Phase	7	8	6	9	9	7	9
Project Scope Management							
PM8 Plan Scope Management	5	6	6	7	8	6	7
PM9 Collect Requirements	8	8	7	8	8	8	8
PM10 Define Scope	6	5	7	7	7	7	7
PM11 Create WBS	6	4	4	6	7	5	7
PM12 Validate Scope	6	7	7	7	7	6	7
PM13 Control Scope	6	8	7	8	8	7	8
Project Schedule Management							
PM14 Plan Schedule Management	8	5	5	6	7	7	7
PM15 Define Activities	8	5	6	7	7	6	8
PM16 Sequence Activities	3	7	8	8	8	7	8
PM17 Estimate Activity Durations	5	7	8	5	8	6	8
PM18 Develop Schedule	2	5	6	4	7	5	7
PM19 Control Schedule	6	8	6	6	8	6	6
Project Cost Management							
PM20 Plan Cost Management	7	5	5	8	8	6	8
PM21 Estimate Costs	8	4	6	8	7	7	8
PM22 Determine Budget	7	5	5	8	8	6	7
PM23 Control Costs	5	6	6	7	8	7	7
Project Quality Management							
PM24 Plan Quality Management	5	5	5	9	8	7	9
PM25 Manage Quality	4	8	8	8	8	7	8
PM26 Control Quality	2	8	8	9	8	8	8
Project ResourceManagement							
PM27 Plan Resource Management	8	6	6	8	7	7	6
PM28 Estimate Activity Resources	7	6	6	7	7	7	6
PM29 Acquired Resources	7	8	8	8	8	8	8
PM30 Develop Team	6	7	8	8	8	7	8
PM31 Manage Team	5	6	8	8	8	7	9
PM32 Control Resources	6	6	6	6	7	6	7
Project Communications Management							
PM33 Plan Communications Management	8	5	5	8	8	7	9
PM34 Manage Communications	7	6	6	7	8	6	8
PM35 Monitor Communications	3	4	4	9	8	8	7
Project Risk Management							
PM36 Plan Risk Management	5	3	3	6	7	5	7
PM37 Identify Risks	3	4	4	5	5	5	7
PM38 Perform Qualitative Risk Analysis	5	2	2	5	6	4	6
PM39 Perform Quantitative Risk Analysis	5	2	2	6	6	4	6
PM40 Plan Risk Responses	4	2	2	6	6	5	5
PM41 Implement Risk Responses	5	4	4	6	7	5	5
PM42 MonitorRisks	3	2	2	3	5	3	4
Project Procurement Management							
Pm43 Plan Procurement Management	7	8	7	8	7	6	7
Pm44 Conduct Procurements	8	7	7	8	6	6	7
Pm45 Control Procurements	8	8	7	8	8	8	8
Project Stakeholder Management							
PM46 Identify Stakeholders	7	7	8	8	7	7	8
PM47 Plan Stakeholder Engagement	6	7	6	7	8	7	7
PM48 Manage Stakeholder Engagement	7	8	7	7	8	8	7
PM49 Monitor Stakeholder Engagement	7	7	7	8	8	7	8
TOTAL	**286**	**284**	**282**	**338**	**357**	**307**	**357**

Table 4-13: System Engineering Processes Case Studies Score

	CS01	CS02	CS03	CS04	CS05	CS06	CS07
TECHNICAL PROCESS AREAS							
SE1 Business or Mission Analysis	5	5	6	6	7	5	8
SE2 Stakeholder Needs or Requirements Definition Process	6	5	5	6	5	6	7
SE3 System Requirements Definition Process	4	5	5	6	6	5	6
SE4 Architecture Definition Process	4	3	4	4	5	4	6
SE5 Design Definition Process	5	6	5	7	6	6	7
SE6 System Analysis Process	5	6	6	6	6	4	6
SE7 Implementation Process	6	5	4	5	6	5	7
SE8 Integration Process	3	5	5	4	5	5	6
SE9 Verification Process	4	6	5	5	6	6	7
SE10 Transition Process	3	5	4	4	5	5	6
SE11 Validation Process	4	6	6	6	6	6	7
SE12 Operations Process	5	6	6	6	5	5	8
SE13 Maintenance Process	5	4	5	5	6	5	8
SE14 Disposal Process	5	4	5	5	6	4	6
TECHNICAL MANAGEMENT PROCESS AREAS							
SE15 Project Planning Process	7	6	7	6	6	6	8
SE16 Project Assessment and Control Process	6	6	6	6	5	5	8
SE17 Decision Management Process	6	5	5	6	6	6	7
SE18 Risk Management Process	3	3	3	5	6	5	6
SE19 Configuration Management Process	5	4	6	3	5	4	7
SE20 Information Management Process	4	2	3	4	5	5	6
SE21 Measurement Process	4	5	4	3	4	5	6
SE22 Quality Assurance Process	3	4	4	4	5	5	6
AGREEMENT PROCESS AREAS							
SE23 Acquisition Process	5	4	5	4	5	5	7
SE24 Supply Process	5	5	6	5	5	5	7
ORGANIZATIONAL PROJECT-ENABLING PROCESS AREAS							
SE25 Life-Cycle Model Management Process	3	6	5	5	5	5	6
SE26 Infrastructure Management Process	4	5	5	4	6	6	7
SE27 Portfolio Management Process	4	5	4	5	6	5	7
SE28 Human Resource Management Process	5	6	5	6	7	5	8
SE29 Quality Management Process	5	7	4	6	5	4	8
SE30 Knowledge Management Process	4	4	5	6	6	5	8
TAILORING PROCESS AREAS							
SE31 Tailoring Process	3	3	4	5	4	3	6
TOTAL	**140**	**151**	**152**	**158**	**171**	**155**	**213**

Now, there are 28 equations with 80 unknowns so, we need to make some assumption to reduce the unknowns the assumptions will be zero's and one's assumptions. Zero's assumptions will be for the redundant processes in Project Management and System Engineering or the overlap between PM & SE that's mean the processes that already in PM and SE as well will assume one of the these zero and take the other one for calculation.

One's assumptions that's mean if there are two, three or four processes integrate each other will assume the sum of these processes equal one that's mean 100%. The assumptions used in this method and the reason for the assumptions as shown in the following table:

Table 4-14: Zero's and One's assumptions

ASSUMPTION	REASON
PM2=0	Because it is covered by SE4
PM6=0	Because it is covered by SE8
PM10=0	Because it is covered by all PM processes and SE processes
PM12=0	Because it is covered by SE11
PM1=0	Because it is covered by all planning processes
PM15=0	Because it is covered by SE4
PM16=0	Because it is covered by plan processes in PM & SE
PM18=0	Because once the plan achieves the optimization that looking for in the research no need to develop the plan during project
PM25=0	Because PM has plan and control quality processes and if that's applied so the manage will be applied by default
Pm27=0	Because it is covered by SE28
PM33=0	Because the most important in communications are manage and control and once these applied no need for manage
PM38=0 **PM39=0**	Because it is covered by SE18
PM41=0	Because it is covered by PM40, PM42 and SE18
PM48=0	Because it is covered by PM43 and SE2
SE13=0	Because in new construction projects no need for maintenance only analysis and management and these covered by PM8 and PM14
SE19=0 **SE20=0**	Because it is covered by SE4, SE2 and SE6
SE21=0	Because it is covered by operation processes
SE26=0 **SE27=0** **SE30=0**	Because it covered by plan and control processes in PM

PM8=0 **PM13=0**	Because it is covered by PM3, PM5, SE15 and SE16
PM4=0	Because it is not important process, this process doesn't have any input or out with other processes
PM32=0	
SE3=0	Because it is covered by SE1 and SE2
PM40=0 **SE1=0**	Because it is covered by SE18
SE14=0	Because in new construction project no need for disposal
PM3+PM5+ PM12=1	The processes complement each other
PM8+PM13=1	The processes complement each other
PM20+PM21=1	The processes complement each other
PM31+PM30=1	The processes complement each other
PM9+SE2=1	The processes complement each other
SE4+PM14+PM11=1	The processes complement each other
PM6+PM11+ PM17=1	The processes complement each other
PM24+PM26+SE22=1	The processes complement each other
PM28+PM29+SE28=1	The processes complement each other
PM36+PM37+PM42+SE18=1	The processes complement each other
PM46+ PM47 + PM49+ SE2=1	The processes complement each other
PM34+ PM31+ SE10=1	The processes complement each other
SE16+ PM5+ PM19=1	The processes complement each other
SE8+ PM20+ PM21 =1	The processes complement each other
PM20+ PM23=1	The processes complement each other
SE25+ SE31+ PM17=1	The processes complement each other
SE5+ SE9+ SE11=1	The processes complement each other
PM43+ PM44+ PM45=1	The processes complement each other
SE22+ SE29=1	The processes complement each other
SE12+ SE23+ SE24=1	The processes complement each other
PM20+ PM24+ PM36=1	The processes complement each other
PM23+ pm26+ pm42=1	The processes complement each other
Pm14+ pm43+ pm47+ se15=1	The processes complement each other

After these assumptions, the total number of equations will be 50, and the total number of unknowns will be 50 so will have a Matrix [50*50] then by solved for A^{-1}. The weights are later found by multiplying [A^{-1}] and [B].

For the results now, we should classify the results for 10 classifications to be between 0% and 100%. So, we should find the max value and the minimum value then find the difference between max and min and divided by 10 intervals to know how much each interval as in the table and chart below

Table 4-15: Statistical Analysis for the Results from the Equations for Bar Chart

max	12.65
min	(19.79)
max-min	32.45
intervals	10
each interval	3.24

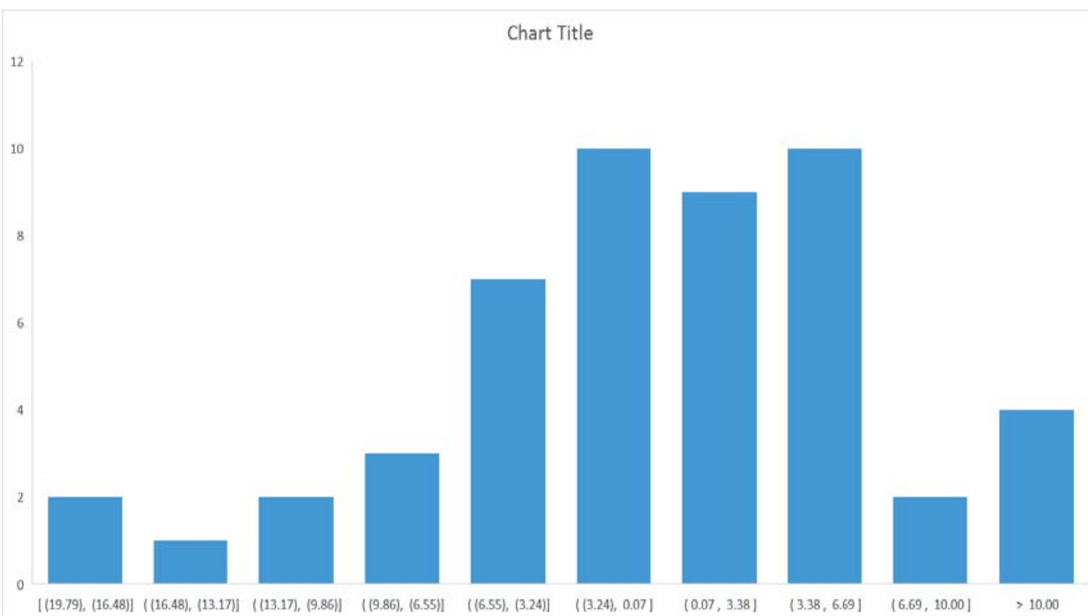

Figure 4-2: Bar Chart for the Numerical Method Results

Table 4-16: The Results of Each Process and Sort It From 0%-100%

-19.79	**PM47** Plan Stakeholder Engagement	1 (0%-10%)
-18.21	**SE17** Decision Management Process	
-14.99	**Pm44** Conduct Procurements	2 (10%-20%)
-11.6	**PM30** Develop Team	3 (20%-30%)
-10.69	**PM37** Identify Risks	
-6.92	**PM34** Manage Communications	4 (30%-40%)
-6.8	**SE16** Project Assessment and Control Process	
-6.75	**SE4** Architecture Definition Process	
-5.05	**PM3** Direct and Manage Project Work	5 (40%-50%)
-5.04	**SE23** Acquisition Process	
-4.69	**SE10** Transition Process	
-4.06	**PM22** Determine Budget	
-4.01	**SE5** Design Definition Process	
-3.68	**PM9** Collect Requirements	
-3.28	**PM36** Plan Risk Management	
-2.97	**PM36** Plan Risk Management	6 (50%-60%)
-2.64	**PM17** Estimate Activity Durations	
-1.68	**PM26** Control Quality	
-1.44	**PM35** Monitor Communications	
-1.36	**PM28** Estimate Activity Resources	
-0.69	**SE6** System Analysis Process	
-0.54	**PM21** Estimate Costs	
-0.54	**PM23** Control Costs	
-0.06	**SE22** Quality Assurance Process	
0	**SE8** Integration Process	
0.81	**SE25** Life-Cycle Model Management Process	7 (60%-70%)
1.06	**SE29** Quality Management Process	
1.54	**PM20** Plan Cost Management	
2.12	**SE9** Verification Process	
2.5	**SE12** Operations Process	
2.74	**PM24** Plan Quality Management	
2.83	**SE31** Tailoring Process	
2.89	**SE11** Validation Process	
3.22	**PM42** Monitor Risks	
3.42	**PM14** Plan Schedule Management	8 (70%-80%)
3.47	**PM49 Monitor** Stakeholder Engagement	
3.54	**PM5** Monitor and Control Project Work	
3.54	**SE24** Supply Process	
4.25	**PM19** Control Schedule	
4.32	**PM11** Create WBS	
4.68	**SE2** Stakeholder Needs or Requirements Definition Process	
5.3	**PM29** Acquired Resources	
5.74	**SE7** Implementation Process	
6.13	**Pm43** Plan Procurement Management	
9.46	**PM7** Close Project or Phase	9 (80%-90%)
9.86	**Pm45** Control Procurements	
11.24	**SE15** Project Planning Process	10 (90%-100%)
11.75	**SE18** Risk Management Process	
12.6	**PM31** Manage Team	
12.65	**PM46** Identify Stakeholders	

4.2.6 Pareto Chart.

Pareto chart is a statistical method that use to know the most important problem or cause for a case, in other way to know the most significant factor, problem, or cause.

In this paper we used Pareto chart for the numerical results to know the most significant process that's meant the processes have high weight percentage and low percentage as well.

Figure (4-3) illustrate Pareto chart for numerical results and identify the most significant processes and the low importance.

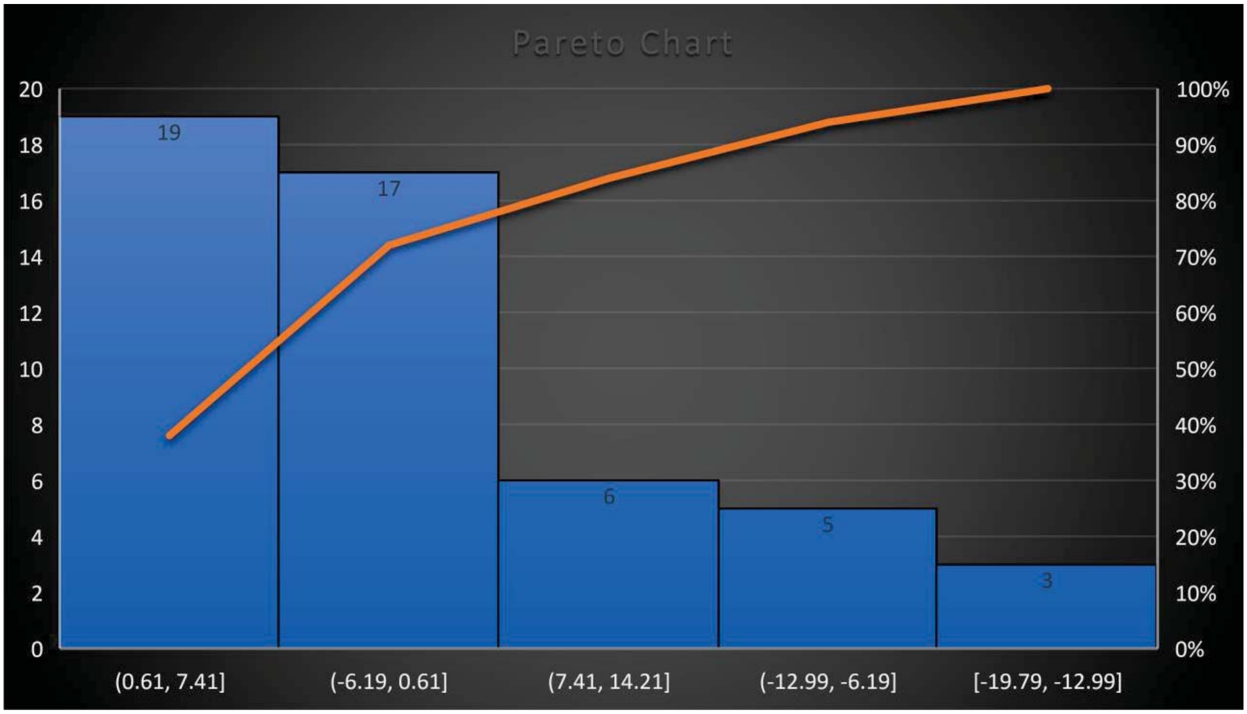

Figure 4-3: Pareto Chart for Numerical Method Results.

As defined and explained in figure (4-3) we got that the processes who have the results between 0.61-7.41 are the most significant processes in our 50 processes and these processes are 19 processes. Table 4-16 illustrate the most significant processes using Pareto Chart.

Table 4-17: The Results Resort using Pareto Chart

0.81	**SE25** Life-Cycle Model Management Process	90% - 100%
1.06	**SE29** Quality Management Process	
1.54	**PM20** Plan Cost Management	
2.12	**SE9** Verification Process	
2.5	**SE12** Operations Process	
2.74	**PM24** Plan Quality Management	
2.83	**SE31** Tailoring Process	
2.89	**SE11** Validation Process	
3.22	**PM42** MonitorRisks	
3.42	**PM14** Plan Schedule Management	
3.47	**PM49** Monitor Stakeholder Engagement	
3.54	**PM5** Monitor and Control Project Work	
3.54	**SE24** Supply Process	
4.25	**PM19** Control Schedule	
4.32	**PM11** Create WBS	
4.68	**SE2** Stakeholder Needs or Requirements Definition Process	
5.3	**PM29** Acquired Resources	
5.74	**SE7** Implementation Process	
6.13	**Pm43** Plan Procurement Management	
-5.05	**PM3** Direct and Manage Project Work	80% - 90%
-5.04	**SE23** Acquisition Process	
-4.69	**SE10** Transition Process	
-4.06	**PM22** Determine Budget	
-4.01	**SE5** Design Definition Process	
-3.68	**PM9** Collect Requirements	
-3.28	**PM36** Plan Risk Management	
-2.97	**SE28** Human Resource Management Process	
-2.64	**PM17** Estimate Activity Durations	
-1.68	**PM26** Control Quality	
-1.44	**PM35** Monitor Communications	
-1.36	**PM28** Estimate Activity Resources	
-0.69	**SE6** System Analysis Process	
-0.54	**PM21** Estimate Costs	
-0.54	**PM23** Control Costs	
-0.06	**SE22** Quality Assurance Process	
0	**SE8** Integration Process	
9.46	**PM7** Close Project or Phase	30% - 40%
9.86	**Pm45** Control Procurements	
11.24	**SE15** Project Planning Process	
11.75	**SE18** Risk Management Process	
12.6	**PM31** Manage Team	
12.65	**PM46** Identify Stakeholders	
-11.6	**PM30** Develop Team	20% - 30%
-10.69	**PM37** Identify Risks	
-6.92	**PM34** Manage Communications	
-6.8	**SE16** Project Assessment and Control Process	
-6.75	**SE4** Architecture Definition Process	
-19.79	**PM47** Plan Stakeholder Engagement	10% - 20%
-18.21	**SE17** Decision Management Process	
-14.99	**Pm44** Conduct Procurements	

4.3 Analysis Method Results and Literature review case studies Comparison

Literature review (academic articles) in Chapter 2 focused and introduced some processes in both the PM & SE fields as the following:

Case Study 04:

- Work breakdown structure
- Task organization
- Planning processes

Case Study 05:

- Risk management
- Technical processes

Case Study 06:

- Change management
- Risk management
- Portfolio Management Process

Case Study 07:

- Change management
- Decision management

Case Study 08:

- Control processes
- Integration process
- Communication management

Case Study 09

- Stakeholder management

- Implementation process

Case Study 10:

- Stakeholder management
- Change management
- Communication management
- Measurement management

Case Study 11

- Change management
- Stakeholder management
- Communication management

Case Study 12

- Change management
- Implementation management
- Architecture Definition Process

Case Study 13:

This case study talks about effectiveness of the projects and the relationship between effectiveness and reduce the cost that's mean between effectiveness and efficiency and focused on the following processes

- Team management
- Risk management
- Human resource management
- Communication management
- Stakeholder management

- Implementation management

Case Study 14:

- Portfolio Management Process
- Sequence Activities
- Estimate Activity Durations
- Architecture Definition Process
- Change management control

After review these processes focused by case studies introduced by literature review (academic articles) and compare these processes got from the results of analysis method used seven practical case studies (construction projects) will see that most of the processes introduced in literature review case studies already got from the results of analysis method even it is both randomly selected and small data sample size.

CHAPTER 5: HYBRID PROCESS PROPOSE

5.1 Introduction

As introduced and analyzed in Chapter 3 and Chapter 4, Chapter 3 explained the methods used in this paper, and Chapter 4 described the analysis and resulted from the method introduced. Now, and from the results obtained in Chapter 4, there are almost 30 ‘zero assumption' constraints, and these zero assumptions arise from the redundant processes in SE or PM inside or between PM and SE. These zero assumptions should be eliminated or removed from the whole set of processes because these ‘zero assumption' processes will increase the price and time and will not give any additional value for the project efficiency or effectiveness. The other type of assumed constraints is the "One Assumptions," with these assumptions arising from processes that complement each other, meaning that these processes are very critical processes, so these processes should have a high weight. In the first part of Chapter 4, some data provided by experts in PM & SE using the Delphi Method, with the data elicited from 8 participants after three rounds of the Delphi Method. The results got from the matrix in Chapter 5, these results actually are the weight of each process after multiplying the weight by the percentage applied for each process in different case studies and equal this multiplying process to the actual effectiveness and actual efficiency for each project in the case studies introduced in the first of Chapter 3. Then after compare, the weights got from Delphi Method, and the results gained from solving the equations, the results got from comparing are very close and make sense for each process weight. So, why we do not make a group of processes that cover SE & PM? As hybrid processes that the team will apply it one time and will get efficiency and effectiveness up to 95% in any project and especially construction projects. These processes are covered both technical and managerial, these processes called Technical Project Management TPM and contains six groups of processes Stakeholder requirements and definition, Planning & Estimation, Integration, Validation & Verification, Optimization, Executing, and Handover.

These six groups of processes will be introduced and explained in this chapter as a synergized between SE & PM to achieve the maximum efficiency and maximum effectiveness of the project. As introduced in Chapter 1 efficiency and effectiveness mean cost, time, risk, and performance. What does this mean?

This means that when the team study the project very well following up the TPM processes, the team can estimate the cost of the project by 90%-95% and estimate the time of executing by 90%-95% because in addition to the technical and management processes and the team got very close cost and time estimation to the actual. The team also will manage the changes during the project (in both field SE & PM) that are the most critical factor might affect the cost and time estimated. Moreover, in the same way, once these processes applied very well, the team will manage the risk of the project and eliminate it, and the project will get the optimization in quality. That is mean the project will get the maximum quality possible and also the highest performance of the team and project in the front of the owner or stakeholder.

Depending on the above reasons and explanations, this chapter will introduce the hybrid processes propose that will cover SYSTEM ENGINEERING & PROJECT MANAGEMENT which called TECHNICAL PROJECT MANAGEMENT (TPM) that will let the team get all aims of SE & PM once they apply TPM one time.

5.2 Project Management and System Engineering Mapping

Table 5-1: Project Management and System Engineering Mapping

Processes group	Process name	PM	SE
	Stakeholder Requirements Definition	90%	90%

Technical Processes	Requirements Analysis	90%	90%
	Architecture Design	90%	90%
	Implementation	90%	90%
	Integration	80%	90%
	Verification	80%	90%
	Transition	90%	90%
	Validation	80%	90%
	Operation	90%	90%
	Maintenance	75%	90%
	Disposal	90%	90%
	Cross Cutting Technology Method	76%	90%
	Work Breakdown Structure (WBS)	90%	80%
Project Processes	Project Planning Process	90%	90%
	Activities Analysis	90%	90%
	Project Assessment	90%	90%
	Procurement Management	90%	70%
	Decision Management Process	90%	90%
	Risk Management	90%	90%
	Monitoring and Control Process	90%	80%
	Configuration Management	85%	90%
	Information Management	80%	90%
	Measurement Process	80%	90%
	Perform Integrated Change Control	90%	80%

	Communication Management	90%	30%
Enterprise & Agreement Processes	System Life Cycle Model Management	75%	90%
	Facilities and Infrastructure Management	75%	90%
	Enterprise Environment Management	75%	90%
	Investment Management	75%	90%
	Project Portfolio Management	90%	90%
	Human Resource Management	90%	75%
	Quality Management	80%	90%
	Acquire Team Training	90%	90%
	Acquisition	80%	90%
	Supply	80%	90%

The processes divided into three group of processes Technical processes, project processes, and agreement processes. PM and SE almost do the all processes in a different covered percentage of each process and different method way. PM follow technique and skills to achieve the process aim, SE follows methodology bath to get the target of the process.

Project Management Triangle (also called Iron triangle) is used to analyze the project, and it has three constraints Scope, Time and Cost. Any changes in each constraint will affect other constraints. For example, if the team needs to reduce the time of the project they should increase the cost and eliminate the scope. There is also another triangle between Risk, Quality and Resources. System Engineering also interested in the same constraint to get the optimization and in a different way and using methods.

Technical Project Management has a triangle (Solid Triangle), the base of this triangle is Project Management Triangle, but also it has a System Engineering experiment, methods, and procedure.

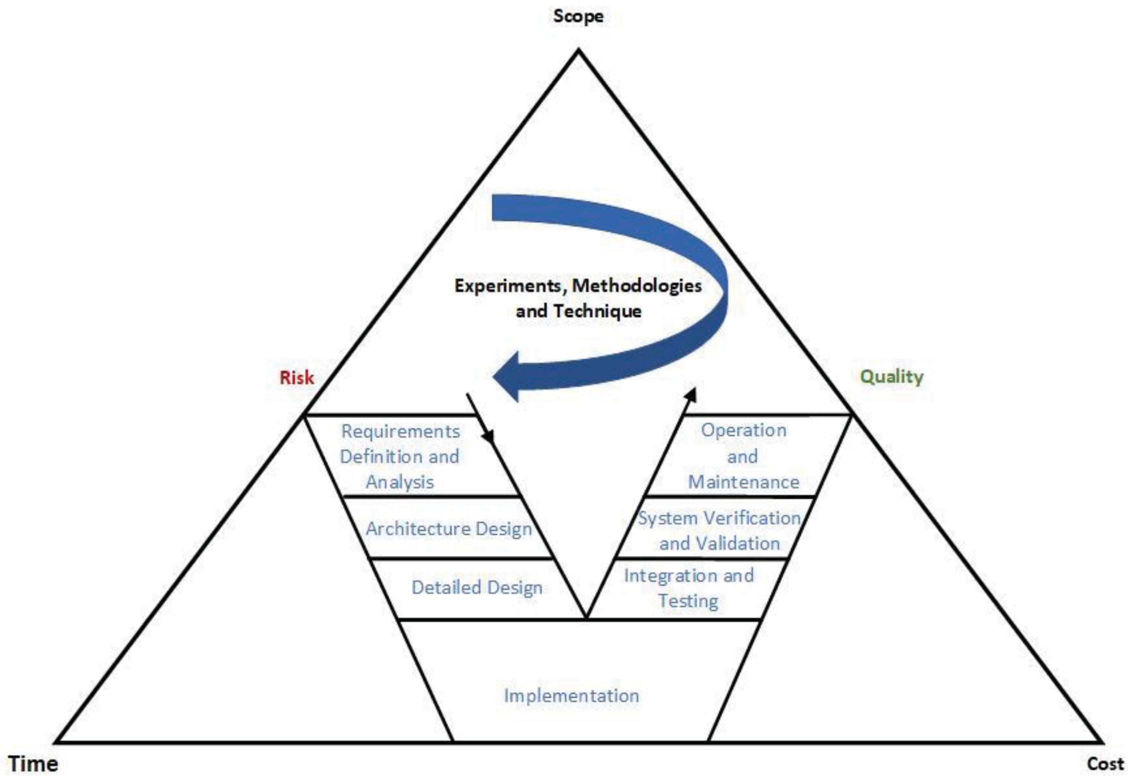

Figure 5-1: Technical Project Management Triangle (Solid Triangle)

5.2.1 Project management and System Engineering processes groups

Project management has five management process, and these processes include skills and techniques to complete the project, phase or product, these five processes are Initial, Planning, Monitoring, and Control Executing and Closing. Any project team should follow these processes to complete the project and success. System Engineering has technical processes follow methods and techniques to get the optimization for the project, phase or product. These processes covered Initial, Managed, Defined, Quantitatively Management, and Optimization.

This research will describe processes that include project management and system engineering these processes will cover the all processes in both fields and the figure below describe the processes of Technical Project Management.

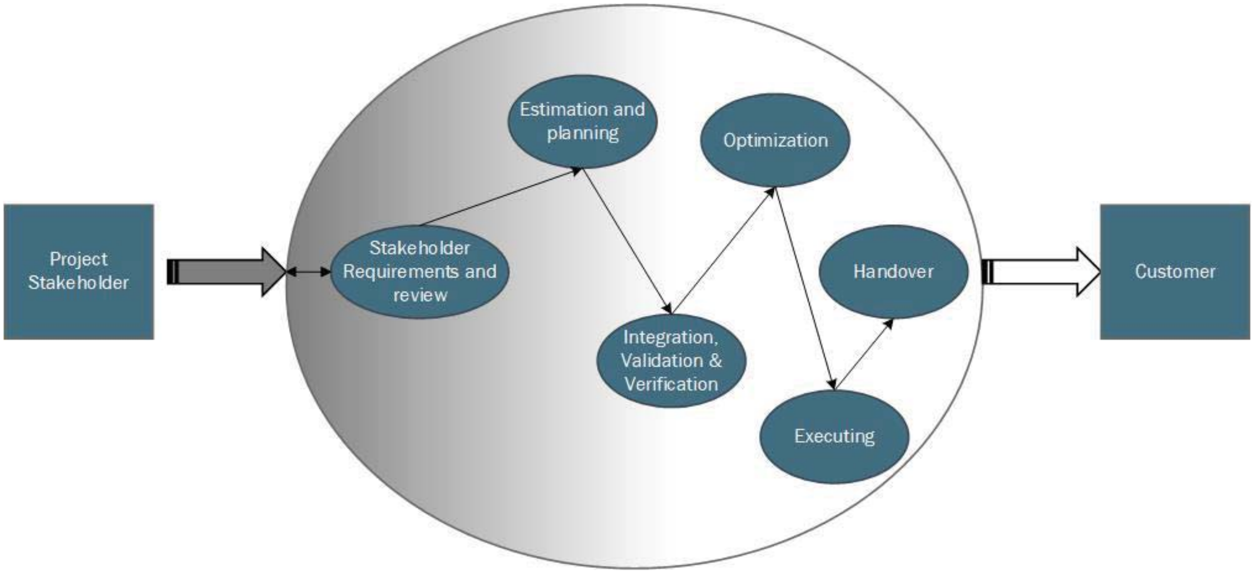

Figure 5-2: Technical Project Management Steps

Technical project management has six technical processes that include management skills and techniques to complete and success the project, and on the same way get the optimization and maximum quality. These processes could apply it for one time for one project and get successful, and optimization and these processes also might be using for several projects in the same field. How? The company can apply these processes in industrial or construction field for several projects by make template for this type of project depends on technical project management. For example, in steel structure projects 80% from the procedure of work from the beginning to close the project is almost similar just values, some quantities and for sure the design but the executing and production works almost the same so once we get the stakeholder requirements and negotiate about it then send it to the planning and estimation process, the planning and estimation procedure is the same for all type of steel structure projects. Then the information goes to IVV (Integration, validation, and verification) process and this process that has the most different between projects but the procedure almost the same, most of different comes from design and specification.

5.2.2 Technical Project Management Processes

Technical project management has six processes to get optimization ad successful review stakeholder requirements, estimation & planning, integration validation verification, optimization, executing and closing. These processes will achieve the optimum cost, time and quality with reducing the mistakes and risk in both fields technical and management.

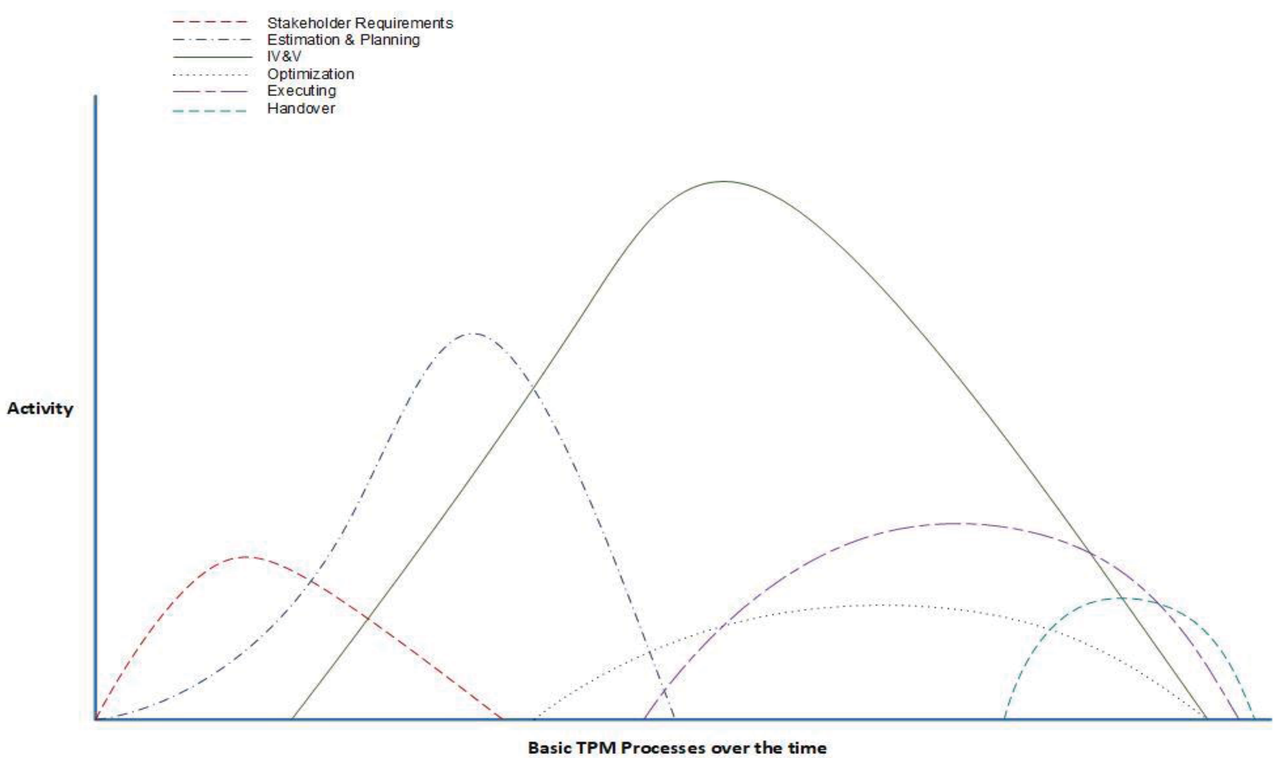

Figure 5-3: TPM Processes Activities over Time

5.2.2.1 Stakeholder requirements and review the requirements

In this process, we will start the project by getting the stakeholder requirements and processes it as a revision and arrive at the optimum requirements. How? When the team reach the requirements from the stakeholder in natural languages or get some specifications project (tender project) if the stakeholder received some highlight project from specifiers, and that is mean tender project. When the stakeholder has a tender project, the stakeholder will have the primary and first design with general specifications depends on the function and the area of the project. This process collects requirements and review requirements. Why should the team discuss the requirements? Because sometimes the first project specifications with the stakeholder requirements ask for a product to achieve the function. Also, sometime this product will achieve more or less than the one want it to accomplish the function so, the technical project management team should review this specification and advise the stakeholder to get the optimum and not over design project. For example, in construction project specially steel structure field some time the stakeholder ask for 100mm thickness of roofing system and on the same way want to achieve 0.3 W/m^2K U-value (Thermal transmittance) but the 100 mm thickness of roofing system will achieve 0.25 W/m^2K U-value, so the product they asked it is over design and we can change it to 75 mm thickness and fulfill the stakeholder requirement.

Figure 5-4: Stakeholder Requirements and Review The Requirements

5.2.2.2 Estimation & Planning:

This process will complete the work in the previous process, study and analyze the project depends on the revision stakeholder requirements. This process will transfer the stakeholder requirements from basic requirements or natural language to basic engineering and math form.

5.2.2.3 Integration, Validation and Verification:

This process is a pure engineering & technical process, by get the estimation and planning output and work in this information to find engineering form and documents. The IVV process includes several issues, for example, analyze traceability, design & evaluate the design, perform criticality analysis, Verify Component test plan, Verify Component test design, Perform risk analysis, etc.

5.2.2.4 Optimization

In this process, we will achieve the optimum in cost, time and quality. After achieving the optimization, we should follow some quality methods to keep our system or project in the same level of optimization. This process will allow the estimation team to know the exact bill of quantity for the project and materials take off. On the same way will allow the top management to know the margin percentage and the profit value, also will allow them and the technical team to know how much exactly time to execute the project and keep the same percentage of margin during the project and keep the stakeholder know the quality level and be trust and comfortable.

5.2.2.5 Executing

After the optimization in the project from the previous process, the project management and technical team (technical project management team) will follow Executing step to execute the project professionally and complete the project at the same level of optimization without wasting time in back-and-forth study and analysis. In the TPM process, the team will back to the estimation and planning process only if there are any changes in stakeholder requirements or back to the IV&V process if there is any changes or problems in the design. However, there are no changes in these both points, so the team only follow it and finish the project with any additional time or cost. The team in this process will follow skills and techniques to do this stage in an optimum way.

5.2.2.6 Handover

The handover process to the stakeholder or the owner of the project occurs to see if each item satisfies the owner and see if the owner asks for additions to the project or additional items to complete the project, product or service.

5.2.3 Technical Project Management Processes Cost:

All companies are looking to make more profit and the maximum percentage of margin, and to achieve the maximum profit, should minimize the cost in each step. The companies should minimize the costs in the materials, overhead, management, and even in the cost of working processes. In all industries, the most critical factor is the cost, besides time and quality, and these three factors are optimized, and the optimization is what we are looking to achieve in this research. Some of the engineering projects can fail, and most of these projects fail by reducing the percentage of margin for many reasons, these reasons include:

- Cost Overruns
- Schedule Overruns
- Performance Failures and Technical Risks

Project management has 49 management processes, and System Engineering has 31 technical processes, in this research, we will study these processes and the optimum number of processes.

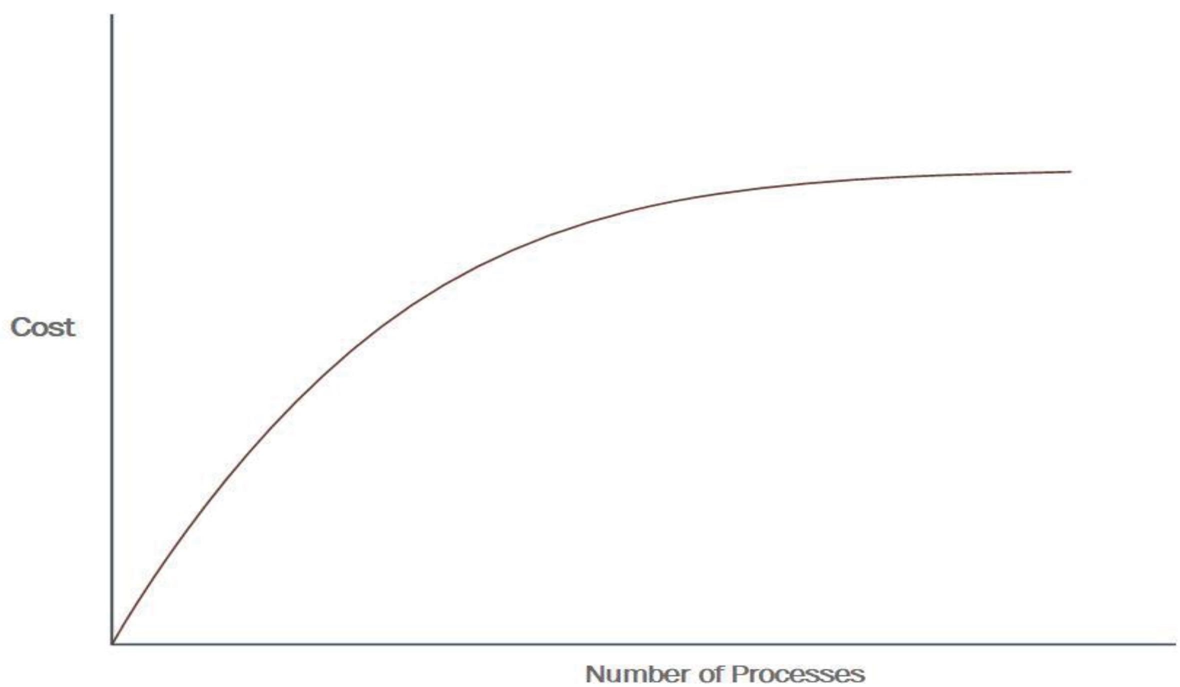

Figure 5-5: Number of Processes Vs. Cost

Technical Project Management has several parameters that affect the cost of technical, management and human. The following are the parameters that affect the cost:

- Requirements Understanding

- Architectural Understanding
- Level of Service Requirements
- Migration Complexity
- Technology Risk
- Documentation
- Number and Diversity of Installations
- Number of Recursive Levels in The Design
- Stakeholder Team Cohesion
- Multisite Coordination
- Heterogeneity (Domain and Culture)
- Personnel Team Capability
- Process Capability
- Personal Experience
- Tool Support

To get the optimization in Technical Project Management processes, TPM will cover all activities with the lowest number of processes to reduce the cost and time.

The most critical steps in TPM are estimation & planning and IV&V. These stages should have more processes than other stages. All technical project management processes are related together and integrate others and should reduce the redundant processes and activities as well. Figure 5-6 illustrates the relative cost of TPM steps.

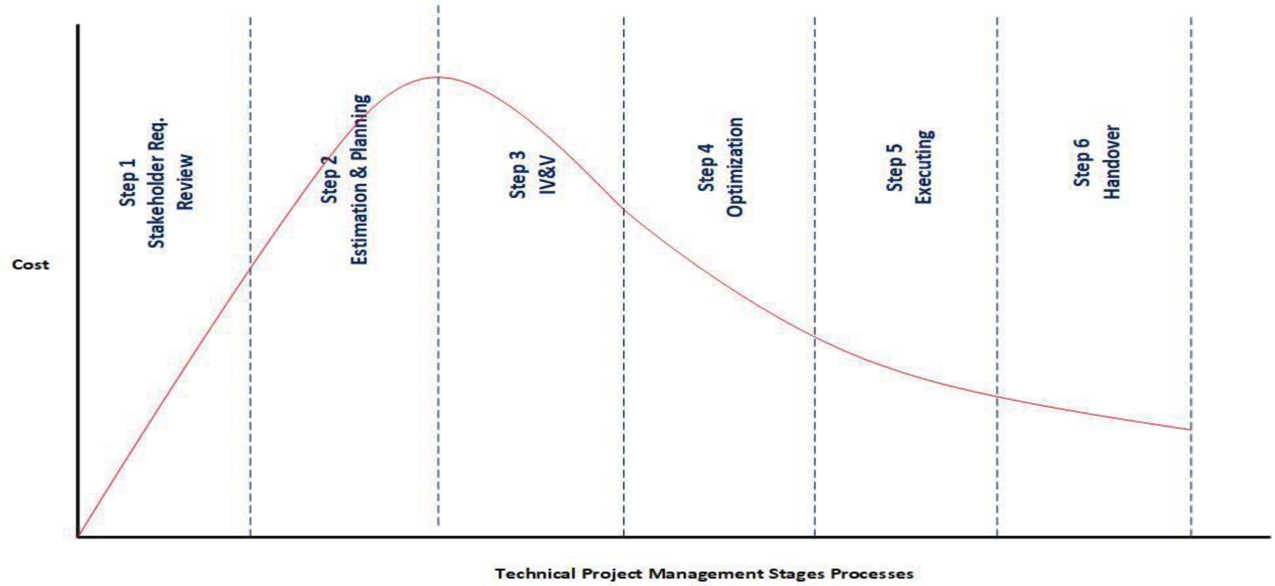

Figure 5-6: The Processes Cost During TPM Steps

Process 1 has processes for stakeholder requirements and how to review these requirements. This process is the most important one because the other six processes are based on this process and on the same way this process has the lowest number of processes.

Process 2 and Process 3 have variety and several processes because these two processes are the most critical processes and if these processes are successful, and the project passes milestones, then the chance to get the optimization will be 70%-80%.

Process 4 has a lower number of processes than processes 2 & 3. This process has quality processes to keep the project, product or service on the same level of optimization achieved in process number 2 & 3.

Process 5 has the most processes related to management skills and techniques, and it has some technical processes to keep the executing on the same level of optimization without mistakes or problem that we should solve it by back to the previous processes and waste time and cost.

Handover process is the last process for TPM, and it has few numbers of processes. These few processes are related to how to submit the project, product or service to the stakeholder on the same requirements and design and get the acceptance of submission from the stakeholder or the owner. This process has processes and procedure of submission the final project or final product.

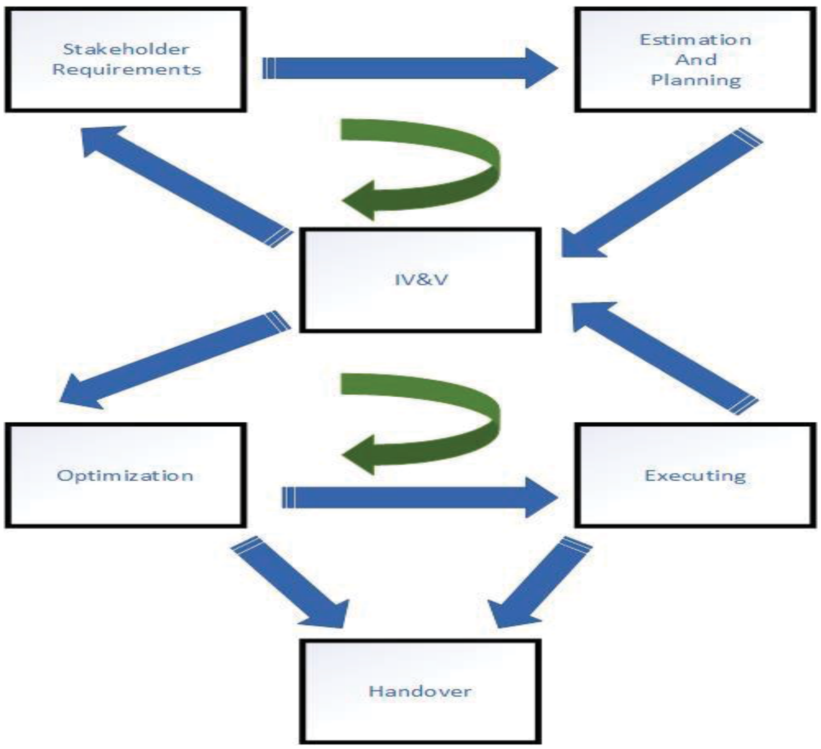

Figure 5-7: Basic TPM Steps

5.3 Stakeholder Requirements Review and Analysis

5.3.1 Business or Mission Analysis Process

Business or Mission Analysis process is the first process in each project to analyze the functionality of the business, setting the requirements depending on the business or the mission. "The purpose of the Business or Mission Analysis process is to define the business or mission problem or opportunity, characterize the solution space, and determine potential solution class(es) that could address a problem or take advantage of an opportunity" (INCOSE SE Handbook v4, 2015, pp. 49).

This process aims to create a system of interest and to achieve this target we should follow some steps*:

- Defining the problem domain
- Identifying major stakeholders
- Identifying environmental conditions and constraints that bound the solution domain
- Developing preliminary life cycle concepts for acquisition
- Developing the business requirements

(INCOSE SE Handbook v4, 2015, pp. 49)

5.3.2 Stakeholder Needs and Requirements Definition Process

5.3.2.1 Stakeholder Requirements Review

There are two kinds of stakeholders, individuals, and organizations, who are involved in projects. Stakeholders are also anyone who affects the project completion or expectations. This process collects the stakeholder requirements and studies and reviews the requirements depends on the Business Analysis.

5.3.2.2 Stakeholder Requirements Analysis

This process analyzes the requirements depends on the functionality and Business Analysis and be sure that there are no mistakes in the requirements and everything matches the expectation.

After obtaining the requirements and during this process the team should study and analyze the requirements then back to stakeholder and discuss with them after study it. For example, in construction project specially steel structure project and metal roofing system some time the stakeholder ask for 150mm thick metal roofing system and on the same way the stakeholder specification (set from the specifier) ask for 0.21 U-value, so in this case and after the team analyze the requirements they will found that 150mm thick will achieve 0.14 U-value so the 150mm will be overdesign then they will propose 100mm thick to achieve 0.21 U-vale.

When we meet the needs of the project and the requirements throughout the life cycle, we can get a successful project depends on System Engineering. "These needs are analyzed and transformed into a set of stakeholder requirements for the operation and effects of the solution, and its interaction with the operational and enabling environments" (INCOSE SE Handbook v4, 2015, pp. 52).

5.3.2.3 Prepare for stakeholder needs and requirements definition:

This process determines and defines stakeholder needs and translates these needs to system requirements.

5.3.2.4 Define Stakeholder needs

This process is almost the first process that uses some engineering skills especially engineering sense. In this process TPM team should elicit stakeholder needs and arrange these needs depends on prioritizing and focus on the requirements that have high prioritized then specify the stakeholder needs.

5.3.2.5 Transform stakeholder needs into stakeholder requirements

This process aims to make balance and consistent between scenarios, interactions, constraints and critical qualities by identify obstacles and specify stakeholder requirements and functions and keep them under monitoring to avoid any changes.

5.3.2.6 Analyze stakeholder requirements

This process reviews the requirements analysis to ensure that the requirements reflect their needs and expectations. This process uses operational measures methods to indicate overall customer satisfaction and to define validation criteria for stakeholder requirements using Measures of Effectiveness (MOE) and Measures of Suitability (MOS). After review and analysis, we should resolve the impractical requirements by negotiating the modifications.

5.3.2.7 Manage the stakeholder needs and requirements definition

As usually described.

5.3.3 Identify Stakeholders

"It is critical for project success to identify the stakeholders early in the project or phase and to analyze their levels of interest, their expectations, as well as their importance and influence" (Project Management Institute, PMBoK v5, 2013, pp. 393).

5.3.3.1 Inputs:

5.3.3.1.1 Project Charter

This document provides information regarding internal and external parties related to the project and affected by the results.

5.3.3.1.2 Enterprise Environment Factors

This section includes but not limited to:

- Organizational Chart.
- industry standard and specifications.
- Global regional local directions and interests.

5.3.3.1.3 Organizational Process Assets

This section includes but not limited to:

- Stakeholder register.
- Experiences from old projects.
- Stakeholder registers from old projects.

5.3.3.2 Tools and Techniques

5.3.3.2.1 Stakeholder Analysis

Stakeholder analysis is a technique of systematically gathering and analyzing quantitative and qualitative information to determine whose interests should be considered throughout the project (Project Management Institute, PMBoK v5, 2013, pp. 394).

The analysis process for stakeholder requirements follows the following steps:

- Identify and define project stakeholders and all related information
- Analyze the impact or support stakeholder could create it or do it, and classify them
- Evaluate all stakeholders' reactions when they have different thoughts

To make the analysis of stakeholder requirements easier, we should make classifications for stakeholders related to the project like the following classifications:

- Power/interest grid
- Power/influence grid
- Influence/impact grid
- Salience model, this model classifies the stakeholders in three classifications depends on their power

5.3.3.2.2 Expert Judgment

To ensure identify stakeholders the team should have some experts who have some previous experience on the same project area or some training and certificates or more

Figure 5-8: Stakeholder Classifications

5.3.3.2.3 MEETINGS

Project meetings help and support understating of project stakeholders. The meetings use to analyze the roles, interest and knowledge

5.3.3.3 Output

5.3.3.3.1 Stakeholder Register

The main output of identify stakeholder is stakeholder register.

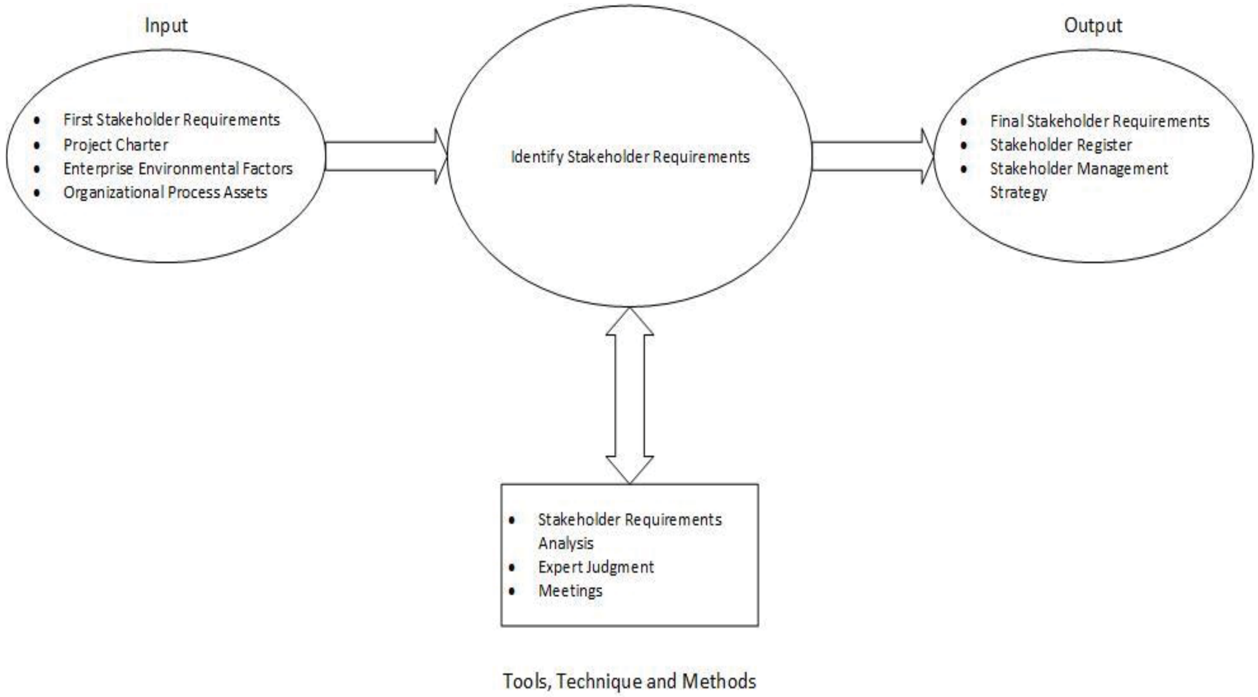

Figure 5-9: Identify Stakeholders Input, Output, and Techniques & Methods

5.3.4 Elicit Stakeholder Needs

This process defines what must be done to gather the information, personnel, and analysis tools to elaborate the business requirements. "This includes gathering stakeholder needs, system/project constraints (e.g., costs, technology limitations, and applicable specifications/legal requirements), and system/project "drivers,"- (INCOSE SE Handbook v4, 2015, pp. 55).

The output of stakeholder requirements supports important technical definition to the acquisition process to issue a request for proposal (RFP).

TPM team spends high effort for eliciting and capturing requirements because requirements are coming from different sources. The Operational Concept (OpsCon) explains and describes the operational plan of the system to let the team understand which requirements need to define.

Requirements elicitation follow techniques and methods like the following:

- Interviews
- Focus groups
- The Delphi method
- Soft systems methodology

To capture and manage the requirements there are a lot of verity tools; the tools would be different between TPM team and another TPM team depend on the experience, province projects on the same area, knowledge, and methods.

5.3.5 Requirements Definition and Analysis Concepts

The objective of the requirements analysis process is to support and describe the interaction between functions to obtain the stability of requirements depends on customer objectives. This is a complicated process and the team has to use performance analysis, trades study, constraint evaluation, and cost-benefit analysis.

Requirements definition and analysis is a stable process that works top-down and bottom-up. Once the team creates the top-level set of system requirements, it is necessary to smooth down to successively down levels.

The output from this process contains attributes for each requirement and this attribute used in verification.

some constraints need to be reflected; this includes the following:

- Standards—understand and analyze standards requirements to match quality or design considerations

- Utilization environments—Identify the utilization environments and all environmental factors that may affect system performance, impact human comfort or safety, or cause human error (INCOSE SE Handbook v4, 2015, pp. 60).
- Essential design considerations—Identify design considerations including human systems integration (e.g., human resources, personnel, training, environment, safety, occupational health, survivability, habitability), system security requirements (e.g., information assurance, antitamper provisions), and potential environmental impact (INCOSE SE Handbook v4, 2015, pp. 60).
- Design constraints—Identify design constraints including physical limitations (e.g., weight, form/fit factors), human resources, personnel, and other resource constraints on the operation of the system and defined interfaces with host platforms and interacting systems external to the system boundary, including supply, maintenance, and training infrastructures (INCOSE SE Handbook v4, 2015, pp. 60).

5.3.6 Characteristics and Attributes of Good Requirements.

The following characteristics should be considered for every requirement:

- **Necessary**: only necessary requirements have to be in specifications. There are two kinds of unnecessary requirements, i) additional specifications of design and this specification the designer will judge if should include or not. ii) a redundant requirement that already exists in other requirements.
- **Implementation independent:** The requirement should specify "what" is to be done at that level, not "how" it is to be done at that level (INCOSE SE Handbook v4, 2015, pp. 60).

- **Unambiguous:** This Characteristic have some questions:

  Are the requirements evident?

  Could explain the requirements in a different way?

  Are the terms are defined?

  Does the requirement impact with or destroy another requirement?

  "The language used must be clear, exact, and in sufficient detail to meet all reasonable interpretations" (INCOSE SE Handbook v4, 2015, pp. 61).

- **Complete.**
- **Singular:** requirements statement should be separated just for a single requirement and never share or combine the function with another requirement.
- **Achievable:** The requirements have to be technically satisfied with constraints and initial specifications with acceptable risk.
- **Verifiable:** Each requirement must be verified at some level by one of the four standard methods (inspection, analysis, demonstration, or test) (INCOSE SE Handbook v4, 2015, pp. 61)
- **Conforming.**
- **Priority.**
- **Criticality.**
- **Risk.**

5.3.7 Plan Stakeholder Requirements.

This process aims to provide a clear plan and to explain the reaction between stakeholders to proceed in the project and get the project interests.

Improving communications and requires and managing the team are very important is Stakeholder Management but it is not only these duties, create and maintain the relationship between the project team and stakeholders also necessary in Stakeholders Management." This process generates the stakeholder management plan, which contains detailed plans on how effective stakeholder management can be realized" (Project Management Institute, PMBoK v5, 2013, pp. 399).

5.3.7.1 Plan Stakeholder Requirements Input

5.3.7.1.1 Project Management Plan

The following information's are some information followed to develop the stakeholder management plan:

- Processes must follow for each phase.
- Explain how the work is running to match the project objective.
- Describe the human resources requirements, responsibilities and staffing management.
- Changes monitoring and control.
- Communications need and technique.

5.3.7.1.2 Stakeholder Register

The stakeholder register provides the information needed to plan appropriate ways to engage project stakeholders. (Project Management Institute, PMBoK v5, 2013, pp. 399)

5.3.7.1.3 Enterprise Environmental Factors

This process determines the best options to support a better adaptive process for managing stakeholders by an importance particular like:

- Organizational culture structure
- Political climate

5.3.7.1.4 Organizational Process Assets

The target of this process and we use organizational process assets as a input to provide insights on previous stakeholder management plans and their effectiveness by some importance particular like:

- Lessons learned database.
- Historical information's.

5.3.7.2 Plan Stakeholder Requirements Tools and Techniques

5.3.7.2.1 Expert Judgment

Expert judgment coming from experience, knowledge, high educations or some history projects on the same area. Expert judgment could be provided by anyone in the project team like:

- Senior management.
- Project team members.
- Other units or individuals.
- Identified key stakeholders.
- Project manager.

- Subject matter experts in business on project area.
- Industry group and consultant.
- Professional and technical associations.

5.3.7.2.2 Meetings

Meetings are significant during the whole project process, because in the meeting with the team or subcontractors or any member in the project the thoughts will be shared and figure out the problems or changes in an early stage, so it will not affect the project as in advance stages.

5.3.7.2.3 Analytical Techniques

The engagement level of the stakeholders can be classified as follows:

- Unaware. Unaware of project and potential impacts.
- Resistant. Aware of project and potential impacts and resistant to change.
- Neutral. Aware of project yet neither supportive nor resistant.
- Supportive. Aware of project and potential impacts and supportive to change.
- Leading. Aware of project and potential impacts and actively engaged in ensuring the project is a success.

(Project Management Institute, PMBoK v5, 2013, pp. 401)

5.3.7.3 Plan Stakeholder Management: Outputs

5.3.7.3.1 Stakeholder Management Plan

This output is the results of plan stakeholder management, stakeholder management plan provides (not limiting to):

- Engagement levels of stakeholders.
- The reaction of changes to stakeholders.
- Specify the overlap relationship between stakeholders.
- The information could share it to stakeholders including language, format, content and level of details.
- Time frame for the required information that have to share it with stakeholders.

5.3.7.3.2 Project Documents Updates

Project documents that may be updated include, but are not limited to:

- Project schedule.
- Stakeholder register.

(Project Management Institute, PMBoK v5, 2013, pp. 403)

5.3.8 Control Stakeholder Engagement

This process is monitoring and control project stakeholder relationships, adjusting strategies and plans for engaging stakeholder. The function and aim of this process are to increase the efficiency and effectiveness of stakeholder activities.

5.3.8.1 Control Stakeholder Engagement: Input

5.3.8.1.1 Project Management Plan

Described in section 5.2.7. The following information are some of information used in control stakeholder engagement:

- The life cycle of the project and the processes used for each phase

- The procedures for execute the project and achieve the project objective
- Human resource management and team management
- Plan change management to control and monitor the changes
- Communication management

5.3.8.1.2 Issue Log

Managing stakeholder engagement may result in the development of an issue log. This log is updated as new issues are identified and current issues are resolved (Project Management Institute, PMBoK v5, 2013, pp. 403).

5.3.8.1.3 Work Performance Data

This mean observations or measurements during activities to carry out the project work. For example, percentage of work completed, number of change requests, number of defects, actual cost etc.

5.3.8.1.4 Project Documents

These documents include but not limited to

- Project schedule
- Stakeholder register
- Issue log
- Change log
- Project communications

5.3.8.2 Control Stakeholder Engagement: Tools and Techniques

5.3.8.2.1 Information Management Systems

This information is information let the project manager capture, store and distribute information to stakeholder about cost, schedule and performance.

5.3.8.2.2 Expert Judgment

In this thesis, the Delphi Method is utilized.

5.3.8.2.3 Meeting

Status review meetings are used to exchange and analyze information about stakeholder engagement.

5.3.8.3 Control Stakeholder Engagement: Output

5.3.8.3.1 Work Performance Information

It is a data collected from controlling processes then analyze it the integrated based on relationships across area.

5.3.8.3.2 Change Requests

These requests are processed by correct actions and prevent actions to improve the future performance and reduce the probability of incurring future negative project performance.

5.3.8.3.3 Project Management Plan Updates

Elements of the project management plan that may be updated include, but are not limited to the:

- Change management plan,
- Communications management plan,
- Cost management plan,
- Human resource management plan,
- Procurement management plan,
- Quality management plan,
- Requirements management plan,
- Risk management plan,
- Schedule management plan,
- Scope management plan, and
- Stakeholder management plan.

(Project Management Institute, PMBoK v5, 2013, pp. 403)

5.2.8.3.4 Project Documents Updates

The documents it may by updated include Stakeholder Register and issue log and more, these are just some documents updated.

5.2.8.3.5 Organizational Process Assets Updates

Stakeholder notifications, project report, project presentations, project records, feedback from stakeholder and lessons learned documentation are some of Organizational Processes Assets updates.

5.4 Planning and Estimation

5.4.1 Plan Stakeholder Engagement

As explained in section 5.2.7.

5.4.2 Plan Schedule Management

Any project and especially construction projects need to have procedures, policies and documentation for planning, developing, managing, executing, validations, verifications, testing and controlling the project schedule. The advantage of this process is to provide guidance and direction on how the project will be managed during the project.

5.4.2.1 Plan Schedule Management: Input

5.4.2.1.1 Project Management Plan

This process like a guide of the project because this process explains how the project will be executed, monitored, validated, verified and controlled which include but not limited to:

- Scope baseline: the scope baseline consists of the project scope statement and work breakdown structure to define activities, activities duration and schedule management.
- Other information: other schedule related costs, risk, and communication decision from the project management plan.

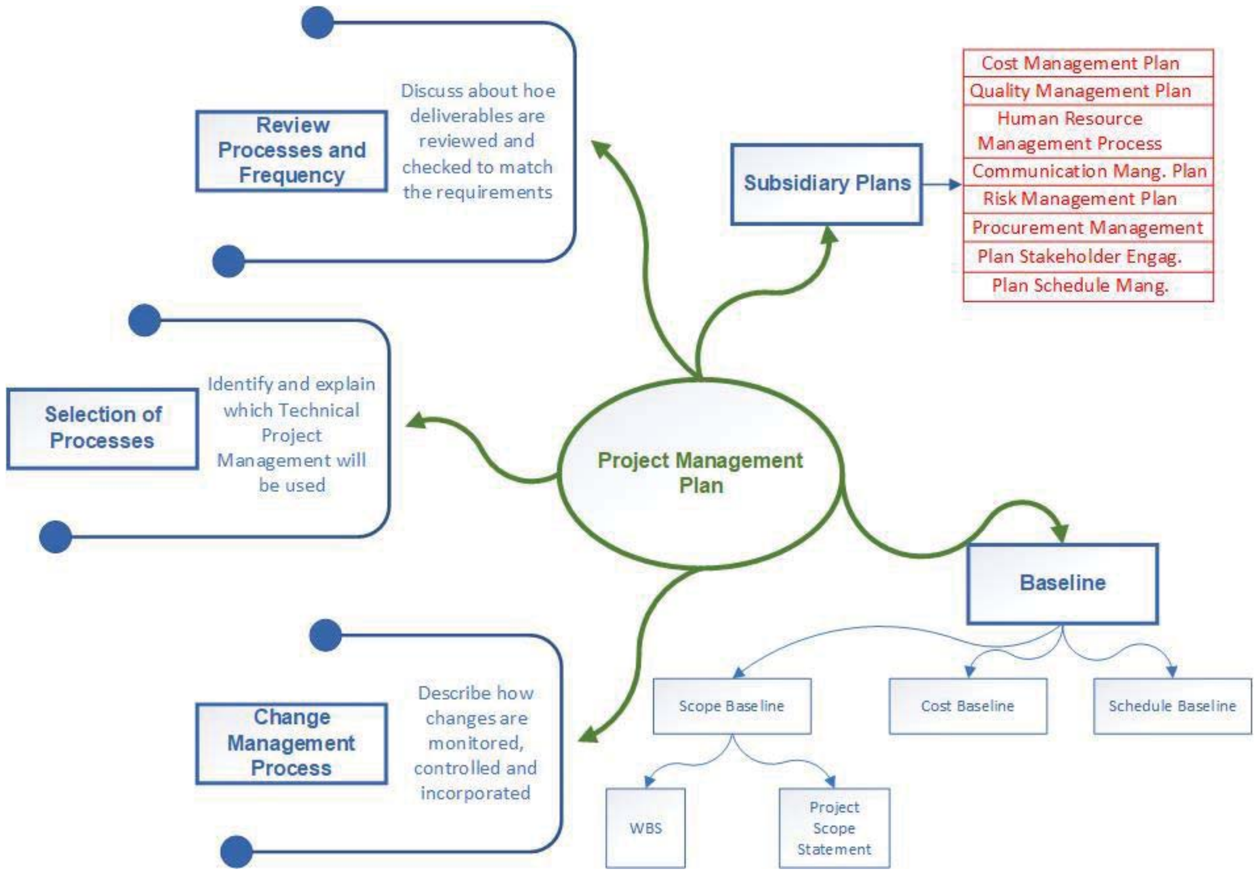

Figure 5-10: Contents of Project Management Plan

5.4.2.1.2 Project Charter

It is the documents issued by the project initiator that provides the technical project manager with the authority to apply organizational resources to project activities. The primary function of project charter that it documents the business needs, assumption, constraints, the understanding of the customer's needs and the high-level requirements, and the new project, product, service or result that it is intended to satisfy.

5.4.2.1.3 Enterprise Environmental Factors

Environmental conditions that are not under the control of project team, may still influence, constrain or direct the project. There are two classifications of Enterprise Environmental Factors:

1. Internal Factors like:
    - Existing people and skills
    - Organizational culture and structure
    - Policies around people
    - Infrastructure
    - Existing communication channels
    - Project management information system
    - Tolerate risk extend
2. External Factors like:
    - Marketplace conditions
    - Political climate
    - Government or industry standards
    - Commercial database

5.4.2.1.4 Organizational Process Assets

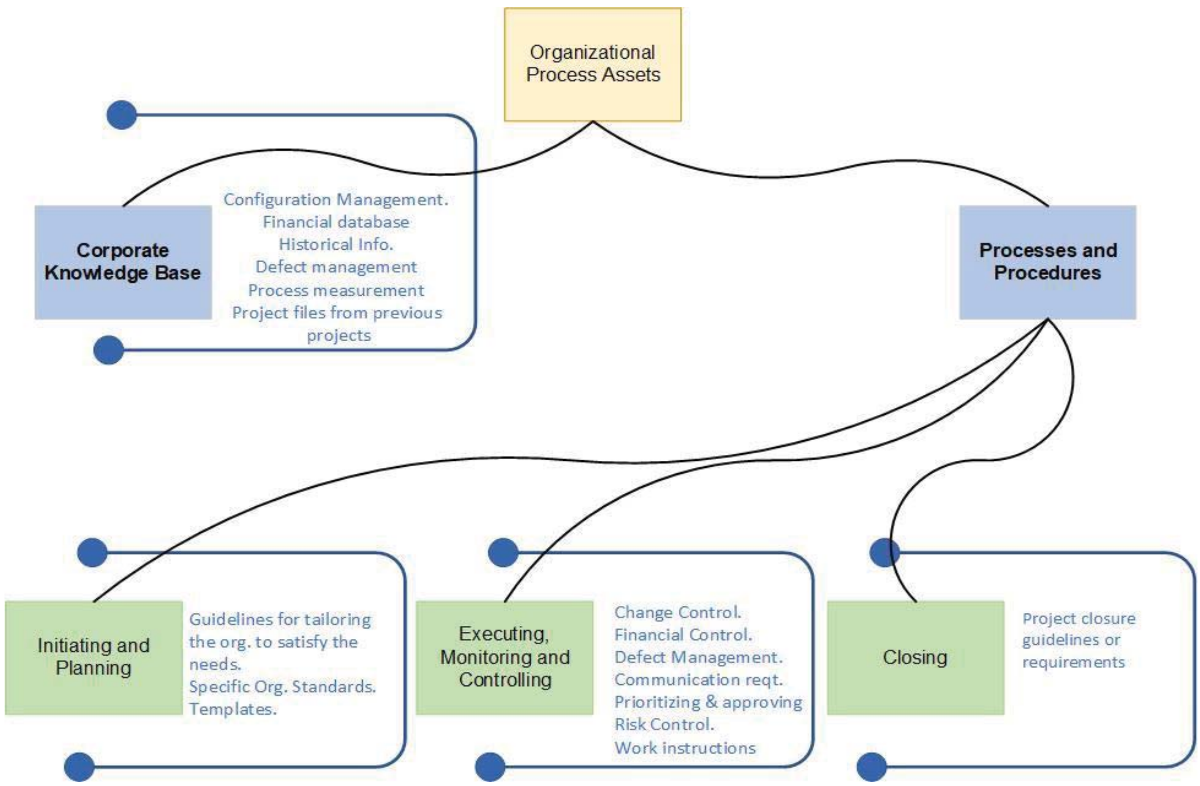

Figure 5-11: Organizational Process Assets

5.4.2.2 Plan Schedule Management: Tools and Techniques:

5.4.2.2.1 Expert Judgment

Judgment based upon expertise in an application area, Knowledge Area, discipline, industry, etc., as appropriate for the activity being performed, should be used in developing the schedule management plan (Project Management Institute, PMBoK v5, 2013, pp. 147).

5.4.2.2.2 Analytical Techniques

Choosing strategic options is one of the duties for plan schedule management and these options estimate and schedule the project like scheduling methodology, scheduling tools, and techniques, formats and project management software. Also, schedule plan support and help for fast track or crash. These decisions like other schedule decisions affecting the project may affect the risk.

5.4.2.2.3 Meetings

Meetings will help the team to develop the schedule management plan. These meeting may include anyone with responsibility for schedule planning and execution with project manager, sponsor and selected stakeholders.

5.4.2.3 Plan Schedule Management: Output:

5.4.2.3.1 Schedule Management Plan

The schedule management plan may be formal or informal, highly detailed or broadly framed based the need of the project and it will establish the criteria for developing monitoring and controlling the schedule.

Plan schedule management could establish some of the following:

- Level of accuracy
- Units of measure
- Project schedule model maintenance
- Control thresholds
- Rules of performance measurement

  Schedule management plan can follow any physical rules to measure the performance and it may specify:

  - Rules for present complete

    - Control accounts at which progress will be measured.
    - Earned value measurement techniques.
    - Schedule performance measurement.
- Reporting formats
- Process descriptions

5.4.3 Architecture Definition Process

"System architecture is more abstract, conceptualization oriented, global, focused to achieve the mission and OpsCon of the system, and focused on high-level structure in systems and system elements" (INCOSE SE Handbook v4, 2015, pp. 64). The target of architecture process is to create alternative architecture through several models to assess the properties of these alternatives. An effective architecture is as design agnostic as possible to allow flexibility in the design space, not only in design is also in all processes like Portfolio Management, planning, system definition, validation, verification, etc.

5.4.3.1 Architecture Definition Process: Input/Output:

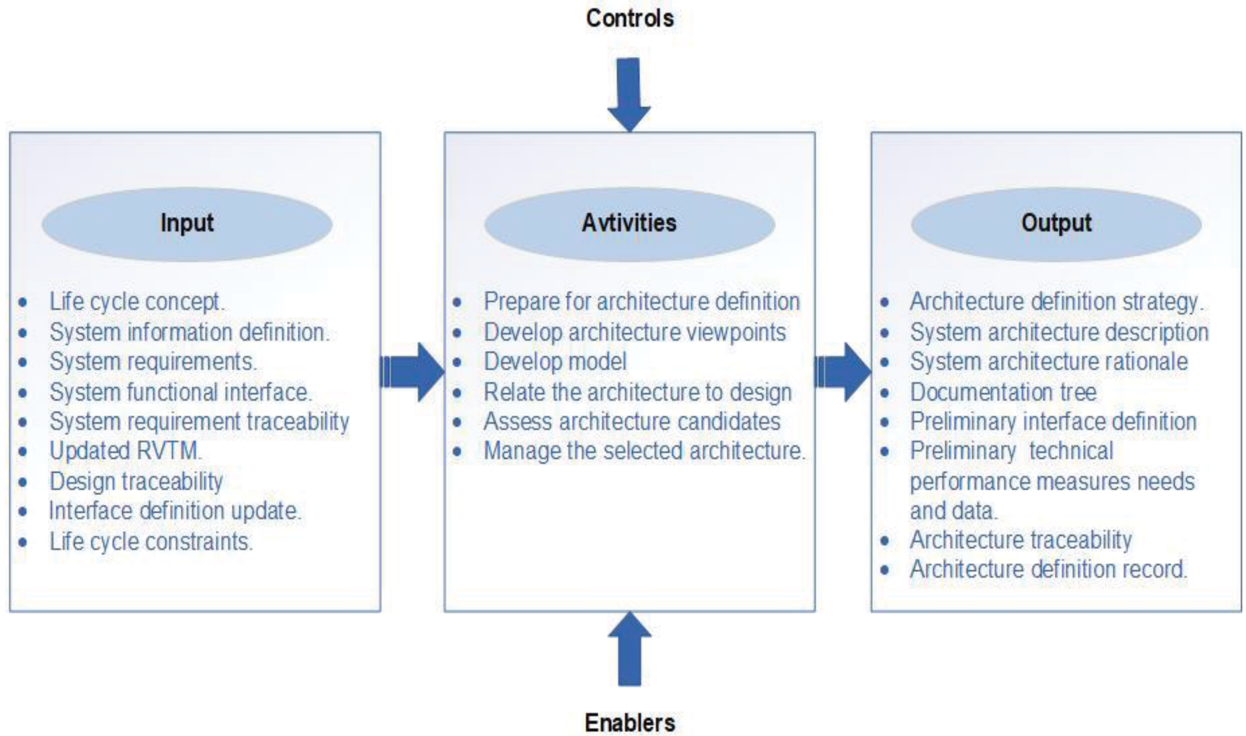

Figure 5-12: System Architecture Input/Output

5.4.3.2 Architecture Definition Process: Activities

5.4.3.2.1 Prepare for Architecture Definition

- Identify and analyze relevant market, industry, business and other information that will help understand the environment for which the solution is needed.
- Analyze the system requirements and tag nonfunctional requirements.
- Capture stakeholder concern related to architecture.
- Establish the approach for defining the architecture.
- Ensure the enabling elements will be available.

5.4.3.2.2 Develop Architecture Viewpoints

Establish and identify the associated architecture viewpoints to support the development of models and views.

5.4.3.2.3 Develop Models And Views Of Candidate Architecture

- Select or develop supporting modeling techniques and tools.
- determine the system context and boundary.
- Determine which architectural entities address the highest priority requirements.
- Allocate concepts, properties, characteristics, behaviors, functions, and/or constraints.
- Select, adapt, or develop models of the candidate architectures of the system.
- Determine need for derived system requirements induced by necessary added architectural entities and by structural dispositions.
- Compose views from the models of the candidate architectures.
- Analyze the architecture models and views for consistency and resolve any issues identified.
- Verify and validate the models by execution or simulation, if modeling techniques and tools permit, and with traceability matrix of OpsCon.

5.4.3.2.4 Relate the Architecture to Design

- Establish guiding principle for the system design and evaluation to check for design feasibility.
- Establish allocation matrices between architectural entities using their relationships.

- Interfaces definition that are important for level of understanding the architecture, include internal interface between the system elements and external interfaces with other system.
- Determine the design characteristics.
- Determine need for derived system requirements.

5.4.3.2.5 Assess Architecture Candidates

This process will be done by applying the system analysis, measurement and risk management process. And select preferred architectures will be done by applying decision management process.

5.4.3.2.6 Manage the Selected Architecture

- Capture and maintain the rationale for all selections among alternatives and decision
- Manage the maintenance and evolution of the architecture.
- Establish a means for the governance of the architecture.
- Coordinate review of the architecture

5.4.4 Elaboration

5.4.4.1 Architecture Representation

The notion of system means design or redesign product, project or service. The system is a solution for a problem, and each problem have several solutions that could address that problem. The solution may less or more complex, and the notion of system is useful to engineer complex solution. The System Architecture represented with functions, function flow, interfaces, resource flow, communication resources, etc.

5.4.4.2 Architecture Description of the System

Viewpoints and views are sometimes specified in architecture frameworks such Zachman (1987), DoDAF (2010), and MoDAF, The Open Group Architecture Framework (TOGAF), etc. "The architecture definition process includes also the possible usage of other viewpoints and views to represent how the system architecture addresses stakeholder concerns, for example, cost models, process models, rule models, ontological models, belief models, project models, capability models, data models, etc" (INCOSE SE Handbook v4, 2015, pp. 68).

5.4.4.3 Emergent Properties

Emergent properties are the result of interaction between the system elements, and this interaction will create desirable or undesirable phenomena, this phenomenon called emergent properties. Emergent properties like inhibition, interface, resonance, or reinforcement of any property. The notion of emergent properties using during architecture and design processes to focus on important derived functions and internal physical on environmental constraints.

5.4.4.4 Architecture in Product Line

The architecture process is a critical and important process for product line and it spread along several design variants, providing a cohesive basis for the product line design by ensuring compatibility and interoperability across the product line.

5.4.4.5 Notion of Interface

When defining the architecture there are several items to consider and notion of interfaces is one of the most important items.

5.4.4.6 Coupling Matrix

Coupling matrices (also called N2 diagrams) are a basic method to define the aggregates and the order of integration (Grady, 1994).

5.4.4.7 Allocation and Partitioning of Logical Entities to Physical Entities

Defining and identify physical interface eligible to carry input/output flows and control flows. Allocation means to separate, gather, or decompose logical entities in to sections and then to make the agreement between the sections and sectional system elements.

Nonfunctional requirements and architecture characteristics are used as a factors and important factors for analyze, assess, and select system elements.

5.4.4.8 Defining Candidate Architectures and Selecting the Preferred One

Any project needs to have alternatives to answer all stakeholder and system requirements; this process will be defined and figure out the best possible architecture made of suitable system elements and interfaces. This best architecture will answer all system requirements but depends on the agreed limit or margins of each requirement. To do the best possible architecture, the team has to produce several candidates' architectures: analyze, assess, and compare them then select the most suitable one.

5.4.4.9 Methods and Modeling Techniques

Some processes or methods used in system architecture to reduce the risk of failure in the finished system, these methods or processes are modeling, simulation and prototyping. Modeling and simulation on large complex use to let the system engineer manage the risk failure to meet the mission and performance requirements.

5.4.4.10 Create Work Breakdown Structure

Work Breakdown Structure (WBS) is process use during the project to manage, estimate cost and control the system and subsystem. This process divides the system or project to smaller components or subsystem and provides the necessary framework for detailed cost estimation and control.

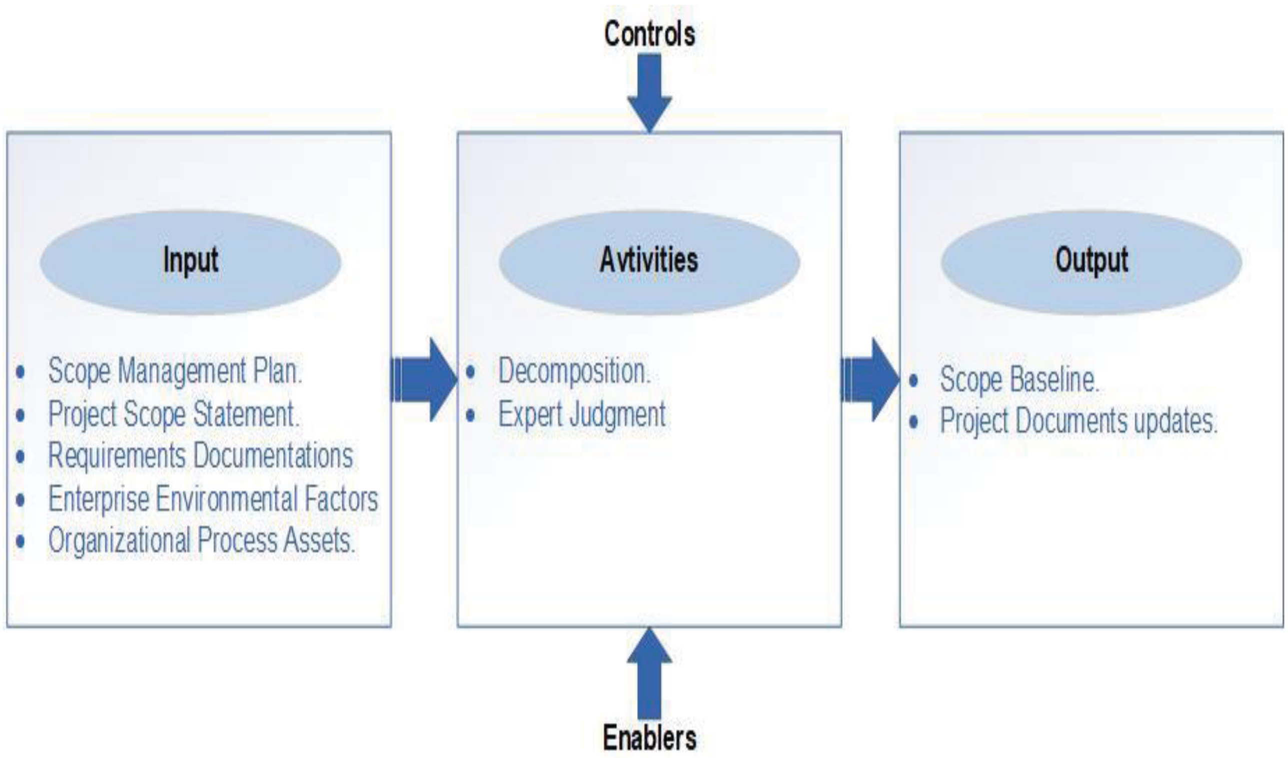

Figure 5-13: WBS Input/Output

WBS comes in several methods that identify the hierarchical breakdown like outlines or organizational chart. As the work is decomposed to higher levels of detail, the ability to plan, manage, and control the work is enhanced.

The WBS represents all product and project work, including the project management work. The total of the work at the lowest levels should roll up to the higher levels so that nothing is left out and no extra work is performed, and this sometimes called the 100 percent rule (Project Management Institute, PMBoK v5, 2013, pp. 130).

5.4.5 Estimate Cost

The function and the target of this process is to determine the amount of cost required to complete the project.

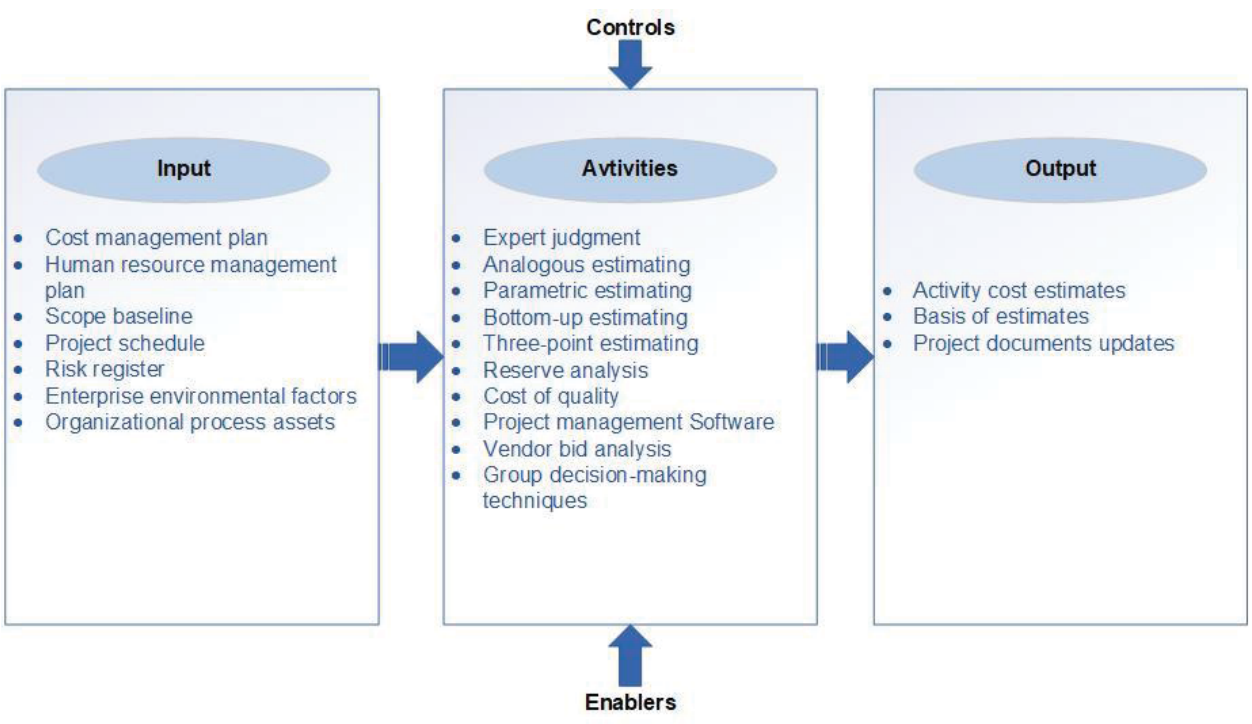

Figure 5-14: Cost Estimate Process Input/Output and Activities

Cost estimates include the identification and consideration of cost alternatives to initiate and complete the project (Project Management Institute, PMBoK v5, 2013, pp. 200).

Project estimate cost mean analyze the cost for the project depends on several factors and way, the analysis of the project cost includes materials take off for the project scope of work and calculate the correct quantity with respect the wastage in materials during production process then calculate the cost of the materials depends on material quantity come from materials take-off process. Also, project estimate cost includes the time for labor and the stuff, that means the overhead for the stuff during the project.

For example, in a construction building project there is an aluminum scope of work, when the main contractor have to start working in this scope of work depends on activities sequence process, the main contractor will send the scope of work with the specifications of this scope to the subcontractor or the aluminum factories the aluminum factories will get this scope of work and start working and estimation to prepare the quotation for the main contractor, the aluminum factory will start materials take off and calculate the exact quantity needed in the project and each scope of work that means in aluminum field there are a lot of items such as aluminum doors, windows, curtain wall, structural glazing system and aluminum cladding 4 mm for wall façade system. So, the scope of work will include what it needs in the project in most cases and project it will consist of all types of aluminum works. Thus, the materials take off department will calculate the quantity of each item and put the specification of each item then contact with the supplies of raw materials and get the price of each raw material and calculate the quantity for each raw material will use in the project. Then the estimation department will calculate the manufacturing cost for the quantities and the time as well with respect to the raw materials wastage during the production process. Then prepare the quotation and submit it to the main contractor.

5.4.5.1 Estimate Cost: Input

5.4.5.1.1 Cost Management Plan

For more specific information regarding earned value management, refer to the Practice Standard for Earned Value Management – Second Edition.

- Reporting formats

  The formats and frequency for the various cost reports are defined.

- Process descriptions.

  Descriptions of each of the other cost management processes are documented.

- Additional details.

  Additional details about cost management activities include, but are not limited Description of strategic funding choices, Procedure to account for fluctuations in currency exchange rates, and Procedure for project cost recording.

5.4.5.1.2 Human Resource Management Plan

Human resource management plan includes but not limited to:

- Roles and Responsibilities.
- Project Organization Charts.
- Staffing Management Plan.

5.4.5.1.3 Scope Baseline

Any project needs to have a product description, acceptance criteria, key deliverables, project boundaries, assumption and constraints and these all provided by project scope statement under the baseline process. Scope baseline comprised of Work Breakdown Structure (WBS) and WBS dictionary.

5.4.5.1.4 Project Schedule

Estimate activity resource identifies the availability of staff, the working time required for the team, materials quantity for the project, and the equipment needed to do the project and perform the activities. Activity duration estimate will affect the cost on any project because the duration of any scope of work included in the cost of this scope so the estimate duration is critical and should consist of plan, design, manufacturing, delivery, executing and handover these all under project schedule, once estimate duration of activities determined so the sequence of activities will run smooth and success.

5.4.5.1.5 Risk Register

The target of risk management is to control and manage risk response cost. Risks in any kind whatever threats or opportunities typically have an impact and affect both activity and overall project cost. The project team should have engineering sense and quick action for any potential opportunities that can benefit and support the business by directly reducing activity costs or by accelerating the schedule.

5.4.5.1.6 Enterprise Environmental Factors

Some of the enterprise environmental factors that affect the estimate costs process are as the following:

- Market conditions.

- Published commercial information.

5.4.5.1.7 Organizational Process Assets

Some of the organizational assets that affect the Estimate Costs process:

- Cost estimate policies
- Cost estimate templates
- Historical information
- Lessons learned

5.4.5.2 Estimate Costs: Tools and Technique

5.4.5.2.1 Expert Judgment

Expert judgment depends on experiences, historical information, knowledge and educational provides valuable insight about the environment and information from prior similar projects. Expert judgment also could determine whether to combine methods of estimating and how reconcile difference between them.

5.4.5.2.2 Analogous Estimating

The Analogous Estimating use previous similar project as a basis for the planning and estimating for the current project, this process estimates the cost by the values scope, budget, and duration or by measures of scale like size, weight, and complexity.

Analogous estimating uses experience, historical information and expert judgment to estimate the cost especially in the early phase when there is a limited amount of detailed information.

Comparing with other techniques of cost estimation, Analogous Estimating is generally less costly and less time but in the same way, it is also less accurate. It is better if analogous estimating use with other methods and it is more reliable when the previous projects are similar not just in appearance.

5.4.5.2.3 Parametric Estimating

Parametric estimating uses some statistical methods to figure out the relationship out between historical and other variables to calculate the estimate cost for the project work.

5.4.5.2.4 Bottom-Up Estimating

This method of estimating is estimating a component of work. This method will estimate the highest level of detail by estimate the cost of individual activities. The cost and accuracy of this method depends on the size and complexity of the individual act6ivities.

5.4.5.2.5 Three-Point Estimating

This method will use three estimates to define an approximate range for an activity's cost, it is more accurate than single point:

- Most Likely
- Optimistic
- Pessimistic

Then after assumed three-point, triangular distribution and beta distribution will be used to provide as expected cost and clarify the range of uncertainty around the expected cost.

5.4.5.2.6 Reserve Analysis

"Cost estimates may include contingency reserves (sometimes called contingency allowances) to account for cost uncertainty". "Estimates may also be produced for management reserve to be funded for the project. Management reserves are an amount of the project budget withheld for management control purposes and are reserved for unforeseen work that is within scope of the project" (Project Management Institute, PMBoK v5, 2013, pp. 205).

5.4.5.2.7 Cost Of Quality

This process will be helped to prepare the activity cost estimate.

5.4.5.2.8 Vender Bid Analysis

When projects are awarded to vender or main contractor under competitive process between the main contractors, some additional cost will be added for examine the price of individual deliverables and to run the cost to final total project cost.

5.4.5.2.9 Group Decision-Making Techniques

The function of this process is to improve estimate accuracy and commitment to the emerging estimates by using some methods like brainstorming, the Delphi or nominal group techniques.

5.4.5.3 Estimate Costs: Output

5.4.5.3.1 Activity Cost Estimates

"Activity cost estimates are quantitative assessments of the probable costs required to complete project work". (Project Management Institute, PMBoK v5, 2013, pp. 206). Cost estimates all resources that applied to the activity cost estimate, these resources include almost all type of cost direct and indirect cost, variable and fixed cost, cost of financing, and influence, or exchange rates.

5.4.5.3.2 Project Documents Updates

As described in section 5.3.8.3.3.

5.4.6 Determine Budget

Determine budget is a process looking to establish cost baseline by estimated costs of individual activities or work packages. "A project budget includes all the funds authorized to execute the project. The cost baseline is the approved version of the time-phased project budget but excludes management reserves."

5.4.6.1 Determine Budget: input

5.4.6.1.1 Cost Management Plan

Described in section 5.4.5.1.1.

5.4.6.1.2 Scope Baseline

Described in section 5.4.5.1.3.

5.4.6.1.3 Activity Cost Estimate

Described in section 5.4.5.3.1.

5.4.6.1.4 Basis Of Estimates

Described in section 5.4.5.1.3.

5.4.6.1.5 Project Schedule

Described in section 5.4.5.1.4.

5.4.6.1.6 Resource Calendars

It is a schedule document between the project team member and document period that each one is available to work on the project, depends on each person's availability

and schedule constraints, including time zones, work hours, vacation time, local holidays, and commitments to other projects.

5.4.6.1.7 Risk Register

Described in section 5.4.5.1.5

5.3.6.1.8 Agreements

That include all types of agreements written or verbal and these used to define initial intention for the project. The agreement may consist of some contracts, service level agreements, letter of agreements, emails, and or any verbal agreements.

5.4.6.1.9 Organizational Process Assets

Described in section 5.3.3.1.3.

5.4.6.2 Determine Budget: Tools and Techniques

5.4.6.2.1 Cost Aggregation

WBS has several functions, one of these functions is collect and figure our cost estimates. Cost estimates are aggregated for the higher-level component of WBS.

5.4.6.2.2 Reserve Analysis

"Budget reserve analysis can establish both the contingency reserves and the management reserves for the project" (Project Management Institute, PMBoK v5, 2013, pp. 210).

5.4.6.2.3 Expert Judgment

Described in section 5.4.5.2.1.

5.4.6.2.4 Historical Relationships

Historical relationship uses to develop mathematical models to predict the total project costs, and these historical relationships are results from parametric estimates or similar estimates. Such models may be simple like residential home construction or complex one model of software development costing

5.4.6.2.5 Funding Limit Reconciliation

The difference between the funding limits and the planned expenses need to have control and reschedule of work to level out the rate of expenses.

5.4.6.3 Determine Budget: Outputs

5.4.6.3.1 Cost Baseline

Any project should have a project balance statement (phased project budget), and the cost baseline is the approved version of the balance statement, except the management reserve.

Figure (5-15) below illustrates the various component of the project budget and cost baseline. Cost baseline and management reserve both together produce project budget. The applicable management reserve funds move to the cost baseline using change control process.

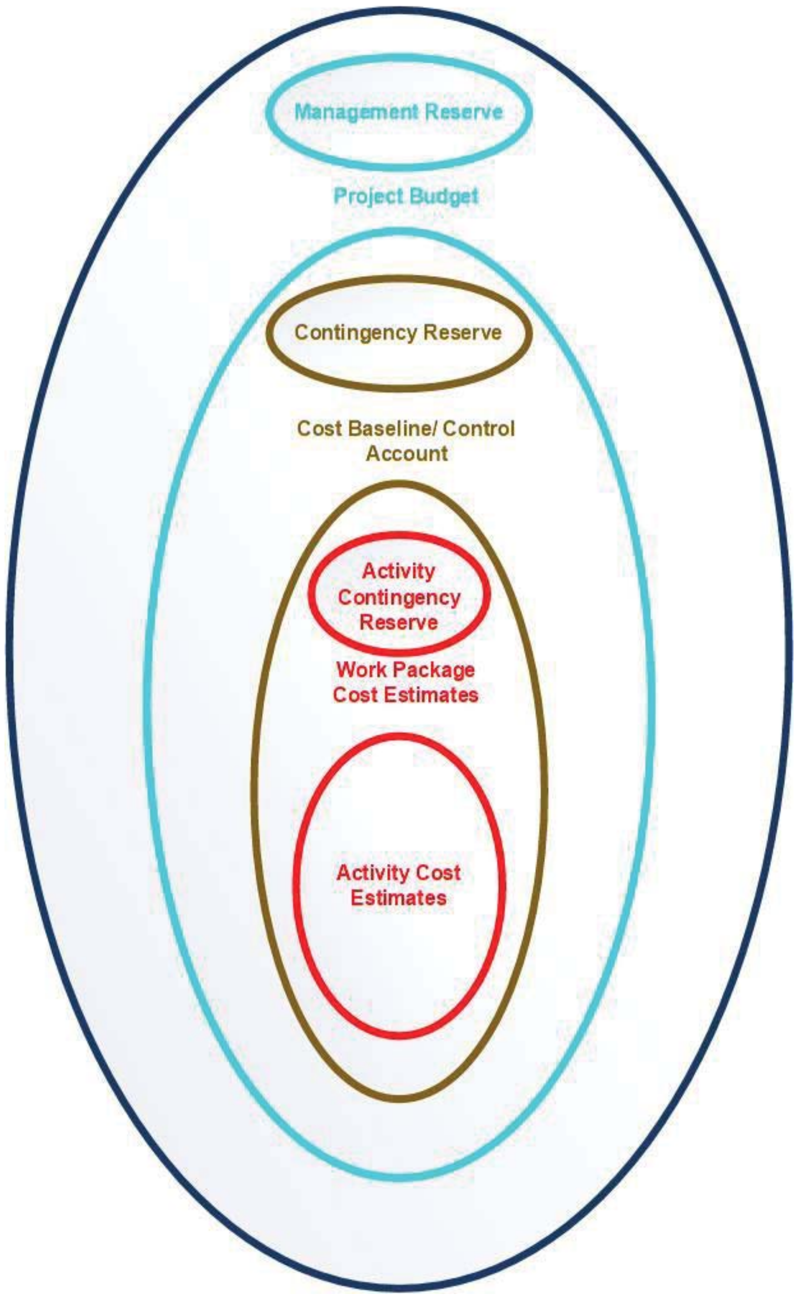

Figure 5-15: Project Budget Component

5.4.6.3.2 Project Funding Requirements

Cost baseline will create and identify the total funding requirements and periodic funding requirements. As introduced in the previous section 5.4.6.3.1 cost baseline is the project balance statement except management reserve. The total funds required include cost baseline and the management reserve.

5.4.6.3.3 Project Documents Updates

Project documents that may be updated include, but are not limited to:

- Risk register,
- Activity cost estimates, and
- Project schedule.

5.4.7 Estimate Activity Resources

Estimate activity resources is one of the primary processes to plan for the project, and this process calculate and estimate materials quantities, human needs in the project, equipment required to perform each activity.

5.4.7.1 Estimate Activity Resources: Inputs

As usually described.

5.4.7.1.1 Schedule Management Plan

Described in section 5.3.2.3.1

5.4.7.1.2 Activity List

Activity list includes all schedule activities, activity identifier, a scope of work description for each activity to be sure that project team understands the work required to be completed.

5.4.7.1.3 Activity Attributes

"The activity attributes provide the primary data input for use in estimating those resources required for each activity in the activity list" (Project Management Institute, PMBoK v5, 2013, pp. 162).

5.4.7.1.4 Resource Calendars

Described in section 5.4.6.1.6.

5.4.7.1.5 Risk Register

As described in section 5.4.5.1.5.

5.4.7.1.6 Activity Cost Estimates

As described in section 5.4.5.3.1.

5.4.7.1.7 Enterprise Environmental Factors

As described in section 5.3.8.1.3.

5.4.7.1.8 Organizational Process Assets

As described in section 5.3.3.1.3.

5.4.7.2 Estimate Activity Resources: Tools and Techniques

As usually described.

5.4.7.2.1 Expert Judgment

As introduced before, expert judgment required in all processes in Technical Project Management.

5.4.7.2.2 Alternative Analysis

Any schedule for any activity should have alternative methods of accomplishment; alternative include a varicose level of resource and skills, different size or type of machines, different tools need in the project and these all help the team to take a decision like rent or buy decision.

5.4.7.2.3 Bottom-Up Estimating

One of the projects plan targets is estimate duration or cost and these factors could figure it out using a method by aggregating the estimates of lower level components of WBS.

5.4.7.2.4 Project Management Software

This process uses some software tool schedule to assist in optimizing resource utilization using resource breakdown structure, resource availability, resource rate, and various resource depends on the software.

5.4.7.3 Estimate Activity Resources: Outputs

As usually described.

5.4.7.3.1 Activity Resource Requirements

This process will determine the quantities and types of resources required for each activity and these resources include the basis of estimate for each resource.

5.4.7.3.2 Resource Breakdown Structure

Breakdown structure divide the system to subsystem, and resource breakdown structure classify and divide the resource to several resources depends on category and type. Categories include labor, material, equipment, and supplies. Types of resources include skill level, grad level, or other information as appropriate to the project.

5.4.7.3.3 Project Documents Updates

Project documents that may be updated include, but are not limited to:

- Activity list,
- Activity attributes, and
- Resource calendars.

5.4.8 Estimate Activity Duration

5.4.8.1 Estimate Activity Duration: Input

5.4.8.1.1 Schedule Management Plan

Described in section 5.4.2.3.1.

5.4.8.1.2 Activity List

Described in section 5.3.7.1.2.

5.4.8.1.3 Activity Attributes

Described in section 5.3.7.1.3.

5.4.8.1.4 Activity Resource Requirements

Activity resource requirements are one of the most critical factors for estimate activity duration because it has direct effect for estimate activity duration. Once resource requirements are known, so the team will know how they will decide if the additional or lower skilled required so this will affect the efficiency or productivity, so the team can decide if they need to do training, increase the communications or coordination need so they can know the duration estimate.

5.4.8.1.5 Resource Calendars

Described in section 5.3.6.1.6.

5.4.8.1.6 Project Scope Statement

Any project has assumptions and constraints. The project scope statement is a process that takes care about these assumptions and constraints, to help the team to estimate duration. Assumptions include existing conditions, availability of information, length of the reporting period, available skilled resources, and contract term and requirements.

5.4.8.1.7 Risk Register

As described in section 5.4.5.1.5.

5.3.8.1.8 Resource Breakdown Structure

As described in section 5.4.7.3.2.

5.4.8.1.9 Enterprise Environmental Factors

Enterprise environmental factors help and support to determine and estimate activity duration, these factors like productivity matrices, published commercial information, and location of team member.

5.4.8.1.10 Organizational Process Assets

The organizational process assets include, but are not limited to:

- Historical duration information,
- Project calendars,
- Scheduling methodology, and
- Lessons learned.

5.4.8.2 Estimate Activity Duration: Tools and Techniques

Tools and Techniques include:

- Expert Judgment
- Analogous Estimating
- Parametric Estimating
- Three-Point Estimating
- Group Decision-Making Techniques
- Reserve Analysis

5.4.8.3 Estimate Activity Duration: Output

Estimate Activity Duration output include:

- Activity Duration Estimates
- Project Documents Updates

5.4.9 Plan Cost Management:

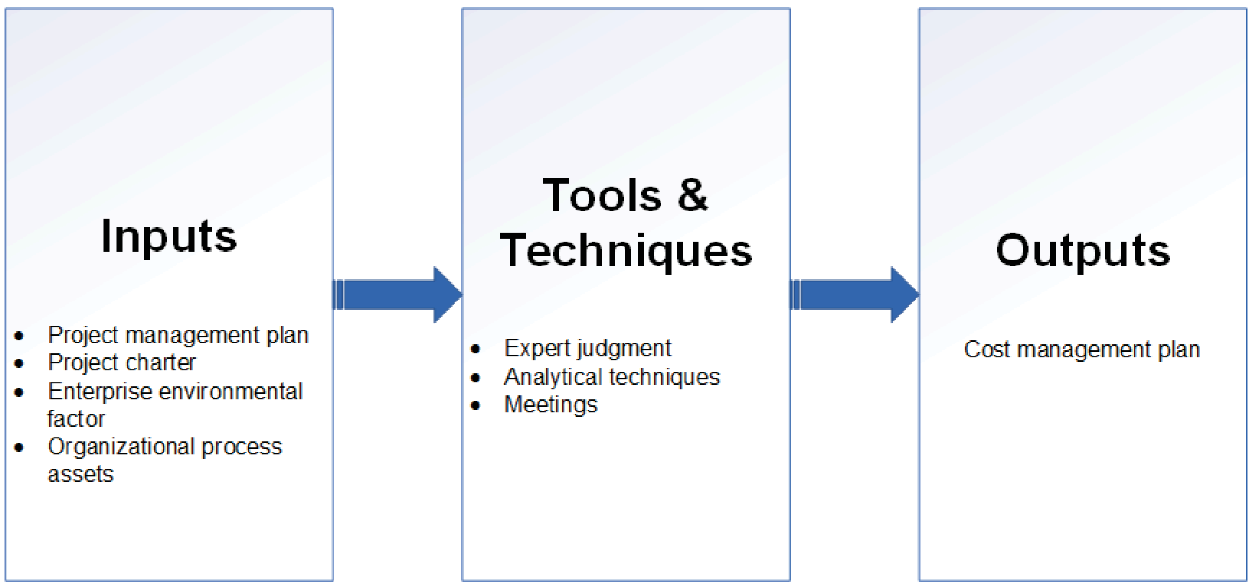

Figure 5-16: Plan Cost Management: Inputs, Tools & Techniques and Outputs

5.4.10 Manage Communications:

Figure 5-17: Manage Communications: Inputs, Tools & Techniques and Outputs

5.4.11 Identify Risk:

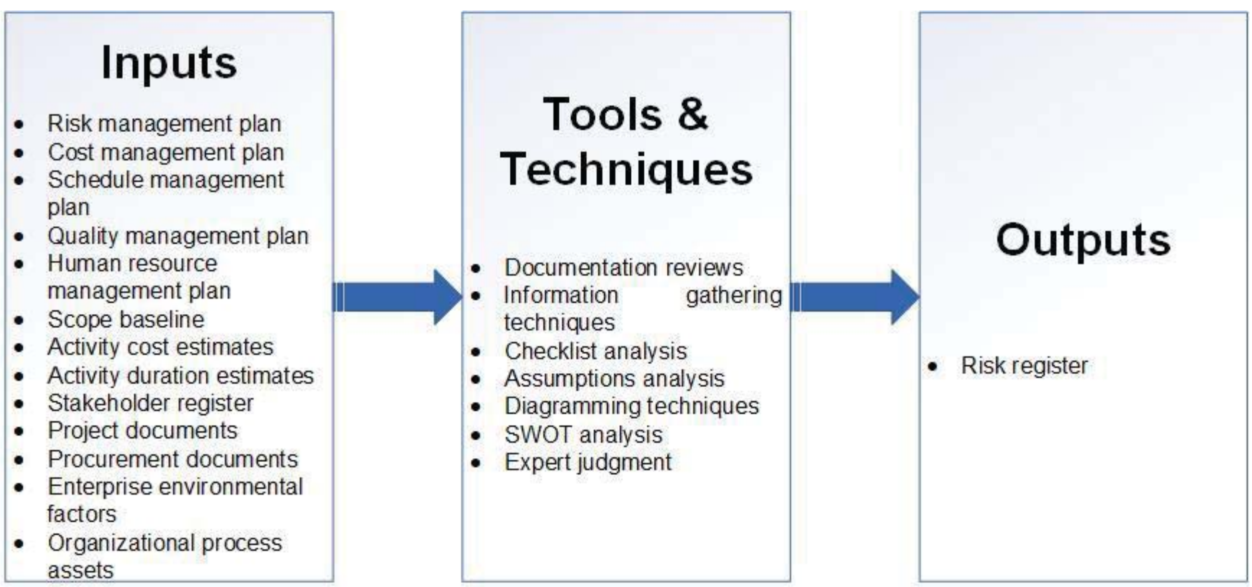

Figure 5-18: Identify Risk: Inputs, Tools & Techniques and Outputs

5.4.12 Plan Risk Management

Input:

1) Project management plan
2) Project charter
3) Stakeholder register
4) Enterprise environmental Factors
5) Organizational process assets

Tools & Techniques:

1) Analytical techniques
2) Expert judgment
3) Meetings

Output:

1) Risk management plan

5.4.13 Plan Quality Management:

Input:

- Project Management Plan
  - Scope baseline. Described in section 5.4.5.1.3
  - Schedule baseline.
  - Cost baseline. Described in section 5.4.6.3.1
  - Other management plans.
- Stakeholder Register. Described in section 5.3.3.3.1
- Risk Register. Described in section 5.4.5.1.5

- Requirements Documentation
- Enterprise Environmental Factors. Described in section 5.3.8.1.3, 5.3.2.1.3 and 5.3.5.1.6
- Organizational Process Assets

Plan Quality Management: Tools and Techniques

- Cost-Benefit Analysis

  Any quality step looking to achieve at least one benefit like less rework, higher productivity, lower cost, increase stakeholder satisfaction, and increase profitability. In this technique, the team will prepare the cost-benefit analysis and compare it with the expected benefits.

- Cost of Quality (COQ)

  There are two classifications of COQ, conformance and nonconformance as described in Figure (5-19) below:

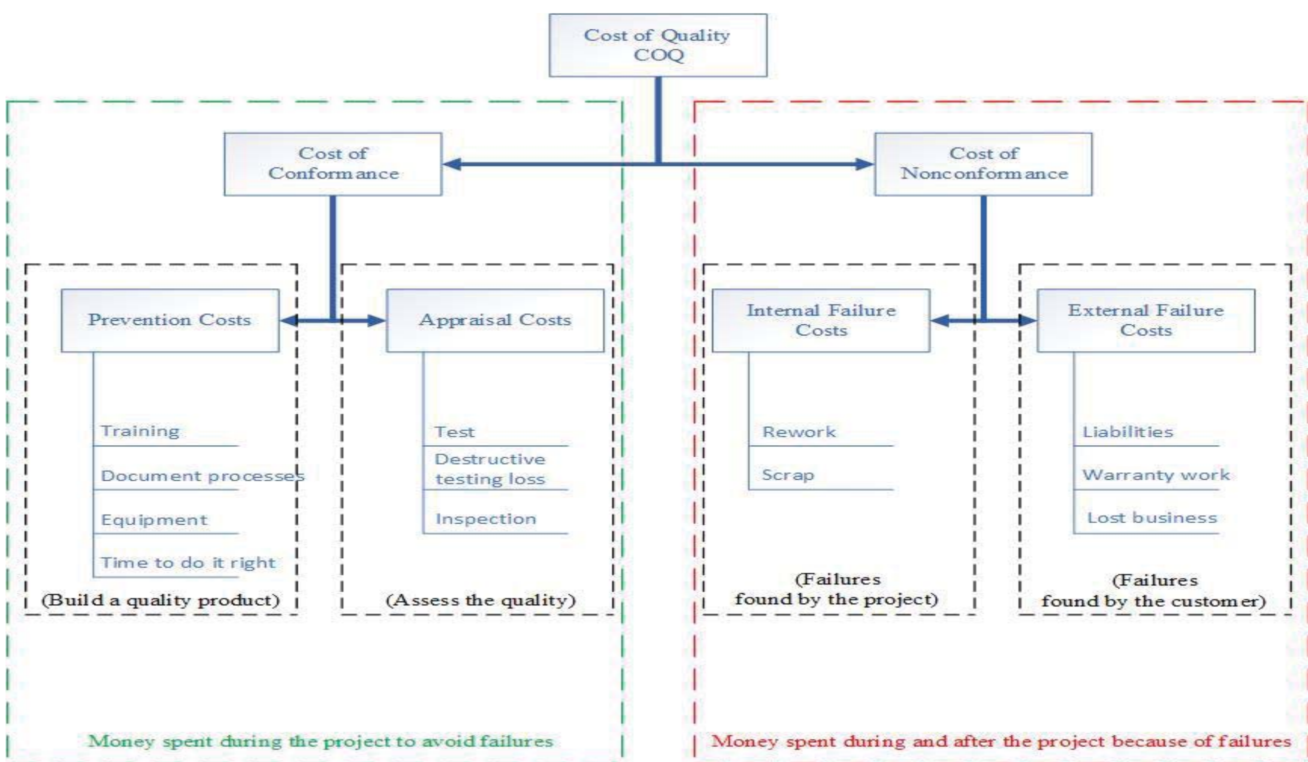

Figure 5-19: Cost of Quality Classifications and Types (COQ)

- Seven Basic Quality Tools
  - Cause-and-effect diagrams
  - Flowcharts
  - Check sheets
  - Pareto diagrams
  - Histograms
  - Control charts
  - Scatter diagrams
- Benchmarking
- Design of Experiments

  This is a statistical method for identifying which factors may influence specific variables of product or process using hypothesis. Hypothesis used to reduce the sensitivity of product performance to the source of variations caused by environmental or manufacturing differences.
- Statistical Sampling
- Additional Quality Planning Tools
  - Brainstorming.
  - Force field analysis.
  - Nominal group technique.
  - Quality management and control tools.
- Meetings

Plan Quality Management: Outputs

- Quality Management Plan

- Process Improvement Plan
  - Process boundaries.
  - Process configuration.
  - Process metrics.
  - Targets for improved performance.
- Quality Metrics
- Quality Checklists
- Project Documents Updates

5.3.14 Plan Procurement Management:

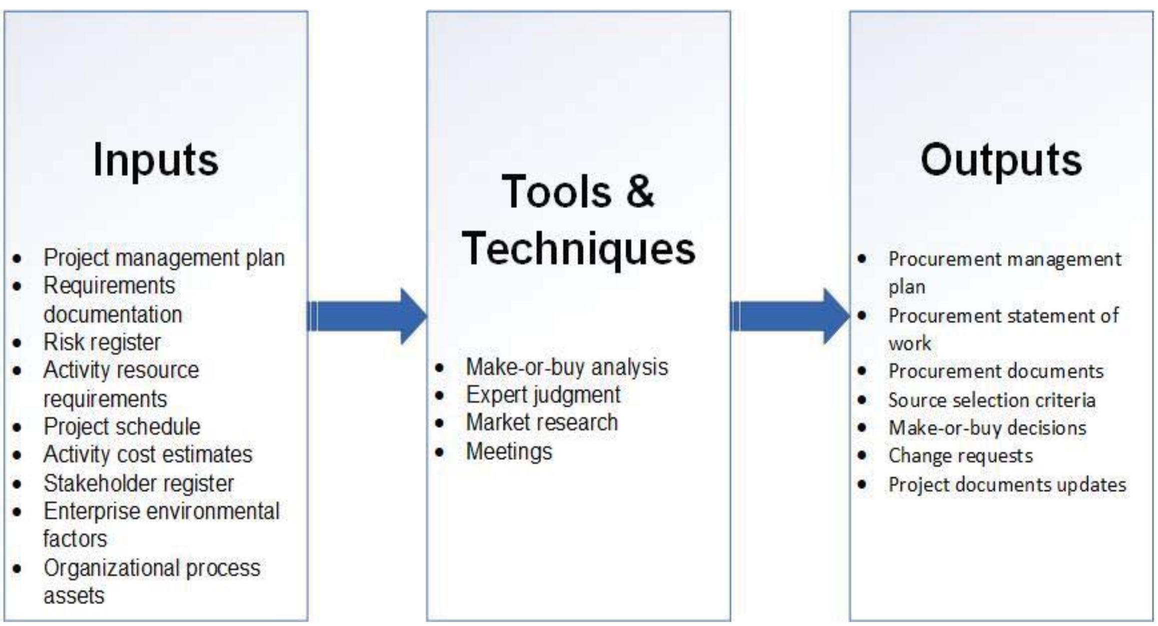

Figure 5-20: Plan Procurement Management: Inputs, Tools & Techniques and Outputs

5.3.15 Project Planning Process

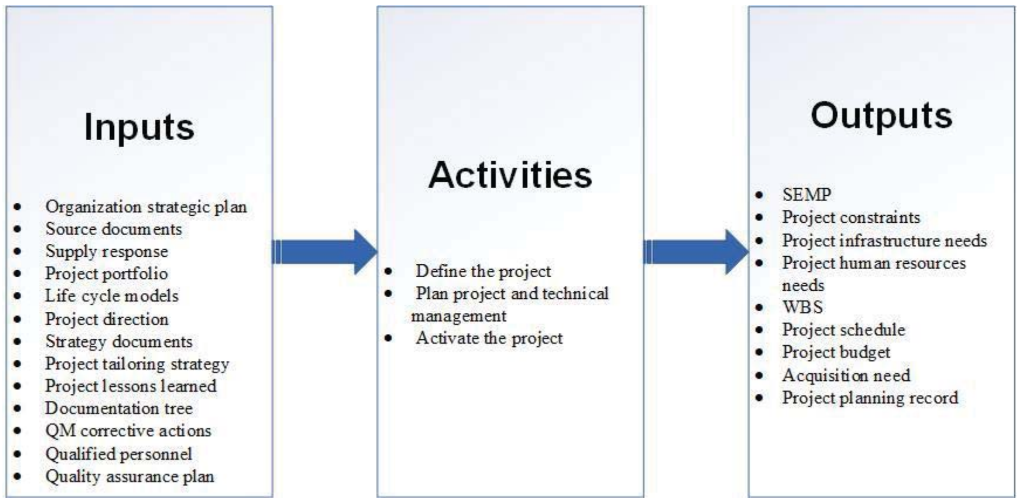

Figure 5-21: Project Planning Process: Inputs, Activities and Outputs

Project Planning Process Activities:

- Define the Project
  - Analyze the project proposal and related agreements to define the project objectives, scope, and constraints.
  - Establish tailoring of organization procedures
  - Establish a work breakdown structure (WBS)
  - Define and maintain a life cycle model
- Plan project and technical management.
  - Establish the roles and responsibilities for project authority.
  - Define top-level work packages for each task
  - Develop a project schedule based on objectives and work estimates.
  - Define the infrastructure and services required.
  - Define costs and estimate project budget.

- Plan the acquisition of materials, goods, and enabling system services.
- Prepare a system engineering management plan (SEMP)
- Generate or tailor quality management, configuration management, risk management, information management, and measurement plans to meet the needs of the project.
- Establish the criteria

- Activate the project.

5.4.15.1 Elaboration

Elaboration include Project Planning Concept and System Engineering Management Plan (SEMP)

- Project Planning Concept

Project planning identifies and estimates project budget and schedule. In this process, the project manager and system engineers should collaborate. System engineers should achieve the project objective by following technical management activities, technical management includes planning, scheduling, reviewing and auditing the SE processes.

- SEMP

This process is essential in planning processes because SEMP guides the project how to be organized, structured, and conducted and on the same way how engineering processes will be controlled to satisfy the stakeholder requirements.

SEMP should prepare in the early stage of the project, submitted to the customer and used in technical management. "The SEMP also reports the results of the effort undertaken to form a project team and outlines the major deliverables of the project, including a decision database, specifications, and baselines". (INCOSE SE Handbook v4, 2015, pp. 107).

The SEMP should include information about the project organization, technical management, and technical activities. A complete outline of a SEMP is available in ISO/IEC/IEEE 24748-4

(2014), which is aligned with ISO/IEC/IEEE 15288 and INCOSE SE Handbook v4, 2015. As a high-level overview, the SEMP should include the following:

- Organization of the project
- Responsibilities and authority of the key positions
- Clear system boundaries and scope of the project
- Project assumptions and constraints Key technical objectives
- Infrastructure support and resource management (i.e., facilities, tools, IT, personnel, etc.)
- Approach and methods used for planning and executing the technical processes described in INCOSE SE Handbook v4, 2015
- Approach and methods used for planning and executing the technical management processes described in INCOSE SE Handbook v4, 2015
- Approach and methods used for planning and executing the applicable specialty engineering processes described in INCOSE SE Handbook v4, 2015.

5.5 Integration, Validation, and verification IV&V

5.5.1 Acquisition Process

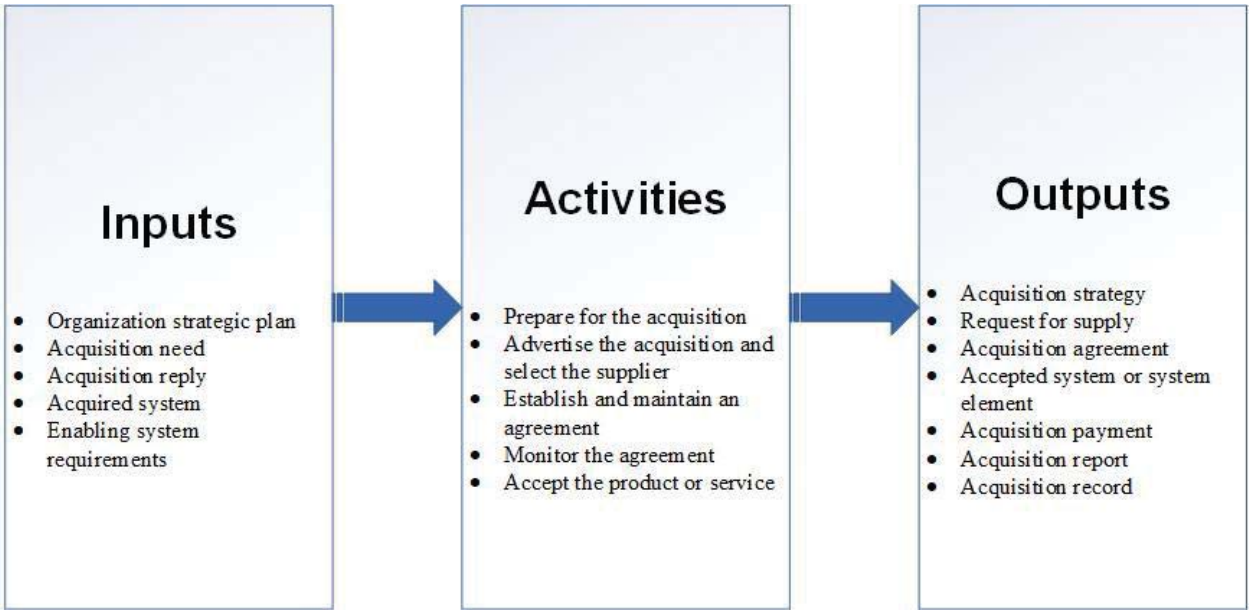

Figure 5-22: Acquisition Process: Input, Activities and Output

5.5.2 System Analysis Process

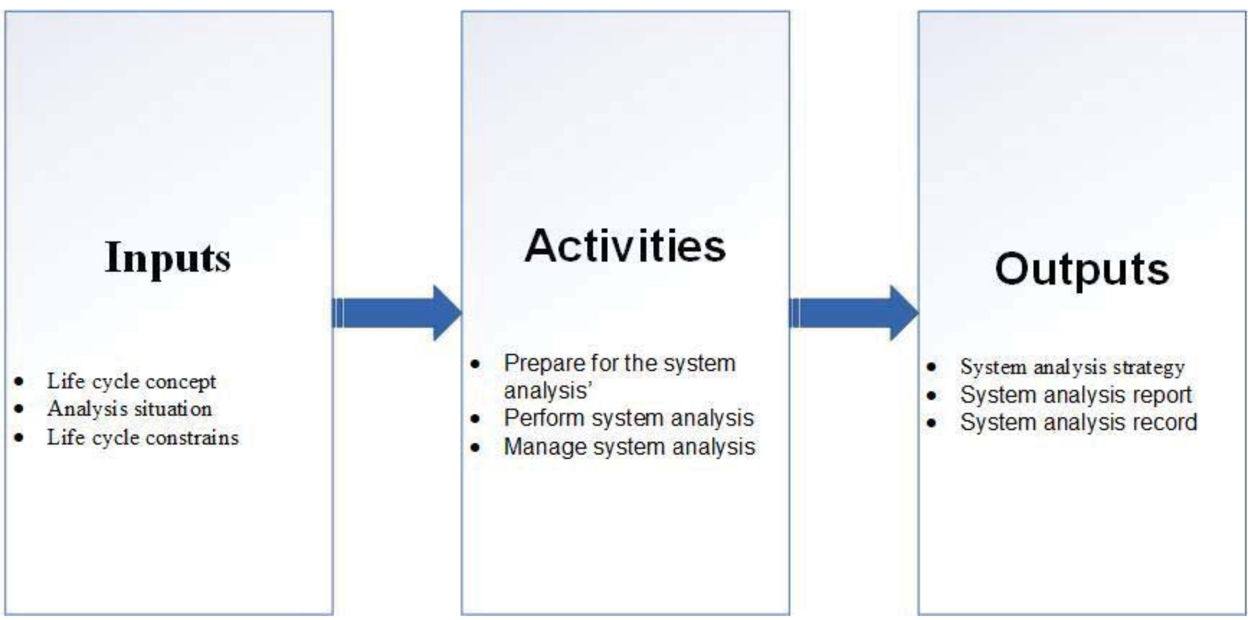

Figure 5-23: System Analysis Process

5.5.3 Design Definition process

- Input:
  - Life cycle concepts
  - System function definition
  - System requirements
  - System functional interface identification
  - System architecture description
  - System architecture rationale
  - Preliminary interface definition
  - Preliminary TPM needs
  - Preliminary TPM data
  - Architecture traceability
  - Interface definition update identification
  - Implementation traceability
  - Life cycle constraints
- Activities
  - Prepare for design definition
  - Establish design characteristics and design enablers related to each system element
  - Assess alternatives for obtaining system elements
  - Manage the design
- Output
  - Design definition strategy
  - System design description

- System design rationale
- TPM needs
- TPM data
- Design traceability
- System element descriptions
- Design definition record

5.5.4 Transition Process

As usually described.

5.5.5 Project Assessment and Control Process

As usually described.

5.5.6 Quality Management Process

As usually described.

5.5.7 Integration Process

As usually described.

5.5.8 Validation Process

As usually described.

5.5.9 Verification Process

As usually described.

5.5.10 Tailoring Process

As usually described.

5.6 Optimization

This group of processes has the following processes:

- Risk Management Process
- Quality Assurance Process
- Quality Management Process
- Control Costs
- Human Resource Management Process
- Transition Process
- Integration Process
- Validation Process
- Verification Process
- Monitor Communications
- Supply Process
- Develop Team
- Project Assessment and Control Process
- Decision Management Process

5.7 Executing

- Decision Management Process
- Direct and Manage Project Work
- Human Resource Management Process
- Control Quality
- Monitor Communications
- Control Costs

- Operations Process
- Tailoring Process
- Monitor Risks
- Monitor and Control Project Work
- Supply Process
- Manage Team

5.8 Handover

- Quality Management Process
- Implementation Process
- Close Project or Phase

5.9 Recommendations for Future Research.

As the concept of open system (systems theory) explained in the figure below, our paper is willing for any development in future research and we will propose some recommendation for future research.

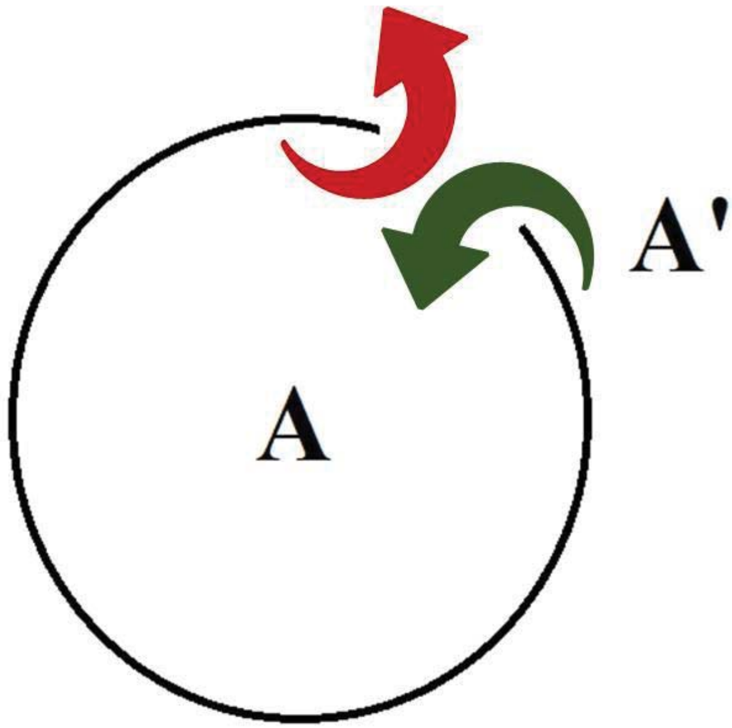

Figure 5-24: Open System Concept

The paper title is Technical Project Management (synergized between SE & PM), and in this paper, we limited this study to construction projects especially steel structure projects and metal roofing system. Our recommendation for the future project as the following:

- Restudy the paper depends on industries and products case studies
- Restudy the paper depends on services case studies
- Focus in one process and study it in deep like Technical Risk Project Management, Technical Quality Project Management, Technical Procurement Project Management, etc.

CHAPTER 6: CONCLUSION

6.1 Conclusion:

Efficiency and Effectiveness are the two factors utilized in this thesis in order to choose hybrid Technical Project Management (TPM) processes from recognized SE and PM processes. The collection of hybrid Technical Project Management processes is a complete set that enables projects to achieve efficiency and effectiveness of 95%, meaning that TPM increases the efficiency and effectiveness more than PM by itself or SE by itself. TPM processes support the approach of optimality. So, the hybrid processes can be applied in one TPM process cycle with a high probability of achieving the expected time, cost, quality, risk, and performance. These actual values for each performance factor will be the same or close to the expected value when the project completes and is handed over. Figure 6-1 illustrates the constraints improved and developed by TPM.

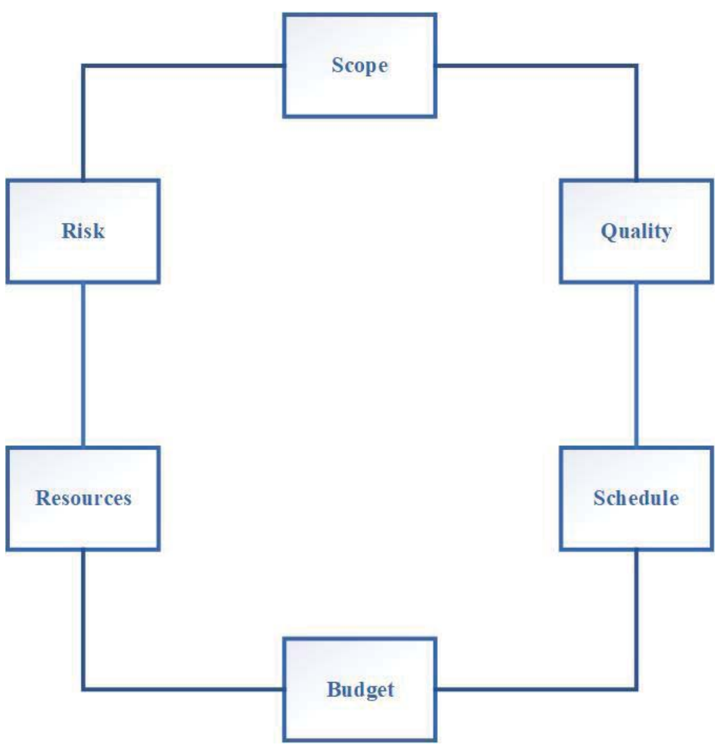

Figure 6-1: Technical Project Management Constraints

These constraints, PM and SE apply to most of them, but neither PM nor SE employs 100% of the constraints, 100% of the techniques, methods, procedures, duties, and processes of the hybrid TPM process. Technical project management achieves almost 95% of each constraint, with the hybrid techniques, tools and methods (obtained from SE and PM) to achieve the maximum practical efficiency and effectiveness, compared to PM, which by itself doesn't meet the maximum efficiency and effectiveness, as SE similarly does not itself achieve maximum efficiency and effectiveness, as there are a lot of weak points in Project Management and also in System Engineering.

This paper combines the function of PM and SE as in their triangles, PM triangle that focused on quality, cost, schedule and SE tringle (V module) is a procedure how to reduce the risk and get the maximum quality that's called optimization.

Now, this paper synergized these two tringles together. Figure 6-2 illustrate the Technical Project Management Triangle that's called solid triangle.

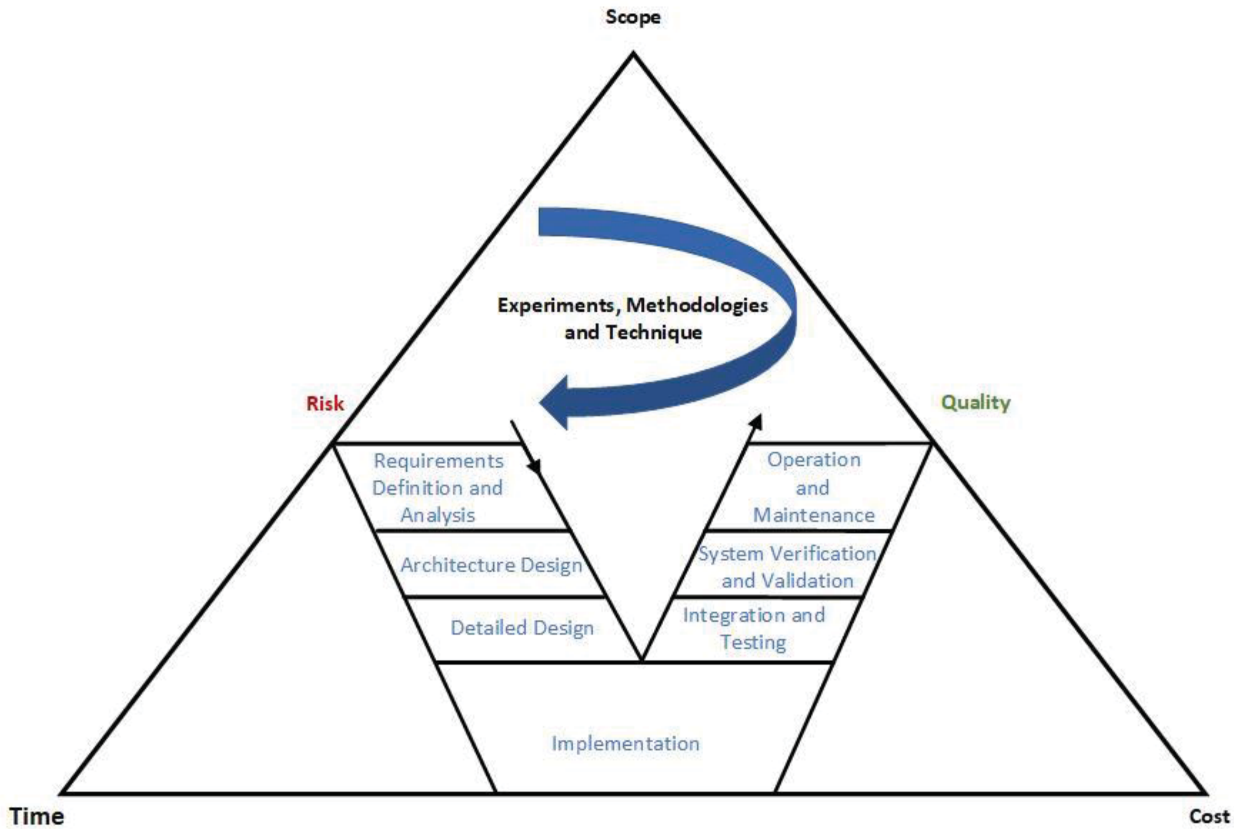

Figure 6-2 Technical Project Management Triangle

In this paper we used Pareto chart for the numerical results to know the most significant process that's meant the processes have high weight percentage and low percentage as well.

Figure (4-3) illustrate Pareto chart for numerical results and identify the most significant processes and the low importance.

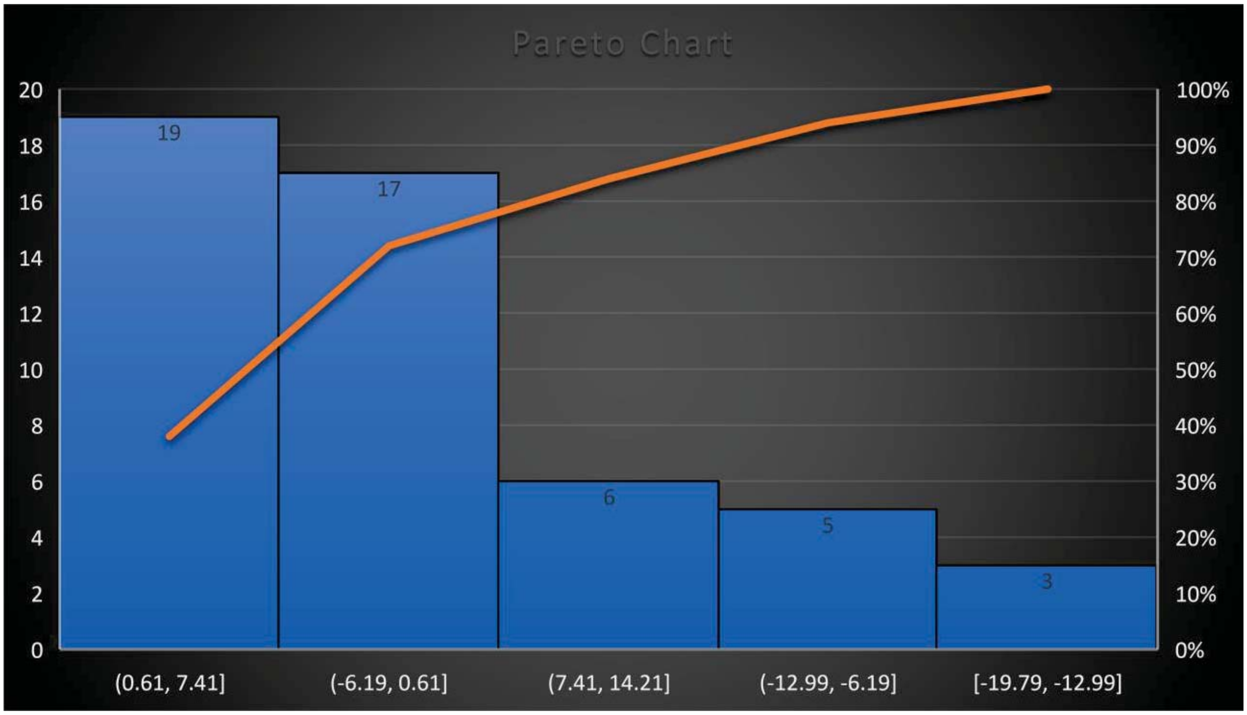

Figure 6-3: Pareto Chart for Numerical Method Results.

As defined and explained in figure (4-3) we got that the processes who have the results between 0.61-7.41 are the most significant processes in our 50 processes and these processes are 19 processes. Table 4-16 illustrate the most significant processes using Pareto Chart.

Table 6-1: The Results Resort using Pareto Chart

0.81	**SE25** Life-Cycle Model Management Process	90% - 100%
1.06	**SE29** Quality Management Process	
1.54	**PM20** Plan Cost Management	
2.12	**SE9** Verification Process	
2.5	**SE12** Operations Process	
2.74	**PM24** Plan Quality Management	
2.83	**SE31** Tailoring Process	
2.89	**SE11** Validation Process	
3.22	**PM42** MonitorRisks	
3.42	**PM14** Plan Schedule Management	
3.47	**PM49** Monitor Stakeholder Engagement	
3.54	**PM5** Monitor and Control Project Work	
3.54	**SE24** Supply Process	
4.25	**PM19** Control Schedule	
4.32	**PM11** Create WBS	
4.68	**SE2** Stakeholder Needs or Requirements Definition Process	
5.3	**PM29** Acquired Resources	
5.74	**SE7** Implementation Process	
6.13	**Pm43** Plan Procurement Management	
-5.05	**PM3** Direct and Manage Project Work	80% - 90%
-5.04	**SE23** Acquisition Process	
-4.69	**SE10** Transition Process	
-4.06	**PM22** Determine Budget	
-4.01	**SE5** Design Definition Process	
-3.68	**PM9** Collect Requirements	
-3.28	**PM36** Plan Risk Management	
-2.97	**SE28** Human Resource Management Process	
-2.64	**PM17** Estimate Activity Durations	
-1.68	**PM26** Control Quality	
-1.44	**PM35** Monitor Communications	
-1.36	**PM28** Estimate Activity Resources	
-0.69	**SE6** System Analysis Process	
-0.54	**PM21** Estimate Costs	
-0.54	**PM23** Control Costs	
-0.06	**SE22** Quality Assurance Process	
0	**SE8** Integration Process	
9.46	**PM7** Close Project or Phase	30% - 40%
9.86	**Pm45** Control Procurements	
11.24	**SE15** Project Planning Process	
11.75	**SE18** Risk Management Process	
12.6	**PM31** Manage Team	
12.65	**PM46** Identify Stakeholders	
-11.6	**PM30** Develop Team	20% - 30%
-10.69	**PM37** Identify Risks	
-6.92	**PM34** Manage Communications	
-6.8	**SE16** Project Assessment and Control Process	
-6.75	**SE4** Architecture Definition Process	
-19.79	**PM47** Plan Stakeholder Engagement	10% - 20%
-18.21	**SE17** Decision Management Process	
-14.99	**Pm44** Conduct Procurements	

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