

Value through Lean – A Residential Building Case study

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ABSTRACT: In obstruct construction project, it is impracticable to control the project through the traditional methods. Delay in execution of activities from its described time as per contract or can be explained as behind schedule to the baseline schedule, directly affecting the described cost. In order to rectify the problem of delayed construction projects, new practical problem resolving techniques are needed to implement on site. Hence lean practices are suggested for continuous improvement in order to reduce variation in construction process. Lean principles are latest emerging circumstance in construction industries and production process for minimization of waste. It is a method for reducing non-value added activities which will impact the entire cost of works. It also develops value for money in construction industries by conserving cost. Value management is a structured approach of attaining the maximum value for customer satisfaction level. Mainly both approaches are focusing the delivery of value from customer perspective. Instead of combining these two processes, by adopting lean practices in construction will impulsively develop customer value. Aim of this research is to attain the best value for client satisfaction by adopting continuous improvement method. A delayed construction of residential building case study was examined for implementation of value through lean strategies. Lean six sigma tool was used to reduce delay with overrun of budget. Finally, satisfaction survey was collected from client in order to explore the process of value creation. Thus the implementation of lean management could certainly yield increased in percentage of value for client satisfaction. The study solidly proposes that application of lean practices will provide value from client perspective.

KEY WORDS: Client satisfaction, Cost, Customer value, Lean six sigma, Timely delivery, Quality assurance.

I. INTRODUCTION

In recent years, all construction companies are seeking perfection in each process of construction project in order to increase the customer satisfaction with minimum utilization of resources. Customer satisfaction is the most predominant factor for all organization to maintain their reputation. Satisfaction level of customer could be increased as maximum as possible by minimum utilization of resources and without any depletion of product. In order to attain that, waste generation in construction industries could be reduced. Waste represents the extra utilization of resources for non-value added activities for which the client is not willing to pay for. Reduction of non-value added activities is possible by adopting suitable lean techniques. Implementation of lean management will produce certain value for customer satisfaction. Instead of integrating both systematic approaches which are lean and value management, it is possible to attain value management by implementing lean management in construction projects. Value through lean is practicable in construction industries for obtaining the best value for customer satisfaction.

A. Lean Management

A systematic approach for reducing waste which will focus on delivering value from customer perspective is known as lean management. It is a method of controlling and assembling work with the aim of upgrading an organization's performance, especially the quality and propriety of its production processes.

B. Value Management

A structured approach which prospects the project's intention and expectations from the customer's perspective is known as value management.

C. Value through Lean

Integration of lean and value management will produce deliver from customer perspective. In order to attain the maximum level of customer satisfaction, lean techniques could be implemented on construction site. Adoption lean practices enhance the increased level of customer value. Implementation of lean strategies, could ensure that the formation of value management automatically in construction project. Application of lean practices could decrease the extra time spent on non-value added activities in construction process which will automatically decrease the unnecessary cost spent on waste. Reduction of extra time and cost spent on construction project definitely increase the level of customer satisfaction.

II. METHODOLOGY

This chapter explains about the steps involved for implementation of lean management in order to attain the maximum level of customer satisfaction in construction. By implementing lean six sigma tool in construction of residential building, how the delay in construction was reduced is explained in this framework. Tools which were used in each phases on lean six sigma were also shown in Annexure 2- figure 2.

A. Framework for this study

Construction site was chosen for doing project implementation. After identifying the construction of Residential building site, required data related were also collected from consultants. Actual problem exists on site was identified. Next to that, data analysis was done by using primavera software. In order to measure delay in completion of activities, data were incorporated into software. After measuring delay, lean six sigma tool was used to reduce delay in construction project. Each phases of lean six sigma consists of various tools for resolving the problem exists on site. Project charter and SIPOC were used for identifying problem in define phase. In measure phase, Voice of Customer (VOC) was collected from client in order to identify their critical requirements. Next to that, analyze phase was done. Two tools were used in analyze phase which are 5Why's and Cause and Effect diagram in order to determine the root causes of major problem. After this, improve phase was done to offer solutions for problem. FMEA and Value stream mapping were utilized for improve phase. Finally Control plan was used in control phase to check whether the improvements were implemented in site or not. In addition to that, Client satisfaction survey was done

to find the satisfaction level of them. Satisfaction survey was done for both current and future state to find difference between them. Finally, customer value was calculated for all three key factors such as time, cost and quality. Value creation was examined and then results were concluded.

B. Research methodology

The diagrammatic representation of research methodology which could be implemented on construction site is shown in Annexure 2- figure 2.

C. Identification of work site

Residential building construction site was identified which is located at KK Nagar, Madurai. It was a G+3 residential building which was planned to construct only up to second floor. After constructing second floor, client has asked to construct an additional floor. Then it was extended up to third floor. Project was started on 23rd November, 2019. Delay in completion of activities was found which was mainly due to COVID-19 and design changes approved by client. Then this project is expected to finish on 15th July, 2021. Estimated budget for construction of residential building was observed as Rs. 76,38,580. After applying changes, there was an extension in time as well as cost. Construction site for residential building is shown in Annexure 2- figure 1.

D. Primary data collection

Original time for construction of residential building was estimated as 11 months. When executing project, it was extended as 19.5 months. Total delay was measured as 8 months. There are 10 number of non-skilled labors, 1 Site Engineer and 1 Project manager working in construction site. There was no availability of storage yard. Hence all materials were stored only in open areas of street. There was no usage of equipment in site due to heavy traffic congestion and narrow width of street. Overall project details are also shown in table 1. Primary data collection was done and it was shown in Annexure 1-table 2.

E. Problem Identification

After collecting data, actual problem exists on site was determined. Major problem which was found in site is project delay. Delay is mainly due to pandemic situation and design changes by client. By manually delay was measured as 8 months.

F. Usage of Software

In order to measure project delay, Primavera P6 software was used. Scheduling of activities for both planned and actual estimate were also prepared by using software. Data collected were incorporated in Primavera software and lag in activities were also mapped in software. Preparation of schedule as per planned was done and actual project updating was also done to find lag between activities. Construction process contains almost 150 activities. After creating WBS for each floor, activities were entered. Next to that, start and finish dates of activities were also incorporated. Planned schedule was first prepared and then updating of project was done. Planned vs actual schedule were compared for measuring exact lag exists between activities. From this, delay was measured and shown in Annexure 2- figure 7.

G. Measurement of delay

By using Primavera software, project lag was measured. Delay due to pandemic situation is considered as unavoidable delay. While delay due to design changes and some other factors is considered as avoidable one. Work has been stopped due to pandemic situation. But delay due to design changes could be recovered by implementing suitable alternatives in site. Delay was shown in Annexure 1- table 3.

III. LEAN SIX SIGMA

It is a framework to eliminate waste and minimize variation in process. In order to improve overall production quality, lean six sigma could be introduced. In order to shorten the production time and cost, lean six sigma methodology was introduced to implement on site. Lean six sigma process is also improving planning and control in process and mainly focus on high levels of customer satisfaction. It is a methodology which consists of five phases which are Define, Measure, Analyze, Improve and Control. Separate tools were used in each phase of lean six sigma. Application of lean six sigma and techniques used were also shown in Annexure 2- figure 2.

1. DEFINE

In this phase problem of project delay which was measured as 8 months has been identified and the customer requirements were also measured. This phase includes developing a problem statement and identifying objectives, resources and project milestones.

a. Project charter

It is a document which contains entire project details from start to end. It formally outlines the entire project and scope, people & stakeholders involved in it. It authorizes the existence of the project and shown in Annexure 1- table 4.

b. SIPOC diagram

It is a tool that summarizes the overall inputs and outputs for doing the steps of process in construction of residential building. It is a simple and high level view of construction process. It is used to identify all relevant elements of process. SIPOC diagram for construction work was prepared and shown in Annexure 2- figure 3.

2. MEASURE

Main objective of this phase is to gather as much information as possible on the existing ongoing project. It was used for measuring the actual needs of customer and their requirements.

a. Voice of customer

By using the voice customer tool, customer feedback for current process was collected. Their actual expectations to be implemented on site were collected and converted to critical customer requirements and shown in Annexure 2- figure 6.

3. ANALYZE

This phase was implemented to identify the problems and root causes of project delay. To find and validate the major root causes of project analyze was done. In order to identify the major root causes, 5Why's analysis was carried out. To determine the minor failure modes which cause major root factors for occurrence of project delay, cause and effect analysis was used in construction site.

a. 5Why's

It is an effective tool for to find the exact reason that causes project delay by asking sequence of 5 times why questions and shown in Annexure 2- figure 4.

b. Cause and effect diagram

A fishbone diagram was used to identify the possible causes for delay in completion of project by graphically displaying and identifies the areas of improvement and shown in Annexure 2- figure 5.

4. IMPROVE

This phase helped to develop ideas and suggest the improvements on process. It confirmed the measurable difference between before and after implementation.

a. FMEA

Main purpose of this phase is to take actions to eliminate waste and reduce the failure modes, starting with the high priority ones. Critical risk factors were determined by calculating the RPN values for each failure modes. Corrective actions to be implemented on site were also determined. FMEA report was prepared and shown in Annexure 1- table 5.

b. Risk Priority Number

It is a numeric assessment of risk assigned to a construction process. By assigning numeric values for each failure mode, RPN values were calculated. To calculate RPN values, occurrence, detection and severity of failure modes could be measured. The following formula shows about the calculation RPN.

$$RPN = S * O * D$$

Where, RPN – Risk priority number
S – Severity (1-10 point scale)
O – Occurrence (1-10 point scale)
D – Detection (1-10 point scale)

c. Value stream mapping

It is a visual tool which enhances entirety of process flow from start to finish and create a plan for optimizing efforts. Both current state and future state map were developed for all floors. Current state map was used to identify the existing process flow and analyze the related data to measure gaps in process. After analyzing the current state map, future state map was created with inclusion of corrective actions. Overall comparison of value stream mapping was shown in Annexure 1 –table 6 and Annexure 2- figure 8.

5. CONTROL

In this phase, the actual changes could be implemented on site. It ensures that all changes whether make improvement or not.

a. Control plan

This is the checklist plan which helps to reduce waste in construction process and mainly focus on the process which is most important to customer.

6. Client satisfaction survey

The satisfaction survey was done based on the following criteria.

- ✓ Personnel
- ✓ Site supervision and contracting
- ✓ Co-operation
- ✓ Timely delivery
- ✓ Project budget
- ✓ Quality assurance and Handover
- ✓ Environment and Safety at work

7. Determination of customer value

After measuring the client satisfaction level, value of customer has been calculated by using the following formula.

$$\text{Customer value} = \frac{\text{Satisfaction level of customer}}{\text{Utilization of resources}} \times 100$$

8. Exploration of value creation

After calculating the risk priority number for each failure modes, value was examined for major three factors time, cost and quality. Annexure 2- figure 9 shows about the comparison of customer value.

IV. RESULTS AND DISCUSSION

As a result of applying lean six sigma tool in construction of residential building, it was noticed that the percentage reduction in time and cost factors. And then increased in percentage of quality factor was also observed. Critical risk factors which are causing delay in completion of activities were also determined by using FMEA analysis and control measures were also given in FMEA report. By the introduction of value stream mapping which is a lean tool, it was observed that 12.48% reduction of total project time from an existing ongoing stage of construction of residential building. Then the cost spent on non-value added activities was also reduced as 2.8% from an actual existing project cost with the help of value stream mapping tool. And there was an improvement in quality was noticed as 33.3% from current state of activities. After collecting the satisfaction survey from client, their satisfaction level was measured and then percentage of customer value was calculated. Finally, increased in percentage of value for customer satisfaction level was observed as 30.53% increase in time, 40.47% increase in cost and 20% increase in quality factors when compared to existing state of activities. Annexure 2- figure 10 shows about the increased level of percentage value for customer satisfaction by implementing value through lean.

V. CONCLUSION

Conclusion

Root causes of delay were identified and could be rectified by implementing lean six sigma tool. Unnecessary cost and time spent on non value added activities were also being reduced as minimum as possible. Satisfaction level of customers will be high while utilization of resources will be low. Customer satisfaction level could be increased while minimizing the utilization of resources without compromising the quality by adopting suitable lean practices. The maximum value of customer satisfaction was achieved for the three major factors which are time, cost and quality. Hence it is possible to attain the customer value through lean by implementing lean six sigma in construction projects.

Recommendations

- ✓ To avoid Risk at the end of finished project, design team could take a regular survey from client.
- ✓ To avoid time overrun of project, work could be executed as per schedule.
- ✓ Timely evaluation of project could be done in order to avoid mishaps.
- ✓ Establishment of continuous improvement method for measuring performance of process.
- ✓ Establishment of monitoring and controlling the labors in order to increase productivity.
- ✓ Parallel processing of work execution could be implemented on construction site to reduce time over-run.
- ✓ Establishment of daily meetings with labors could enhance the reduction of failure to meet deadline of project.
- ✓ In order to decrease the low productivity which causes delay in completion of activities, more focus could be done on unproductive time.
- ✓ Precise quantity estimation could ensure the avoidance of shortage of materials.
- ✓ More attention could be paid on delayed activities and over time could be managed.

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ANNEXURE 1

Table 1 Description about construction site

SITE DESCRIPTION	
Project Name	Residential Building
Location	KK Nagar, Madurai
Civil Contractor	RAM FOUNDATION, Madurai
Plot Area	1270 sqft
No.of.Storeys	G + 3
Project Duration	19.5 Months
Total Cost	Rs.79,01,230
Labors	10 nos
Project Manager	1 no
Site Engineers	1 no

Table 2 Data about Residential building

Parameters	Planned value	Actual value
Project duration	344 days	601 days
Estimated cost	Rs.76,38,580	Rs. 79,01,230
Project start date	23 rd Nov 2019	23 rd Nov 2019
Expected Project finish date	31 st Oct 2020	15 th July 2021

Table 3 Details about project delay

Project Start date	23 rd Nov 2019
Expected Finish date	15 th July 2021
Total project duration	601 days
Work stopped due to COVID-19	23 rd Mar 2020 – 26 th Jun 2020
Delay due to COVID-19	95 days
Work stopped due to Design changes	14 th Nov 2020 – 1 st Dec 2020
Delay due to Design changes	18 days
Delay due to other factors	144 days
Total project delay	257 days

Table 4 Project Charter

GENERAL PROJECT INFORMATION	
Project Name	Construction of a Residential Building
Location	KK Nagar, Madurai
Client Name	Mr.I.Arun Vignesh
Project Manager	R.Vadakaraiyan
Company Name	Ram Foundation, Madurai
Phone Number	9843270805
Start Date	23 rd November 2019
Expected Completion Date	15 th July 2021
Estimated Costs	Rs.79,01,230
PROBLEM, ISSUE, GOALS, OBJECTIVES	
Problem Statement	<ul style="list-style-type: none"> Project delay was observed as nearly 8 months. Lack of client's satisfaction due to project delay and additional cost spent on extra time.
Purpose of Project	To expand and improve the asset in order to increase income from residential rental property by establishing new construction.
Business Case	Contribution to business strategy: <ul style="list-style-type: none"> To make the project best in customer service. Delivering project in timely manner. To ensure customer satisfaction without compromising quality.
Goal Statement	<ul style="list-style-type: none"> To find root causes for project delay and hence reduce delay as minimum as possible. To attain the maximum level of customer satisfaction by reducing additional cost and time spent on non value added functions.
Expected Deliverables	Completed building with minimum over run of cost and time.
PROJECT SCOPE & PROCESS	
Scope	To find and reduce root causes of delay in order to prevent from cost and time over run of project.
Process	Process start: To find out the causes for project delay within the construction process. Process end : Data analysis by using lean six sigma tool and hence reduce construction delay and extra cost spent
PROJECT RESOURCES & COSTS	
Project Team	<ol style="list-style-type: none"> Project manager Site Engineer Non skilled labors
Cost of construction	<ul style="list-style-type: none"> Total cost of Ground floor : Rs. 22,49,000 Total cost of First floor : Rs. 18,81,950 Total cost of Second floor : Rs. 20,59,850 Total cost of Third floor : Rs. 17,10,430

PROJECT BENEFITS & CUSTOMERS	
Key Stakeholders	<ol style="list-style-type: none"> 1. Company owner 2. Project team 3. Project manager 4. Supplier 5. Customer
Final Customers	Single client will offer houses for rental purpose to some other clients.
Expected Benefits	<ul style="list-style-type: none"> • Increased reputation of Construction Company by erecting the building with good quality. • Make happier customers by satisfying their expected requirements about that building. • Improved lifetime of establishment. • Increased revenue for client by offering rental purpose of residential building to some other customers. • Afford accommodation for moreover persons.
PROJECT RISKS, CONSTRAINTS, ASSUMPTIONS	
Risks	<ol style="list-style-type: none"> 1. Design changes approved by client during execution of second floor construction. 2. Work had been stopped due to pandemic situation COVID-19. 3. Time and cost overrun of project.
Constraints	<ul style="list-style-type: none"> • Availability of non skilled labors was restricted to 10. • No usage of equipment in site due to inadequate spacing of street. • Schedule was not explained to labors in advance. • Labors were idle at site. • Improper communication between executive to labors.
Assumptions	<ol style="list-style-type: none"> 1. Establishment of residential building will be completed as per schedule. 2. Construction cost will not exceed the overall budget. 3. Client satisfaction level will be increased.

Table 5 FMEA report

Process step	Failure mode	Effect of failure	Potential causes	S	O	D	RPN	Corrective action
Construction of 1 st floor	Delay due to COVID-19	Project suspension	Pandemic situation	9	10	9	810	Parallel processing of activities
Construction of 3 rd floor	Changes in design order	Delays in project commencement and completion	Different preferences	9	9	9	729	Set realistic goals
Execution of 3 rd floor construction	Slowness in decision making	Delays in activities and total projects	Lack of adequate information	10	7	10	700	Pull ahead the client to take resolution
Execution of 3 rd floor construction	Shortage of materials	Delays in activity/ project completion	Poor quantity estimation	9	8	9	648	Build precise quantity estimation

At the completion stage of 2 nd floor	Design changes during the project	Delays in completion of tasks	Different preferences	8	10	8	640	Parallel processing of activities
Entire project work	Idle at site	Failure to meet deadlines	Low motivation	9	7	9	567	Daily meetings
Entire project work	Low productivity	Delays in activity/ project completion	Poor work environment	9	6	9	486	Focus on unproductive time
Execution stage of 3 rd floor	Delay in approving design document	Failure to meet deadlines	Behind schedule, information was passed by client	7	9	7	441	Pay attention to activities and manage overtime
Entire project work	Improper storage of materials	Loss of materials/material damage	No storage yard	9	5	9	405	Providing storage yard within site area

Table 6 Comparison of total time and cost

Aspects	Current state	Future state	% Reduction
Total Cycle time	245 days	219 days	10.61%
Total Lead time	386 days	321 days	16.84%
Total Project duration	601 days	526 days	12.48%
Total Project cost (Excluding plastering, electrical & plumbing, painting and fixtures)	Rs.64,01,230	Rs.62,21,980	2.8%

ANNEXURE 2

Fig 1. Construction site



Fig 2. Research methodology

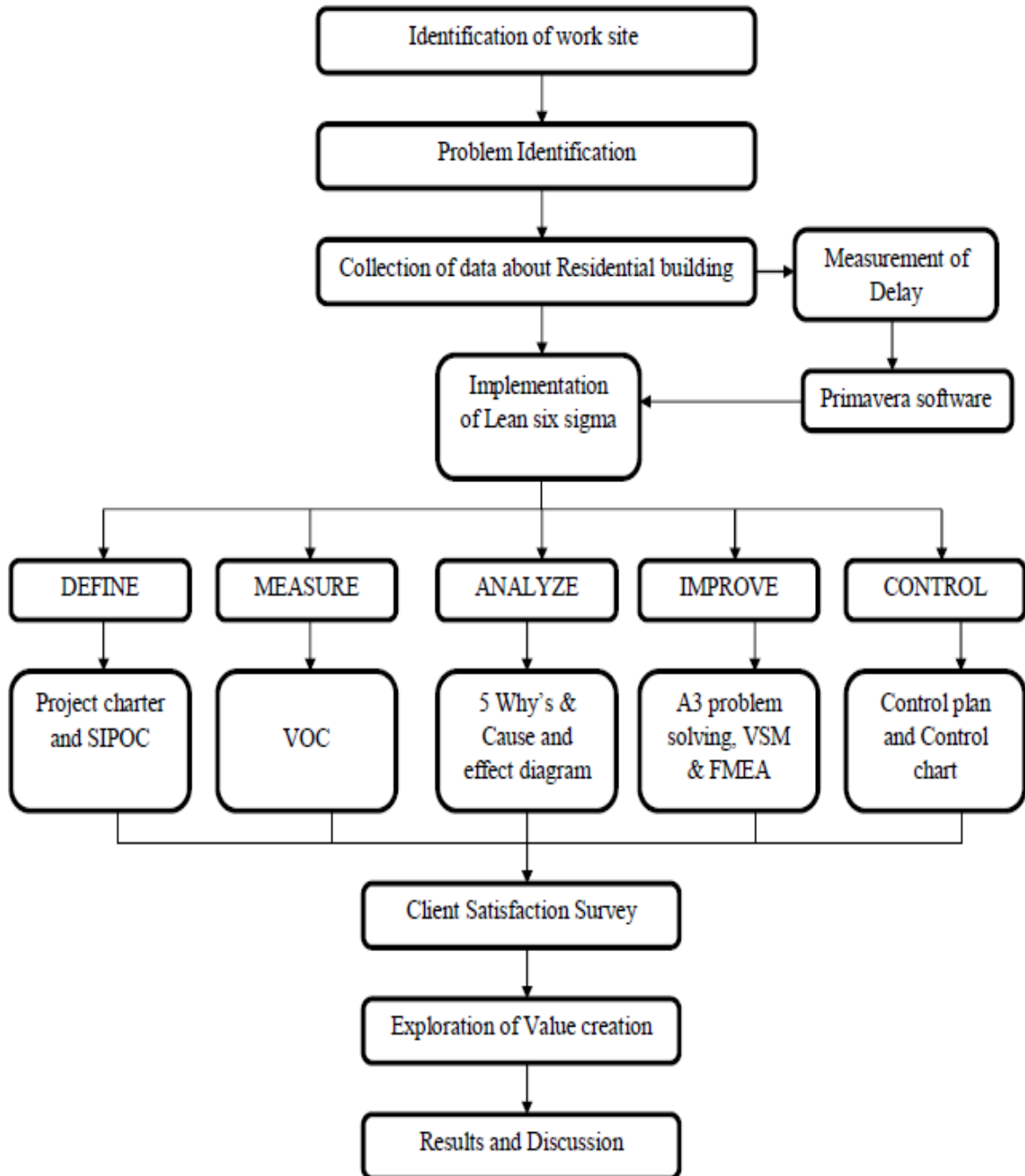


Fig 3. SIPOC diagram

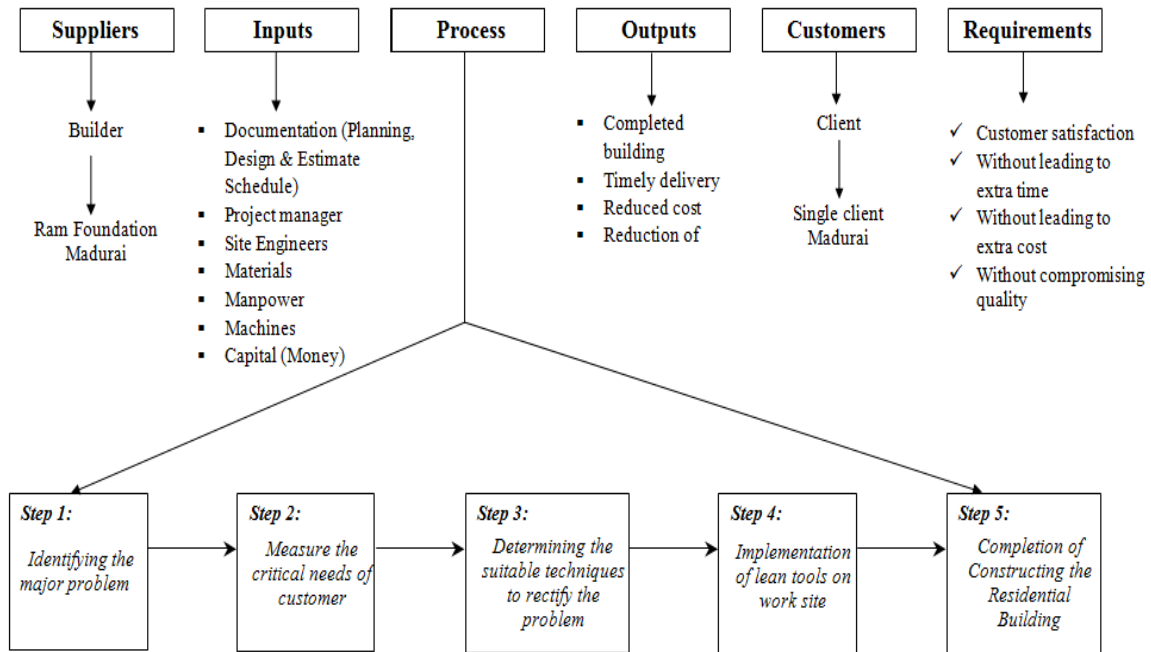


Fig 4. 5Why's analysis

DEFINE THE PROBLEM	Delay on constructing the Residential Building was observed as additional 8 months.	
WHY IS THIS A PROBLEM?	<p>PRIMARY CAUSE Why is it happening?</p> <p>1 It is happening because of pandemic situation COVID-19 and delay due to rain.</p> <p>Why is that?</p> <p>2 It is happening because of design changes approved by clients at the stage of completion of building.</p> <p>Why is that?</p> <p>3 It is happening because of improper handling and storage of construction materials.</p> <p>Why is that?</p> <p>4 It is happening because of non utilization of suitable equipment due to inadequate spacing of street.</p> <p>Why is that? ROOT CAUSE</p> <p>5 It is happening because of idling and low productivity of non skilled labors.</p>	
CORRECTIVE ACTION TO TAKE	<p>CORRECTIVE ACTION</p> <ol style="list-style-type: none"> To motivate labors to complete the work as per schedule without leading delay. To eliminate the non value added functions from job plan in order to reduce delay. To increase the labor strength to complete the work as earlier as possible. To find needs of customer and satisfying their requirements. 	<p>MAJOR PROBLEM Project Delay = 8 months</p>

Fig 5. Fishbone diagram

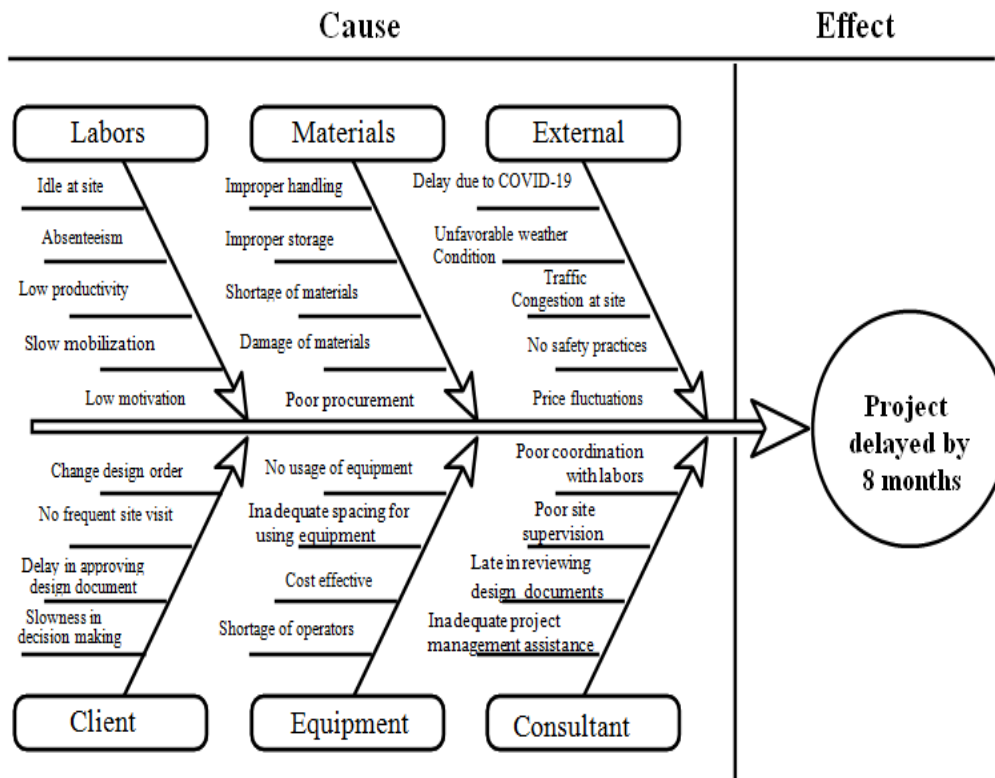


Fig 6. Voice of customer

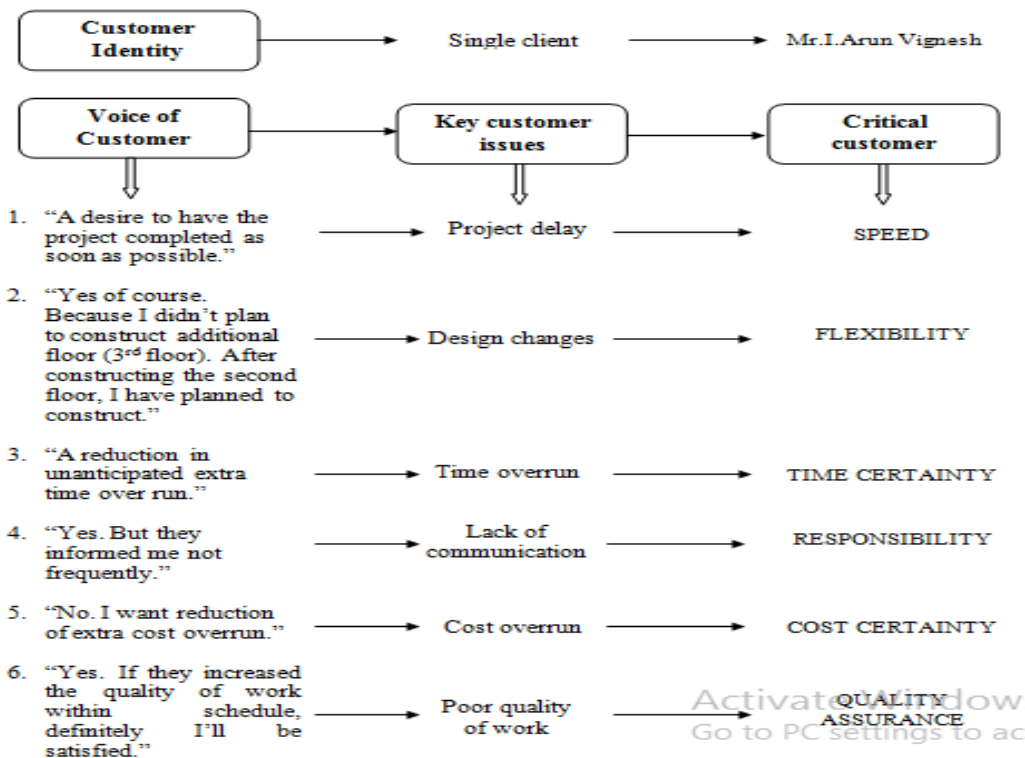


Fig 7. Comparison of schedule

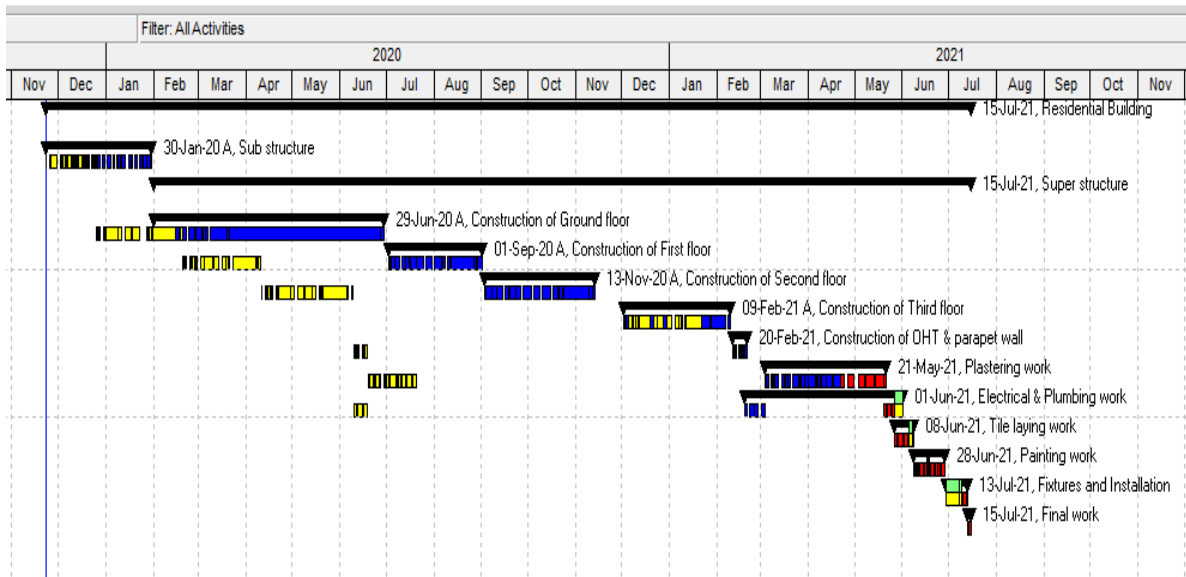


Fig 8. Comparison of VSM

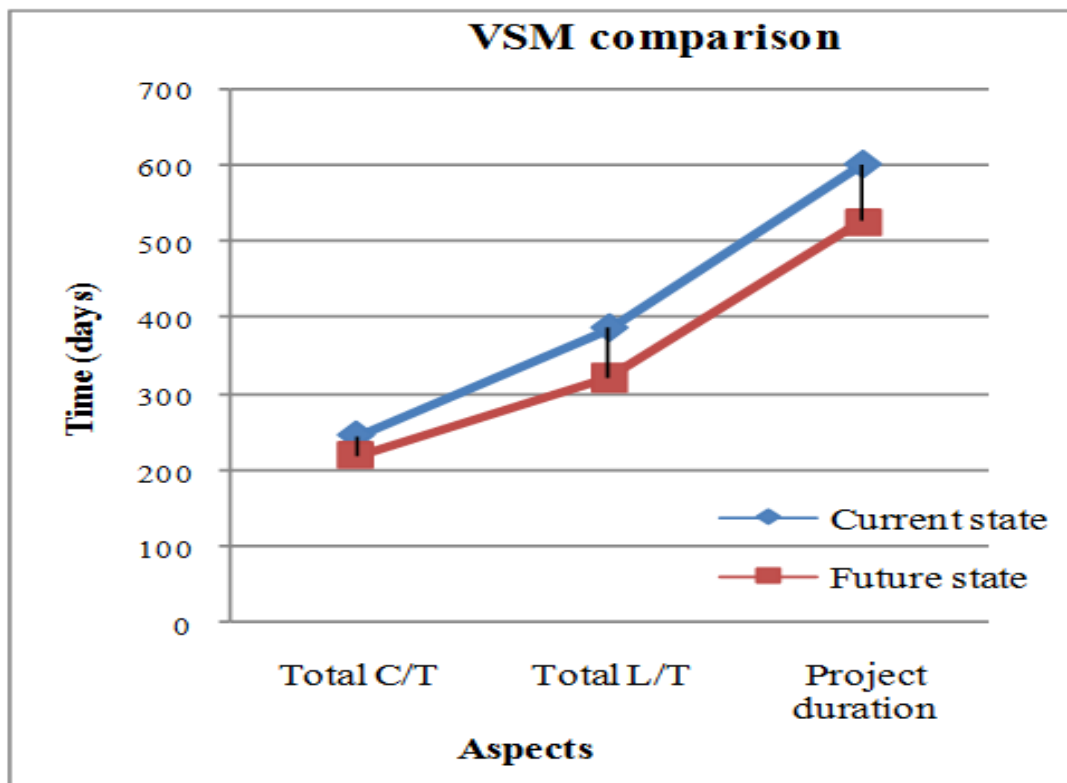


Fig 9. Comparison of customer value

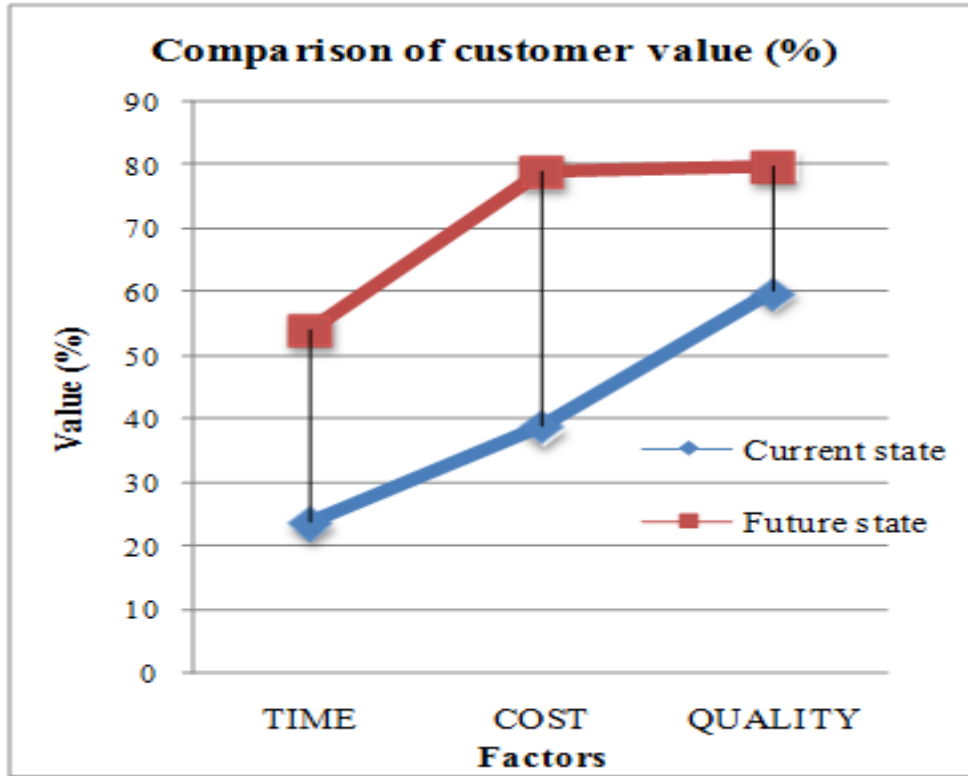


Fig 10. Value through lean

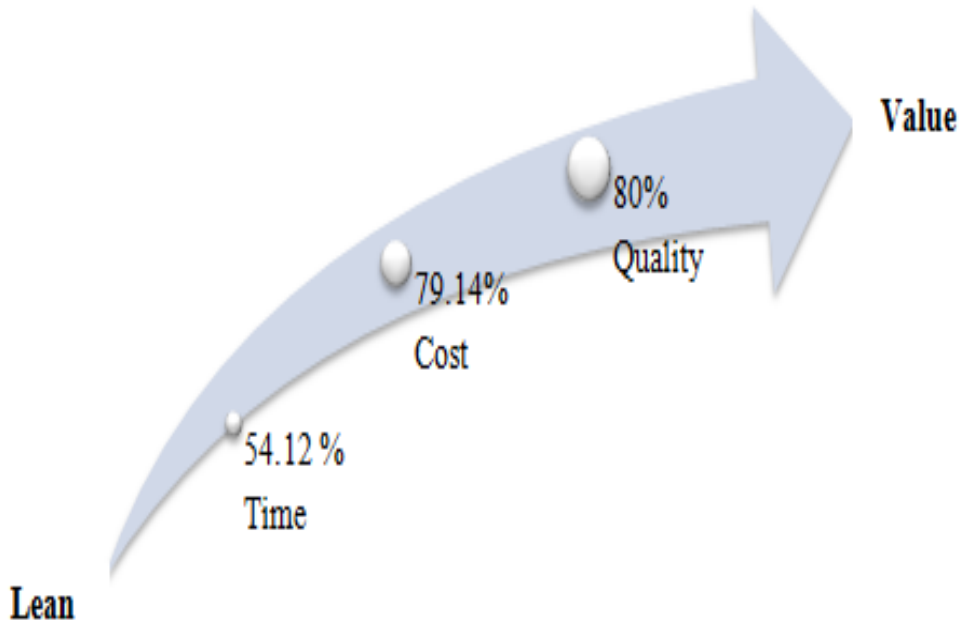


Fig 11. Current state map for substructure

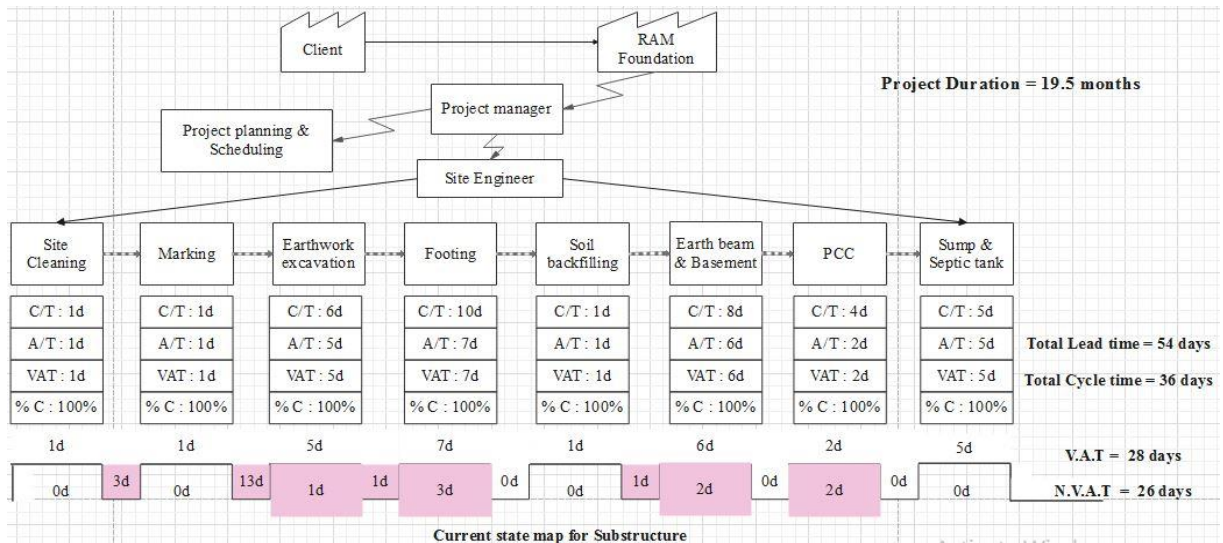


Fig 12. Future state map for substructure

