Delay & Cost Overrun in Construction Projects: Implementation of Lean Techniques for minimizing the risks on Time & Cost

Master thesis

International Master of Science in Construction and Real Estate Management
Joint Study Programme of Metropolia UAS and HTW Berlin

Submitted on 20.01.2020, Berlin

Name: Gaurang Ghule

Registration number: s0562614

First Supervisor: Prof. Dr. Ing Nicole Riediger

Second Supervisor: Prof. Dr. Ing Dieter Bunte

Acknowledgment

I would like to acknowledge my gratitude and render my warmest thanks to my supervisors, Prof. Dr. Ing Nicole Riediger & Prof. Dr. Ing Dieter Bunte, who made this work possible. Their guidance and expert advice have been invaluable throughout all stages of the work in the research of the thesis. I take this opportunity to thank them.
Special thanks are due to my family for his continuous support and understanding.

My thanks are extended to my brother Pranav Ghule & all others who had unconditional support & helping hand in the success of the thesis. Sincere gratitude & thanks to my cousin brother Vinod Ghule & his family for continuous support during the master's period. My professional's colleagues from way back my country for their constant inspiration & information in the success of the research. Last but not least, all my friends who have provided their support & motivation during this period.

Gaurang Ghule
20 Jan 2020

Copy of proposed conceptual formulation

Research Proposal

Date: 10.08.2019

Master Thesis for Mr. GAURANG

GHULE Student number: S0562614

Topic:

Delay & Cost Overrun in Construction Projects: Implementation of Lean Techniques for minimizing the risks on Time & Cost

General Introduction:

The Construction business greatly affects the economic structure of most developed countries. It is one of the parts that give central findings towards the improvement of the economy. Because of poor cost management and time nowadays, the construction business is confronting a huge loss in the measure of cost invade. This has moved toward becoming a severe issue for the construction business. Poor cost overruns and delays are a collateral issue and an intense issue with regards to extending cost in both existing and developing nations. The expanding framework and nature inside which they have built a more noteworthy interest for a construction business to proper extend on schedule, inside the arranged spending plan, and with high & desired quality. A more significant number of projects in India have been postponed because of different issues related to cost overruns & time delay (Shete & Kothawade, 2016).

It is critical to apply the most extreme endeavors to do such an investigation to find the above variables in various nations with different conditions. It is too crucial to even think about carrying for all the general and nearby disappointment and powerless focuses on all perspectives toward the issue, and like this, giving definite methods to maintain a strategic distance from time and cost overruns at construction business development activities is imperative (Changiz, 2012).

It is not unexpected to see a construction project to arrive at its targets inside the anticipated expense. Cost overrun is a typical issue that nearly connected with the more significant part of the activities in the construction business. It is increasingly severe.

In creating nations like Iran and Turkey, where these overwhelms some of the time, go past half of the normal expense of the task. For instance, in the venture of the "state and Road project" in Turkey, the cost overrun was about 56.4% of the actual assessed plan (Changiz, 2012).

Delay is one of the most common, noteworthy, and difficult issues which affect the time factor in civil engineering development ventures. Indeed, even with mechanical advances, furthermore, showing signs of improvement comprehension of undertaking the executives by administrators, a time delay is a primary factor. It is required for a point by point evaluation to perceive the delay factors and pick the exact and right activities to diminish the effect of delays on the length of the projects (Changiz, 2012).

Questions to be Research:

As a response to the construction problems previously discussed, author seeks to identify & research the following questions : (1) Determine the effects & various causes of delays & cost overrun on project challenges (2) Examine general perceptions for lean six sigma & 5S practices to overcome delay & cost challenges in industry; (3) Identifying & analyzing construction delays under various lean tools like six sigma & 5S to increase the reliability of the process (4) Investigating the relationship between lean construction and other improvement tools management programs in construction organizations in minimizing the effects of delays & cost. (5) Who bears risk client or contractor in case of failure of the project due to the impact of delays & cost overruns & any safeguard available for claims & guarantees regarding the completion.

Research Methods:

In research studies, there are number of techniques that can be applied during a literature survey analysis, and the decision of the correct one to be used is a sensitive procedure of the fact that the utilization of various strategies in a similar field may seem to have opposing results. As per the project topic will be focusing on both the delays caused in the tendering phase as well as the execution phase of the construction project. Some of the cases where considerable delays have taken place in any of the fore-mentioned phases will be selected, and the significant reasons and factors affecting the planned work schedule will be studied and analyzed & how various lean techniques like six sigma & 5S would help in bringing the cost & time within limits. The questionnaire will consist of construction project-oriented questions that will help us to reach up to a solid conclusion and rate the causes and impact of delays accordingly.

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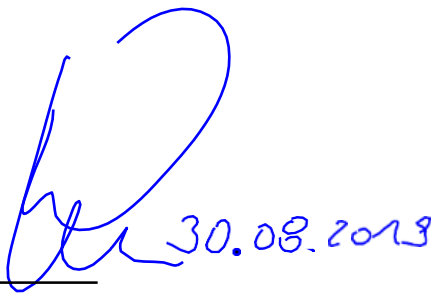

Signature of the Supervisor

Abstract

Major challenges faced by the Construction Industry in today's competitive market are delay & cost overruns. Many projects be in any sector energy; construction causes inefficiency in the outcomings of projects due to process or productivity reduction, quality standards & specifications, poor management practices, leading to an increase in cost & delay overruns. Many types of research in the past have researched these delay & cost overrun issues in general & propose suitable measures to overcome the issue. The research aim is to study various causes of delay & cost overrun in the construction industry & propose a strategy in minimizing risks for future projects by implementing six sigma & 5S operations.

The methodology adopted during research to validate the study is the literature review, case study, questionnaire survey. Results from each helped in finding a strategy & validating results through a mixed approach of triangulation. The research provides a strategy by integrating lean, six-sigma & 5S techniques in a project to overcome the issue of proximity of delays & cost overruns by adopting various management standards.

The strategy consists of management of quality, site, planning, procurement practices in the project. These will help in improving & managing complex construction projects in the future in avoiding risk. The findings are analyzed theoretically & statistically, to overcome the challenges. There is a need for incorporating such management practices to improve the early drawbacks of various quality standards, stakeholders' issues, site practices in the construction projects.

The research helps in integrating & providing knowledge of various practices that can be implemented in various aspects of construction to improve construction practices & reduce significant delay & cost overruns issues. The strategy formulated by the author could help avoid & minimize risk & could be adopted in future projects.

Keywords: Lean Construction, Six – Sigma, 5S Tools

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List of Abbreviations

ABBREVIATION	EXPLANATION
DMAIC	Define, Measure, Analyze, Improve, Control
SOP	Standard Operating Procedure
5S	Sort, set in order, shine, standardize, sustain
JIT	Just in Time
NC	Non-Conformance
IFC	Issue for construction
HSE	Health, Safety & Environment
COPQ	Cost of Poor Quality
LC	Lean Construction
IMS	Integrated Management System
DPMO	Defects per Million Opportunities
EIC	Engineer in Charge
CTQ	Critical to Quality
FMEA	Failure Mode Effective Analysis
LSS	Lean Six Sigma
4W	What, Who, When, Where
KPIV	Key Process Input Variable
VOC	Voice of Customer
QA/QC	Quality Assurance / Quality Control
QMS	Quality Management System
TAT	Turnaround Time
CAPA	Corrective Action Preventive Action
RCA	Root Cause Analysis
QHSE	Quality Health Safety Environment
PDCA	Plan, Do Check, Act
ROI	Return on Investment
PCS	Project Controlling System
SWLA	Six-week lookahead Plan with constraints analysis
WWP	Weekly Work Plan
PM	Project Manager
PPC	Percentage Plan Completed
LPS	Last Planner System
WO	Work Order
QDC	Quality, Delivery, Cost
MW	Megawatt
NA	Not Available
SPSS	Statistical Package for the Social Sciences
CSF	Critical Success Factors

1. Introduction

The Construction business greatly affects the economic structure of most developed countries. It is one of the parts that give key findings towards the improvement of the economy. Because of poor cost management and time nowadays, the construction business is confronting a considerable loss in measure of cost runs. This has moved toward becoming a severe issue for the construction business. Poor cost overruns and delays are a collateral issue with regards to the increase in cost in both poor and developing nations.

Regarding the problem, the researcher aims to identify possible causes of delay & time overruns in a construction project. There exists a research gap on how lean tools like six sigma & 5S when used in the construction industry help in minimizing the risk. The author, with the help of tools like six sigma & 5S which are the quality tool in construction, will be used to bring the complexity of the issue to a minimum. Application of such tools in construction helps in increasing productivity of the process, reduces quality issues, improves procurement management issues, which would result in cost-saving for all stakeholders in the project.

1.1 Background

Though Project Management techniques are essential tools in today's era which are being widely used in the construction industry, results from past researches show a poor record in the management of construction projects in solving the issue of cost & time delays. Many projects have been unsuccessful in meeting the sets benchmarks of cost & time. The major is the project being affected & completed late from originally planned & accordingly recurrence issue is indicative that the problem is not solved completely (Müller & Jugdev, 2012).

In Construction, processes are mainly divided into four important phases, namely Design/ Engineering, Procurement & Construction, & maintenance, the success of each of which depends on three essential parameters Time, Cost & Quality (Habibi & Kermanshachi, 2018). Projects in the construction industry continuously change over time because of various changes in scope definition, communication issues between stakeholders, design issues, quality parameters violation, financial problems.

Delay is one of the most common, noteworthy, and severe issues to be resolved, which affects the overall performance in the civil engineering development organization. Indeed, even with advances in the construction industry, furthermore, showing signs of improvement of undertaking the issue by researchers, a time delay is an essential factor that can be considered to be a critical factor in project performances. According to (Ahbab, 2012), there are various purposes behind the deferral in the delay issue. Causes, for example, "delay of material conveyance to the site of whichwas experienced" at "Air terminal Development venture" in the Philippines, machine failure or equipment failure which was experienced at "Xieng Khouang street improvement venture" are likewise reasons and occasions for delay failures (Ahbab, 2012).

It is expected to see a construction project to arrive at its targets inside the anticipated expense. Cost overrun is a typical issue that is nearly connected with the more significant part of the activities linked to each other in the construction business. It is increasingly severe in developing nations, where these results, some of the time, go past half of the normal expense of the task, which was planned. For instance, according to (Adam et al., 2017), 63 % of projects funded by WB (World Bank) have exceeded the planned budget.

Another major problem in the construction industry identified is a waste due to rework, loss of material due to improper storage area resulting in loss of resources & time. Such losses due to waste to rework & storage can be related to delays that are highly predictable & can be prevented by adopting lean techniques like six-sigma & 5S. A process, when identified as a significant problem, can be solved through the identification of root causes of failure of process, value stream mapping. Many methods have been developed to overcome the issue but are the processes effective enough to provide a better solution to a project. The key lies in identifying wasteful processes & suggest a technique to increase the productivity of the process to remain competitive in the market workplace. The aim of refining processes should be identified from customers' view to provide better services & eliminate processes.

Because of these reasons in view of the author, there lies an opportunity by implementing Lean Six-Sigma & 5S tools in the construction industry. By proper application of such techniques, there lies an equal advantage for all stakeholders across the supply chain of the project to be viable in terms of delay & cost.

1.2 Research Problem

At the time of awarding the contractor only, the completion time of the project is decided, but the project gradually incurs time overrun because of various reasons. These delays lead to loss to each participant directly or indirectly involved in the construction. To the owner, the delay means loss of revenue through a lack of production facilities and rentable space or dependence on present facilities. In some cases, to the contractor, the delay means higher overhead cost because of a more extended work period, more material costs through inflation, and due to which labor cost increases. Delays lead to claims in terms of extension of time or liquidated damages, disputes, arbitration, etc. from the concern parties. Projects, if completed with schedules planned, indicate efficiency, but in construction, processes are subjected to many variables and unpredictable factors, which results in delays in the completion of projects.

At the point when construction projects are delayed, they are either extended from the set planning period of completion and, thus, bring about an extra cost in the project. The standard practices generally permit a level of the incurred cost due to delay, as a possibility in the agreement, cost to be incurred, and this is usually found on the contract. Even though the agreement parties concur upon the additional time and cost-related with delay, by and large, there are issues between the owner and contractor concerning whether the contractor is qualified to claim the additional expense. Such circumstances bring about addressing contract issues(Ramanathan et al., 2012).

Delays & cost overruns thus cause many irregularities in a project to all stakeholders, & the primary responsibility of the Construction Manager is to cut down effects related to delays to improve the quality of the project. Many researchers have identified stating various factors causing delays and cost overruns, productivity improvement, Poor quality measures, safety issues, execution errors.

Based on these problems due to delays & cost overruns, how lean tools six – sigma & 5S can help minimize the risk on the project will be discussed by the author, improving the performance of the process, quality aspects of construction, site management, site logistics, planning.

1.3 Purpose & Objective of Research

Till date, many kinds of research have been conducted on the delays in construction projects in the execution phase, but delays not only occur in the execution phase, a significant lag in the project schedule is possible due to the factors causing delays in planning as well as tendering phase. So, this thesis will attempt to study the factors causing delays in both tendering and execution phases & how the implementation of six sigma & 5S tools helps in reducing the delays & cost overruns in the construction phase of the project.

The objectives of this research are to:

- Analyzing various significant factors responsible for cost & time overrun; to indicate the importance of such elements & reducing them
- The second objective is to evaluate the factors based on the questionnaire & Case Study through various programs of six sigma QC tools. This includes identifying different parameters for delay & cost overruns in view of respondents & comparing them.
- The third objective is to assess the significance of the lean six sigma & 5S tools used for client, contractor, and consultants in minimizing risks.
- The fourth objective is to formulate a six- sigma or 5S strategy to avoid the effects of delays with different programs.

1.4 The methodology of Work

To reach a result of the evaluation, several sub research questions will be answered through theoretical background and data analyzed. A detailed methodology of work is presented in Chapter 3 of work, where the author explains data & methods considered for achieving desired results.

- Determine the effects & factors of delays & cost overrun on projects (Literature Review & Questionnaire survey).
- Examine general perceptions for lean six sigma & 5S practices to overcome challenges in the industry (Literature review, Case Study, Questionnaire).
- Minimizing construction waste under various lean tools like six sigma & 5S to increase the reliability of the process (Case Study).
- Investigating the relationship between lean construction and other improvement

tools programs in construction organizations in minimizing the effects of delays & cost (Literature review, Questionnaire, Case Study).

- Who bears risk client or contractor in case of failure of the project due to the effects of delays & cost overruns & any safeguard available for claims (Literature review, Case Study)

This thesis is structured as follow:

- Literature review attempts to discuss various causes of delay & cost overruns in phases of project & ranking them according to severity, showing how lean tools like six sigma & 5S helps in minimizing risks through process development, quality impact, etc.
- Analysis/Findings/ Results include questionaries' obtained from a literature review. The aim of questionaries' will be to understand the perception of construction professionals from a quality management procedure and process improvement. Three case studies will be selected, considering how six sigma tools can be useful in improving management parameters wrt time & cost.
- The discussion chapter will focus on various parameters & management programs where the lean six sigma & 5S tools can be used to reduce the effects of delay & cost overruns.
- The conclusion answers the main implications of research by the results of the Literature Review and Analysis & Findings. Additionally, this part includes the author`s reflections about this study.
- Reflections/ Recommendations for further Research attempts to give useful ideas for a future study about process improvement and Six Sigma.

1.5 Scope of Work

Research work concentrates on analyzing delays in Project phases. For which first, the delays were recognized, and based on it were divided into two parts, delays in the tendering stage and delays in the execution phase. After analysis, for avoiding some delay, recommendations were given based on applying lean tools on case study & questionnaire floated.

2. Literature Review

2.1 Introduction

This chapter presents the literature review for the issue of time and cost overruns for various causes and factors responsible for the management of projects. The review begins by explaining the apparent issue between the development of the delay and cost overrun and the challenges of the construction business in the performance of the project. Lean tools that have been implemented to improve the performance of the project through various principles are reviewed. This is followed by a review of literature by researchers on how six sigma and 5S tools can help in minimizing such impacts. It then identifies various management parameters to bridge the knowledge gap in reducing the risk.

2.2 The review of Literature

Financial related delay in a project is mainly faced by the client, such as cash flow, but the contractor and other stakeholders of the project are the main reason for delay. The significant effect of this delay is nothing, but cost and time overrun, but time overrun has more impact as compared to cost overrun. This could be the impact of the inability of the contractor to reach deadlines, error in implementing design and drawing correctly, etc. It was noticed that arbitration was no more prolonged effect of delay as they were already implementing risk management and hence resulted in fewer numbers of claims and disputes or any court proceeding in relation to a contract (Oyewobi et al., 2016).

It can be noted that there should be proper allocation of time to the economical production of design and completed tender documents to improve the quality of the document because it will save time by minimizing errors and discrepancies and will ultimately reduce the cause of delay.

The approach in finding delays by (Aibinu & Jagboro, 2002) found that important factors that resulted in delays were interference of the client, the inadequate experience of contractor and financing of work, and from sub-contractors' side labor productivity, improper planning, slow decision making were some of the reasons for the delay. The contractor and consultant also contributed to delay by adopting the wrong construction method, improper site management, unavailability of materials, and equipment. To overcome these problems, it was recommended to include liquidated clauses in the contract and to offer an incentive for early completion. It is suggested appointing human resources in the construction industry, which will help them to plan training programs and to decide how much to spend on training. It gave one suggestion that rather than carrying unit to the price in the contract, they should focus more on the capability and performance of the contractor.

According to the survey done in Saudi Arabia reflected the severity, importance, and frequency of causes of delay. Researcher (Assaf & Al-Hejji, 2006) listed out 73 main reasons for the delay and combined them in nine groups of clients, contractor, consultant, labor, material, and equipment, design, project, external. It was found that 76% of contractors have indicated the time overrun of about 10-30% of the original duration of the project, and about 56% of consultants contributed to the same, 50-30% time overrun was a contribution of 25% of consultants. It was found out that the client and consultants tend to pick the lowest bidder, which results in time delay while the contractor thinks the delays are mostly from the client-side. There is only one reason for the delay for which both the stakeholders are responsible, and that is a change order by the client during construction.

It has been recommended for all the stakeholders of delay such as for contractor they suggested that they should have enough number of employees so that they won't face a shortage of labor's, proper planning should be done by contractor, proper site management is necessary as soon as the project is awarded. From client-side suggestions were given to pay time to the contractor, to minimize change, and to award the project to the deserving contractor. To consultant, they asked to review and approve the drawings appropriately before releasing, and they should be flexible and should not compromise in quality for cost-saving (Assaf & Al-Hejji, 2006).

The study conducted by (Sambasivan & Soon, 2007a), and it highlights the ten most causes of delay, and they were:

- Contractors planning in carrying out work according to the original schedule
- Poor site management principles due to lack process defined
- Related experience in a similar project
- Finance & Cash-Flow
- Internal communication issues within stakeholders
- Material Shortage
- Labor inefficiency & shortage
- Equipment Failure
- Contract not properly defined by contractors to next sub-contractors
- Construction errors

Six significant delay effects were observed during study mainly

- time overrun due to delay in a process
- cost overruns
- disputes between stakeholders
- total abandonment
- arbitration
- litigation.

There are many numbers of reasons that result in delay and have several effects that the project into more significant risk and also impacts on performance. Some of the causes are delay in payment to contractor from client, poor project planning, claims, and compensation issues, etc. in the same way the effect of this delays are cost overrun, time overrun, under or overutilization of resources, etc. so it was recommended that they should plan their budget correctly, communication should be there between parties, skills of project manager also plays a vital role (Sambasivan & Soon, 2007a).

The aim of the project could determine the success of any project, i.e., their predetermined objective, which is mainly completion of project within stipulated time and cost and according to the specified quality. The magnitude of delay is different for different projects.

- **Time Overrun Definition:** It can be defined as when projects planned of their schedule go-ahead from baseline due to various factors caused in the project, which are usually referred to as delays in a construction project. Delays cause increase rise (days) in part of the project (Kavuma et al., 2019).

- **Cost Overrun Definition:** The actual rise in cost from originally estimated by quantity surveyor or estimator is referred to as Cost Overruns. The terms “cost increase” and “budget overrun” are used in the construction industry to mean cost overruns. The difference defined between the actual cost to complete the project and the original cost planned is cost-overruns (Kavuma et al., 2019). It can be expressed as in the form of the equation as follows:

According to (Kavuma et al., 2019), Cost Overrun = Final Contract Amount – Original Contract Amount / Original Contract Amount.

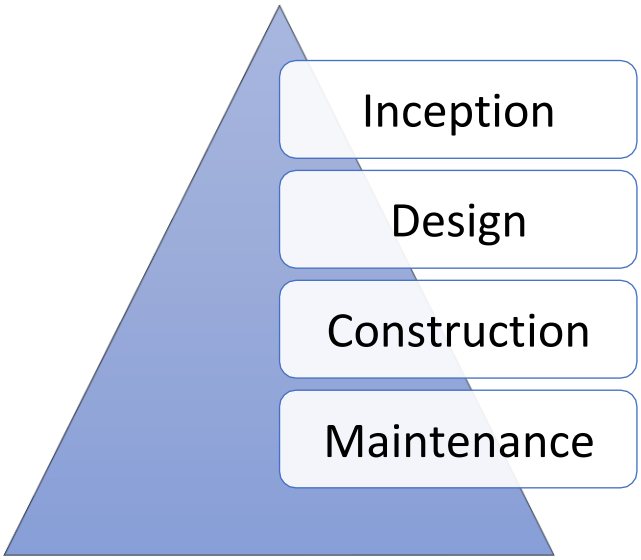


Figure 1*:* Phases of Construction Projects, Source: (D. W. Chan & Kumaraswamy, 1997)

According to (D. W. Chan & Kumaraswamy, 1997), construction projects can be grouped into four main categories namely

- project conception with tendering operations
- project design stage / Engineering
- project construction
- Maintenance

The issue of delay & cost overruns is mainly found in the construction phase of the project. When projects get delayed from the base schedule, contractor tends to increase the speed of construction, sometimes leading to an increase in the cost of poor-quality measures. Also, a percentage of the project known as contingency allowance should be included in the contract for such delays, & this percentage is based on judgment or experience of the party involved. Even though the parties involved in the project concur upon the additional time and cost-related with delay, by and large, there are issues between the client and contractor regarding whether the contractor is qualified to guarantee the additional cost (J. H. L. Chan et al., 2011). Such circumstances bring about addressing specific facts and agreements between parties. It should be properly defined in the contract agreement clause regarding party involved for related delays & entire responsibility should not be on the contractor.

Based on the study, delays in construction projects have drawbacks related to cost, time, resources to all stakeholders involved in project & hence the major aim of Project managers should be channelizing & identifying such delays through proper techniques & suggesting suitable improvement & control methods in construction.

Many studies in the past show various reasons for the issue, resulting in low productivity, process improvement methods, quality improvements in projects, improving site management practices, thus resulting in techniques that focus on aspects of project performance. Experts based on prior knowledge in the construction industry should identify possible measures to reduce the effect of delays observed by implementing various techniques & educating the industry to overcome the issue (Ramanathan et al., 2012).

2.3 Cost of Poor Quality

Another measure of performance of the project is the cost of poor quality. According to (Harrington 1999) he classified the traditional cost of quality consists of four categories: internal failures, external failures, appraisal, and prevention. The aim is to increase the preventive cost of quality and to reduce the internal failures, external failures, and appraisal components. Commonly, not all of the costs of poor quality are estimated in an organization's framework; in this way, it takes both effort & time to

appraise the expense of low quality precisely. The author presents a list of failures & prevention methods in table 1.

Table 1: Cost of Poor-Quality Measures, adapted from (Harrington, 1999)

Internal Failures	External Failures	Prevention
Failures in execution	Customer Dissatisfaction	Proper Planning & Scheduling
Design Errors	Machine Failures	DMAIC cycle
Re-inspection	Excess Inventory	Knowledge Management
Cost of repair	Excess Material Testing	5S Tool
Rework	Penalties due to delays	QA/QC Tool
Scrap	Contract Errors	Training
Engineering Changes		Audits

According to (Krishnan, 2006), Cost in a project can be visible & hidden. The hidden cost can be many in a project & sometimes around 3 to 4 times visible cost depending on project type. The author presents some of the Visible & hidden cost in a construction project below:

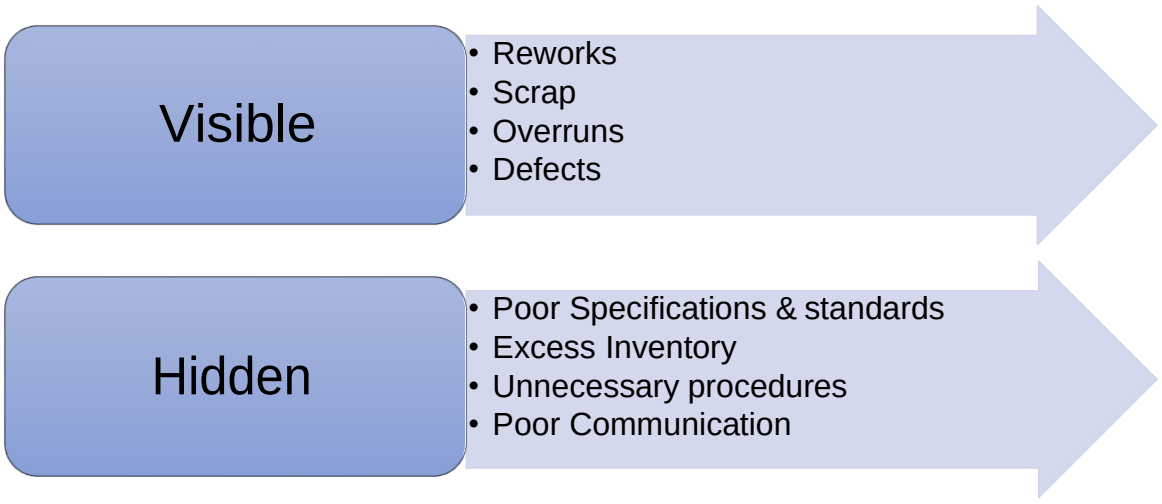


Figure 2: Visible & hidden Cost of Poor Quality, adapted from (Krishnan, 2006)

2.4 Causes of time & cost overruns

A project in construction is considered to be successful when it is completed within the stipulated time, desired quality & within cost estimated (Mpofu et al., 2017). It has been usually seen in a project; cost overruns often accompany delays in a project.

2.4.1 Delay & Cost Overrun Issue

Overrun in time irrespective of whether the overrun is beyond the completion date mentioned in the contract or the overrun is in the period agreed by both the parties, i.e., the delivery of the project is the definition of delay. This is a common problem in the construction industry that means many of the construction projects slips over their planned period. Outcomes of delays are different for both client and contractor. From the clients perspective, it is the loss of revenue because he lost his chance of earning the income that maybe because he is not able to give that space on rent, or he is not able to use that place for production, or if he is dependent on the facilities available in that space, etc.

Completing the project on time reflects the efficiency of the contractor; hence, he needs to avoid delay even in one activity on time because it results in overhead cost as he works for a longer duration(Zailani et al., 2016). Also, the loss of material changes due to inflation and labor cost get affected.
Knowledge of project management is not enough for overcoming the delay in any project. The project may get off track, and maybe behind schedule, the reasons will be different, and it can be prevented by prior planning. If the planning is not done correctly in the initial stage only, you will observe delays.

The methodology adopted by the engineer to judge the execution period keeps the project within the estimated time as well an estimated cost. Usually, delay occurring during the execution phase, many of them involve unforeseen factors. Even any change in the objective/ scope of the project will also lead to a delay in the project. The impact of delays is mostly in the financial part for both client and contractor. It is up to parties how they want to resolve the dispute as a result of the delay. They may go to court or may go for arbitration and determine who is responsible for the delay

and will bear the consequences. While handling such delays, court and arbitrator both consider several factors such as contract document, cause of delay, etc. and based on that, they decide who will be allotted the risk (J. H. L. Chan et al., 2011).

Delay may occur in all the phases of the construction project and very frequently, whose impact is different at different stages. Delays also affect the productivity, efficiency, and effectiveness of the contractor.

2.4.2 Types of Delay in Construction

According to (Ansah & Sorooshian, 2018), there are three ways to categorize delays:

- Excusable or Non-Excusable
- Concurrent or Non-Concurrent
- Compensable or Non-Compensable

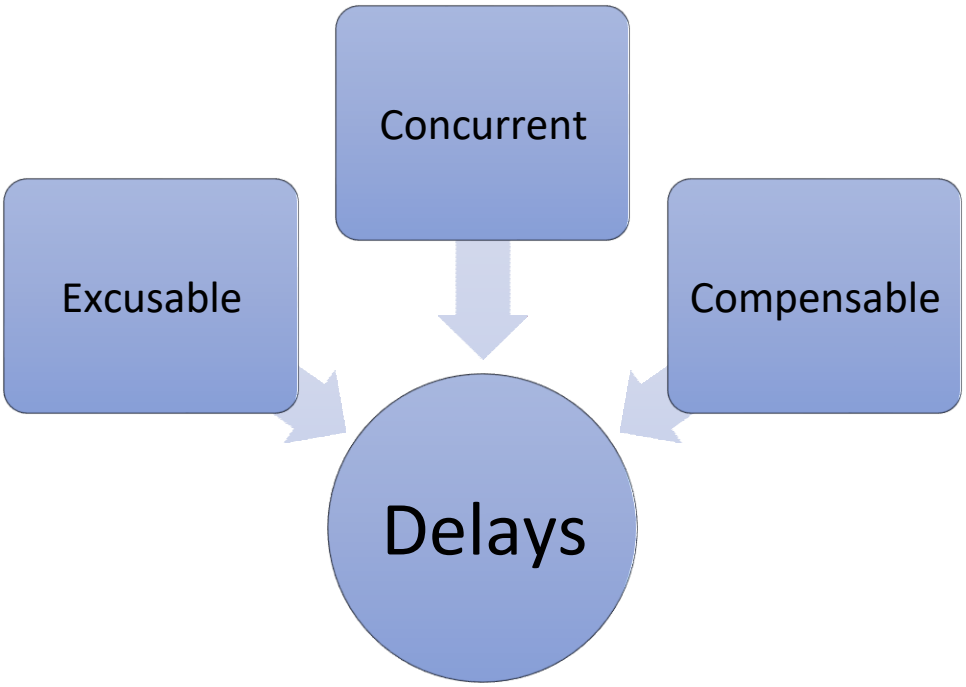


Figure 3*:* Types of Delays in Construction, adapted from (Ansah & Sorooshian, 2018)

- **Excusable Delay**

Excusable Delays are delays that occur due to circumstances that are not attributable to the contractor and are out of control of the contractor or the third party for whom the contractor is responsible. According to the situation, an extension of time for performance or, in some cases, the contractor is given delay damages by the client. This includes delay by the client and delays which are already excused in contract document and includes delays which are unforeseeable by both the parties at the time of contracting (Ansah & Sorooshian, 2018).

- **Non-Excusable Delay**

Non-Excusable delays are due to some faults of the contractor or the third party for whom the contractor is responsible. As the contractor is liable for the delay, he is not entitled to get an extension of time or compensation. This reflects the inability of the contractor. In this case, the contractor is liable to pay owner delay damages or liquidated damages (Ansah & Sorooshian, 2018).

- **Non-Compensable delay**

Non-Compensable delays usually are due to act of God, fires, unusually severe weather, strikes, floods, etc. There is always misunderstanding whether to consider delay due to weather under non-compensable suspension or not, but it only takes into consideration severe weather conditions. That means only that type of weather is found which is not anticipated at that time in that place. Non-compensable delays that are entitled to the contractor, and hence no time extension is given. But the contractor by proving his point that the delay as out of his control and ask for compensation but still he is not entitling to get money. The contractor is given a time extension, and he has to pay liquidated damages(Ansah & Sorooshian, 2018).

- **Compensable delays**

The contractor must prove that the delays are attributable to the government, and it resulted in an overall delay in project duration. He also needs to confirm that the delays were out of his control. When he goes for recovery of the delay, he needs to prove his point and give a proper reason. If the delay entitled to government is non-compensable, then he is not entitled to get compensations (Ansah & Sorooshian, 2018).

- **Concurrent Delays**

Concurrent delay is a result of one event which is delayed. It reflects a complicated situation where one or more delay occurs at the same time, but the contractor is not entitled to claim an extension of time or loss and expenses for every setback. There may arise a situation where two or more delays rise independently at the same time, but together, they affect the completion period of the project. But if the client is entitled to any of those delays, then the contractor can claim for the loss and expenses (Ansah & Sorooshian, 2018).

2.4.3 Effects of Delays

The effect is nothing but change. The result may occur due to the impact of delay in the project. This effect can be a substantial financial cost for both client and contractor. Mostly it includes arbitration, time overrun, cost overrun, disputes, litigations, and may the project will be stalled forever (Amoatey et al., 2015). Delay in any project primarily results in time overrun as the contractor will need an extension of irrespective of whether the delay is attributable to the client or contractor. Still, it is not necessary that the cost overrun is bear by the client only. The delay will also lead to cost overrun for the contractor as he is required to pay penalties for delays. But the client will also lose his revenue from the project due to this delay.

The most time taking effect of delay is a dispute as it involves both the party's client and contractor for claims. To satisfy parties many times, they go for arbitration. If they are not able to conclude the issue in this way, they at last go for legislation. Mainly the dispute is between two party's client and contractor, but the whole project suffers. For minimizing the disagreement, they use the schedule submitted by the contractor at the initial stage as a contract document (Zailani et al., 2016).

For the most effective and efficient and fair evaluation of the impact of delay, the proper method should be used. Studies show that the effect that you can see in most of the projects is time overrun then followed by cost overrun and then come arbitration, litigation. After the occurrence of delay, there is a chance to cut the value of the project; the manager may compromise on the quality of work by degrading the quality of the material.

Time and cost overrun may impact an increase in the selection time of material or may be due to unavailability of material, so it is essential to estimate the time of every activity according to the event, skills required the efficiency of workers, etc. Delay also affect the image of the contractor by giving them negative points irrespective of whether the contactor's performance was excellent, and he contributed a lot toward the project. Delay also results in low productivity of the contractor and increases the cost for him.

2.4.4 Various Causes of Delays & Cost Overruns

(Habibi & Kermanshachi, 2018) categorized the delays into nine significant groups:

- Project-related factors include type, political, and social influences delay, etc.
- Contractor related factors include inadequate contractors experience, improper planning, poor site management, improper execution of sub-contractor, etc.
- Client similar factor includes slow decision making, unrealistic contract completion duration, delay in payments, etc.
- The material related delay includes unavailability
- Consultant related approval of drawings, contracts
- Contractual factors include delay due to any negotiation and disputes during the project, the communication gap between the stakeholder's plan, etc.
- Labor and equipment factors consist of inadequate labor supply, low productivity, unavailability of equipment, breakdown of equipment at peak hours, etc.
- Contracts factor includes misinterpretation, change orders, discrepancies, etc.
- The external element comprises a change in government rules and regulations, site conditions, weather conditions, etc.

Based on various literature studied & past researches, the author in the table.2, gives a specific reason for delays & cost overruns observed in the construction project.

Table 2: Causes of delay & cost overruns

Research Study	Major Causes
Causes of Delay in Large Building Construction Projects (Assaf et al., 1995)	• Financial constraints from the client to the contractor • Contractor Financial Difficulties • Inflation
A comparative study of causes of time overruns in Hong Kong construction projects (D. W. Chan & Kumaraswamy, 1997)	• Frequent Variations of work • Incompetence Project Team • Technology issues • Design errors
Causes of construction delay: Traditional contracts (Odeh & Battaineh, 2002)	• Slow site Handover • Approval of Drawings • Decision Making • Terms & Conditions Unrealistic
Causes of delay in large construction projects (Assaf & Al-Hejji, 2006)	• Poor Site Management Practices • Delay in Work due to shortage of labor • Unrealistic Planning • Method of Construction
Causes and effects of delays in the Malaysian construction industry (Sambasivan & Soon, 2007b)	• Material Shortage • Frequent changes in scope / Scope undefined • Procurement issues / Late delivery • Quality Standards not defined • No proper storage
Causes of construction delay: traditional contracts (Odeh & Battaineh, 2002)	• The conflict between stakeholders due to frequent changes in scope • Mis-coordination issue • Unorganized Contract for various sub-contractors in project • Cash Flow issues

	• Legal disputes
Causes of delay and cost overruns in the construction of groundwater projects in a developing country (Frimpong et al., n.d.)	• Poor Contract & Site Management • Cash Flow problems • Procurement & delivery of materials • Phases & milestones
Delays in construction projects: The case of Jordan (Sweis et al., 2008)	• Financial problems of contractor • Scope changes / No standards defined • Poor Planning • Unskilled workers • Less technical staff
Causes of Delay in Large Building Construction Projects (Assaf et al., 1995)	• IFC drawings not issued • Contractual problems • No proper SOPs or procedures defined for a process • Safety accidents • More Cycle Time in approval of drawings from the client
Important causes of delay in public utility projects in Saudi Arabia (Al-Khalil & Al-Ghafly, 1999)	• Lowest Bid Win system procedure in the contract without identifying the experience & skill of the contractor • Permits from government • Financial constraints
The Importance of New Technology for Delay Mitigation in Construction Projects (Sepasgozar et al., 2015)	• Design Issues • Changes in WO (Work Order) • Procurement Planning • Surprises in Site conditions from stated design • Natural Calamities

2.4.5 Delays in Tendering

As tendering is one of the fundamental and most significant stages in a development phase of the project, so any delays observed in this stage could eventually bring about an increase in the general completion and may likewise affect the general expense of the project (Rosenfeld, 2014). Delays & subsequent cost overruns in this phase are presented in the table.3, based on the literature reviewed.

Table 3: Delays in Tendering

Sr. No	Tendering delays based on Literature Review
1.	Obtaining permits from Government
2.	Poor preparation of tender documents in terms of drawing, Bill of Quantities
3.	Scope Changes, poor communication between stakeholders
4.	Tender-winning prices are unrealistically low
5.	Unclear, ambiguous, and contradicting terms in the tender documents
6.	Clear risk undefined defined between contractor & client
7.	Legal documents, contract for claims undefined

2.4.6 Execution Delays

The Delay in the execution occurs when the unplanned, unexpected, and unknown accident happens. The leading causes of delays in the execution phases are stated in the table.4, based on various literature studied.

Table 4: Delays in Execution

Sr. No	Execution delays based on Literature Review
1.	Poor site management practices and supervision
2.	Cash flow problem financial difficulties
3.	Design Change, Scope unclarity during Construction Stage of Project
4.	Poor planning management of the project
5.	Slow preparation and approval of shop drawings
6.	Communication issues between stakeholders of the project
7.	Unrealistic time estimation provided by Client
8.	Shortage of supply of required inventory’s
9.	Procurement of materials
10.	Construction Method

Conclusion: Based on the above delays identified from various literature, cost overruns are observed accompanying delays & subsequent methods to overcome the issue will be discussed in the chapter of the discussion used in minimizing such delays.

2.5 Need for Lean in Construction

Since construction industry has a noteworthy impact in each national economy and numerous different sectors, rely upon the construction sector as far as acquiring inputs and giving materials to pretty much every other industry, decreasing or eliminating waste in the business would result in extraordinary cost reserve funds for the organization just as for the general public. The following factors, as stated below, identify the significance of lean development and reasons why its application is essential for the construction business.

It must be noted that value for work with quality, cost & time is what the customer is truly paying for the task to be delivered for a project. LC is a way to deal with a specific set of techniques to improve workflow, desired quality, reduce waste of time, to achieve value for a project (Ansah et al., 2016).

UK studies by (Aziz & Hafez, 2013) showed that up to 30% of the issues in construction are rework issues, 40–60% of causes due to labor efficiency, safety issues can represent 3–6% of the cost. In any event, 10% is due to the loss of materials. The expense of rework in the Australian construction industry has been accounted for as being up to 35% of project costs and contributes as much as half of project overrun costs. Based on the above facts, rework is one of the essential components adding to the Construction industry's poor performance and efficiency (Aziz & Hafez, 2013).

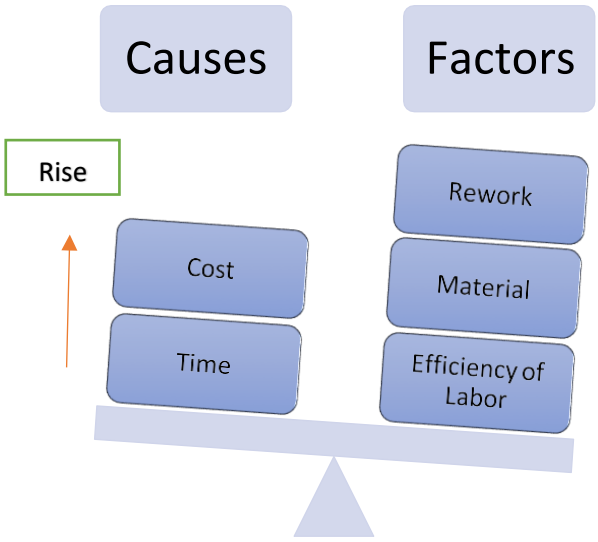


Figure 4*:* Cause & Rise of various factors due to delays, adapted from (Aziz & Hafez, 2013)

Based on the above facts (Sui Pheng & Hui Fang, 2005) presented in following 11 lean principles how it can be useful in increasing the efficiency of process & reduce waste in a process summarized by Koskela (1997) for the construction industry. The author presents the principles as related to each other & how they can be used in avoiding delays as a whole value add process:

- **Reduce the share of non-value-adding activities (waste).** Non –value-added activities generally bring an increase in cost & time for a project. Proper identification & reduction of such activities in a project helps in resource optimization & balanced cost benefits for a project. One of the major causes of delay found in industry is drawing / design changes due to improper specifications specified or failure in the identification of defects leading to waste.

- **Increase output value through systematic consideration of customer requirements**. For a contractor, the customer in a project can be of two types, one client & another consultant. By identifying & constructing through set guidelines decided between stakeholders of the project, will increase & fulfill customers' requirements for quality & increase value.

- **Reduce variability. Identified two reasons for reducing process variability**. If variability in a project is not identified & eliminated, it will increase non – value-added activities for a project. In the construction industry, there are various processes & inventory, which results in variation, for example. Cement comes from different vendors with different specified parameters. Hence to reduce variability, set protocols or SOPs should be defined from the beginning of a project, to add value.

- **Reduce cycle times.** The cycle time in a construction project can be reduced by various methods depending on the type of use. The major drawback in delay causes is late delivery of material or materials are delivered well in advance, creating an increase in resources & space constraints. By implementing JIT technique cycle time for materials, delivery can be solved with delivering material on specified date & location, reducing resources, cost & time.

- **Simplify by minimizing the number of steps, parts, and linkages.** By process improvement, & minimizing the process has direct cost impact & time reduction for a process. By adopting lean techniques helps in achieving the desired target by reducing non-value-added activities.

- **Increase output flexibility**. Flexibility in a construction project can be achieved by resource identification, proper education, training, audits, set defined protocols for a process to be followed.

- **Increase process transparency.** Transparency in a process can be achieved when results are visible for employees. Proper Set of protocols should be defined like checklists between stakeholders, which act as a standard transparent visible document identifying success or failure of a process.

- **Focus control on the complete process**. It is suggested by appointing a single responsible person for a process that will act as a single point of contact during errors & accountable for fixing the issue. Communication & co-operation within different stakeholders is vital for SOC, to achieve optimized workflow.

- **Build continuous improvement in the process.** It can be achieved by continuously reducing waste in a process & adding value to the project by standardization, increase transparency between stakeholders.

- **Balance flow improvement with conversion improvement.** The relationship between flow and conversion improvement relates to new investments, a new technology that can be improved & control by the enhanced workflow. Implementation of new techniques will generate more benefits by controlling & monitoring the process.

- **Benchmark.** Benchmark defines sets of strengths, weakness of a process affecting a project. Hence, when combined with improved process-driven methods helps in reducing various factors affecting delays for a project.

2.6 Lean defines Waste in Process

Waste in the construction business has been the subject of a few kinds of research, far and wide as of late in recent years. An activity that consumes resources resulting in increased cost & time without adding value to the project, can be defined as Waste (Razak Bin Ibrahim et al., 2010).

The main categories of waste during construction processes can be classified into three main types, namely construction site, methods in construction & external factors. Waste resulting from the site includes waiting time, debris, excess materials. Waste to process due to lack of constructability, design errors, specifications issues, poor material allocation, unnecessary material handling, and material waste. Accordingly, (Oguntona et al., 2019) classified waste in the following categories in the various construction industry & the author aims to suggest how waste can be reduced.

Possible types of waste in construction:

- **Waste due to Overproduction**: Overproduction is identified with the production of more material than required, or that should be expected from the original specified. Also, organizations sometimes have excess inventory of materials than what required to keep the project running. In any case, excess inventory results in a waste of material, which eventually leads to scrap. A set percentage of material allowance should be allowed to produce to be used to keep it for emergency purposes. This sort of waste is likewise found in renewable sectors where large no. of C-sections is used.

- **Waste from Rejects**: Waste from rework/reject happens when a process doesn't fit the quality specifications of a process already defined. A defect is an error made in a procedure that makes the work less significant to a customer, or that requires extra control to address the issue. Rejects mainly occur due to poor communication, design errors, errors in construction, in-efficiency of workers. These eventually lead to rework, with an increase in cost & time to complete the process with equal resources. Hence, new quality techniques should be adopted to reduce defects in construction.

- **Waste in Transportation:** In construction, workers & materials are usually transported from one place to another work location to complete the process. These frequent transportation in materials generally result in increased cost to shift material from one location to another. Also, the quality of material gets affected during transportation due to continuous movement, excessive handling. To overcome these wastes, materials should be delivered to the exact site location when & where required to be used, saving cost & time.

- **Waste in Processing:** Waste in over-processing is due to excessive use of resources, which can be due to the inefficiency of the skill of the employee. These results in the overutilization of resources to complete the task. Correct processes defined should be followed to overcome the waste & these also usually depend on employee's creativity, skill & knowledge of past similar works.

- **Waste from Inventory**: Large no. of Construction materials & raw materials are found to be in excess than required resulting in chances of theft, storage site not proper. Most of the construction projects have excess materials on-site to avoid delay for the failure of any kind & these resulting in excess inventory at the site leading to an increase in cost to cover, protect the material till the time it has been used leading to delay & cost overruns. These are a result of a lack of resources or inefficiency in the planning process or estimation of quantities.

- **Waste from Waiting:** Waste resulting from waiting is easy to identify, & these could be due to waiting for material, waiting for drawings to start a process, or waiting for due to changes in some processes/information. These wastes can be overcome by continuously engaging workers in a different process, operating an equipment irrespective of demand. If significant construction processes are interlinked with each other, these can be reduced by having continuous movement of workers & equipment. Project to be successful, the process in construction should be smooth & continuous.

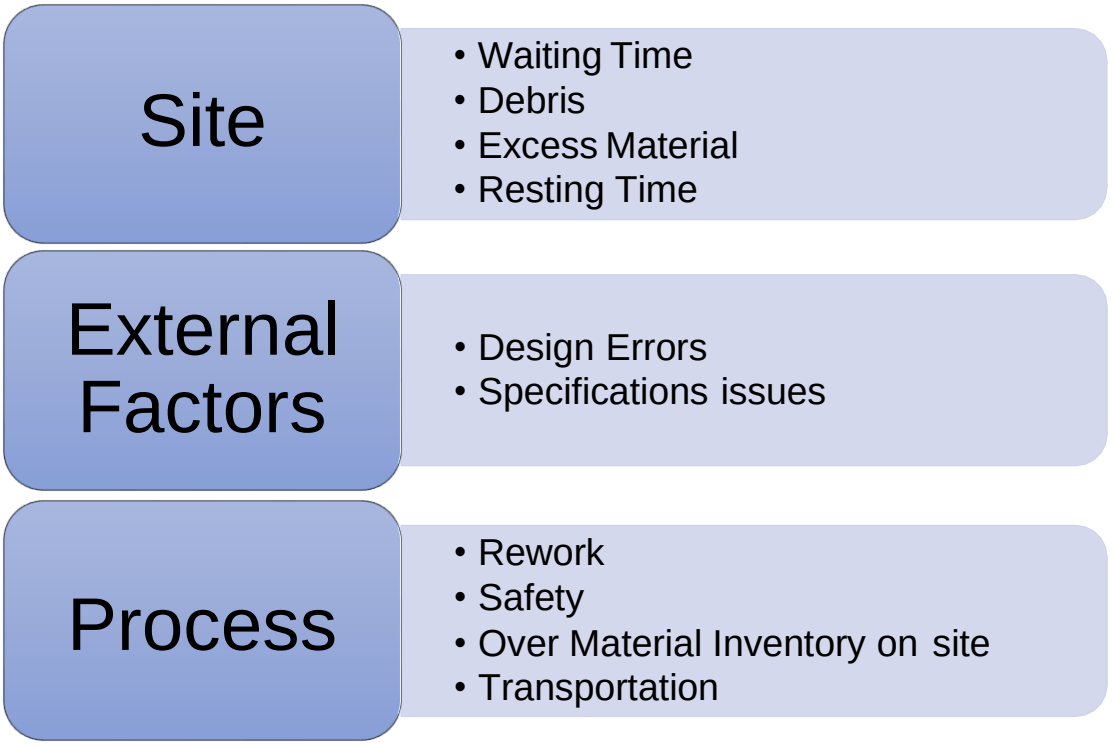


Figure 5: Construction Waste

Figure 5, showing construction waste due to site, process, & external factors. Due to each of the waste stated, the construction project accounts for delay & cost overruns in a project. Significant waste is generated through process operations in construction & these can be due to no sets of guidelines decided before the start of a process, safety operations not followed due to no IMS policy guidelines followed by stakeholders, loss of materials due to no proper storage at site, logistics issues.

Lack of lean tools integrated with quality tools are being used in industry, but still, there are problems in controlling & improving waste after elimination. There exists a gap in identifying the actual root causes of a problem & managing them within different stakeholders to be operational in the project (Garza-Reyes, 2015).

All these delays can be minimized by adopting six – sigma methodology & 5S tools, which will be discussed in the subsequent section

2.7 Why move to six-sigma & 5S

Lean-to be implemented in any project has a significant drawback in finding is measurement or problem definition to be measured across projects, which enables to improve & control for the process. For any process, what is measured is of importance, which would lead to cost & quality benefits.

Lean being used as an operational approach in construction; it is not used structurally to improve a process & reduce variation within the process. These don't allow to identify the root cause of a problem to be addressed & subsequently results in low decision making for an organization (Chauhan & Singh, 2012). Thus, they may not eliminate the root cause of the problem, having a risk that the issues can resurface again.

One of the principal challenges is to distinguish construction has a process having various activities related to each other & as a procedure in the identification of activities that don't add value, create waste. Because of this limitation, a process is improved only after the identification of nonvalue added activities. The limitation exists to identify in which area or part the defects are in existence. Six Sigma tool helps in identifying the actual root cause where the problem exits & helps to measure, improve & control the defect with proper techniques that can be adopted in construction.

Lean doesn't target specific reduction & variation in a process. In the case of reducing inventory can't be achieved only by pull planning, the planner in this case also needs to take into account variations that are observed in demand, supply (Garza-Reyes, 2015).

Six Sigma & 5S tools are the quality tools used in construction to facilitate faster & quality construction by process improvement to increase productivity through customer view, reduce the cycle time between activities, identify actual problems & causes for failure & improving & controlling by adopting suitable measures. The above limitations & challenges for the lean call for a tool can be integrated with lean-to overcome the issue & helps in reducing or eliminate the above problems called Six – Sigma & 5S.

2.7.1 Six Sigma – History & Definition

The background of Six Sigma is well-known in many kinds of research & has been documented one and consequently to note here that it was developed as a quality improvement approach during the 1980s followed by the American electronics company, Motorola where an objective of improving all items products by magnitude (for example a factor of ten) inside five years was set up. This gave a significant rate in increasing the quality of products & providing a better solution for customers (Gamal Aboelmaged, 2010).

These methods focused on reducing human efforts, reducing cycle time for a process, increase satisfaction among customers, increase in quality for a product. In regard to these, a precise method was launched in 1987 called six – sigma in improving the process for better efficiency (Klefsjö et al., 2001). Accordingly, six – sigma helps in the following ways:

- Process improvements
- Reducing cycle time
- Eliminating defects
- Improving & controlling a process
- Customer-based improvements.

(Schroeder et al., 2008) stated that in statistics language, sigma is a measure of the variation of a process, represented & evaluated in terms of the standard deviation and six sigma, by and large, suggests the event of defects which occur “at a rate of 3.4 defects per million opportunities (DPMO)” for defects to emerge from a process. These indeed result that for one million defects, there are 3.4 defective units, as any given unit is complex enough to create various defects in a process resulting from multiple factors.

Schroeder & Linderman, in 2008, defined Six Sigma as “A disciplined method of using extremely rigorous data gathering and statistical analysis to pinpoint sources of errors and ways of eliminating them” (Schroeder et al., 2008).

Hahn et al. (2000) described Six Sigma to be a quality tool in improving process & increasing quality-related parameters for a process by saving cost & time benefits (Hahn et al., 2000).

2.7.2 5S - History & Definition

5S is a combination of five Japanese words, usually referred to as sort, set in order, shine, standardize & sustain. They are useful tools implemented in construction in maintaining the workplace, remove inefficiency in practices, minimization of resources by defining sets of protocols & guidelines, proper housekeeping (Tezel & Aziz, 2016). These method helps in reducing wastage of materials which is a significant issue for the cost increase in construction.

To achieve proper housekeeping in a project depends on the mentality, skill, behavior of workers, & the process that can't be enforced directly on an individual. The EIC (Engineer in Charge) should have awareness & create among workers the basic knowledge of housekeeping explaining a set of advantages while leaving the workplace. 5S system of lean is challenging to apply if employees or workers have little or no attitude in implementing the principles. The process of 5S should be followed by all project participants, including the CEO, keeping his area of work clean(Salem et al., 2005). The author realizes that attitude, commitment, discipline are vital parameters in the implementation of the 5S tool in an organization. These principles should be set up in the IMS policy of an organization.

The 5S approach way was created in Japan and was officially presented toward the later stage of the 1960s, while the significant system for implementing and applying 5S was proposed by Osada (1991) and Hirano (1995). Because of these, 5S was executed at Toyota Motor Corporation of its designed framework, in particular, Toyota Production System (TPS). Osada (1991) has presented 5S as a quality tool to improve & systematically keep the workplace to avoid loss of delays & cost arising from the loss of materials (Randhawa & Ahuja, 2017).

The 5S procedure viably eliminates various shortcomings of the organization and helps in increasing the general development-related key points of organizations. 5S enables acts as a measure for the fulfillment of comprehensive quality management in construction organizations. It helps in achieving continuous improvement in a process by eliminating waste, reducing defects & motivating employees in the workplace to achieve set objectives (Randhawa & Ahuja, 2018).

2.7.3 Six Sigma Methodologies

Today, in this competitive marketplace, organizations take measures to have an improved degree of processability and a diminished degree of cost of poor quality (COPQ). The main concern & fundamental objective of an organization is to produce an overall increase margin in profit and maintaining a position in the market. COPQ is the expense related to the low quality of work done due to poor administration or no set of quality defined techniques used in the process. For a construction organization, COPQ is the absolute cost of rework, scrap, design errors, poor site management, construction errors due to inefficiency or skill of workers (Prashar, 2014).

Six Sigma DMAIC methodology is utilized & implemented to improve existing processes that need productivity improvement parameters and had been demonstrated to be effective in reducing costs, improving process durations, defects reduction, increasing consumer satisfaction, and essentially expanding benefits in each industry and numerous associations around the world.

The fundamental tool utilized in five phases of the DMAIC system help recognize, evaluate and eliminate various root causes related to waste or rejects and support & sustain the improved processes with control measures to be implemented in the future (Desai & Shrivastava, 2008).
The objective is to stop the defects before they appear and reduce the COPQ by implementing a predictive methodology toward rejection and rework.

The DMAIC model stands for define the actual problem to be studied, Measure through identifying root causes, Analyze the problem, suggest Improvement methods, & Controlling the process to be implemented (de Mast & Lokkerbol, 2012). Accordingly, DMAIC Cycle is explained below by the author:

- **Define**: The success of any project depends on the project definition. Over 50% of projects fail due to a lack of proper definition. Define phase set common goals for all stakeholders in a project, which facilitates project execution. CTQs, customer requirement, Project charter needs to be defined. Tools used in phase are CTQs, Project charter.

- **Measure**: Measure phase includes quantifying project objectives by identifying various root causes for which the problem is defined. Helps in identifying baseline problems for project definition. It validates the current situation is understood in detail from a variety of perspectives so that strategies/ solutions can be developed to address it. Tools used in measure phase include Checklists, Data collection methods, communication mails.

- **Analyze**: Identification of non-value-added activities & removing them through process changes, simplification, mistake proofing. It helps to develop a sustainable process development for long term benefits. Tools used in these phases include a fish borne diagram, 5Why analysis, FMEA Analysis.

- **Improve**: Improvement is a continuous process that is done in stages. It follows the PDCA cycle of analysis. Tools used in these phases include benchmarking, Cost-Benefit analysis, poka-yoke, which is an error-proofing technique, 4W Tool.

- **Control:** For improvements to be sustainable, control measures need to be implemented by awareness training, documentation control, SPC, Automatic Controls.

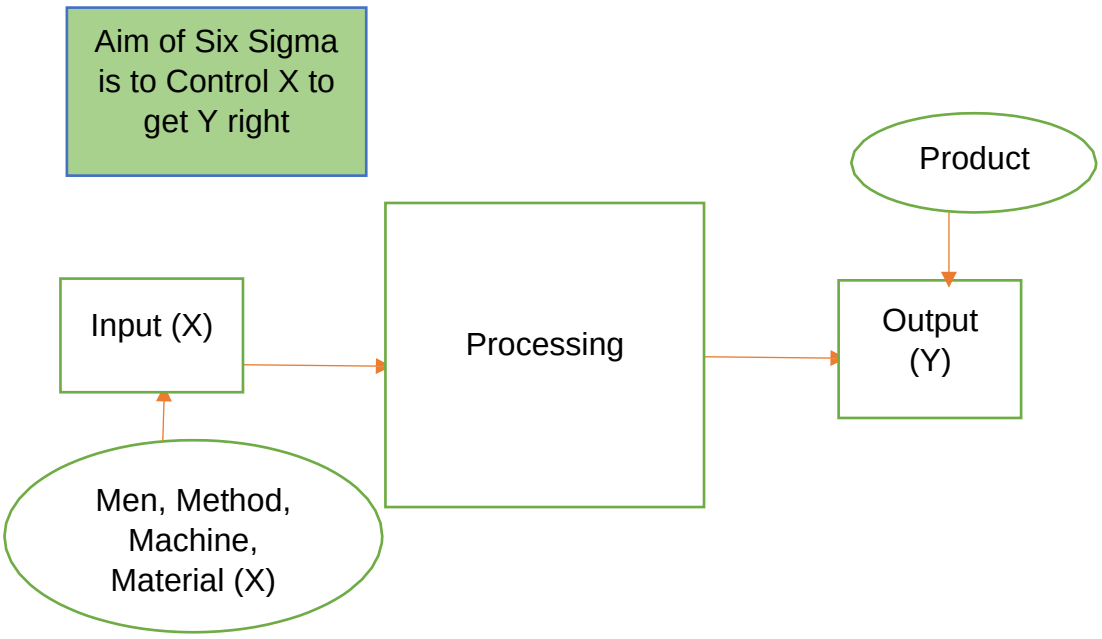


Figure 6: Six Sigma Concept, adapted from (Zare Mehrjerdi, 2011)

2.7.4 5S Methodologies

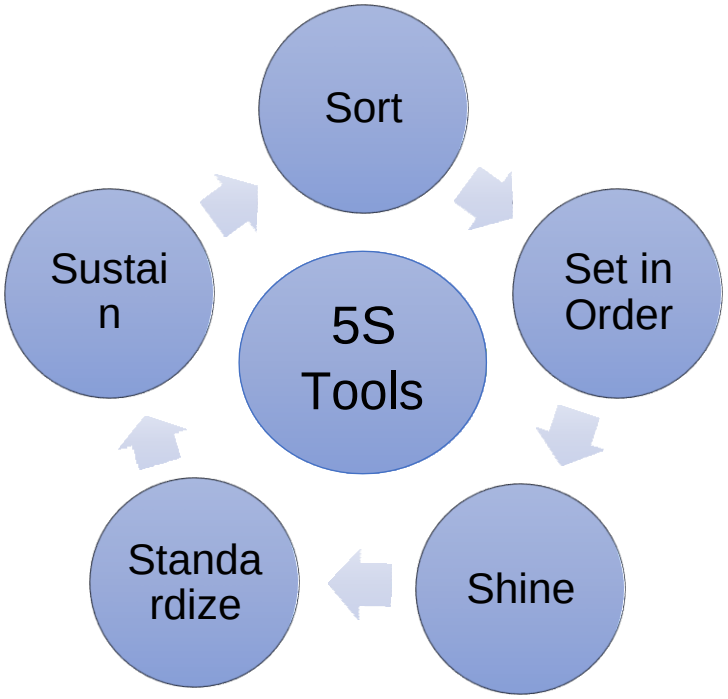


Figure 7: Elements of 5S, Source: (Randhawa & Ahuja, 2017)

One of the significant causes found from the various literature review in delay & cost overruns studied earlier is the loss of material in the construction industry. The loss in the material can be due to material damage in the site, poor site management practices, storing & handling of materials, frequent shifting of materials from one place to another due to no proper storage area defined. Because of these, a quality tool 5S needs to be implemented in construction to achieve the loss of material from the above effects.

In line with IMS policy, continuous quality improvement should be constant endeavor, which should be believed that will earn respect & admiration to one and all. By implementing 5S at all our workplaces, which is conceptually simple, this initiative is aimed at improving our work environment, which should also be the objective of an organization.

Following “5S”, will help to: -

- Clean our workplace clean, neat and easily accessible

- Enhance safety practices
- Eliminate waste and thereby increase efficiency
- Take ownership of activities
- Embed total quality in services or process
- Serve customer in the best possible way

(Randhawa & Ahuja, 2017) describe elements of 5S in following ways & their relevant advantages in the industry:

- **Sort:** The principal component of 5S is 'Sort' (Organization) is tied in with arranging or keeping the vital things or materials to be used at their defined spots. Sort calls for the successful use of workable space. It adheres that the material or types of equipment should be isolated carefully as per the usage & specification for which it is used by red tagging & when required to be used in the working space. The sort is a useful component for evaluating the material or material reconciliation for the present and future use, which is essential to avoid loss of material. Sort encourages by maintaining a strategic policy by keeping unwanted inventories or materials away from a defined scrap place & thus preventing the flow of work to be disturbed (Ghodrati & Zulkifli, 2012).

The advantages of the first element of the 5S tool include:

- Increased saving & searching for required material time is short
- Maintaining a safe and clean workplace for employees
- Easy identification of damage to materials.

- **Set in Order:** The goal of the second component of 5S is to build up the practical utilization of workspace with perfect and efficient storage of materials, by setting a defined storage area. Set in order requires prioritization of the need and significance of materials to simplify the area of location. This ease to get the required material when needed for any person in the project with proper identification, resulting in minimum loss of material. This phase sets everything in the appropriate place for quick retrieval & storage.

- **Shine:** The third S, Shine, signifies 'Cleaning,' which results in self-investigation of the workplace, cleanliness in the workplace, and making a perfect work environment for workers. This incorporates three essential steps that need to be included, namely getting the working environment clean, managing their workplace by making it clean, and utilizing preventive measures to keep it clean. In this phase, everyone should be a janitor.

The useful checklist should be developed that helps in maintaining the workplace by cleaning the workplace & assigning responsibilities for individuals. It focuses on cleaning a workplace by forming teams & storing materials at the workplace already defined. These results in an increase in the quality of the workplace, proper storing of materials & an overall cheerful working environment (Sorooshian et al., 2012).

- **Standardize:** The fourth S signifies 'Standardization,' that is, managing up to one's working place with the goal that it is beneficial and can be manageable by implementing the 3S discussed. The advantages of Standardization incorporate low overhead cost, based on customer requirement process improvement, low maintenance cost. This S standardizes the way of maintaining orders & cleanliness (Sorooshian et al., 2012).

- **Sustain:** The fifth S (Sustain) presents for maintaining & implementing all the previous S used. The fifth S is challenging to implement and workable on the grounds as it requires proactive changes in the conduct of workers at all levels inside an organization & creating sustainable efforts to maintain it.

These can be achieved by proper training, audits, increasing awareness among workers, these make the way of life in the worker, which also means commitment towards work (Kobayashi et al., 2008).

2.7.5 Integration of Lean, Six Sigma, 5S in Construction

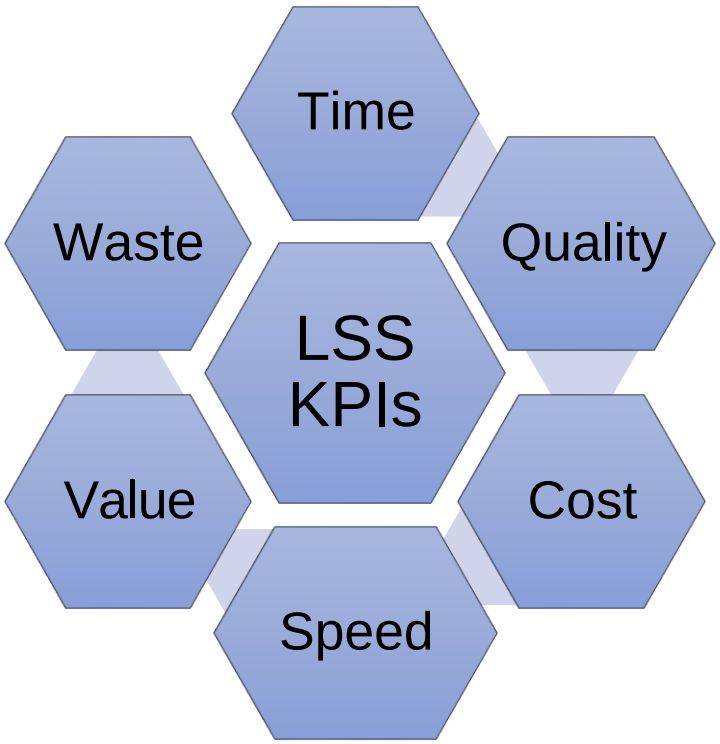


Figure 8: Lean Six- Sigma KPIs, adapted from (Al-Aomar, 2012)

(Al-Aomar, 2012) presents various advantages of integration of Lean with six -sigma & 5S techniques when used in construction:

- **Cycle Time:** It can be estimated from the time required to carry out a given set of activities, with given resources to complete a task. Resources have certain productivity with which they work & generally, these depend on construction methodology, the sequence in which construction activities are executed & productivity of resources. LSS helps in increasing the productivity of a process &, in turn, reduces cycle time, cost & time for a process.
- **Reducing Waste:** Waste is non- value-added activities in the project, having a negative impact on cost & time delays. Significant waste in the construction industry is due to various interruptions in a process. These interruptions can be due to a lack of resources, information, or communication issues between multiple stakeholders. To achieve desired & optimized work, each activity is connected to another activity having required & defined a set of resources &

information to complete that particular activity.

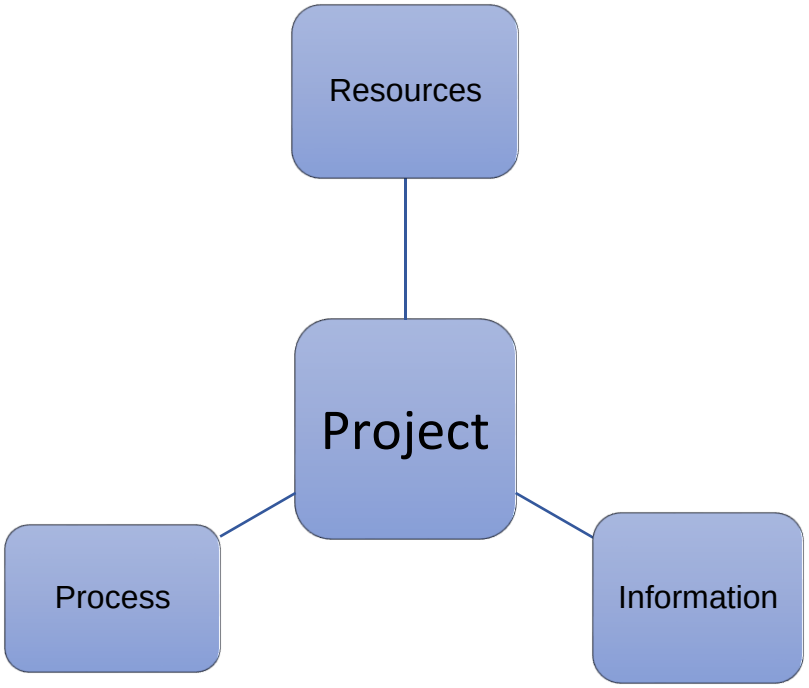


Figure 9: Factors affecting Project

- **Value:** For any construction project, the cost in terms of quality of work to be achieved is essential for customer satisfaction. Lean construction helps in adding value by eliminating non- value activities from the project. Six sigma reduced defects or errors by identifying the root cause of a problem. Thus, LSS, when used in construction, provide value for work by eliminating & reducing errors, enhancing the overall quality of work.

- **Improvements in Cost, Quality, Time:** LSS has a significant advantage that it helps in the improvement of the process, which leads to saving in cost & Time. For, ex. Implementation of the 5S tool will help improving logistics on-site & help in eliminating the waste due to material loss. Also, resources required could be controlled & managed, & effective communication between different stakeholders regarding material storage. These results in the reduction of rework, which is a significant waste in construction.

2.8 Research Gap

The literature reviewed elaborates on the capability of how six sigma & 5S can be used in construction for minimizing risks on delays, accordingly (Han et al., 2008), introduce six sigma concepts to implicate the performance of construction by adopting lean & six sigma as a concept. The research had benefits of six sigma being used & its advantages over other construction techniques in the industry. The six-sigma method isn't just a tool for efficiency and quality improvement, yet additionally, the research said it as a tool for quality and procedure control to set standards & guidelines. With the guide of the six-sigma rule technique, quality changes or CTQs associated with project development procedures can be controlled in approaches to fit in the desired construction. The research will try to bridge the gap by implementing how to lean six sigma tools & 5S techniques to help in minimizing risks through case study & questionnaire survey.

(Brue, 2002), stated the majority of 25% of revenue in the organization is lost due to labor cost, waste, delays, resulting in an increase in cycle time for a process, cost increase, & overall dissatisfaction for customers. Six sigma aims at reducing cost by improving process & increasing productivity.

(Nave, 2002) Integrated six sigma & lean principles in achieving the better performance of construction projects. By integrating the following advantages were summarized by the author:

- Six Sigma reduces variation in a process, while lean removes waste
- In six – sigma actual issue is identifying the problem definition problem while in the lean actual flow identification is the problem.
- Primary effect resulting in the uniform process for a project, while for lean it reduces flow time
- Secondary effects are less waste, minimize cycle time, improved quality.

Six Sigma methodology is feasible in construction & quality management according to a study by (Tchidi et al., 2012). Construction companies need to understand the practicality and significance of the six-sigma strategy. For the most part, the utilization of Six Sigma standards is to build up a quantitative and subjective development

designing quality framework that may result in a decreased cost. In any case, from the point of view of long advantage, applying Six Sigma, builds & increases quality management. It is accordingly critical to improve the cost of poor quality, which is essential for the construction business. The Construction Industry Review Committee (2001) detailed that numerous quality frameworks and methods of quality control, cost control, total quality management has been implemented by multiple companies, but still, significant issues that the ideal quality standard has not generally been achieved.

According to a study by (Kwak & Anbari, 2006), various benefits in terms of process improvement, productivity improvement, quality management, site management was identified by applying six -sigma principles in multiple sectors like financial, manufacturing, health care, Research & Development. Accordingly, in the construction sector, six sigma was first implemented by Bechtel Corporation to prevent & identify reworks in various phases of the project & results showed considerable saving in cost by the implementation of such techniques.

According to (Ansah, Sorooshian , Mustafa , & Duvvuru , 2016) around 20% increase in productivity & 10% decrease in delay & cost reduction by 20-40 % is recorded by implementing various lean tools like six sigma, 5S, Last Planner System. Singapore's case study for Public Housing studied by (Pheng & Hui, 2004) suggests that by six sigma implementation following parameters are well achieved in a construction project:

- Process Improvement
- Customer Satisfaction
- Quality improvements
- Cost improvements

2.9 Conclusion

Based on studied literatures, Hypothesis can be stated: Higher implementation of six-sigma & 5S practices higher the quality of the process, higher customer satisfaction, higher process improvement for increasing productivity. Accordingly, to validate the hypothesis, a questionnaire survey is floated & case study would be studied to replica the hypothesis to be true or false. The research methodology in detail will be discussed in the next chapter.

3. Research Methodology

3.1 Introduction

The chapter discusses the research methodology adopted identifying various issues related to delay & cost overruns in a construction project. Why the selection of various research methods is adopted in research is presented with the selection of participants for a questionnaire survey, selection of case study is discussed. The explanation of various methods of analysis is discussed, along with substantial results. The chapter is concluded with the approach to the triangulation method of the research of study.

3.2 Research Design

According to (Hollweck, 2016), there are mainly three guidelines on which type of method can be used for a research study. Based on these, the primary three guidelines to be followed are:

- Research question type
- Control of researcher over results
- Degree of focus on past events

The research question to study is delay & cost overruns in a construction project's, Case Study & Questionnaire survey can be considered as the most appropriate method for such type of research. Reliability of research is an essential criterion of research & hence, Case Study & Questionaries' survey approach was used.

Consequently, a mixed method of literature review, case studies, and a questionnaire survey were used in the research. According to (Love et al., 2002), a singular method of analysis won't generate a kind of reliable result that a mixed approach will bring in. The ways in which triangulation could be used as:

- Time as a source selecting case study with varying intervals of time & in different sectors of industry
- A different source of evidence resulting from various kinds of literature, surveying with a different perception of different people
- collaborating results from different research done in the past on the issue

- The different methodology used for different analysis
- Validating results from various methods of research

For this research, the author considered various case studies from a distinct time & distinct sector of the business interval as the primary method of analysis, while the survey method is adopted as a secondary method of research. The case study method will provide insight detail of the real causes of failure of the project. The questionnaire survey will generalize results from case study & professionals' perceptions on the problem &, in general, how can implementation of lean techniques helps in reducing the effect.

3.3 Research Procedure

A literature review was studied out for information gathering from web science, science direct databases to gain insight about the problem of delay & cost overruns. These were formulated by the identification of such cases in various countries stating issues related to various stakeholders of the project in the execution & tendering phase of the project. Based on results from the literature review, a questionnaire survey is floated for investigating the problem of delay & cost overruns & the general perception of professionals in the industry can issue be solved by implementation of lean tools like six sigma, 5S. These is followed by considering 3 case studies identifying root causes of delay & cost overruns in project & applying six sigma (DMAIC) cycle approach to minimize the risk on the project.

Comparing results from all research methods & generate a strategy to be followed using the DMAIC cycle of six sigma to overcome the issue for future projects. The proposed solution would result from each case study in controlling & improving respective projects & identifying the root causes of the problem. The research question in the study was to identify various factors causing delay & how lean tools can minimize the risk. To discuss this following sub-question were considered:

- Importance of such techniques on project delivery?
- How will such techniques help in increasing productivity, reduce cycle time for a process?
- How much Customer satisfaction & financial gains for a project?
- How much profitability for the project?

A descriptive approach for the research methodology discussed above is shown below in figure 10, for clear understanding.

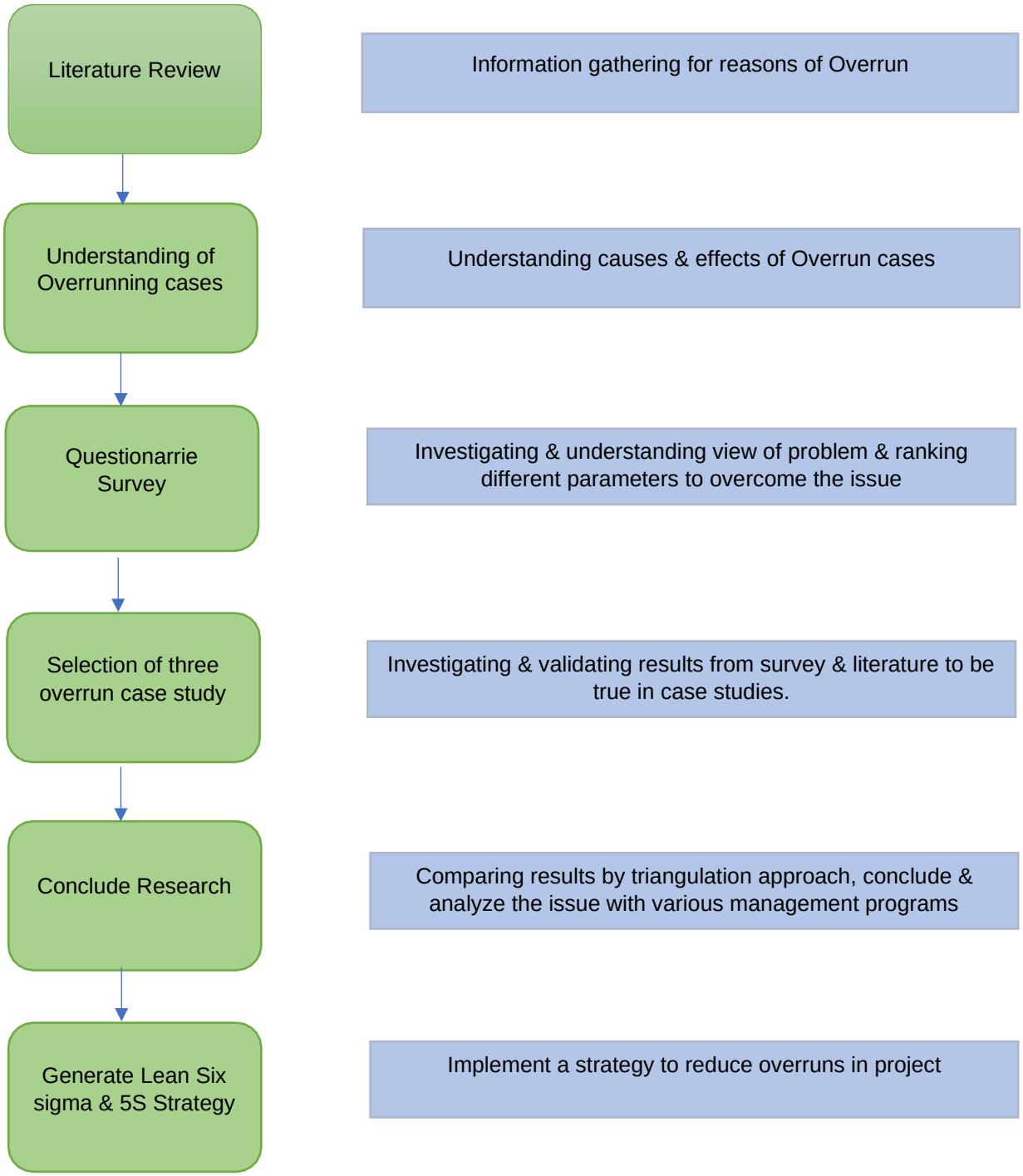


Figure 10: Research Procedure

3.4 Questionnaire Survey

After reviewing the literature, the author found out a survey method would be best in gathering views on hypothesis & data to be collected & to validate the objective of the research. Accordingly, the Questionnaire survey data tool is used for this study.

3.4.1 Strength & Weakness of Questionnaire

According to (Saunders et al., 2009), the strength of the survey approach lies in it can have a wide range of data of people's beliefs & perceptions to a research hypothesis. Accordingly, reliability & validity are two main criteria for a questionnaire to hold true. Also, pilot testing should be done before the distribution of the questionnaire to check the validity of the survey (Saunders et al., 2009). The questionnaire is piloted to 7 experience professionals who are a green belt in six sigma methodology, & accordingly, a question was added based on responses. The questionnaire was designed on a Likert scale of 6. The approach used in the questionnaire survey is descriptive statistics.

3.4.2 Reliability & Validity of Questionnaire

In this research, the survey was chosen as a method to find out perceptions of professionals in the industry on six sigma & 5S advantages for a project in reducing cost & time variable through a self-made questionnaire survey. According to (Saunders et al., 2009), surveys have been found out to be a valid data collection tool in scientific research methods to validate the hypothesis. Also, such data collection tools can reach out to large no. of people, thus collecting various information for research.

According to (Saunders et al., 2009), the importance of reliability and internal validity of a form was stressed as a legitimate tool that permits assembling information that measures the investigated ideas. Cronbach’s alpha is one in every of the popular and wide accepted methodology for activity; the internal reliability of responses to a collection of questions and a minimum internal consistency threshold of Cronbach’s alpha 0,7 is needed for reliable responses in the analysis. The validity of the questionnaire is done through content validity, according to the literature reviewed.

A sample test for reliability check is done with 7 participants, who were not part of the final survey conducted. The results of reliability with the SPSS tool is as presented in table.5. A result of 0,725 is achieved for the test, which satisfies the criteria 0,7.

Table 5: SPPS for reliability

Case Processing Summary

		N	%
Cases	Valid	7	100.0
	Excluded[a]	0	.0
	Total	7	100.0

.

Reliability Statistics

Cronbach's Alph[a]	Cronbach's Alpha Based on Standardized Items	N of Items
.725	.714	6

3.4.3 Population for Survey

The primary respondents in the survey had knowledge & experience in lean six sigma techniques. Authors' past working experience in which the majority of colleagues were Green belt in six -sigma were interviewed for the survey. Respondents were identified through professional networking sites. The group selected thus having prior knowledge of technique was chosen in the survey with people having a background of lean construction. A sample size of 80 is expected for investigation.

The questionnaire is divided into three categories. The first part enables us to know the necessary qualification, years of experience in the construction industry. The second part seeks to identify various causes of cost & delays in projects based on the experience of respondents. The third part of the questionnaire helps in identifying various programs & parameters which can reduce errors in construction, by adopting such tools in the construction organization.

3.4.4 Measurement of Variables

The views of respondents will be measured on a Likert scale of 6 for phase three of the questionnaire in identifying the parameters of the program. The 6-point Likert scale of a = very high, b = high, c = medium, d = low, e = very low, f = no answer is used for recording views of respondents.

3.4.5 Return Rate of Questionnaire

According to (Mellahi & Harris, 2016), return rate between 50 – 80 % for research to hold valid, with 55% has average to be considered as reasonable for research. The response rate for the survey is within the desired criteria limit, as already stated above. The response rate received during the survey was found to be 60, having a return rate of 75%.

3.5 Case Study Method

The case study research method validates in carrying in-depth investigation of root causes and possible failures that causes delay & cost overruns issue in a construction project. These methods are less concerned about phenomena but the actual cause of failure.

Accordingly, a holistic approach is observed in these research methods to magnify the issue & study of factors & how they interact. Detailed results from the case study will also help in providing a strategy that can be helpful for future projects.

According to (Fellows & Liu, 2015), the case study research method gives detailed knowledge & a clear understanding of an issue to be researched, gaining insight & ideas to validate the phenomena. Two case study selected are projects constructed by Mahindra Susten, EPC contractor with whom the author was part of both cases. Issues relating to all phases of analysis of delay & cost overruns were helpful, considering the expertise of EPC contractor & views of participants involved.

The strategy used in selecting the case study in which the following points were considered before choosing the cases:

- Selecting different & variant study which would give a clear understanding of the issue
- A typical case study in real estate & renewable sector to understand the defect

In regards, a total of 3 case study were considered each being different from each other in terms of field of use to get a better result:

- Case Study 1- M&M SBU Kanhe Project, India
- Case Study 2- 40 MWp Astra Solren, Charanka, India
- Case Study 3 – Nigerian Construction Project

Multiple case studies were used in this research to generalize the research result. It was used in the following three ways:

- By Predicting similar results across the case study
- Predicting contrary results across various studies
- cross-case comparison

3.6 Approach to triangulation method

Triangulation method is adopted in the research method with the following factors considered in research design:

- Different literatures reviewed for analyzing cost & delay overrun's effect in construction project
- Two separate research approach: Questionnaire survey describing general views of professionals on delay effect & whether lean tools can help minimize the risk on the project & case study
- Input results from one were compared to another research method with corresponding results from the case study & questionnaire

The results from the case study method helped in identifying the root causes of delays & how the team can overcome by applying lean tools. The questionnaire survey gave an insight into various issues related to delays in a project & to confirm results from the literature review & case study. The survey would be useful in the outcome of multiple shortcomings resulting from the general effects observed in the case study method of research.

3.7 Conclusion

The research adopted is mixed triangulation, with the case study as the main source of data analysis & Questionnaire survey using various data collection methods. All the data collection techniques with results from a case study & survey approach will be explained & stated in the next chapter.

4. Research Results

In this chapter, the author will summarize results based on the 3 Case Study & Questionnaire survey, which is carried out related to the application of the Six Sigma Methodology (DMAIC cycle) in various Construction projects. The study is chosen based on data available in different countries. The questionnaire survey helps in identifying perceptions of people on causes of delay & cost overruns.
This study helps in identifying how the lean six sigma (DMAIC) cycle can be applied on real projects & how control can be achieved in minimizing delays.

4.1 Introduction

The author in all 3-case study has applied the DMAIC cycle, which is explained below:

- **Define:** The author in this phase will define the project based on VOC & CTQ parameters; in these regards, the problem statement of study & desired goal to be achieved. Project Charter tool will be used in defining the project problems.
- **Measure:** The author in this phase will list all possible reasons for delays & cost overruns in the project based on data availability & identify the root cause of the problem. Various causes for delays will be listed down, having an impact on the project.
- **Analyze:** Based on results from reasons of delay, the author will carry out analysis of problem-based on Fish Borne diagram, 5Why Analysis tool, FMEA tool of analysis & giving solutions for better results by applying various lean techniques.
- **Improve:** The author in these phases will provide an Action plan with the 4W tool of improvement to propose solutions to the process & alternative process to overcome challenges.
- **Control:** The author will suggest various control processes that can be implemented during the project.

The application process of the DMAIC cycle is represented as below:

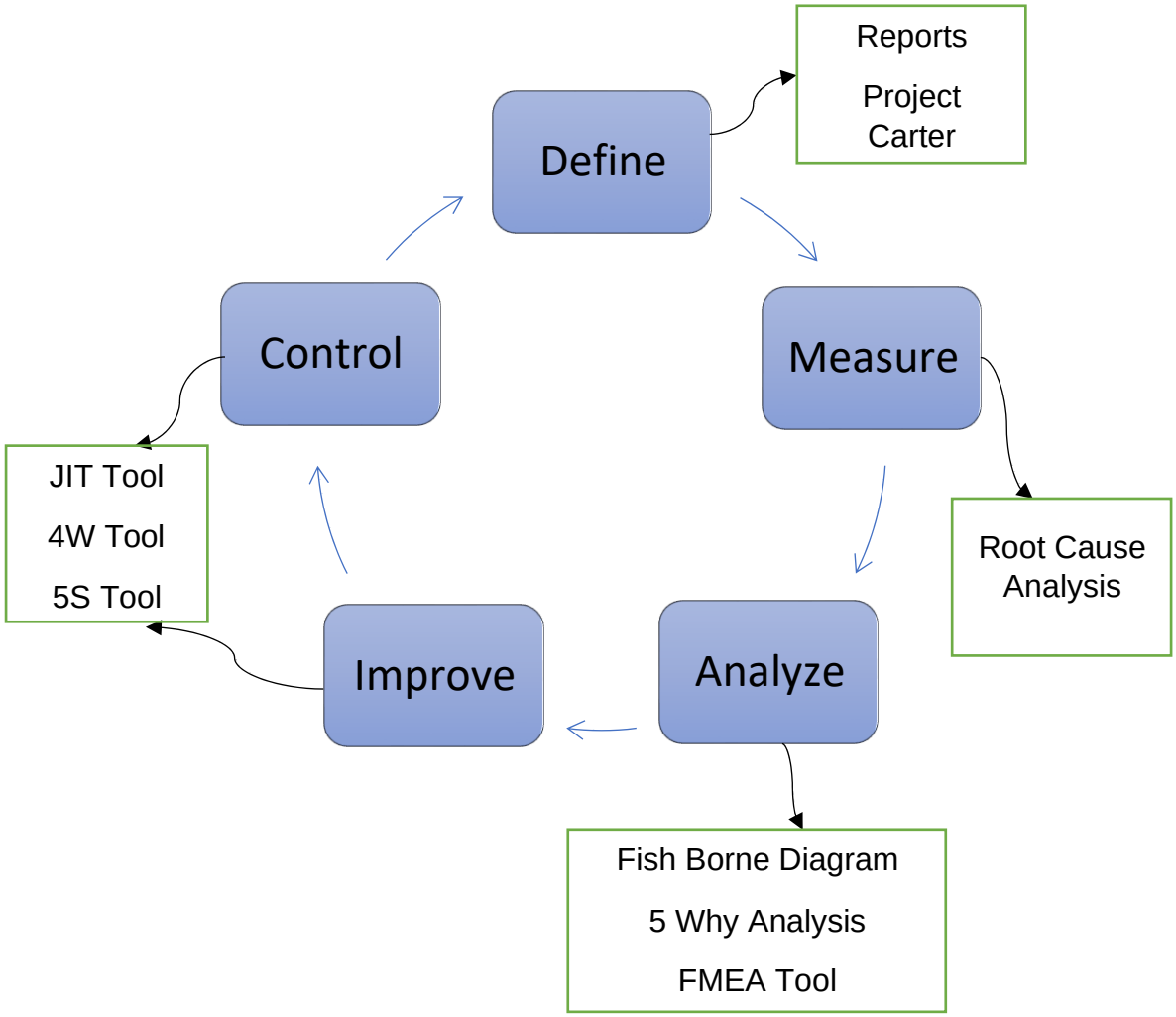


Figure 11: DMAIC Cycle Analysis with different Tools

4.2 Case Study 1: M&M SBU Kanhe Project, India

Project Description: The project consists of constructing a warehouse in Pune district, India. The warehouse is constructed to facilitate medicines manufacturing & includes various & heavy machines installed. During the initial investigation from the client, the surface soil found to be was murrom. Still, later in deep excavation, hard rock was encountered in the execution phase leading to changes in planning, resources, & overall leading to delay & cost overrun & still not completed from baseline scheduled completion date.

The scope of work for the project is as presented in figure 12.

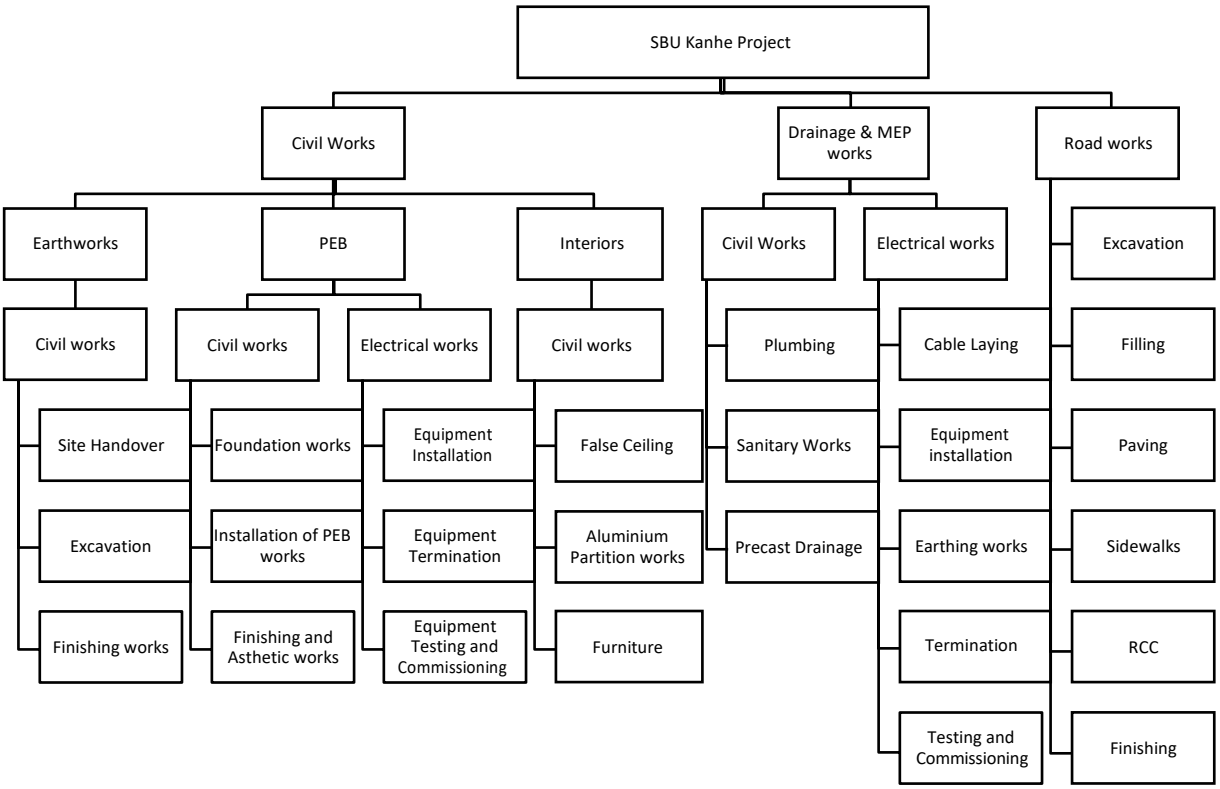


Figure 12: Scope of Work for case study 1

Project Contract Data: The following table 6 shows data for the project indicating Contract Information.

Table 6: Project Information Case Study 1

Total Contract (INR)	123 Million INR	1540078,17€
Final Amount (INR)	128 Million INR	1597502,13€
Cost Increase (%)	3.4%	
Project Start Date	30 July - 17	
Project Completion Date	01 June - 19	

Table 7: Project Details & Milestones

Task No.	Milestone	Baseline Start
	Project Commencement Date	30-07-17
1	LOI Issuance	30-07-17
2	Completion of Main Plant	05-08-17
3	PEB Works Delivery	10-10-17
4	Completion of FRC Flooring Works	7-04-18
5	Completion of Finishing Works	10-08-18
6	Completion of Utility boiler and Chillar building- L5	05-10-17
7	PEB Material Delivery for Utility	03-09-17
8	Finishing Work for Utility boiler and Chillar building	25-05-18
9	Block Work & Plastering (Peripheral)	15-10-17
10	Completion of Utility substation Building- L5 Schedule	29-07-18
11	Completion of Veg Processing Plant- L5 Schedule	03-01-18
12	PEB Material Delivery for Processing Plant	13-5-18
13	Finishing Work for Processing Plant	18-8-18
14	Punch Points Clearance	25-05-19
15	Project Completion Date	01-06-19

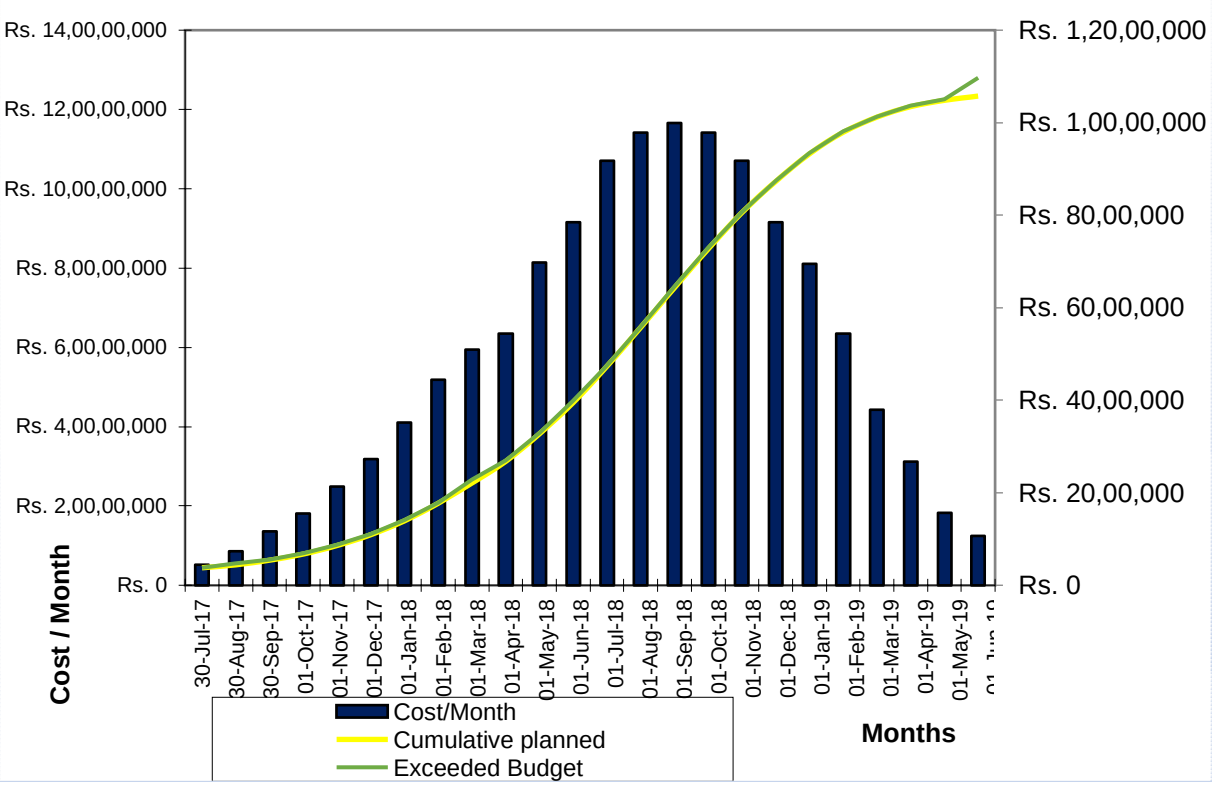


Figure 13 : Cost S- Curve, Source : (Planning Department, 2019)

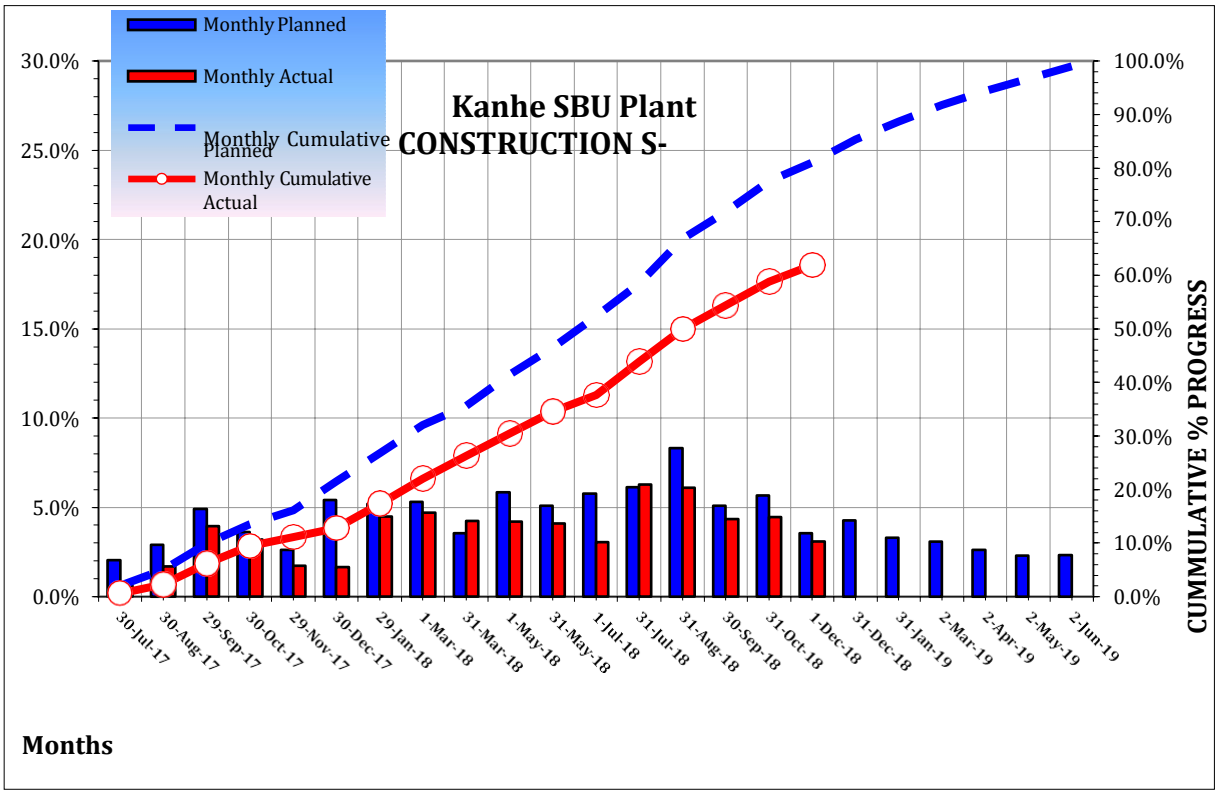
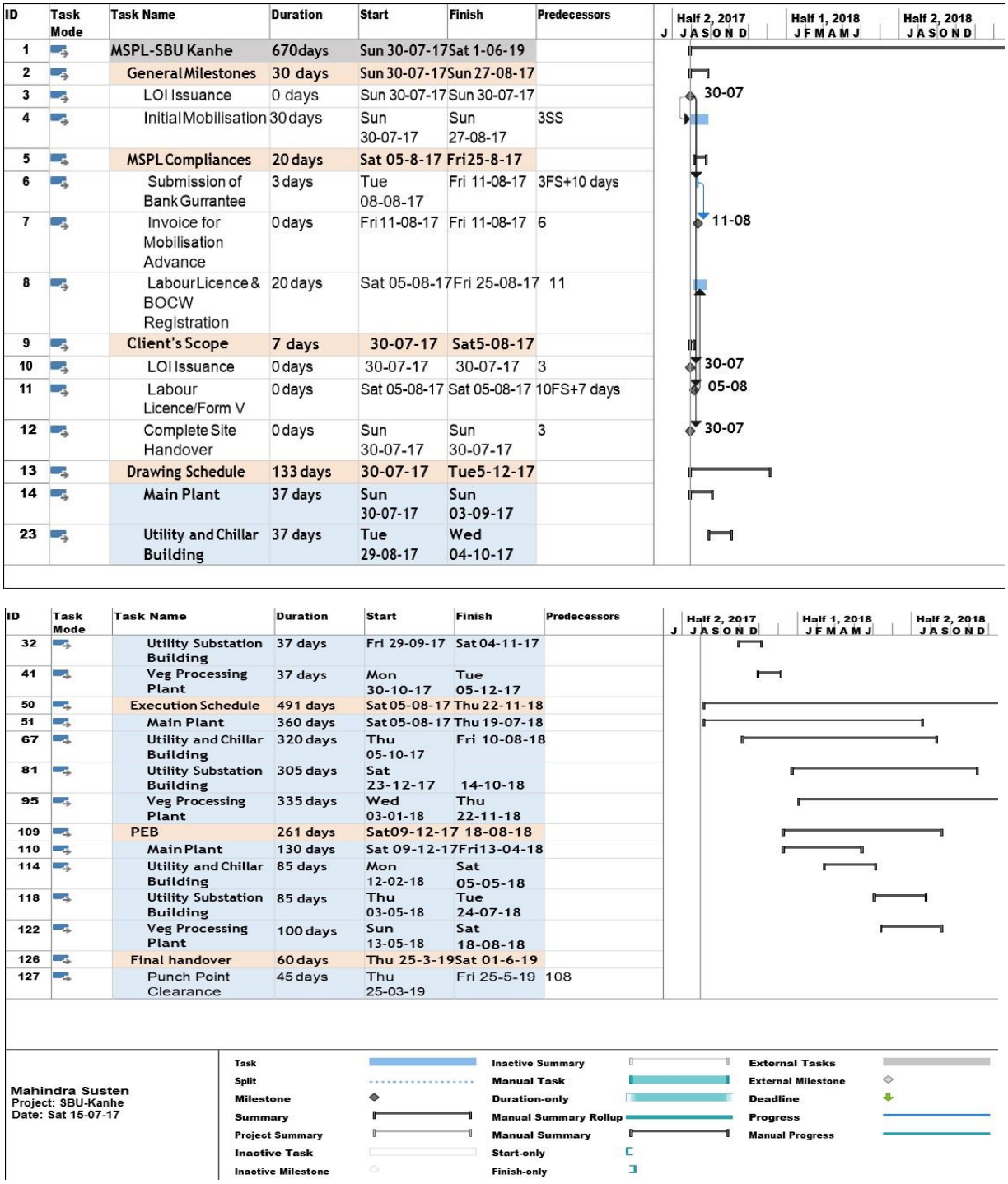


Figure 14: Schedule S- Curve, Source: (Planning Department, 2018)



ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		MSPL-SBU Kanhe	670days	Sun 30-07-17	Sat 1-06-19	
2		General Milestones	30 days	Sun 30-07-17	Sun 27-08-17	
3		LOI Issuance	0 days	Sun 30-07-17	Sun 30-07-17	
4		Initial Mobilisation	30 days	Sun 30-07-17	Sun 27-08-17	3SS
5		MSPL Compliances	20 days	Sat 05-8-17	Fri 25-8-17	
6		Submission of Bank Gurrantee	3 days	Tue 08-08-17	Fri 11-08-17	3FS+10 days
7		Invoice for Mobilisation Advance	0 days	Fri 11-08-17	Fri 11-08-17	6
8		Labour Licence & BOCW Registration	20 days	Sat 05-08-17	Fri 25-08-17	11
9		Client's Scope	7 days	30-07-17	Sat 5-08-17	
10		LOI Issuance	0 days	30-07-17	30-07-17	3
11		Labour Licence/Form V	0 days	Sat 05-08-17	Sat 05-08-17	10FS+7 days
12		Complete Site Handover	0 days	Sun 30-07-17	Sun 30-07-17	3
13		Drawing Schedule	133 days	30-07-17	Tue 5-12-17	
14		Main Plant	37 days	Sun 30-07-17	Sun 03-09-17	
23		Utility and Chillar Building	37 days	Tue 29-08-17	Wed 04-10-17	

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
32		Utility Substation Building	37 days	Fri 29-09-17	Sat 04-11-17	
41		Veg Processing Plant	37 days	Mon 30-10-17	Tue 05-12-17	
50		Execution Schedule	491 days	Sat 05-08-17	Thu 22-11-18	
51		Main Plant	360 days	Sat 05-08-17	Thu 19-07-18	
67		Utility and Chillar Building	320 days	Thu 05-10-17	Fri 10-08-18	
81		Utility Substation Building	305 days	Sat 23-12-17	14-10-18	
95		Veg Processing Plant	335 days	Wed 03-01-18	Thu 22-11-18	
109		PEB	261 days	Sat 09-12-17	18-08-18	
110		Main Plant	130 days	Sat 09-12-17	Fri 13-04-18	
114		Utility and Chillar Building	85 days	Mon 12-02-18	Sat 05-05-18	
118		Utility Substation Building	85 days	Thu 03-05-18	Tue 24-07-18	
122		Veg Processing Plant	100 days	Sun 13-05-18	Sat 18-08-18	
126		Final handover	60 days	Thu 25-3-19	Sat 01-6-19	
127		Punch Point Clearance	45 days	Thu 25-03-19	Fri 25-5-19	108

Figure 15: MS project schedule L3 for Case study 1, Source: (Planning Department, 2017)

Documentary evidence, data analysis to the client, checklist regarding delays & subsequent cost overruns, as seen in fig 13,14 & 15, in the project was used in identifying various reasons for root causes for a project delay. Six- Sigma approach is as implemented by the author for detailed analysis & implementing control measures. L5 MS project schedule for the delay observed is attached in Annexure A.

- **Define:** The problem defined by the author, in this case, is through project charter, which facilitates a common problem identified during the project, estimating a possible solution for future projects. These sets as a common goal for the entire team & facilitates project execution. The Project Charter is described in table 8.

Table 8: Project Charter for case study 1

Project Name: SBU Kanhe
Problem Statement: Poor Site practices leading to Cost & Delay
Goal Statement: Analyzing various factors for future Projects

- **Measure:** Based on documentary data, CTQ measure checklist, the author identified the major root cause for the delay observed in the project based on the author being part of the project in the initial phase & interviews with stakeholders involved. Based on the above data author categorizes the root causes in 5 main fields, namely Tendering issues, Drawings & specification clarity from the client, Planning contractor side, Quality issues from contractor & Execution errors. Table.9 presents various root causes observed in the project.

Table 9: Root Cause Analysis for case study 1

Description	Reason for Delay & Cost Overruns
Data Availability from Client/ Tendering Issues	• During Tendering, Initial surface as normal murrum, but during execution, Rock was encountered. • No Drawings Provided for Electrical Layout • Temporary Pad Construction, No consideration in Tendering stage • Last-Minute Changes / Scope changes

Drawings & Specifications	• Late Approval • Revision of IFCs Drawing • Design Errors • Missed co-ordination of Drawing No & approved IFC during Construction
Planning	• Wrong Estimate of Time as given by Client • Co-ordination issue between different contractors • Late Time Delivery of Materials • Payment issues
Quality	• No SOPs for a process • No proper training before the start of the activity • Checklist not followed • Improper Storage of materials at the site
Execution	• Labour Shortage • Unskilled Workers • Safety Issues • Strikes

- **Analyze:** Based on identified root causes of the problem of delay, the author in these section by Fish Borne diagram explains various sub-clause reasons for delays. These help in identifying sustainable improvement for more extended benefits. It helps to visualize possible relationships between causes for any problem in the current or future. Fish Borne diagram for possible causes of failure for the case study is as described in figure 16.

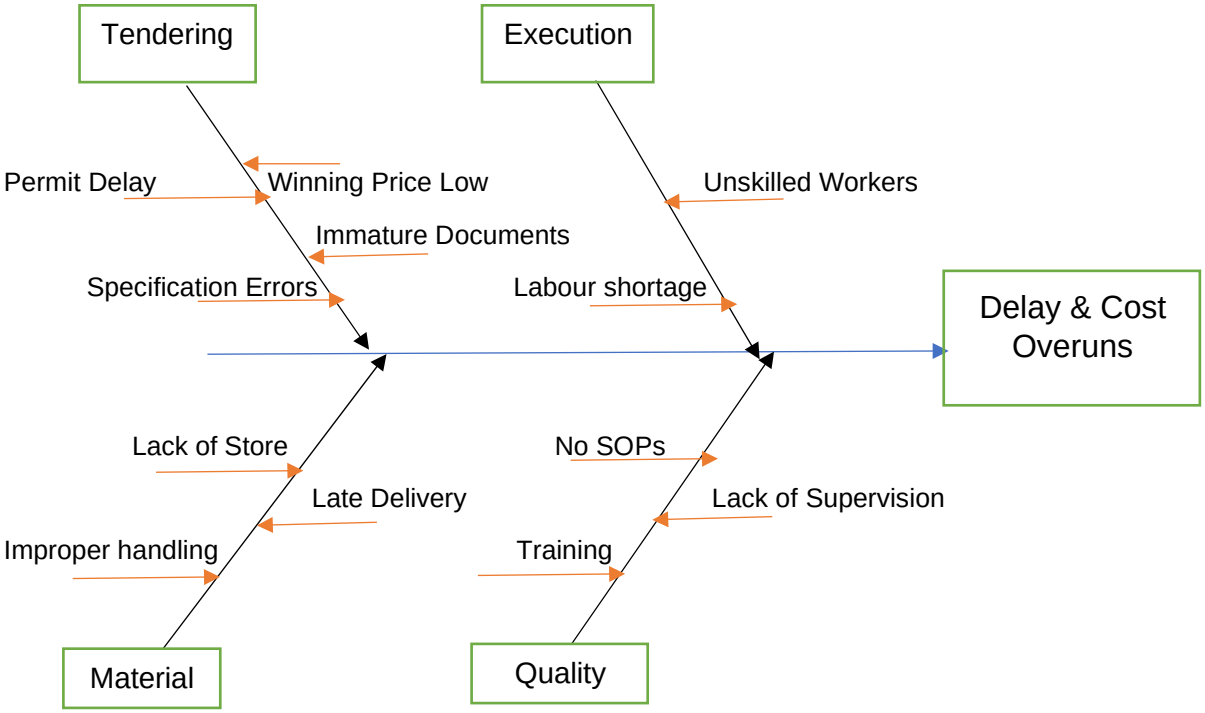


Figure 16: Fish Borne Diagram for case study 1

FMEA (Failure Mode & Effect Analysis): In the Analyze phase, a potential cause for failure modes give us X or KPIV (Key Process Input Variable). The process is to identify the failure mode, which would result in underperformance of CTQ. The author identifies all the failure causes for prioritization & suggests corrective action for further action. FMEA process is as presented by the author in table 10.

Table 10: FMEA for case study 1

Process	Failure Mode	Effect of Failure	Potential Cause	Corrective Action
Unskilled Worker	Lack of Training	Poor Construction	Lack of skilled workers	Development of Quality Team & Proper Knowledge Management System
Improper Storage	No storage	Material Loss	IMS Policy not followed	5S system
Incorrect Specifications	Low price by client	Inefficient selection of the contractor	Technical staff	Specifying Proper T&C in contract
Procurement	Late Delivery	Delay Overrun	Lack of Planning	JIT method

- **Improve:** In this phase, the data analysis during the previous period gives an action plan (What) to be done to avoid such errors. It is carried out by following the 4W tool:

- When does the problem occur?
- Where does the problem occur?
- Who is involved when a problem occurs?

The author list down the following techniques what can be implemented for various reasons for delays observed in table 9:

Table 11: 4W Tool for case study 1

Action Plan (What)	Who	When (Timeline)	Where
Inclusion of Quality SOP manual for construction	Quality Team (QA/QC)	Before Project Commencement	During Project Initiation
5S Tool	Project Manager	During Execution	Throughout the Project
JIT	Procurement Manager	During Contract with contractors	Material Delivery
Proper Scheduling	Project Manager	Before Project Commencement	Throughout Project

- **Control**: The author suggests the following operations for better control of the project.

- Standard Operating Procedures (SOP) for each process to have better quality achievements
- Continuous Education, Awareness & Training
- Documentation of Improvements
- Integrating Improvements to Quality Systems
- Periodic Knowledge sharing sessions, job orientation, ramp up plans
- Six Sigma team needs to carry out surprise checks/ audits to know the exact status of continuous implementations.

4.3 Case Study 2: Solar Plant - 40 MWp, Astra Solren, India

This case study is based on constructing a solar plant of 40Mwp Astra Solren in Gujarat, India. The scope of work includes constructing & monitoring Powerplant with both civil & electrical considerations for the project. The case study will show why did the project slipped from the original planned schedule & reasons for delays & cost overruns identifying root causes by Minutes of meetings, Documentary analysis & author being part of the execution process during the project. The scope of work is as presented in figure 17.

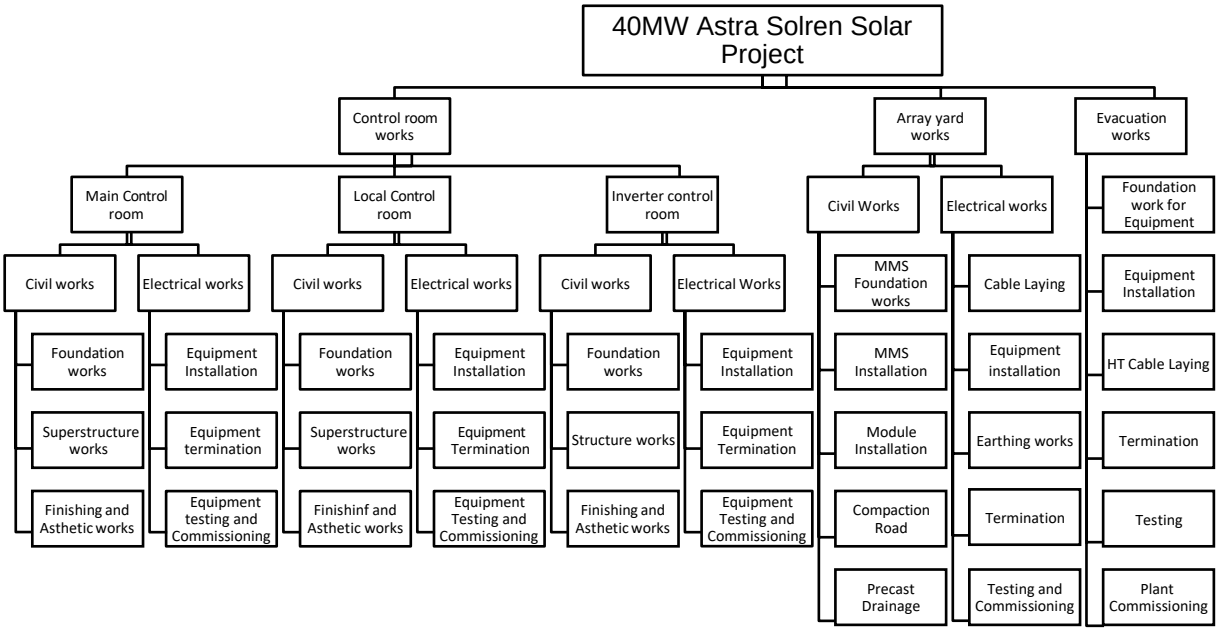


Figure 17: Scope of work for case study 2

Contract Data Information: The data information for the project is as presented in table 12.

Table 12: Contract Information for case study 2

Total Contract (INR)	60 Million INR	747282,41€
Final Amount (INR)	64 Million INR	797186,74€
Cost Increase (%)	3%	
Planned Completion Date	30th Nov-2016	
Actual Completion Date	10 Jan-2017	
Delays (Days)	40 days	

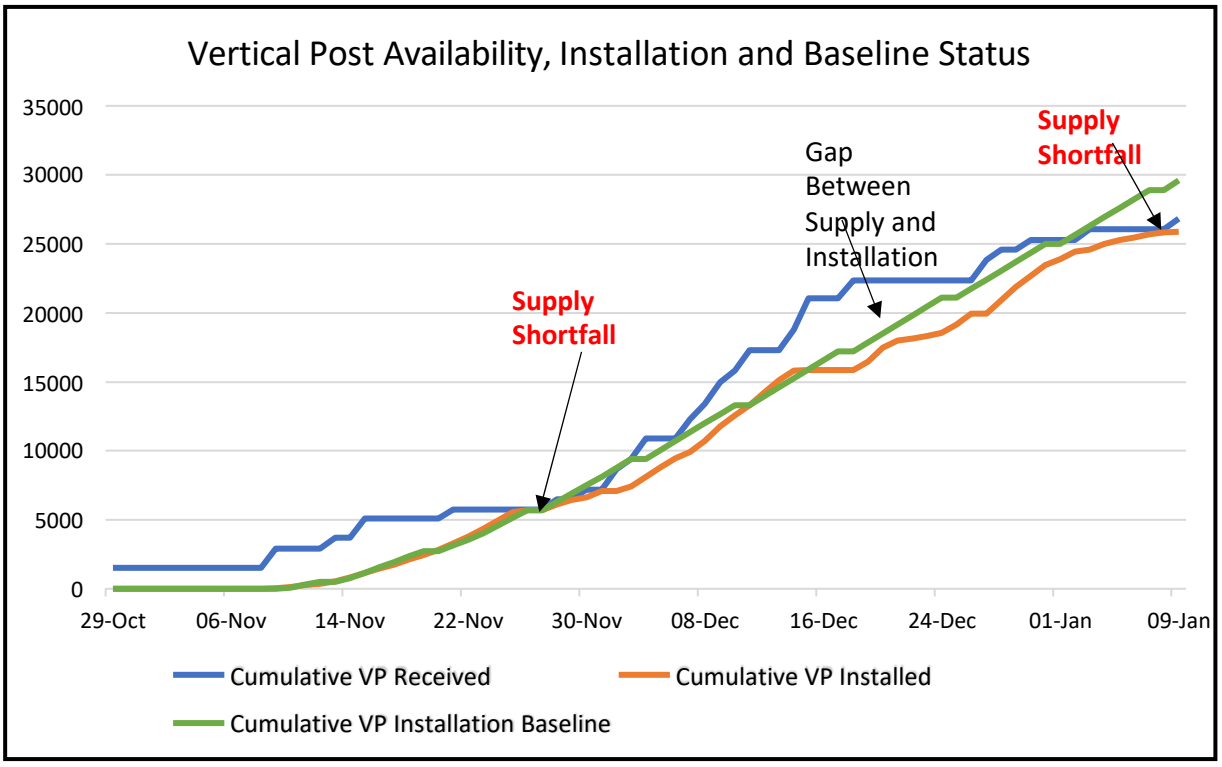


Figure 18: Delay due to shortfall & process from baseline, Source: (Ghule, 2017)

Based on the information & data in Appendix B, significant delay leading to project was a process piling & supply of Vertical post as presented in figure 18, & thus author implies six-sigma methodology on the process, identifying root causes due to various reasons & suggesting improvement & control measures. The author will discuss the entire productive improvement process in the Discussion chapter under Process Improvement.

Six – Sigma DMAIC cycle is as implied by the author as described below:

- **Define:** The project charter for the case study is as described below. The major issue for the delay in the project is low productivity in the Pilling process. The author, in these cases, wants to improve the process leading to delay through Six-Sigma methodology.

Table 13: Project Charter for case study 2

Project Name: 40 MWp Astra Solren, Charanka, India
Problem Statement: Low Productivity & Material delay leading to Cost & Delay
Goal Statement: Analyzing various factors for future Projects for process Improvement

- **Measure:** Based on documentary evidence, the author who was part of the project has identified significant reasons for delays in cost & time for the project. The major issues observed by the author during the study were client issues, site issues, electrical, process improvement, procurement. The root causes are identified in table 14.

Table 14: Root Cause Analysis for case study 2

Description	Reason for Delay & Cost Overruns
Client Issues	• Delay in Land Handover • Delay in regulatory approvals • Delay in Decision Making • Last-Minute Changes • Ineffective Planning Strategy

Site Management	• Scope Changes Frequently • Geological Surprises • Design Errors • Unavailability of Fund • Disputes between contractors
Electrical Issues	• Workfront availability • Design issues, falling of Pile pad with Electrical Cable laying • Late Time Delivery of Inverters & Transformers
Procurement	• Weak Procurement Planning • Material Price rise beyond imagination • Improper Storage of materials at the site
Process Improvement	• Poor Selection of Technology/ Working Method • Unskilled Workers • No process defined

- **Analyze:** The author in this section analyzes the delay in the piling process through 5Why analysis. 5WHY analysis was carried out by the author to get the main cause after each process. During the last phase of analysis, it was noted that no SOP was defined between stakeholders, which leads to Quality issues. For this reason, creations of the proper knowledge management system should be implemented before the execution process. The process is shown in table 15.

Table 15: 5Why Analysis for case study 2

	5 Why Analysis for Delay in Pilling Process
Why -1 Why is there low productivity/ Delay in Piling process	Due to Lack of Material Availability
Why-2 Lack of Material Availability	Because of No proper Procurement Planning during Schedule Preparation
Why -3 No proper Procurement Planning during Schedule Preparation	No SOPs defined for identifying Good vendors
Why-4 No SOPs defined for identifying Good vendors	Proper Knowledge Data Base Management System identifying Stakeholders
Why-5 No Proper Knowledge Data Base Management System identifying Stakeholders	Knowledgebase Management system must be set up for avoiding delays & selection of skill contractors

- **Improve:** The author recommends the following suggestion for improving a process for the delay in the future if there are delays observed.

- Improvement of Construction Processes wrt designed SOP
- Proper Specification document availability from Client
- Proper Contractor selection by creating Knowledge Data based on Past experiences & reviews
- Frequent Audits
- Establishment of 5S tools for material handling & to avoid loss of materials
- Regular Evaluation of Project with all stakeholders
- Proper Allocation of Cash flow at definite stages to have the availability of Funds during various stages of construction

- **Control:** Following control measures can be set up for future projects to avoid such issues:

- Establishment of QMS plans
- Benchmarking of Process must be maintained
- Establishment of Productivity improvement techniques

4.4 Case Study 3: Nigerian Construction Projects

The case study was conducted by (Mansfield et al., 1994) on various Nigerian construction projects. The researcher states multiple reasons for the cause of delay & cost overruns by the questionnaire survey method by taking perceptions of around 50 personnel, including contractors, clients & consultants. The major drawback resulting from the analysis found by the researcher was better defining of contract period due to miscommunication between various stakeholders, poor site management practices, material delivery & loss of materials, improper planning, inflation.

Contract Information: Below Project data shows the duration of the project, % of work completed & lapse from decided contract period & relative expenditure till the time of the report.

Table 16: Contract Information for case study 3, adapted from (Mansfield et al., 1994)

Contract Code	Duration (Months)	% of work complete	Lapses from the contract (%)	Expenditure till date (%)
1	12	76.84	141.67	79.25
2	23	65.08	97.83	65.92
3	12	80.56	91.67	86.11
4	24	97.36	126.92	90.64
5	27	100.00	106.20	100.26
6	30	100.00	175.00	91.05
7	15	94.00	120.00	92.87
8	28	93.79	100.00	74.03
9	7	99.00	342.00	76.87

As seen from project information, the delay overruns in one case is as high as 342% & expenditures have crossed the set budget, while projects are still not completed. These effects can be due to various reasons & have been identified by root cause analysis carried by the author in the DMAIC phase.

Based on this, the author by applying DMAIC Cycle of six -sigma, defines, measures & suggest suitable control measures for delay & cost effects.

- **Define:** The author presents the project charter for the case study in table 17.

Table 17: Project Charter for case study 3

Project Name: Nigerian Construction Project
Problem Statement: Factors leading to Cost & Delay
Goal Statement: Analyzing various factors for future Projects for process Improvement

- **Measure:** The author in these sections identifies the various root cause for delays in multiple projects. Based on the table.18, presents significant root causes for the project.

Table 18: Root Cause Analysis for case study 3

Description	Reason for Delay & Cost Overruns
Poor Contract Management	• Subcontractors & Suppliers selection • Design Changes • Negotiations in contract Management • Nonadherence to Contract Conditions • Changes in the contract period • Communication errors • Undefined quality standards
Site Management	• Changes in site conditions • Construction errors • Quality issue / No proper inspection • Construction Method • ill practices • Poor technology
Financing & Payment	• Price fluctuations • Inaccurate Estimates of scheduling • Insurances • Un-availability of Fund

Procurement	• Shortage of Material • Material delays • Improper Storage of materials

- **Analyze:** The author in this section explain various causes of failure by fish-borne diagram & FMEA diagram. It helps to visualize possible relationships between causes for any problem in the current or future. Fish Borne diagram for possible causes of failure for the case study is as described in figure 19. The author identifies all the failure causes for prioritization & suggests corrective action for further action. FMEA process is as presented by the author in table 19.

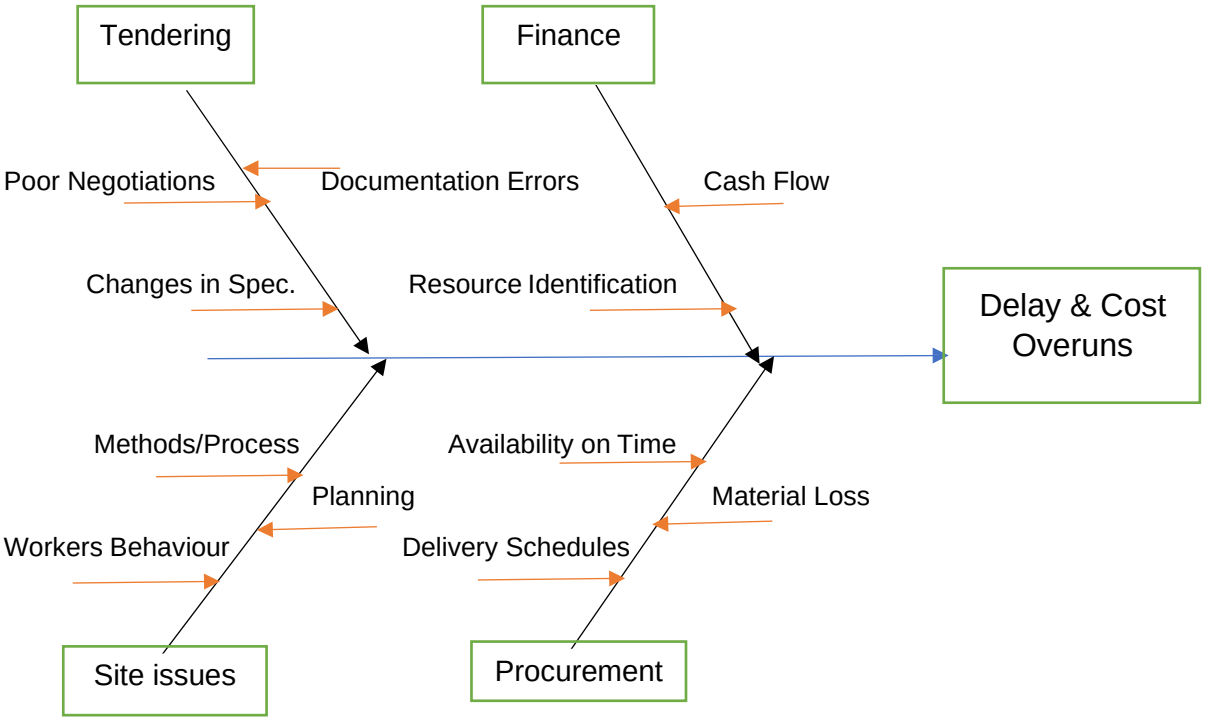


Figure 19: Fish Borne Diagram for case study 3

Table 19: FMEA Analysis for case study 3

Process	Failure Mode	Effect of Failure	Potential Cause	Corrective Action
Planning	Documentation requirement not properly identified	More Time spent on document creation	Standard Format not available	Creation of Knowledge Management system
Resources assessment	Inadequate Manpower	Delay in completion of the process	Poor Resource & Productivity rates calculation	Resource Planning
Material Loss	In the application of modern techniques	Loss in Time & Increase Cost	No proper storage area defined	5S Tool
Construction Method	Quality issues	Delay Overrun	Lack of standard & modernization	Process Improvement Technique
Document Specifications	Low price by client	Inefficient selection of a contractor	Technical staff	Knowledge Management

- **Improve:** In this section, the author, according to the 4W tool, identify an action plan for the project to avoid delays & cost overruns. Table 20 presents an action plan suggested by the author.

Table 20: 4W Tool for case study 3

Action Plan (What)	Who	When (Timeline)	Where
Knowledge Document Management	Planning Team	Before Project Commencement	During Project Initiation
5S Tool	Project Manager	During Execution	Throughout the Project
JIT	Procurement Manager	During Contract with contractors	Material Delivery
Process Improvement	Six Sigma Team	Before Project Commencement	Throughout Project

- **Control:**

- Six sigma team to monitor the processes
- Proper Training to Workers / Staff.
- Improvements to be monitored & Controlled by Qa/Qc Team.

4.5 Questionnaire Data Analysis

4.5.1 Introduction

This section presents data analysis from the questionnaire survey. The results of survey were used to obtain views, beliefs of respondents regarding causes of delays & cost overruns & identifying CSF for hypothesis that higher implementation of six-sigma & 5S practices higher the quality of the process, higher customer satisfaction, higher process improvement for increasing productivity to hold & validate the literature review & case study. The questionnaire & results for the entire questionnaire is graphically presented, which obtained from google forms is presented in appendix C part of the thesis. The tabulation results are as shown below:

4.5.2 Respondents

The below table 21 & 22 shows the participants involved & their respective specialization & years of experience in the construction industry. From results, the significant groups identified were construction manager, project managers, senior management position having experience of 3-20 years in the construction industry.

Table 21: Respondents data

Category	Frequency	Percent (%)
Civil Engineer	20	33,3
Architect	4	6,7
Construction Manager	16	26,6
Project Manager	16	26,6
Senior Management Position	4	6,7

Table 22: Years of experience in Industry

Years of experience in construction	Frequency	Percent (%)
Up to 3 years	9	15,0
3-10 years	42	70,0
10-20 years	9	15

4.5.3 Performance of Project

According to results for performance, majorly 7 out of 10 projects have cost & time overruns in a project due to various factors described in next section & 74% of respondents identified that problem has not been solved & is presented below & need for support the literature by (Ramanathan et al., 2012) for implementing a quality tool to improve the process of construction.

Table 23: Performance of project data

Question	Frequency	Mean	Std. Deviation
According to you, how many projects have the issue of delay on a scale of 10	60	7,1	2,9

Table 24: Problem Responses

Question	Frequency	Yes	No	Not sure	No (%)
Has the problem been solved?	60	12	44	4	74 %

4.5.4 Causes of Cost & Delay in projects

The results for the major phase in which the issue been observed are Project management & construction, as stated in literature by (J. H. L. Chan et al., 2011) & various causes by respondents are presented below by cause map for various stages of the project.

Table 25: Data for causes in project phases

Phases	Frequency	Percent (%)
Inception	3	5,0
Tendering	12	20,0
Project Management & construction	40	66,7
Others	5	8,3

Various causes of effects were recorded & grouped into major categories as presented below in cause map.

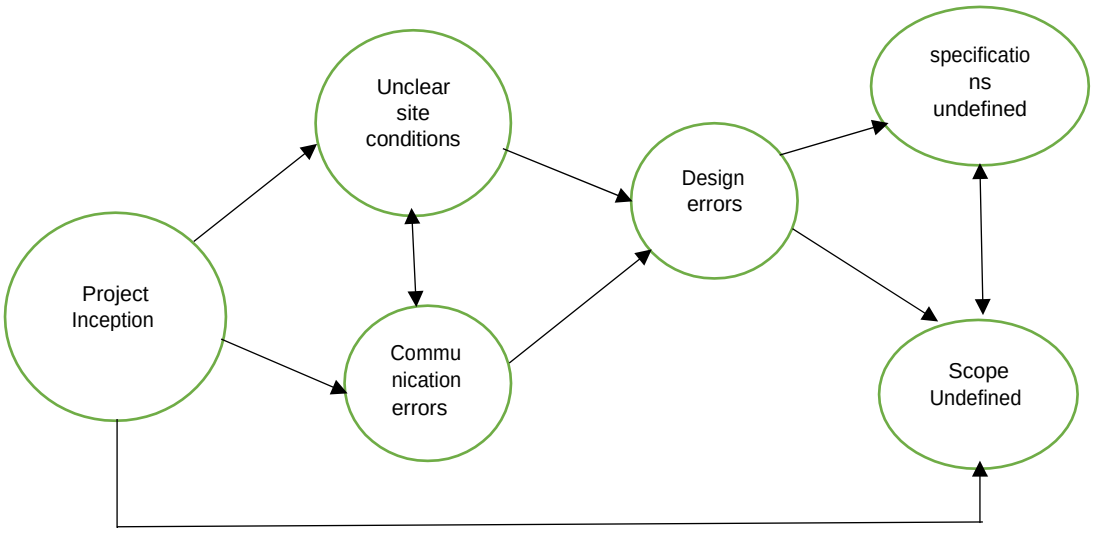


Figure 20: Causes at Inception

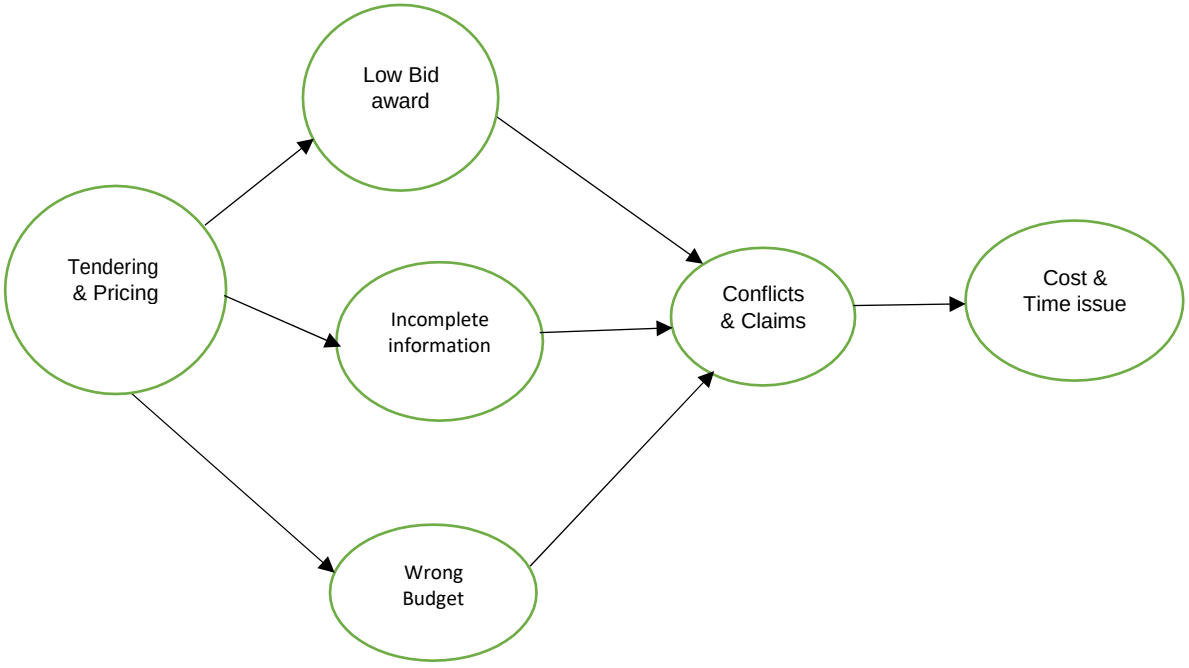


Figure 21: Causes at Tendering stage

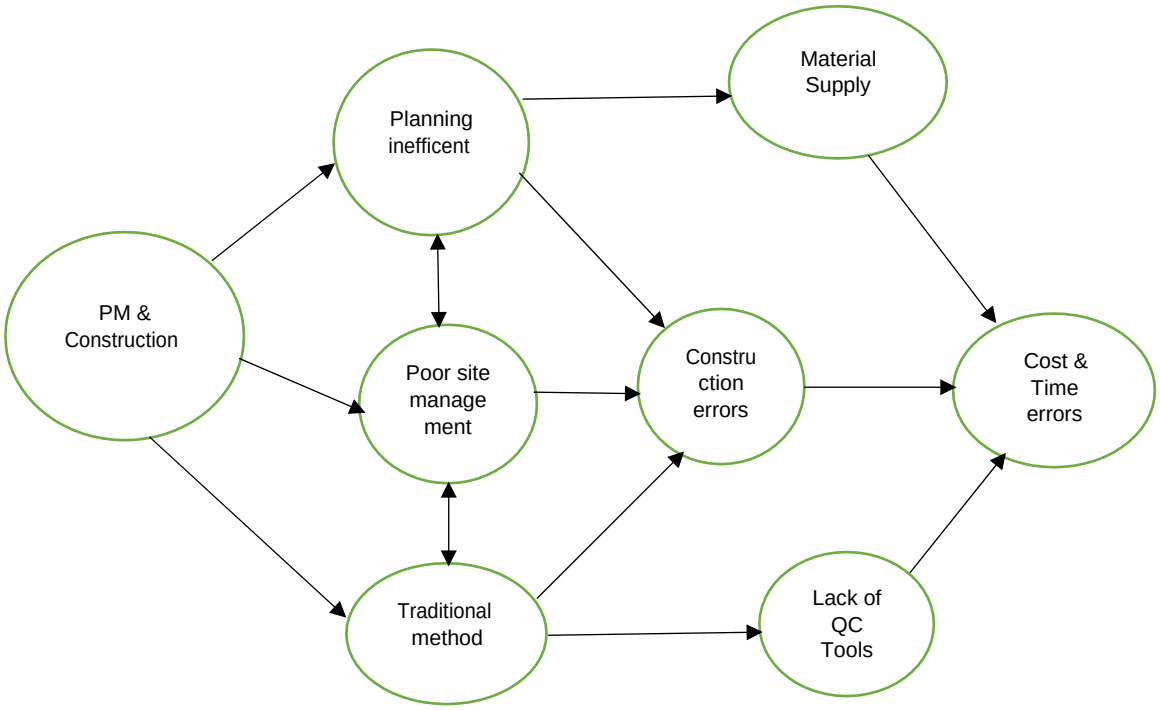


Figure 22: Causes in PM & Construction phase

The major causes in view of respondents were recorded & in light of earlier case study & documentary review studied, a significant cause in various phases were identified & cross-compared to validate the results. Major drawbacks observed were in the construction phase of the project; hence a strategy or tool to be used should be adopted to reduce errors in construction.

4.5.5 Waste in construction

According to respondents & (Oguntona et al., 2019), the significant waste in construction is waste resulting from rework due to various causes. The data results are as presented below:

Table 26: Waste in construction in view of respondents

Waste	Frequency	Percent (%)
Waste from rework	42	70,0
Waste from waiting	31	51,7
Waste from inventory	21	35,0
All the above	1	1,7

4.5.6 Use of Lean Sigma & 5S in construction

According to the results of the survey, implementation of lean six sigma & 5S in construction will help minimize rework & sub-sequent cost & delay impacts. From a sample of 60, around 90,0 % stated for implementation of such tools in construction & these support our literature study by (Kwak & Anbari, 2006).

Table 27: Implementation of lean six -sigma & 5S

Will implementation of six - sigma & 5S help in reducing cost & delay	Frequency	Percent (%)
Yes	54	90,0
No	6	10,0

4.5.7 CSF for lean sigma & 5S

In view of the research question, to achieve a relationship between various lean tools used in & the previous hypothesis stated, CSF factors & listing them in the manner it improves construction process for overcoming the issue, it was important to identify & rank them in responses received.

According to (Saunders et al., 2009), essential data collection tool for the hypothesis to be true is as presented in the below table:

Table 28: Data Collection table

Research Objective: Examining the relation between lean parameters			
Type of research: Descriptive identifying various programs for CSF of implementation of six sigma & 5S			
Investigate Question	Variables	Data Measured	Check Measurement
Will implementation improve the process	Behavior of participants	6 Likert scale	Data Statistics

Table 29: CSF for implementation of techniques

Parameter	Various program	Mean	Std. Deviation	Rank
Implementation of six sigma & 5S in construction organization	Increase Productivity	2,20	0,7983	1
	Planning efficiency	3,033	0,901	5
	Quality increase	2,220	0,8039	2
	Customer Satisfaction	2,5667	1,11	4
	Cost Reduction	2,433	1,12	3
	Communication	3,4167	0,8495	6

The approach used here is descriptive statistics; the analysis is carried out by SPSS data analysis software. Mean & standard deviation is used to interpret results from the survey. A 6-point Likert scale was used for analysis with 1 is Very High & 5 is Very Low, 6 is no answer from respondents. Mean & standard deviation was calculated for each result & mean value near to 2, indicates the use of programs by participants, knowledge of six sigma & 5S & way in which implementation is useful to construction organization. The ranking of parameters is given based on the order of results achieved.

From, results of the survey, the hypothesis & study by (Pheng & Hui, 2004) & (Ansah, Sorooshian , Mustafa , & Duvvuru , 2016) that implementation of such tools helps in increasing productivity, quality satisfaction & balance cost & delay impacts of project & hypothesis holds true. The statistics data for SPSS is presented in the appendix part C of the thesis.

Accordingly, F-test is used for comparing two levels of KPIV. If the p-value is less than 0.05, the KPOV variation is statistically significant at two chosen levels of KPIV. It helps to find in which KPIV level induces high variations and hence vital for process improvements.

Table 30: Descriptive Statistics for F-Test

Variable	N	StDev	Variance	95% CI for σ
Productivity	60	0.790	1.033	(0.849, 1.100)
Quality	60	0.804	0.468	(0.466, 1.037)

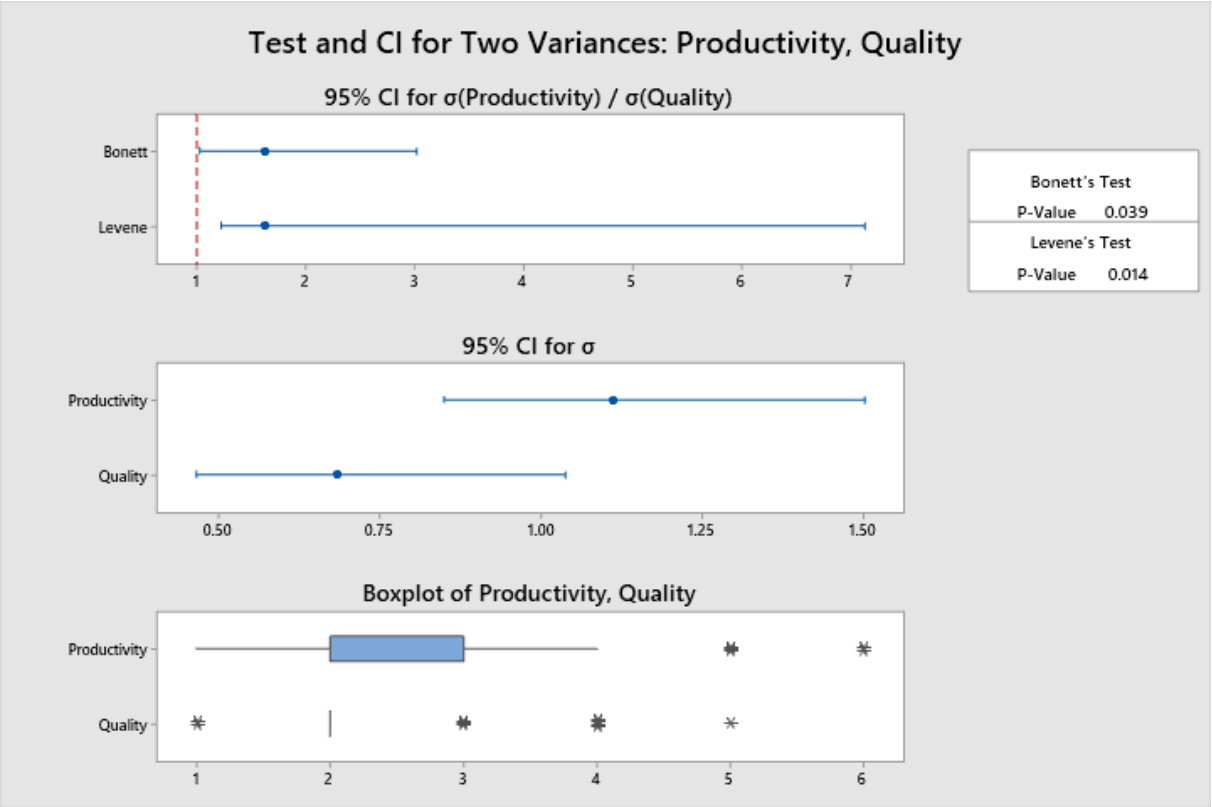


Figure 23: Test of variance for Productivity & Quality

Table 31: F- Test for Data Variations

Null hypothesis	$H_0: \sigma_1 / \sigma_2 = 1$
Alternative hypothesis	$H_1: \sigma_1 / \sigma_2 \neq 1$
Significance level	$\alpha = 0.05$

Method	Test Statistic	DF1	DF2	P-Value
Bonett	4.28	1		0.039
Levene	6.22	1	118	0.014

Analysis of F-test data shows that p<0,05 & hence the variation in data for productivity, quality is significant. Productivity has a higher impact & vital for process improvements by the implementation of lean tools in construction.

4.5.8 Conclusion

The results of the questionnaire survey indicated that the issue of cost & delay impact has not yet been resolved due to various factors & implementation of proper lean tools with defined parameters of quality, process improvement, customer satisfaction can be achieved by adopting such programs in the industry.

4.6 Results from Case Study & Questionnaire Survey

The cross-case study comparison from all 3-case studies & survey analysis below shows the major reason for cost & delay overruns in a construction project. Various factors influencing the delay in the project are summarized below. Most of the delays observed from the case study are grouped due to the following factors:

- Process Inefficiency
- In-efficient Planning
- Site Management issues
- No Quality Parameters defined (Qa/Qc) measures
- Procurement / Logistics issues
- No control on Documents & Knowledge sharing between different Stakeholders
- Contract errors

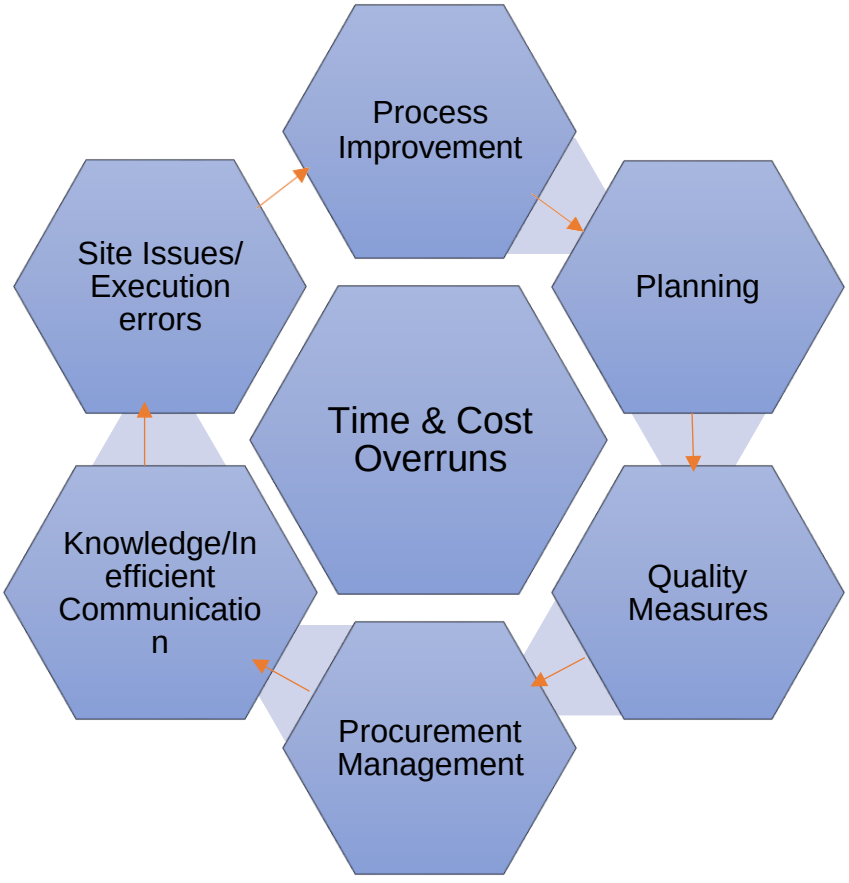


Figure 24: Results from the case study & Questionnaire

4.7 Conclusion & Implication for Projects

Results from various case studies show the reasons & effects of cost & delay overruns are similar across different construction projects. Most delays in the construction project are observed during the construction phase. With the help of a case study, implementation of the six sigma DMAIC cycle with various tools can help in maintaining the delay risk within the limit.

However, certain drawbacks can be observed while applying specific techniques. The drawbacks areas are listed below:

- The commitment of Top Management in applying such techniques in construction.
- Lack of Standards defined in implying such techniques
- The motivation for workers & staff in applying such technique
- Active participation of all stakeholders for implementing various six sigma tools.
- Proper communication with different stakeholders.
- Improper implementation without prior SOPs defined
- Time, Money, Effort in applying such techniques.

5. Discussion

The result chapter resulting in various leads through case study & questionnaire survey to show that time and cost overruns on construction projects are often due to poor implementation of site management practices, communication issues between various stakeholders resulting in changes in execution processes, lack of planning, process & productivity inefficiency. The author introduces the strategy which can be related to & implemented in construction projects to improve various parameters by integrating lean, six sigma & 5S tools. Following the implementation of strategy in various stages of construction will help bring the cost & time delay parameters for a construction project.

5.1 Introduction

Based on results from the literature, case study & questionnaire survey, various delay & cost influencing parameters have been identified. In accordance, the author tends to integrate lean tools with six sigma, 5S, to achieve desired results. The author in this section by implementing six – sigma & 5S in various fields identifies & wishes to help in bringing the risk to a minimum. Case study & various parameters resulting in the delay of the project will be discussed in detail, with each aspect showing the results of the implementation of six -sigma & 5S. In each strategy aspect, the author, with the help of site photos, data, documentary evidence, to achieve desired results. The following seven major fields will be discussed in detail:

- Process & Productivity Improvement
- Quality Management
- Site Management
- Knowledge Management
- Procurement Management/ Supply chain
- Planning Management
- Contract Management

5.2 Proposed Strategy

5.2.1 Process & Productivity Improvement

During case study-2 primary reason for the cause of delay found out was less productivity in the pilling process, which resulted in increased cost of resources. The author in this section implements various 7 QC tools of six sigma in increasing the productivity in the pilling process in a solar project to reduce cost / MW of the entire process. The DMAIC cycle for productivity improvement is as implemented by the author in the following stages:

- **Define:** The project charter for problem definition is as presented by the author in table 32.

Table 32: Project Definition for process improvement

Project Title: Improving Productivity/process improvement in the pilling process
Problem Statement: High quantum of workforce & machinery deployed, leading to increase cost & Time.
Goal Statement: 50 % improvement in productivity
Expected Business Results: 50 % savings

- **Measure:** The process of piling is divided into four stages, namely: Peg marking, Boring, Alignment & concreting of Vertical post. The data showing the process are attached in appendix D part of the thesis. The author, based on data available, aims to find mean, standard deviation from set productivity for each of the processes by Minitab software of statistics. Graphs & data analysis are performed for only Peg marking process.

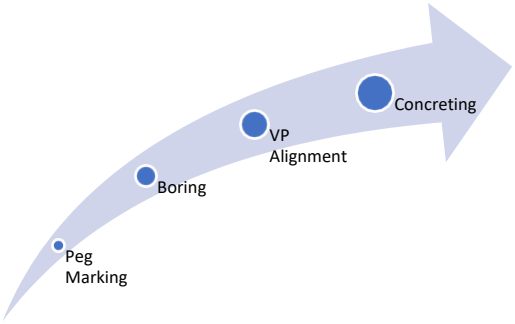


Figure 25: Process of Pilling

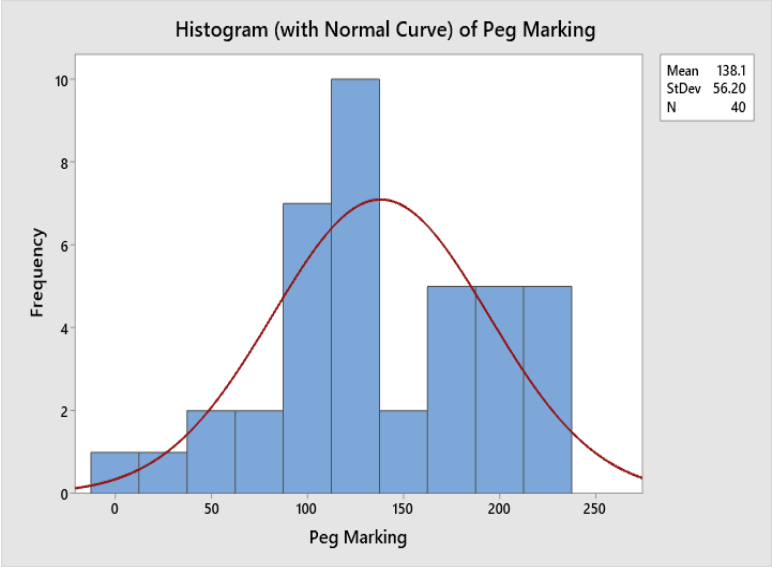


Figure 26: Histogram with Mean, Std. Deviation of process

The standard deviation of Peg Marking, which indicates the productivity of the process is 56, so required productivity for 50 % improvement required is 86.

Process Capability: In six – sigma, to have insight on the process, before moving to analyze phase, six-pack plots of six sigma determine the capability of a process. This analysis indicates the direction for RCA to improve the process. The overall potential capability of a process is indicated on the right-hand side in fig 27. Based on values obtained Cp = 0.28 indicates process not capable (Cp>1). In addition, Cpk = 0.28 <1, indicates improvement in process is necessary. Cp, Cpk is a potential capability index.

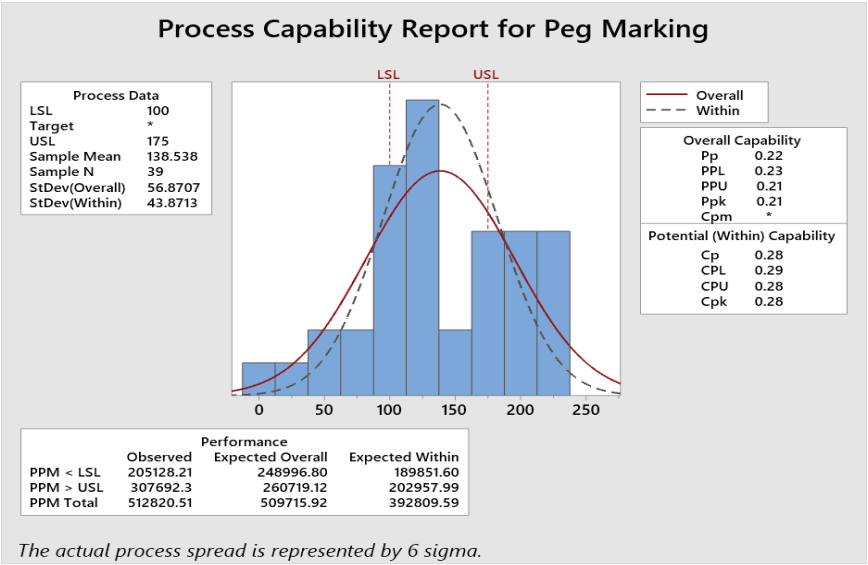


Figure 27: Process Capability for Pilling Process

- **Pareto Chart:** Listing of all-important parameters from RCA Analysis, decreasing productivity of the process. Results concluded Peg Survey NA as an essential cause from a table 14, of root cause analysis in case study 2.

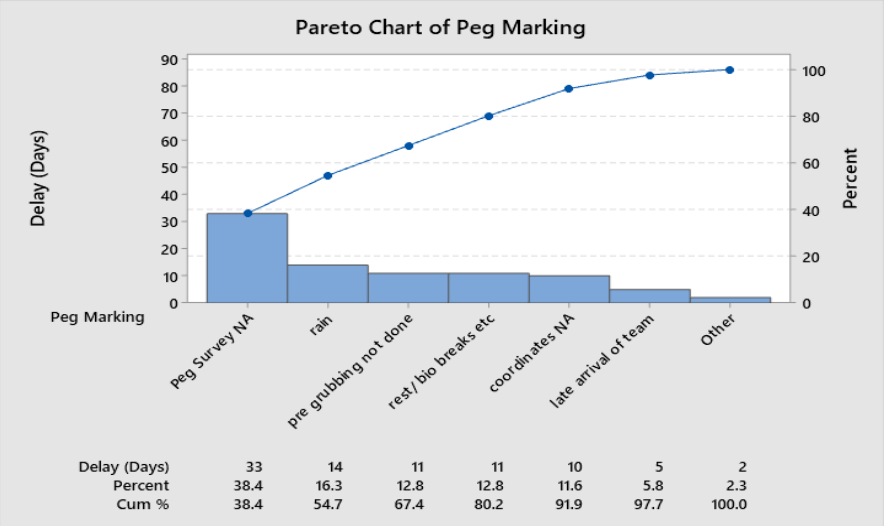


Figure 28: Pareto Chart

- **Analyze:** Based on data & root cause analysis identified, the primary reason for low productivity is indicated by Fish- borne diagram, indicating various reasons for Peg Survey Not Available at the site.

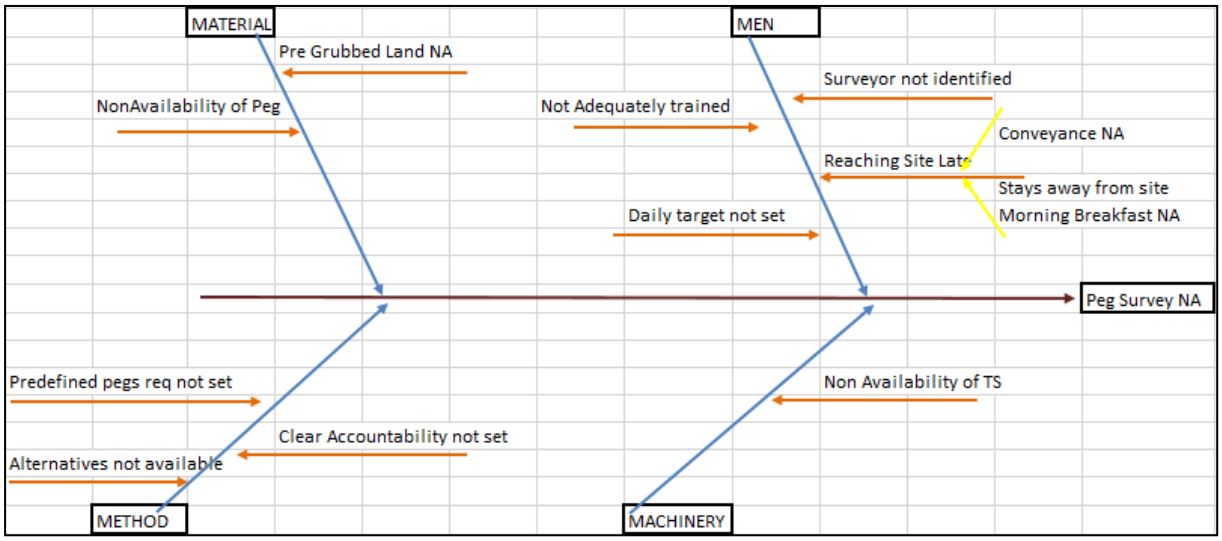


Figure 29: Fish borne diagram for Low productivity in the pilling process

Failure Mode & Effect Analysis: Indicating maximum risk due to a significant cause of failure in a low productivity process.

Table 33: FMEA Table

Item/ Function	Potential Failure Mode	Effect of Failure	Causes of Failure	Controls	Risk
Construction	Low Productivity	Increase in cost	Land NA	During land hover	
		Delay Schedule	Non- availability of Peg	Planning	High
		Resource Idling	Required nos. not set	Daily DPR	High
			Clear Accountability not set	Start of execution	
			No Training	During Execution	
			Daily target not set	Daily plan	
			Non- availability of TS	WO release	

- **Improve:**

Solution Prioritization: Matrix Diagram

Matrix diagram is one of 7 QC tools of six sigma used to prioritize/select alternatives. Ratings of 1,3,5 are given to each based on three parameters **cost of implementation** in which 1 being high cost, 5 low cost, the **feasibility of implementation** in which 1 being low, 5 being high, 3 being medium, **impact on solution** in which 1 for low impact, 3 for medium, 5 for high. The solution having the highest impact should be selected for implementation. Based on results from the grand rating, two major reasons which can be adopted in future projects where inclusion of target to be achieved in DPR & inclusion of peg marking & boring as a single process in contract to increase productivity.

Table 34: Solution Prioritization

Solutions	Cost	Feasibility	Impact	Rating
Accommodation of Rain in schedule planning	5	3	3	45
Inclusion of Target to be achieved in the daily plan	5	5	3	75
Inclusion of Peg marking & boring in the scope of contractors	5	5	3	75
Labour Colony at the site to avoid cycle time	3	5	1	15
Vendor Qualification	3	3	5	45

Action Plan for Implementation: Following plans should be adopted for the implementation of process

Table 35: Implementation process

Action Plan (What)	Who	When (Timeline)	Where
Including daily target as DPR	Planning Team	Before Project Commencement	Throughout the Project
Capturing cycle time for the process	Project Manager	During Execution	Throughout the Project

Benefits for the process:

- Focus on individual activity of peg marking, boring, centering & leveling, and concreting rather than piling as the overall process.
- Finalization of contractors for future projects based on the productivity captured
- Setting of Daily targets for these activities and being aligned to the same from the contractor level.

Chi-Squared test of Hypothesis: To validate the set parameters, the chi-squared test of the hypothesis was used for the below sample size, if the peg survey available, no. of days delay observed in the project is 7 & productivity rises to 273. As p-value 0.011<0.05 supports our claim that if the peg is available, productivity increases & thus, the null hypothesis is rejected.

Table 36: Chi-squared test for the potential cause

Description	No. of Days (Delays)	Productivity
Peg Survey NA	13	185
Peg Survey Available	7	273

Descriptive Statistics

Test

Null hypothesis	$H_0: p_1 - p_2 = 0$
Alternative hypothesis	$H_1: p_1 - p_2 > 0$

Method	Z-Value	P-Value
Normal approximation	2.29	0.011
Fisher's exact		0.021

Sample	N	Event	Sample p
Sample 1	185	13	0.070270
Sample	273	7	0.025641

Table 37: Data for hypothesis testing

- **Conclusion:** Based on the above significant results, the following observations were taken into consideration in the next project & the subsequent reduction in cost & productivity increased is recorded. Due to privacy for cost in companies, individual groupings cost cannot be made available in the public domain. So, the scope for cost assessment is based on MW/ Cost in the market for Indian Solar Industry.

Table 38: Cost reduction

Cost reduction	Cost / MW	Std. deviation (Peg Marking)	Std. deviation (Boring)	Std. deviation (Centring)	Std. deviation (Concreting)
Before	1.54 Lac INR	56	115	86	86
After	92,143	93	131	101	129
% Reduction	% 40.58				

5.2.2 Quality Management

According to (Karthi et al., 2012), lean Six Sigma's DMAIC steps along with the Lean Six Sigma tools and techniques "essential for integrating Lean Six Sigma through ISO 9001:2008 based QMS" have been enumerated under DMAIC phases in the following subsections. DMAIC Cycle is as explained for quality inspections:

- **Define** Identifying VOCs & CTQ parameters, which usually deviate from drawings, specifications, SOPs, Checklist. Quality parameters can be usually defined through
  - CTQ report
  - NC reports
  - Material Inspection report
  - Safety accidents

- **Measure:** Measuring the parameters of quality through following parameters & including it in daily DQR
  - Responsibility of individual to control the quality issue raised
  - TAT (Turn-around time) from initiation to time to close the quality parameters.
  - Reporting Near Miss identifying various aspects for safety issue which could result in a significant incident

- **Analyze:** Analyzing various setbacks in quality log due to above-discussed issues by identifying
  - RCA Analysis
  - Why – Why Analysis
  - CAPA report

- **Improve:** Improving the processes by identifying critical to quality parameters from analyzing reports.
- **Control:** SOPs, checklist, documentation for QA/QC can be control measures for quality management at the site.

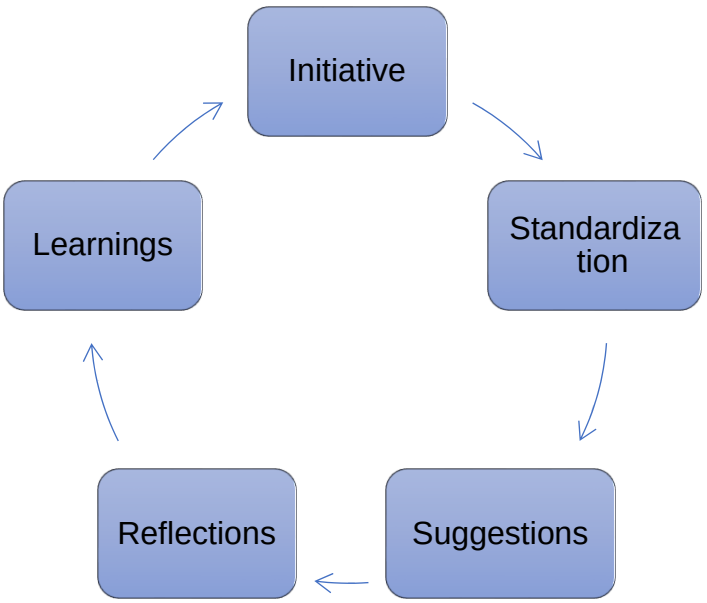


Figure 30: Kaizen cycle, Adapted from (Randhawa & Ahuja, 2017)

5S & KAIZEN QC TOOLS: According to (Randhawa & Ahuja, 2017), 5S and KAIZEN in combination are quality tools that improve TQM for an organization & when used in construction, help in increasing overall quality, generating new initiatives for the process, decrease in cost for a process, rectify errors, enabling set guidelines for a process.

To use 5S & to manage Kaizen. The steps are as follows:

- **Sort the kaizen:** Identifying various quality parameters that can be useful in productivity development or process improvement from the view of workers/ engineers should be recorded & awarded through recognition program, motivating the workers in taking initiatives & reporting near miss.

- **Set the kaizen in order:** Implementing the suggested kaizen by proper defining of SOP parameters or CMS (Construction Method statement) for work. These acts as a checklist or guide for performing the work with the desired quality.

- **Sweep the kaizen:** To improve current SOPs, new techniques can be experimented & solutions can be given by creating a benchmark to compare the results achieved from both techniques & identifying useful techniques for future projects.

- **Standardize the kaizen:** It is a channel for workers/engineers to express their dissatisfaction regarding quality of work, material, or any other discomfort or hindrance created in completing the task. Implementing of set kaizen guidelines & standardize for the process defined.

- **Sustain the kaizen:** A framework is developed, which acts as a PDCA cycle to sustain the kaizen. A lot of effort is required to manage the kaizen suggesting system to manage nos. of kaizen initiatives. These acts as a guideline & checklist can be implemented for construction after PDCA cycle approval.

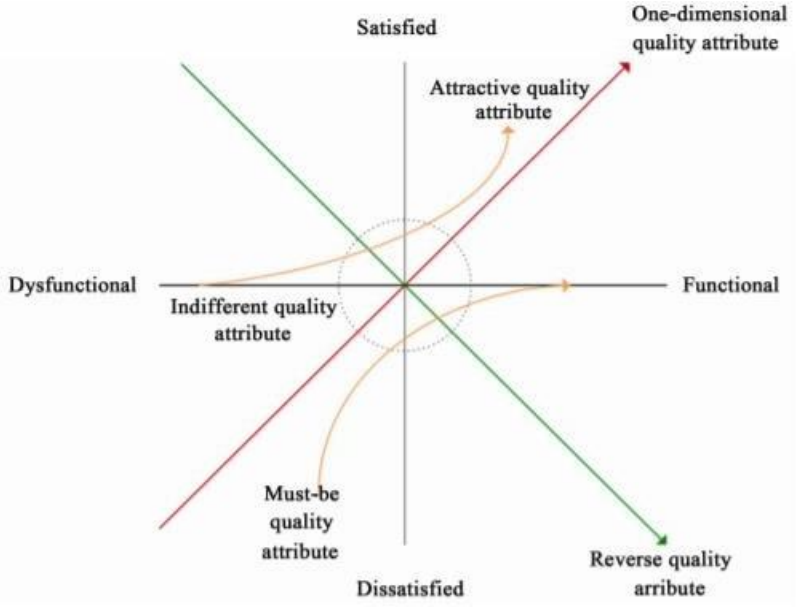


Figure 31: Kano Model of Quality, adapted from (Huang, 2017)

Construction companies nowadays are facing problem to meet the demand or requirements of customers. The only solution to the satisfaction of the customer is by process & quality improvement to meet the needs of customers to survive in the market. Based on NCs (Non- Conference) reports, punch point reports, safety accidents given by the customer, Kano Model of quality can be used for improving customers' needs in a future project to increase the value of given work by reducing cost & time by above-mentioned quality checklist tools and thereby enhancing quality parameters.

5.2.3 Site Management

This section will deal with site management techniques 5S in improving the tasks on the construction site. In construction, the major cause of delays & overrun has found out from the literature, case study & survey is a delay of the process due to loss of materials. These delays are mainly due to the logistics issue. Proper Housekeeping is not maintained at the construction site & as a result, there is a loss of material at the construction site. These can be achieved by implementing 5S techniques in workplaces, giving regular training to workers before the start of each construction activity. Also, in a competitive marketplace to sustain other vital parameters like HSE (Health Safety Environment) is also an essential parameter for TQM (Total Quality Management) & these can also improve by proper implications of 5S techniques at the construction site.

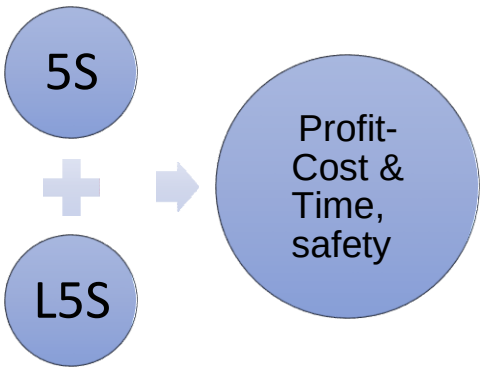


Figure 32: Integration of 5S & Lean, Source: (Ho, 2010)

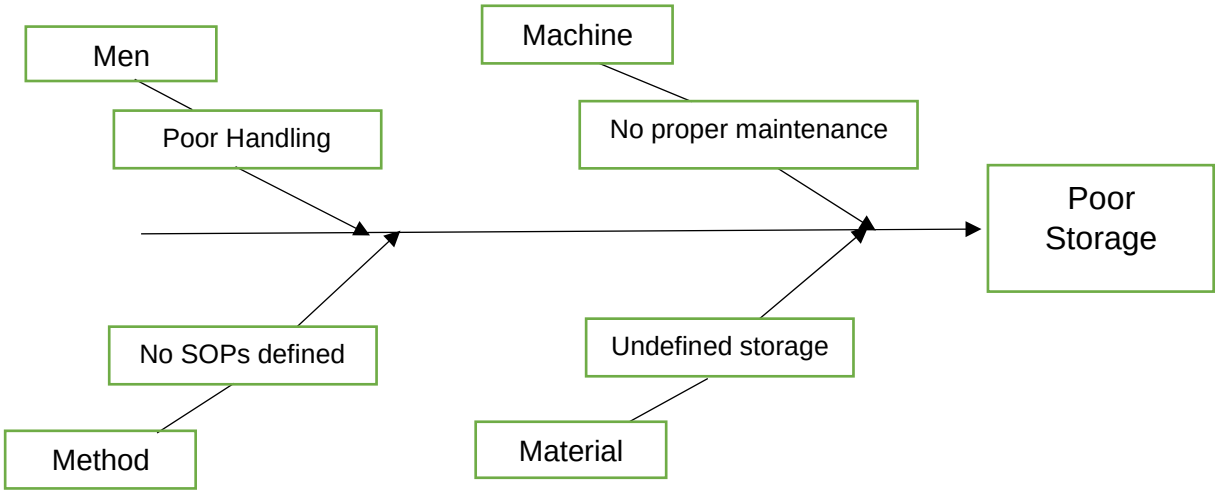


Figure 33: Cause & Effect Diagram for poor storage

During case study 1, where the delay is affected because of loss of materials & improper storage at site, for this reason, a dialog session with the managers to define a proper storage area to improve the process & prevent loss of materials at the site is conducted. A detailed organizational chart with the responsible person, with plant layout with identifying responsibilities, was set up to avoid delays due to loss of materials.

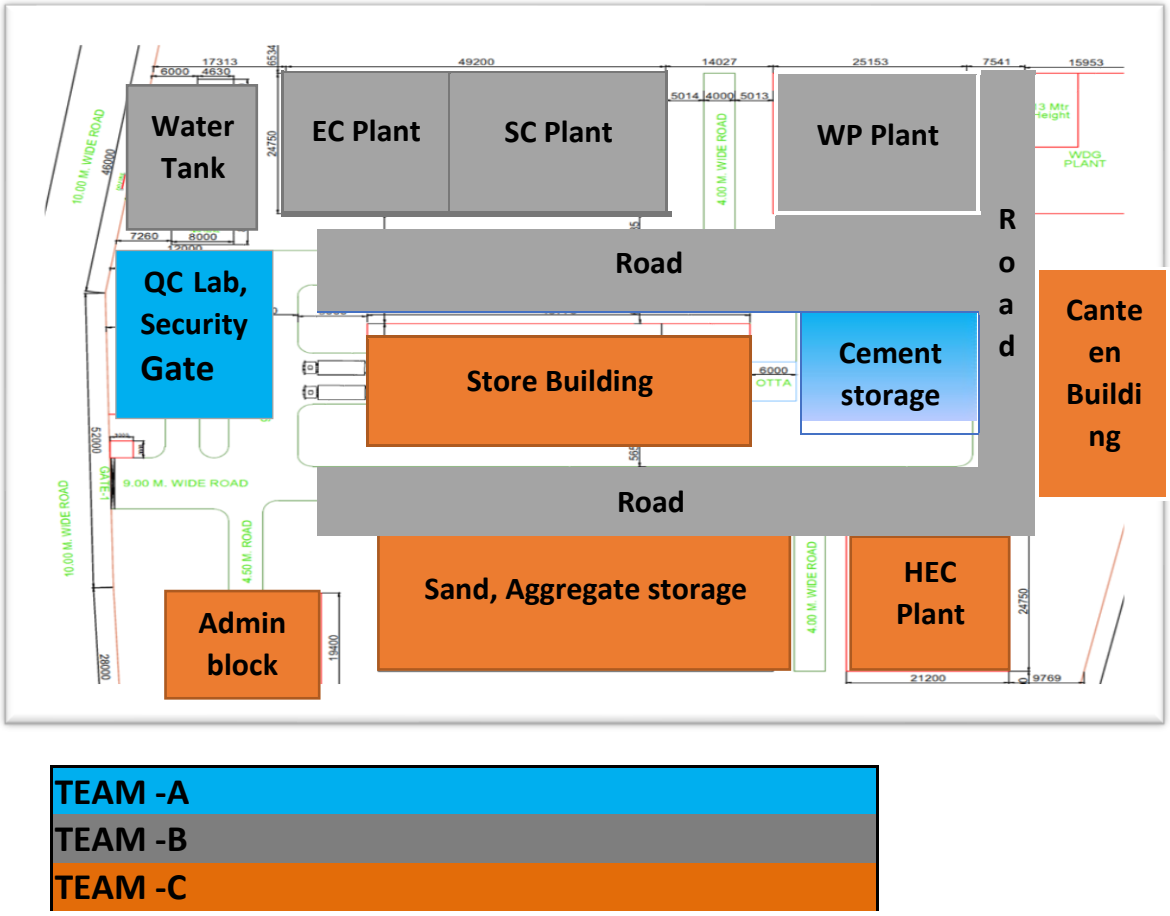


Figure 34: Layout of the site with 5S responsibilities, Source: (Planning Department, 2017)

Figure 35: 5S Implementation, Source: (Planning Department, 2017)

BEFORE **AFTER**

Figure 36: Before & After results of implementation of 5S, Source: (Planning Department, 2017)

- **Stage 1: Sort** As per organizational chart stating clear responsibilities of each on-site, the team started arranging the things by letting the staff & workers understand items or materials and choose whether it is essential to keep it. The vital elements were stored and put away on the storage area defined, though

the unneeded things were rethought by the staff to choose whether they can be reused, recycled, or disposed of for the future use.

- **Stage 2: Set in order** We found the materials which are relevant and develop a strategy to locate these near to workplace which could help reduce transportation time, increase productivity for workers by keeping in a single place.

- **Stage 3: Shine** All unwanted materials were removed from the workplace & placed in a defined scrap area, where it can be used for recycling or reworks. Cleanliness should be included in the daily routine of the workplace & not when the place gets dirty, resulting in loss of time, quality aspects, increase in various cost parameters. By adopting the procedure, workers attitude towards safety & quality parameters increases QHSE parameters.

- **Stage 4: Standardize** The team focused on implementing & creating standards every day in which every representative needs to keep up the work territory clean and during and toward the finish of each work. Every representative required to do his/her part to guarantee that the 5S implementation is being executed.

- **Stage 5: Sustain** A checklist & SOP clearly defines the roles & responsibilities of an individual is used to sustain the 5S protocol at the site. Weekly audits helped in maintaining a 5S procedure by the client.

Underscoring the significance of the materials & their relative savings in the construction industry about bringing down cost, improved item quality, decreased process duration, and improved work. Organizations can make a quality working environment by creating procedures & standards that move them towards world-class execution practices. The execution of housekeeping practices like 5S will enable the administration to show representatives, clients how such practices improve by and large overall working environment & increase customer satisfaction & avoiding delay & cost parameters.

5.2.4 Knowledge Management

Project data and information gathering, just as information obtained in various stages, are firmly associated with all construction phases of the life cycle of the project namely in the project initiation, planning, construction, & maintenance cycle of a project. It is likely to be seen that the data and information must be shared from every single stakeholder body and associations taking an interest in the project, for example, be it a customer, consultant, or contractor, because communication between these intra-discipline shareholders is frequently dangerous, in construction if wrong information reaches any of stakeholder & the absence of coordination between these business stakeholders can be seen as a significant contributory factor to the poor performance of the project to fail(Tupenaite et al., 2008).

Poor knowledge management leads to a decrease in productivity of a process due to communication errors between stakeholders & the effect being repeated in future projects. In view of these, a proper KM strategy with six – sigma can be implemented for better management of information within different groups in construction projects. As seen from various factors for causes of Delays & Cost overruns are:

- Poor Scope Definition
- Lack of communication
- Shortage of Manpower resources
- Lack of control & monitoring of quality
- Defective & Damaged Materials.
- Design errors / Execution errors

In view of this, there was a vital need to have a strategy to handle these problems. The first method of addressing the above problems was to take a more practical approach to quality control with all parties having the same level of knowledge of work wrt checklists, SOPs, etc. These can be achieved by having a Proper Database Management System (DBMS) in an organization for smooth workflow by comparing previous drawbacks of the project. A knowledge sharing between various stakeholders, so each participant is at the same level of understanding should be adopted, having the same quality parameters, drawing parameters within the project.

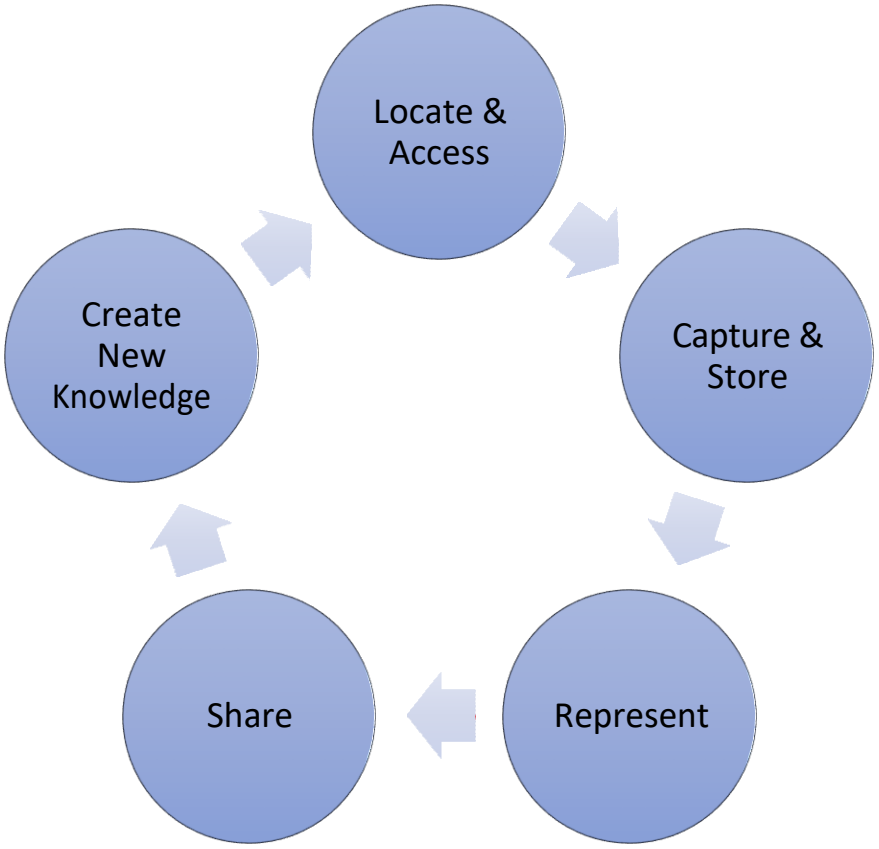


Figure 37: Information/ Knowledge Management Cycle, adapted from (Tupenaite et al., 2008)

By, adopting & implementing knowledge management cycle, helps in achieving the following objectives in construction:

- Standardization of drawings, execution process to be followed
- All stakeholders have the same level of understanding, no disputes
- Continuous suggestions & feedbacks during the project life cycle of the project
- Efficiency in a process is improved reducing the time for completion
- A transparent database system is common to all stakeholders where any changes can take place in the design or procedure of work.

Knowledge/Information cycle along with the DMAIC cycle methodology can be implemented within the project charter for proper clarity of information assuming reference & various effects in project delivery from a previous project & implementing the aspects in the new project. Integration is presented below by the author:

- **Define:** Defining the goals of the improvement process given as CTQ by the customer during the start of a new project. These can be achieved by stakeholder meetings, making a project charter explaining roles & responsibilities defined, having a clear idea from the beginning. In the case of design errors, execution errors, a clear SOP defined between various stakeholders helps in achieving the desired objective.

- **Measure:** Measuring & implementing reliable processes in the system concerned with different parties. The preliminary data analysis tool that can be used for measuring the concern is VOCs.

- **Analyze:** Analyze & identifying the critical parameters to eliminate gaps within the system. Five whys, root cause analysis, can be used for determining the actual cause of failure, be it design failure or execution error due to communication, which can be changed in drawing & execution of work done with previous drawing approved. In these cases, the project manager should have a drawing register with an approved drawing revision number & should be conveyed to each stakeholder concerning the work.

- **Improve:** Improving the overall system through Benchmarking with the previous process by applying a corrective action plan (CAPA).

- **Control:** Controlling the new system & preparing SOPs (Standard Operating Procedure) for each process & delivered to each project participant. These must be followed & ensured by EIC.

The reuse of knowledge from past experiences can be helpful for future projects in the following ways:

- The probability of problem being repeated can be reduced
- The cost of the problem is reduced.
- Enhance the overall quality of the project & makes the project viable to happen.
- All stakeholders of the project are on the same platform with approved SOPs; the task needs to be performed.
- Eliminating wastes & avoiding rework

5.2.5 Procurement or Supply Chain Management

One of the significant causes of delay & cost overrun found out from the research study is in the availability of materials at construction sites & wastage of material due to inefficiency or carelessness of workers. To avoid one of the major seven wastes, which results from inventory, lean Just in Time (JIT) delivery methods can be implemented at the project site. These will help in bringing down the cost of the project by delivering the material at proper location when demanded by the contractor.

Material management in any project ensures that the right quality, quantity is supplied to the project participants at the right time for the project to work smoothly without any delay. As seen, Site management is a critical criterion defining the exact place where the material should be delivered near to the place of work resulting in a decrease in cycle time for a process to complete. To eliminate excess inventory & wastage at the site, JIT & 5S methods can be integrated to achieve better quality at the workplace, reducing cost & delay effects of a project (Low & Ang, 2003).

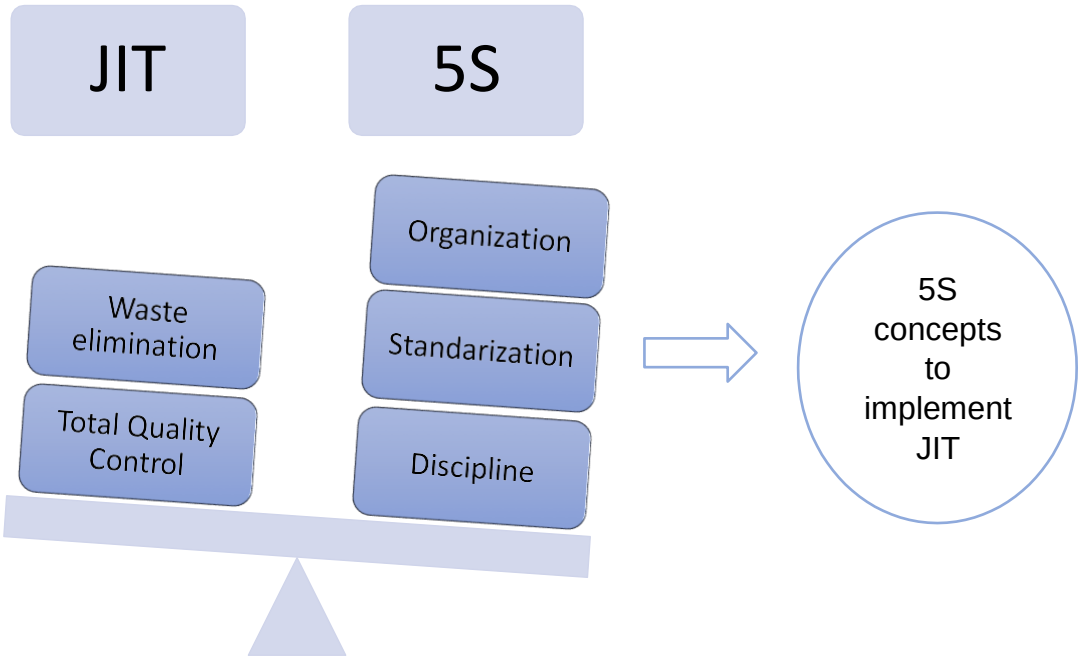


Figure 38: Integrating JIT with 5S, adapted from (Low & Ang, 2003)

Elimination of Waste:

With the help of JIT & 5S lean techniques, the following waste can be eliminated on the construction site:

- **Waste from Overproduction (Sort):** The utilization of project master schedules along with JIT can likewise encourage the end of the overproduction of materials stating requirements of type, specific date, the location where material needs to be delivered. Schedules help in enabling the project manager to plan to deliver required stock segments in the construction yard on the given location, which was causing a delay in the process. This guarantees the overproduction of components parts is maintained to avoid any surplus stock causing a rise in the material at the site.

- **Waste from waiting time (Set in Order):** The schedule plans, which are always modified depending on various actual changes happening in the project due to multiple causes, additionally enable the project manager to know following actual site conditions which activities are occurring at & for what span. With these schedules, the site PM, as well as the Construction Manager supervisor, can precisely plan and secure the materials required for an activity. The JIT delivery of these materials to site diminishes the requirement for extra space to store, & also with JIT delivery of content is delivered at an exact location, reducing travel, waiting time to transport.

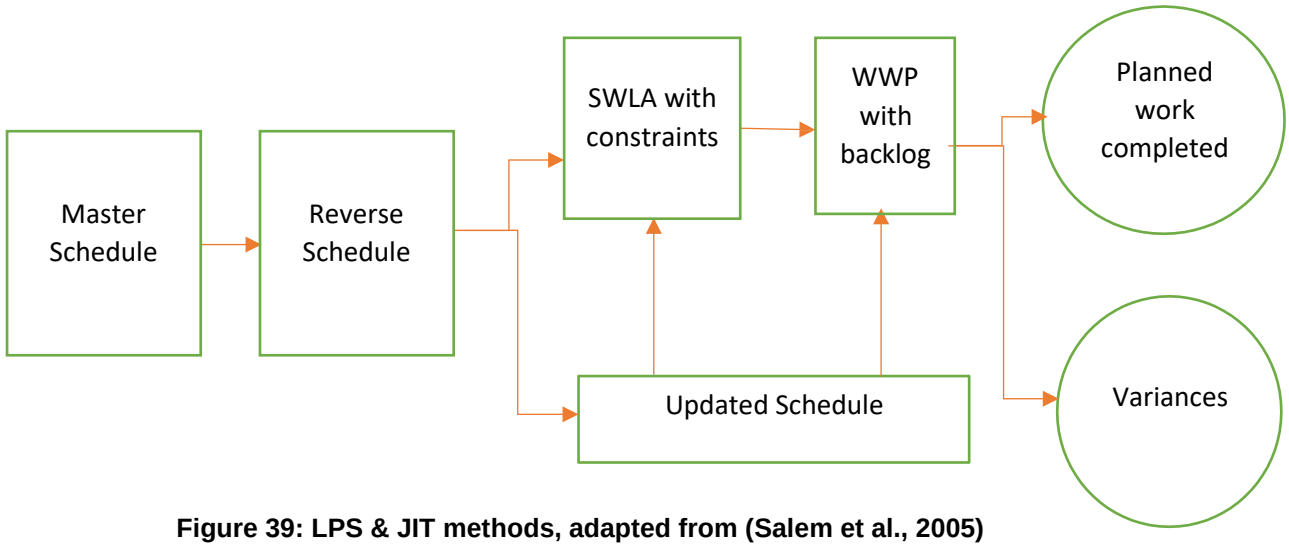


Figure 39: LPS & JIT methods, adapted from (Salem et al., 2005)

- **Waste of Motion (Shine):** Waste of motion can likewise be reduced or eliminated by the clear marking of the various zones and materials identifying specific material with certain characteristics & specifications to be kept in the designated locations. This enables the units to be moved directly from the construction yard to areas alongside their spot of utilization as opposed to putting away them at a typical storage zone. The use of marking on units helps in reducing the right component used in construction with drawing specified avoiding rework.

- **Inventory Waste (Standardize):** By methods of schedules and drawing & specification received, the project manager & engineer verify real ground situation on-site & based on requirement determine material requirement or shortfall to complete an activity. With continuously monitoring the schedule & project material plan, the project manager ensures the right quantity of material is delivered. These help in standardizing the process to bring the loss of inventory.

- **Processing Waste (Shine):** Plant and machinery, for example, tower cranes, crawler crane, and testing gear, are checked and maintained to guarantee that they stay in excellent working conditions. This eliminates out waste coming because of the breakdown of the plant/hardware because of an absence of maintenance, causing the delay in a process & subsequent cost overrun.

Visual guides, for example, color coding (Standardization), are utilized in construction to encourage communication and maintain a strategic distance to avoid confusion. Different color paints are being used to check out various components for various use. This empowers the laborers to distinguish, for example., which are the water pipes, gas pipes, or electrical conductors and how every one of these runs depending on the identification of color-coding. This helps in reducing the error of the wrong component to be installed, giving a clear idea for workers in case he isn't educated about the specification for a type of material used.

5.2.6 Planning Management

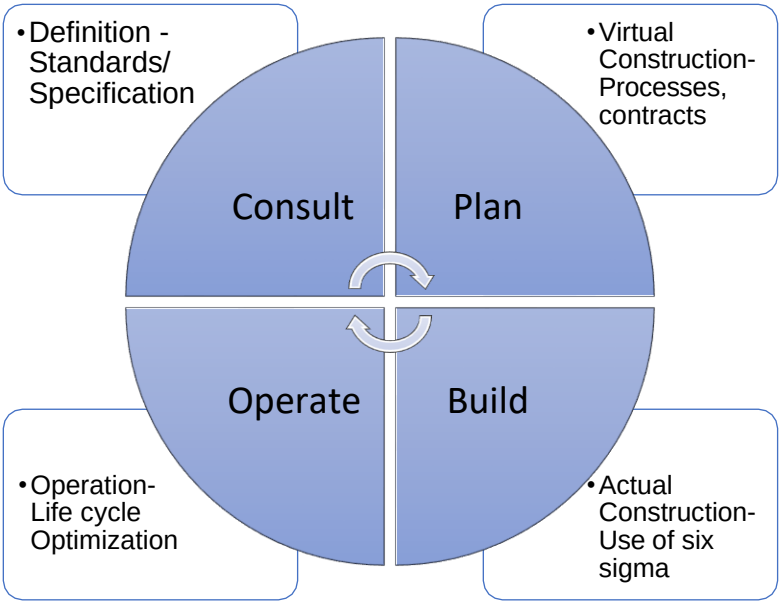


Figure 40: Planning Management

The significant causes of delay & cost overruns identified from the literature review & case study analyses are lack of planning the project from phase zero. The author in fig 40, suggests the following measures in various aspects of the project to avoid the effects of ill planning

- **Conceptual Planning:** Early definition of objectives based on the economic need of customers. If ROI is achievable, the planning is considered to be viable.
- **Economic Planning:** PCS (Project Communication system) between stakeholders should be defined to avoid any confusion. Lean Tools like six – sigma, 5S, LPS should be effectively used for economic planning reducing defects.
- **Effective Planning:** Adopting takt time planning, having sufficient resources & trades that don't clash with each other, and implementing a Visual planning board daily for better control of resources.
- **Operation Planning**: Effective elimination of defects, reduce delays by adopting six sigma / 5S methodologies. Defect management & data management task force initiatives to be adopted in the process.

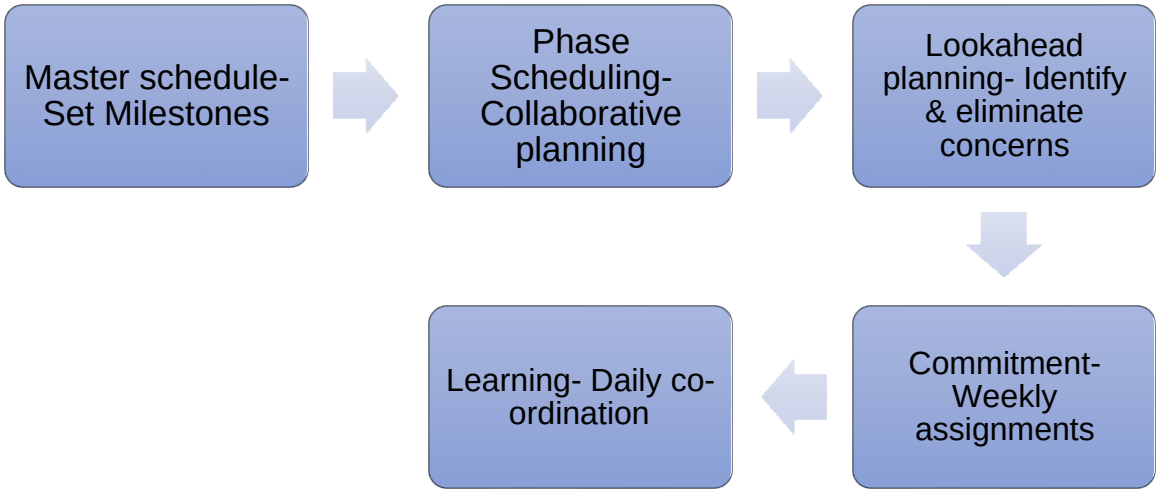


Figure 41: LPS integrated with DMAIC

Integration of LPS with DMAIC cycle:

- **Master Planning:** What should occur should be defined with set milestones in the master schedule, in the same regards as defining the stage of the DMAIC cycle defining the problem.
- **Pull Planning:** Strategically identifying segments of activities to enable Weekly Work plan in terms of what should occur. The primary objective of pull planning is to achieve optimize workflow & create a balance of payments to maintain resource optimization within groups.
- **Look ahead, Planning:** Identifying & Eliminating risk, which can cause a setback in the successful planning of the project. Enables Identifying & Analyzing the problem for hinderance of the task.
- **Weekly Work Planning:** Collaboration of work completed, to have an idea on work completed & planning for future weekly assignments. What will occur is a significant idea in WWP. It Improves activities to be planned in the future.
- **Learnings:** What has occurred & what can be fixed to improve next week's work planning, enabling control measures for a future week.

Integration of LPS with DMAIC can be helpful in the following ways:

- A reliable workflow control for customer
- Able to respond to changes due to frequent changes in construction
- Enhancing daily productivity with the removal of waste
- Defined work sequencing within the different teams in the project in terms of when to start, when to finish avoiding conflicts.

5.2.7 Contract Management

Based on results from the literature review & case study, another drawback in delay & cost overruns is the effect of changes in scope, objectives at frequent intervals during the execution process. These pre-requisites should be clearly defined during the tendering phase of a project to avoid disputes once the contract is signed & contractor claiming for loss of time.

Figure 42: Pre-Award steps in the contract

Figure 42 presents all possible criteria that should be defined before contracting. By integrating lean thinking in contract management in the tendering phase helps in reducing the following wastes:

- **Specify Value:** Value should be clearly defined in the contract by client specifying targets in terms of scope, quality, time to deliver already set in the contract.
- **Identifying Value Stream:** Value stream in terms of defining sets of responsibilities clearly for minimizing waste, defects & dividing value chain into design, planning & execution tasks, helps in claim disputes.
- **Flow**: Identifying links & creating interactions among stakeholders in a construction project to minimize various waste resulting from delay of one stakeholder to others.
- **Pull:** To avoid waste in the contract due to a lack of information.

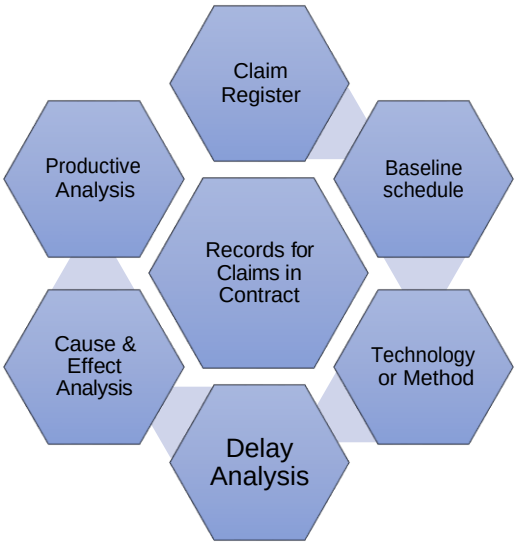


Figure 43: Records for Claims in Contract Management

Fig.43 presents a list of records, according to FIDIC contracts for international standards that can be kept by the contractor for legal claims if the owner is responsible for the delay. Before concluding a contract, following suggestions given by the author should be incorporated in the contract legally:

- Good Quality of Tender documents
- Co-ordination between various stakeholders
- Including a change process in the contract
- Naming an expert / Arbitrator in case of disputes

Fig.44 presents safeguard claims & risk allocation for the individual party in case of delay due to any of force changes or due to any stakeholder involved in the contract.

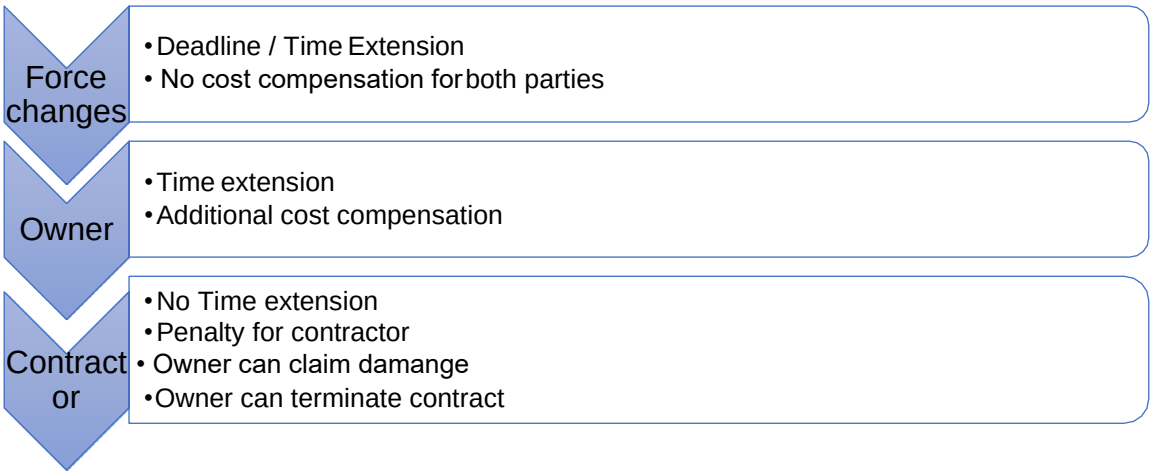


Figure 44: Scheduling Claims & Risk allocation for different parties responsible in case of delays

5.3 Proposed Implementation of Strategy

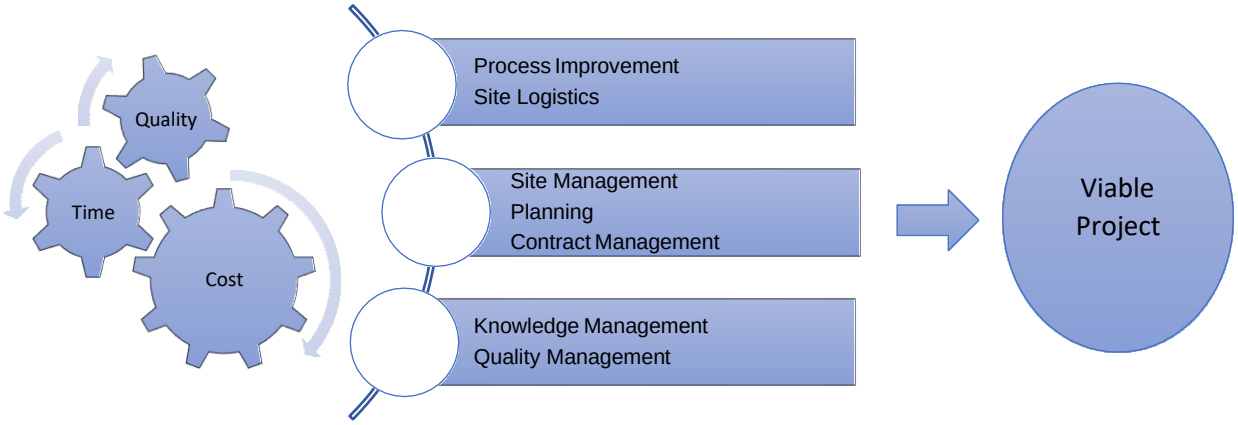


Figure 45: Implementation of Strategy

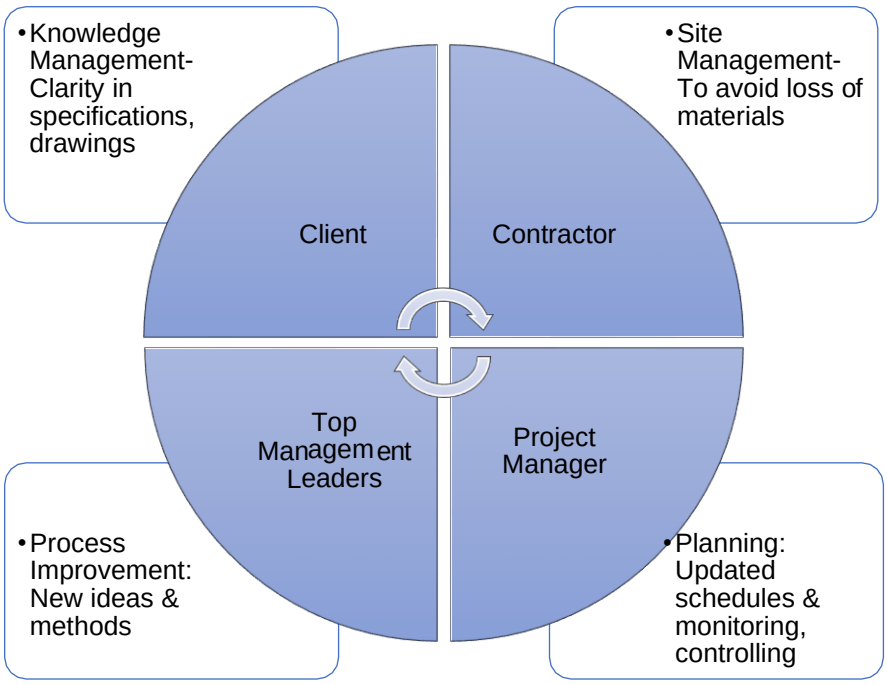


Figure 46: Involvement of various stakeholders for implementing the strategy in avoiding the risk

A clear set of responsibilities, when defined for each project stakeholder in the project, has presented in figure 46., can help implement the strategy in various phases of the construction project. By applying the following principles can help in:

- Reduce risk in project
- Increase value for the customer
- Reduction in rework & errors in construction
- New techniques/tools for increasing productivity in construction.

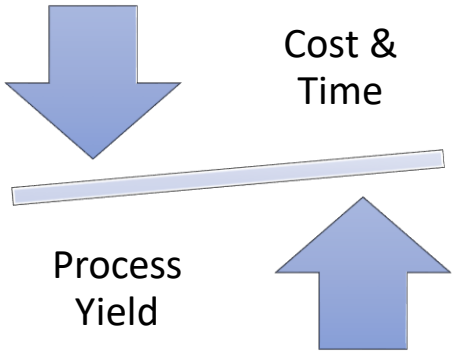


Figure 47: Yield vs. Cost-delay by implementing techniques

Fig.47 & 48 present an increase in yield in the process due to faster construction & 4C cost approach & improvements in various cost groups that are visible in the project by the implementation of such techniques. Accordingly, the table. 39, presents a strategy for risk mitigation & impact on time & cost in case of delays observed.

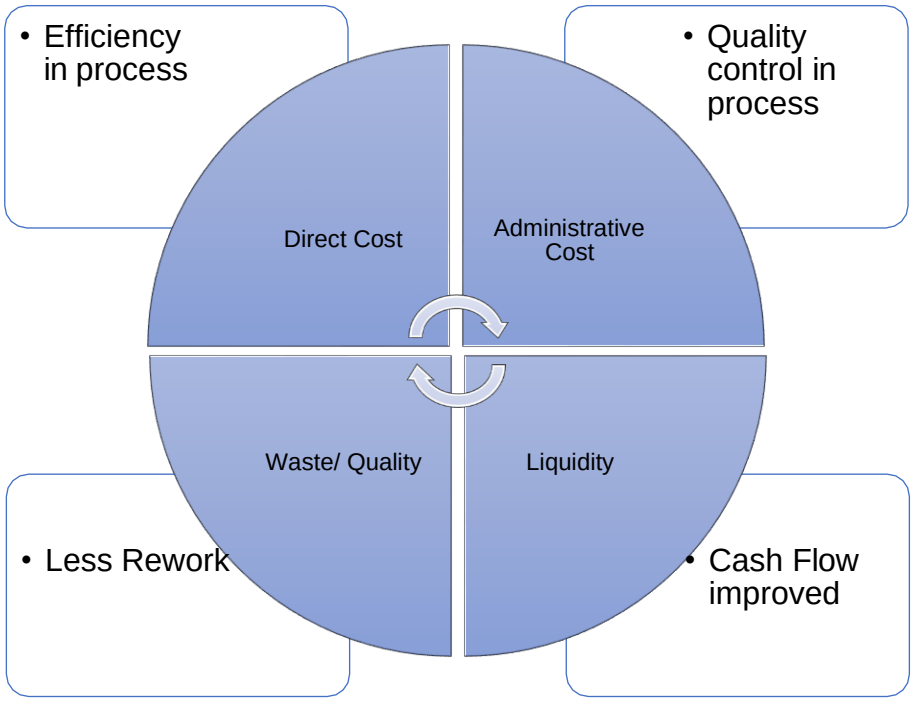


Figure 48 : 4C Cost Approach

- **4C Cost Approach**

As presented in fig.48, by implementing six sigma & 5S techniques in construction following cost can be reduced by adopting the approach:

- **Direct Cost:** As these techniques increase the efficiency of process & lead to new process invention can lead to savings in direct cost wrt labor, material supplier, process, etc.
- **Administrative Cost:** As six sigma processes improve standardization in process with set guidelines for SOPs before starting work with productivity rates captured can lead to saving in resources use.
- **Liquidity:** Early completion of the project & subsequent increase in yield leads to cash flow improvement, which can help in the market image of the developer for future projects.
- **Waste/ Quality:** Cost of Poor Quality due to rework, delays, poor construction method, late inventory can be reduced & has long term cost benefits in project success.

Table 39: Strategy to eliminate the risk

Project Parameters	Risk Factors	Impact on Time & Cost	Solutions
Process Improvement	Improper method of construction	High	Productivity capturing & six sigma methodology for continuous improvement
Quality Management	Sets of guidelines & protocols undefined	High	Clearly defining SOPs, checklist before the commencement of Project
Knowledge Management	Poor scope Definition, miscommunication among stakeholders	Moderate	Creating a Database knowledge management system for effective communication with revisions in any of document notifying to each stakeholder for effective communication
Site Management Practices	Poor Material handling, storage, loss of materials	High	Adopting 5S methods for better handling, storage

Procurement or Supply Chain Management	Late delivery of materials	High	Implementing JIT method for control & in line with the schedule
Planning Management	Improper planning, aggressive scheduling	High	LPS method integrated with DMAIC for better planning & optimization
Contract Management	Unclear clarity in scope, claims	Moderate	Specifying value & identifying value stream in contract & corresponding cost claims

5.4 Verification of Proposed Strategy

Verification of the results and the undertaking the procedure was done through the strategy by triangulation method, utilizing documentary analysis, case study investigation, and questionnaire results. From the case study analysis & literature reviewed, results showed seven major causes in the construction industry, leading to cost & time overruns. Results indicated various methods integrated with six sigma tools & 5S to improve the overall process of project parameters. The strategy, if implemented practically & theoretically & proves a major reduction can be achieved if implemented in industry. The questionnaire survey was utilized as a benchmark for affirming the general idea of the outcomes from the literature analyzed. The general factors that lead to delays were confirmed with the help of questionnaires. The survey additionally helps in enlarging knowledge into the strategies that could be utilized to improve the management of undertakings and an overall decrease in the issue related to delays from the perspectives of the respondents.

5.5 Conclusion

Based on the strategy proposed by the author, the minimum amount of CTQs or VOCs identified by the client regarding delay & cost issue can be overcome by proper adoption & implementation of tools in the various project life cycles of the project. In a construction project, these results can help in driving the team & mainly the client for whom cost & delay are the essential factors in a project. Implementation of such tools & techniques in various construction projects can make a project more sustainable to survive in the industry.

6. Conclusion & Future line of Research

Current challenges which construction industry is facing nowadays is low-profit margins, competition from various stakeholders, the competition of project within stipulated time & cost, with the overall increase in quality. Because of these, it is essential to implement methods in construction that can help in achieving the needs of the customer to bring down cost & time & enhance the quality of the project. These can be defined by identifying root causes for a problem of a particular aspect of a project & consequently apply the DMAIC cycle of six sigma for problem definition.

The problem of cost overruns & time delays is persistent in the construction industry & because of these many kinds of research have been done in the past, stating various reasons for the issue. Construction Industry faces many challenges relating to cost & time overruns in a project which affects the project performance. The industry aims to endeavor many improvements in the project processes itself through various techniques. Regarding this philosophy, reliable methods or improvement processes were not identified for improving project performance. Lack of methodology to set a goal to bring down the issue & increase quality levels in construction processes were not correctly defined, increasing cost & time delays. To achieve the desired result, six sigma & 5S were integrated with the lean methodology to improve the performance of the process & overall quality aspect of a construction project in this research. To fill the gap, from past research, the attempt is carried out to bridge knowledge between delays & implementation of lean techniques like six sigma & 5S.

It is practically impossible to eliminate the risk arising from delays completely; however, there appears the possibility to mitigate the factors from this research by the implementation of lean techniques. Through the research, the author bridges the gap between various delays caused in a project through multiple kinds of literature, case study & perceptions of people in the industry with proper lean management principles which can be considered as base or SOP definition before the commencement of a project & agreed by all stakeholders. Implementation of such techniques during the project life cycle makes the project more viable for the industry & helps the professional to use them frequently.

6.1 Outcome of Investigation

Based on results from documentary research & case study investigated, significant causes of cost & delay overruns affecting the poor cost of quality are poor planning management, loss of materials, materials not delivered at site, Quality errors like design, execution errors, poor material management, poor communication between stakeholders of the project. The author in view of overcoming these delays & cost overruns, suggested & implemented six -sigma DMAIC cycle & 5S techniques in following management aspects namely:

- **Process & Productivity Improvement:** Six sigma being a process improvement tool helps in increasing productivity & process improvement. The process can be used with different 7 Quality tools to improve any defective process resulting in any loss of delay & cost in construction.
- **Site Management:** Improving site practices by the implementation of 5S principles to avoid material loss, transportation time, eliminating waste.
- **Quality Management:** Improving quality protocols in execution by proper defining & setting guidelines in terms of creating SOP for a process, the checklist for material quality. Small improvements or suggestions, namely called kaizen, should be incorporated in the beliefs & habits of employees to increase quality management at the site.
- **Knowledge Management**: Improving communication between stakeholders of projects resulting in miscommunication errors in drawings, documents by creating a standard DBMS having IFC documents with changes approved by all stakeholders.
- **Procurement Management:** To avoid any loss or delay due to materials, the JIT method of lean can be integrated with 5S techniques to improve site procurement. Visual color coding can be used for easy identification of materials at the site.
- **Planning Management:** LPS integrated with the DMAIC cycle will create resource optimization, changes in the master schedule, looking at constraints for future weeks, continuous workflow.
- **Contract Management:** Integration with lean philosophy to avoid schedule claims.

6.2 The implication of Proposed Strategy

Results from the literature review, case study, questionnaire survey suggest cost & time delays caused due to various internal & external factors in a project. The results help in reducing possible delays in a construction project by implementing lean six sigma & 5S strategy by improving the process, increase quality measures across the project. Thus, having a proper well-defined plan from initiation of the project helps in minimizing the risk, which will improve the cycle time of a project. These will also result in increased efficiency of the project.

The proposed strategy implied to the project will increase competence in the project management phase of the project. The strategy is aimed to increase the level of experience of professionals, workers by the continuous implementation of such techniques with the help of training, audit. The strategy in the Lean Management process aims by appointing champions (Green Belt, Black Belt) in six -sigma at organization levels & thus formulating processes to reach to next team in the early phase of a process. The strategy to imply requires a consolidating approach from all members of the team, including various stakeholders involved in the project.

6.3 Novelty of Research

Unlike other research these studies which have a singular approach in finding delays in a project, a triangulation approach was used in the study by examining various literature, case study, survey. These will help in understanding a detailed analysis of how future projects can be avoided with the effects of delay & cost overruns by providing realistic & detailed strategy. These will identify actual root cause measures.

Significant Findings from these researches' areas listed below:

- Using a combination of various literature studied, case study, questionnaire a wide data in understanding the root causes of delays. The data analyses can be helpful for future research on similar topics.
- How can six sigma & 5S strategy tools be used in a project for reducing & minimizing risks on the project

6.4 Limitation of Research

The research was limited to a small construction project in different countries so that results can be valid for similar small projects. A large real estate project can be considered for future research. Statistics method of analysis was not used for real estate project in this research; these was theoretical research & hence, result validated are theoretically. Statistics approach was adopted for the renewable sector of construction & result validated hold true in considerable saving for cost & delay.
Also, the strategy is not practically verified & tested in the industry. Companies & organizations with professionals of six sigma knowledge are sought to verify the strategy for future research.

6.5 Recommendations for Future Research

The implementation of six sigma tools & 5S tools is intended to improve & in minimizing risk observed on time & cost factors in construction. Due to data availability & real case project, it was possible to investigate with a company-based approach project. The research, however, doesn't examine the merits & demerits of applying such techniques within the different construction industry. Six Sigma & 5S are process-driven tools that help in improving a process, but how overall a project can be enhanced with such tools can be a topic to research in the future.

Following recommendations are suggested by the author for future research:

- To conduct practical analysis with the integration of Lean, six sigma, 5S, & verify the effectiveness of such a mixture.
- Level of implementation of six sigma tools in the construction industry in different countries
- Financial feasibility analysis in applying such techniques
- Detailed guidelines in identifying CTQs before customization in construction firms.
- Analyzing possible barriers in implementing such tools & develop a strategy to control such tools in the process.
- Development of KPI indicators for implementing such techniques in the construction Industry.

Declaration of Authorship

I hereby declare that the attached master's thesis was completed independently and without the prohibited assistance of third parties, and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

Berlin, 20.01.20	Gaurang Ghule
Location, Date	Signature of the student

Appendix

Appendix A

L5 MS project Schedule, Company Confidential

Appendix B

Table 40: Status of Delivery of Material, Company Confidential

Appendix C

Research Questionnaire

The survey is intended to identify various causes of delay & cost overruns in construction projects & give insight to the researcher to implement lean six sigma & 5S tools in construction with different parameters to minimize the risk on the project.

Part – 1

1. Please Indicate in which category of construction profession you belong

    - Civil Engineer
    - Architect
    - Construction Manager
    - Project Manager
    - Higher Management Position.

2. Please indicate your years of experience in the construction industry

    - Up to 5 years
    - 5 - 10 years
    - 10 - 20 years
    - >20 years

3. According to you, how many projects have the issue of delay out of the scale of 10?

4. In your view, it has the problem of Cost & Time overrun solved.

    - Yes
    - No
    - Not Sure

Part – 2

5. In which phase of the project, you find significant drawbacks for Cost & Time overrun?

    - Inception
    - Tendering & Pricing Phase
    - Project Management & Construction
    - Others

6. What would you consider significant causes for the above-selected Cost & Time overrun phase?

7. In lean, what you considered waste?

   - Waste from rework
   - Waste from waiting
   - Waste from inventory
   - All the above

8. Can the implementation of lean six -sigma & 5S help in minimizing risk?

   - Yes
   - No
   - Not Sure

Part – 3

9. In your view, how much will implementation of Lean Six Sigma & 5S techniques increase the productivity of construction processes?

   - Very Low
   - Low
   - Medium
   - High
   - Very High
   - No answer

10. Will implementation of LSS & 5S techniques increase planning efficiency for a process?

    - Very Low
    - Low
    - Medium
    - High
    - Very High
    - No answer

11. How much Will implementation of Techniques help in reducing Costs in Construction Projects?

    - Very Low
    - Low
    - Medium
    - High
    - Very High
    - No answer

12. How many implementations of LSS & 5S techniques will help in increasing the Quality of Construction Project?

    - Very Low
    - Low
    - Medium
    - High
    - Very High
    - No answer

13. Will all these initiatives be effective in increasing customer Satisfaction?

    - Very Low
    - Low
    - Medium
    - High
    - Very High
    - No satisfaction

14. According to you, to what extent can LSS & 5S be implemented for better management of information within different groups in construction projects?

    - Very Low
    - Low
    - Medium
    - High
    - Very High
    - No answer

Thank You for your Participation.

Appendix D

Table 41: Peg Marking Data, Company Confidential

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