DIGITALIZING QUALITY MANAGEMENT IN CONSTRUCTION

A Thesis

Submitted in partial fulfillment of the requirements for the award of
Master of Architecture degree in Building Management

by

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BONAFIDE CERTIFICATE

This is to certify that this Report is the bonafide work of **MONISHA MARTIN (40840009)** who carried out the Thesis entitled "**DIGITALIZING QUALITY MANAGEMENT IN CONSTRUCTION**" under our supervision from January 2022 to May 2022.

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PLACE: Chennai **SIGNATURE OF THE CANDIDATE**

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this Thesis project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. Devyani Gangopadhyay, Dean and Head of the department, Dept. of Architecture, School of Building and Environment,** for providing me necessary support and details at the right time during the progressive reviews.

My special thanks to **Dr. Suresh Kuppusamy,** our Design chair and **Ar. Sarath C Kanth** (External guide) and **Ar. Sukirtha Suresh** (Thesis Coordinator) for their valuable comments and guidance during the project work.

I would like to express my sincere and deep sense of gratitude to my Project Guide
Ar. Sukirtha Suresh for her valuable guidance, suggestions and constant encouragement which paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of Architecture who were helpful in many ways for the completion of this Thesis.

I would like to thank The CBRE team for their support. Also, I would finally like to thank my family without whose support all of this won't have been possible.

ABSTRACT

The cost & size of upcoming construction projects has gone up exponentially. Large scale construction projects & infrastructural projects are now very common. Continous monitoring during construction is often a laborious task for the stakeholders. Conventional Quality management system proves to be inefficient & ineffective. Decision making often is time consuming. There is an immediate need for a change in scenario with respect to quality management. This instigates the use of technology to bridge the existing gaps.

The aim is to create a comprehensive quality management plan at various stages during execution. The methods adopted will integrate both the theoretical & practical aspects. Data collection would be though primary sources & by closely reviewing the existing quality control plans. The summary would include identifying the gaps in the existing system including an attempt to break away from the customary configurations into a framework that can be easily adopted on site, layered with technology by means of dynamic checklists, mobile applications etc. which would be user friendly, stage specific & time saving hence alleviating issues currently faced and bridging the gaps amongst the various stakeholders involved

Keywords: Digitalization, Quality management, Design thinking, Workflow methodology, Mobile application.

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LIST OF SYMBOLS AND ABBREVIATIONS

QM	-	Quality Management
PM	-	Project Manager
NCN	-	Non - Conformance Notice
SN	-	Site Note
QA/QC	-	Quality Assurance/ Quality Control
TQM	-	Total Quality Management
QMS	-	Quality Management System
ISO	-	International Organization for Standardization
RP	-	Research Paper
MIR	-	Material Inspection Report
MTC	-	Enterprise Resource Planning
ITP	-	Inspection & Testing Plans
MTP	-	Material Testing Plans
MS	-	Method Statement
FW	-	Formwork
FMEA	-	Failure Mode Effect Analysis
UI	-	User Interface

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

This study will focus on deploying, using and evaluating the benefits of digital quality control on site - requirements for digital control, digital control principles, digital control tools and their capabilities, outputs from digital quality control, utilization and implementation of digital quality control and its benefits for design, implementation and evaluation in the building's execution for the RCC related activities including blockwork & plastering.

Quality control forms an integral part of any construction system. A comprehensive quality management system for the execution of civil works which will encompass all the stakeholders involved with a dynamic framework which is both user friendly & stage specific is currently lacking. Also, this instigates the use of technology to bridge the existing gaps. This will enable transparency among stakeholders with constant monitoring at various stages during execution through continuous improvement.

The standard tests involved, roles of inspectors and corrective actions on-site necessary will be highlighted. Critical issues pertaining to the quality management will be reviewed. These will include all the parameters which could potentially affect the efficiency of the quality system. The results will highlight aspects of quality management processes that may be re-engineered through appropriate applications.

1.2 AIM

To create an algorithm & Mobile application UI for digitalizing quality management to mitigate the issues currently faced during execution stage in order to achieve optimum quality & efficient inspection

1.3 OBJECTIVE

- To understand & review the prevailing techniques
- To cater the quality management for Indian context
- To analyze the effectiveness of quality management tools & techniques and to recommend for better outcomes.
- Validate need for digitization in quality management

1.4 RESEARCH QUESTIONS

- Which factors contribute to the issues during the execution
- How to improve the existing quality control system digitally
- What are the critical issues related to the quality of the structure

1.5 LIMITATIONS OF THE STUDY

The research will be focused on building construction during the execution stage of RCC related activities – reinforcement, formwork & concreting in IT buildings.

1.6 IMPORTANCE OF THE STUDY

- To enable transparency among stakeholders with constant monitoring at various stages during execution by continuous improvement.
- Bridge the existing gaps in the current execution of construction, high competition & globalization
- To highlight the advantages that can be achieved by digital quality control resulting in efficient project execution

1.7 NEED FOR THE STUDY

Current market: Lack of digitization for holistic quality management. Some of the issues include:

- Delay in decision making
- Stakeholders not involved/ updated at the right time
- Workflow not monitored at every stage
- Many repetitive errors
- Many NCN's & SN's remain open for long time
- No proper ownership & responsibility of issues with assigned deadlines etc.

1.8 METHODOLOGY

The research methodology is divided in two parts: theoretical aspect & practical aspects. The former discusses the building technology according to Standards, Codes and system requirements. The latter concerns with current operation process.

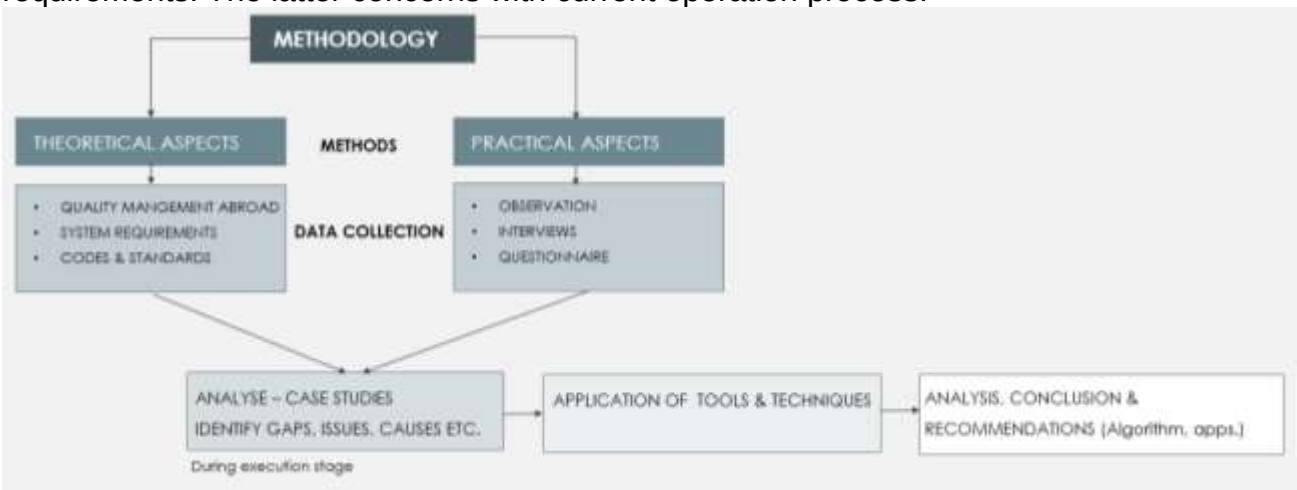


Fig 1.1 Methodology steps

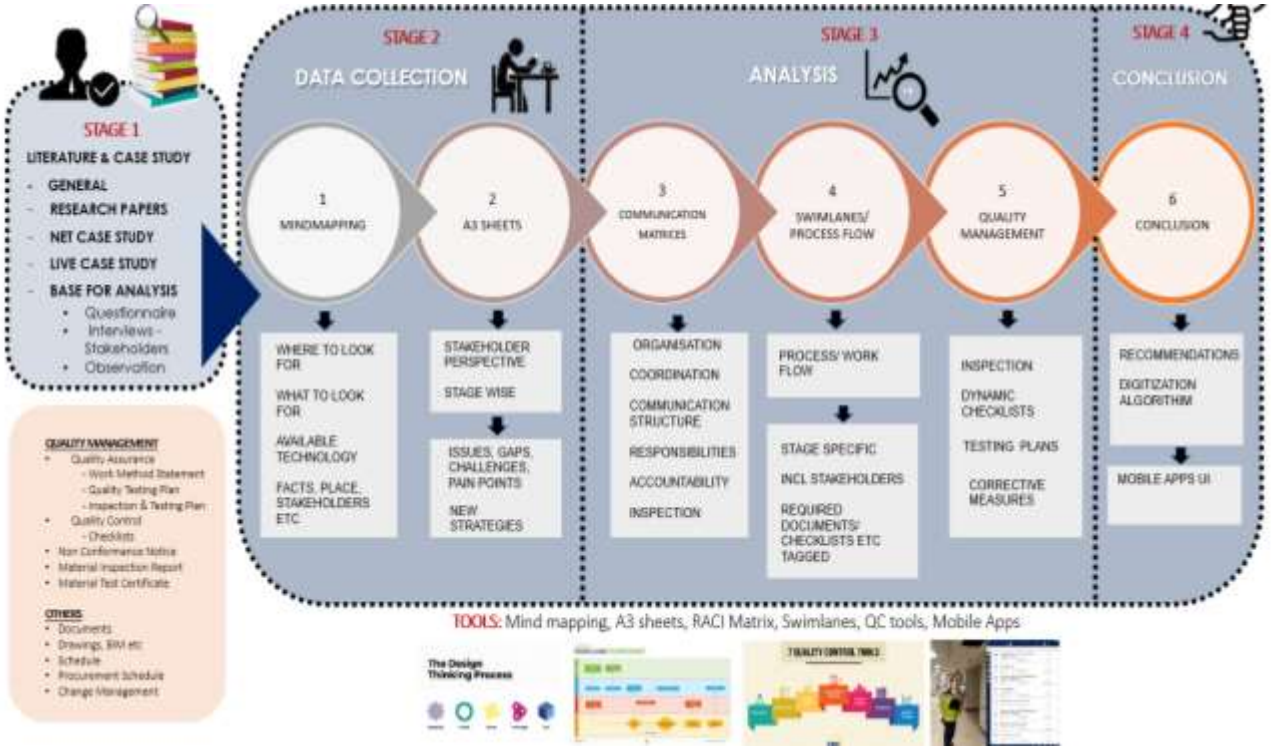


Fig 1.2 Methodology stages

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Quality - Is the characteristic element of an item that can be evaluated as a meeting standard, whereby if it meets or exceeds the standard, it can be said to be of good quality or high quality. However, if the item does not meet the standard, it is considered poor quality *(Mincks, W. R.1997 and Johnston, H. 1997)*

Fig 2.1 Construction Project QM

2.2 QUALITY MANAGEMENT SYSTEM

Quality management system - Is the interaction of people, processes and documentation to meet both customers" stated and implied needs *(Mohammed, H. 2006 and Abdullah, M. N. 2006)*

- **Quality planning** - A quality plan is a document/ several documents, that specify quality standards, practices, resources, specifications, and the sequence of activities relevant to a particular product, service, project, or contract.
- **Quality control** - Emphasizes testing of products to uncover defects and reporting to management who make the decision to allow or deny product
- **Quality assurance** - Attempts to improve and stabilize production and associated processes to avoid, or at least minimize, issues which led to the defects in the first place.

Fig 2.2 PM Golden Triangle

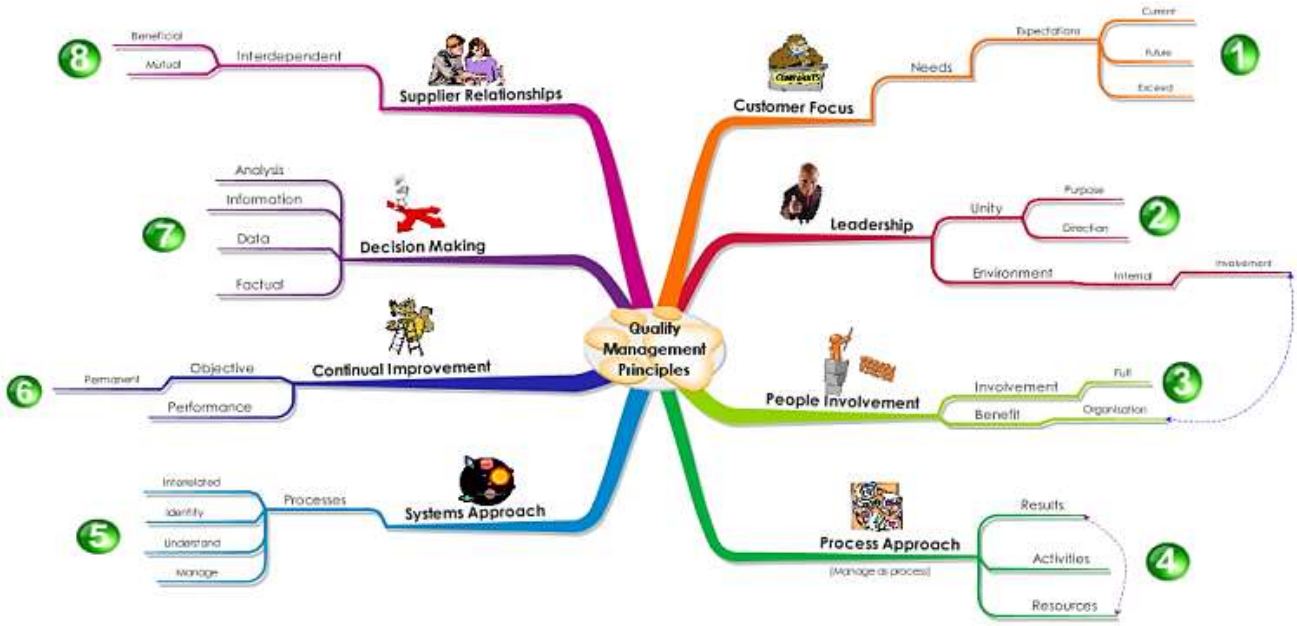


Fig 2.3 Mind mapping QM

2.3 TOTAL QUALITY MANAGEMENT

Total Quality Management (TQM) - A management approach to long-term success through customer satisfaction. In a TQM effort, all members of an organization participate in improving processes, products, services, and the culture in which they work.

ADVANTAGES:

- Strengthened competitive position
- Adaptability to changing or emerging market conditions
- Higher productivity
- Enhanced market image
- Elimination of defects and waste
- Reduced costs and better cost management
- Higher profitability
- Improved customer focus and satisfaction
- Increased customer loyalty and retention
- Increased job security
- Improved employee morale
- Enhanced shareholder and stakeholder value
- Improved and innovative processes

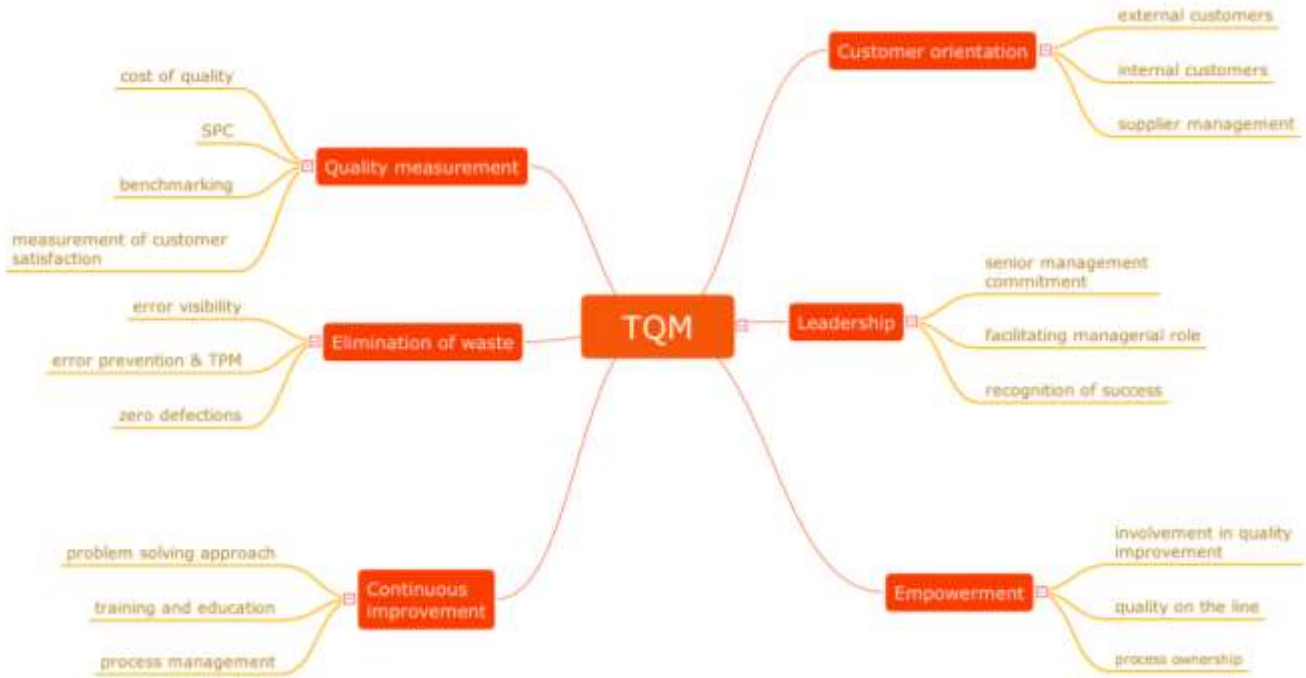


Fig 2.4 Total Quality Management

2.4 INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO 9000 Quality System Requirements *(Napiah, M. 2012)*

- In terms of Engineering, the requirements include holding the key engineering meetings and maintain records of meetings as well as maintaining engineeringrevision sheets (ERIs).
- For the documents part, includes the need to maintain document approval procedures, record issuance or receipt of all transmittals and documents, maintain and control ERIs and maintain latest issues of applicable law and regulations.
- Disposition of Nonconformity includes action and report on each nonconformity, issue nonconformance reports and feedback data sheets
- Corrective Action to maintain control sheets on request, execution and review on corrective actions
- Training qualification, record for each personnel and training in each project organization.

ISO 9001 - Is defined as the international standard that specifies requirements for a quality management system (QMS).

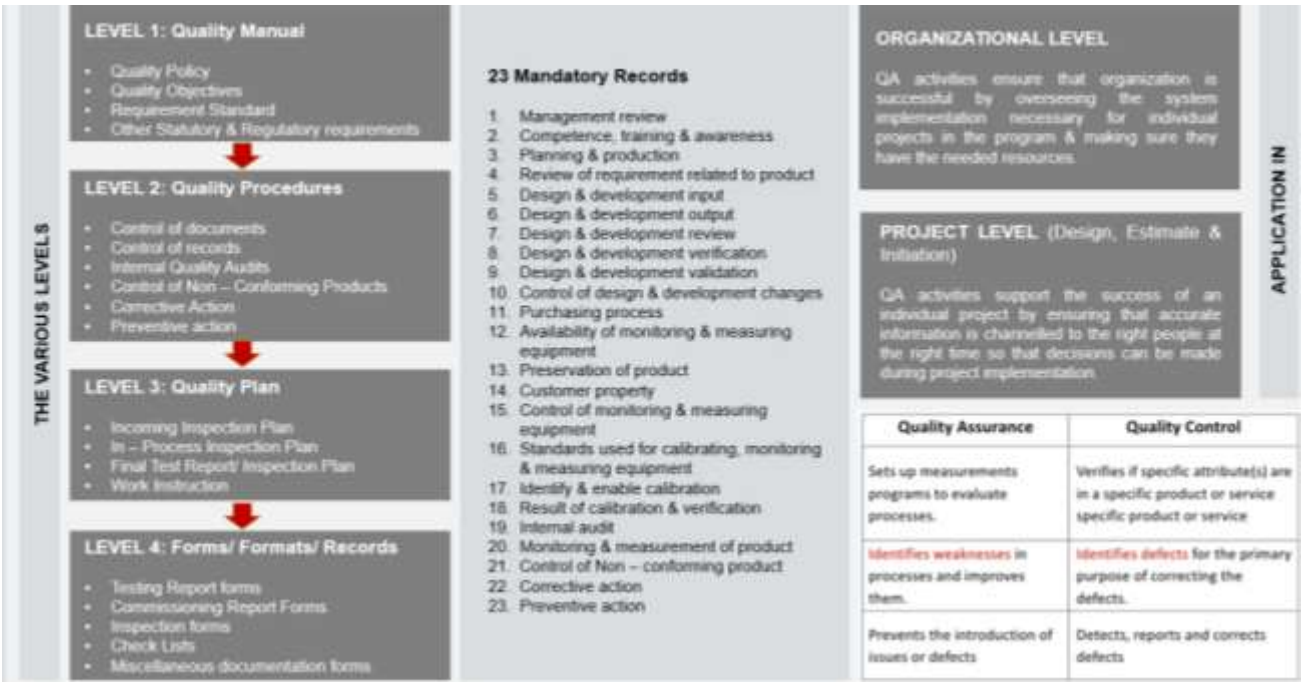


Fig 2.5 ISO 9001

Table 2.1 Summary of journals related to QM

No.	Author	Findings
1	David Arditi and H Murat Gunaydin (1997)	• All customers must be satisfied. These customers include internal customers (employees, units, departments within an organization) and external customers (owner, designer, contractor, etc.). • The requirements of the owner must be clearly defined at the beginning of • the project & be agreed to by both the owner and design Firm. • The more time and effort are spent at the beginning in defining requirements, the more smoothly the project will progress. • Objective setting is important because it provides a focus for scope definition, guides the design process, controls the construction process, and influences the motivation of the project team.
2	Ilias Said, Abd Rahaman Ayub, Arman Abd Razaki, & Tee Kuan Kooi (2009)	Main advantages of implementation of QMS are: • Enhanced Image and Reputation of Organization • Performance Improvement and Increased Customer Satisfaction.
3	Srinidhi (1998)	Establishes that effective quality management cannot be practiced in isolation from other initiatives or the overall strategy of the firm.
4	Taylor et al. (2003)	Senior managers' involvement, understanding and customer focus are essential antecedents of TQM success
5	Mane & Patil (2015)	Quality is one of the critical factors in the success of construction projects. Check lists → quality tool, quality control measure as quality in workmanship due importance to be given for customer satisfaction
6	Tan et al., (2003)	To survive in the current business environment, it is necessary to look for ways to improve quality and productivity in order to enhance their competitive edges
7	Lydia (2010)	• Stakeholders to be included in the task of quality planning for the project • Establish and define the purpose of the quality system • In the plan, minimize the effort required to amend copies of documents
8	Pheng (2004)	TQM could be replicated in the construction industry as in manufacturing. The benefits : • Terms of reduction in quality costs • Better employee job satisfaction

2.5 RESEARCH PAPERS

2.5.1 Research Paper – 1

Quality management system at construction projects

Pravin P. Mane, Dr. Jalindar R. Patil | INDIA | 2015

Abstract

The Quality Management System (QMS) in construction industry refers to quality planning, quality assurance, quality control. The main goal of construction industry is to ensure that construction projects are successfully completed within the constraints of best quality, stated period and at minimum possible cost. The research based on QMS recommended that construction companies should create a flexible and conducive organizational atmosphere which encourages the development of quality management system in all aspects of their work.

Quality management system

- Is a continuing process of improvement involving all aspects of the business?
- To prevent mistakes before they happen.
- The three phases of QMS are as *Quality Planning, Quality Control and Quality Assurance.*

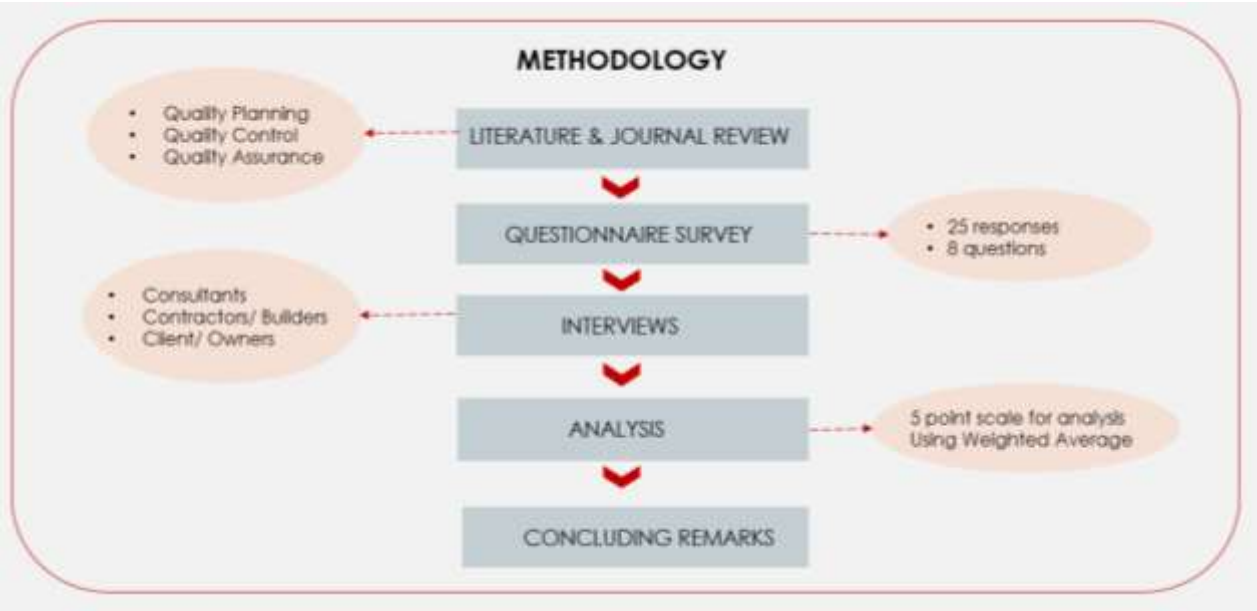


Fig 2.6 RP – 1: Methodology

Conclusion

The very strongly quality tool used at construction project is check lists. Issues with respect to quality:

- Poor planning
- Not giving importance to the customer satisfaction.

- Importance not given to test reports from suppliers.

Challenge: Implementation of quality management plan on site
After study following concluding remarks:

- Satisfaction of all stakeholders in the industry.
- Better understanding on quality control procedure.
- Satisfaction of Client.
- Suitable quality control method for the project.
- Development of the quality of strength in construction.
- Total Quality Management at construction projects.

2.5.2 Research Paper – 2

Critical factors affecting quality performance in construction projects
K. N. Jha & K. C. Iyer | INDIA | 2014

Abstract

A preliminary survey identified 55 attributes responsible to impact quality performance of the projects. Further analyses of individual sets of success attributes and failure attributes separately grouped them into fewer critical success and failure factors. Project manager's competence and top management support are found to contribute significantly in enhancing the quality performance of a construction project.

Critical success factors

- Project manager's competence
- Top management's support
- Monitoring and feedback by project participants
- Interaction among project participants
- Owners' competence

Critical failure factors

- Conflict among project participants
- Hostile socio-economic environment
- Harsh climatic condition
- PM's ignorance & lack of knowledge
- Faulty project conceptualization
- Aggressive competition during tendering

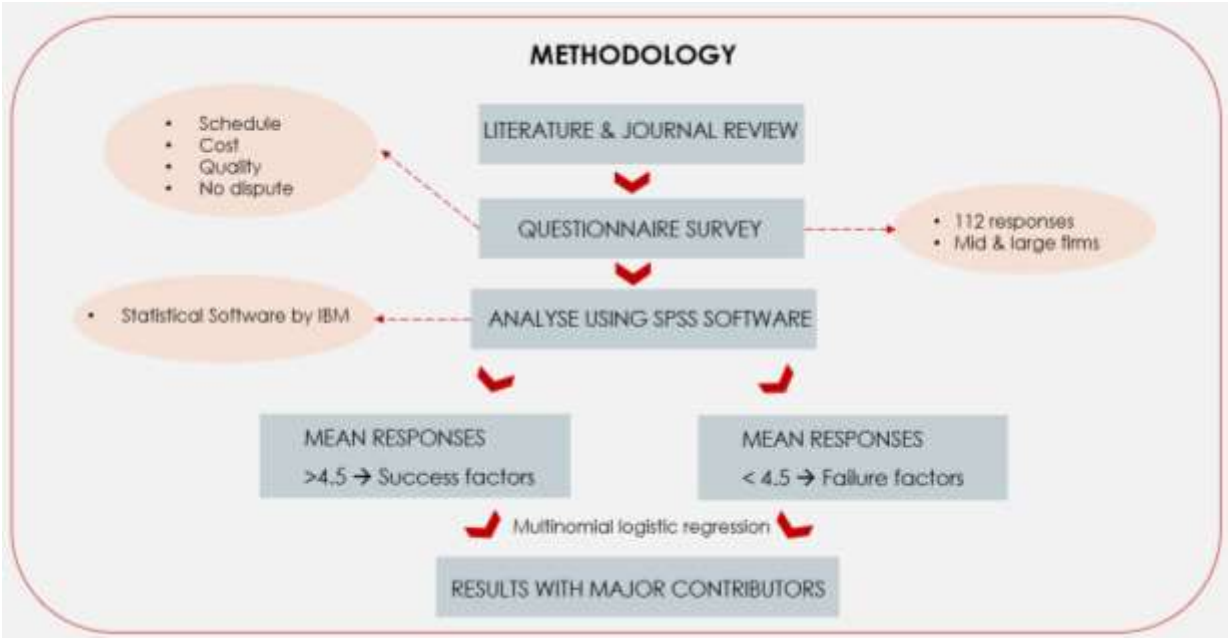


Fig 2.7 RP –2: Methodology

Conclusion

The repercussions and consequences of poor quality can be:

- A loss in productivity;
- Additional expenditure by way of rework and repair;
- Loss of reputation,
- Leading to loss in market share;
- Eventually being put out of business.

The results of the study prove to be closer to Juran's philosophy that middle management (project manager and his team in this case) play a more important role in most stages of the project, although the top management's role becomes more significant in further enhancing the level of quality when the existing level is already high.

2.5.3 Research Paper – 3

Digital quality control of construction work

Jaroslav Synek | CZECH REPUBLIC | 2019

Abstract

Emphasizes on deploying, using and evaluating the benefits of digital quality control on site - requirements for digital control, digital control principles, digital control tools and their capabilities, outputs from digital quality control, utilization and implementation of digital quality control. Advantages for design, implementation and evaluation in the building's life cycle.

Characteristics of construction projects

- Long period (months to years)
- Associated amount of changes over time (slow & inaccurate)
- Great diversity
- Many suppliers

The result is complex project management. Digitization rationalizes procedures, refines and enables reviewing.

Prerequisites for digital efficiency

- Professional competence
- Co-operation in project operations
- Coordination of participants to achieve project goals

Need of digitization in quality management

Problem 1: Current procedures - laborious, inaccurate, unavailable for use after the end of the project.
Solution 1: Digitization changes processes, outputs, and uses of quality control results – Efficient

Problem 2: Quality control generally assumes unambiguously defined requirements at each stage of the project
Solution 2: The digitization of control refines and accelerates activities, brings added value

Streamlining advantages

- Limitation of routine non-systemic activities
- Reduction of finishing errors
- Unambiguous identification (subject, place etc.)
- Higher efficiency of control activities
- Activities are not duplicated.
- Time savings,
- Limitations of non-system procedures
- Improves management efficiency
- Increased accuracy and processing speed
- Accessible to all project participants
- Allows gradual transition of project management to full digitization.

Conclusion

Proven benefits include:

- Unification
- Operational Processing
- Optimization of Outputs
- Standardization of Operational Procedures
- Acceleration
- Higher Quality
- Less Error of Information.
- Accurate Information (Clear- cut, Up-to-date, Readily available)

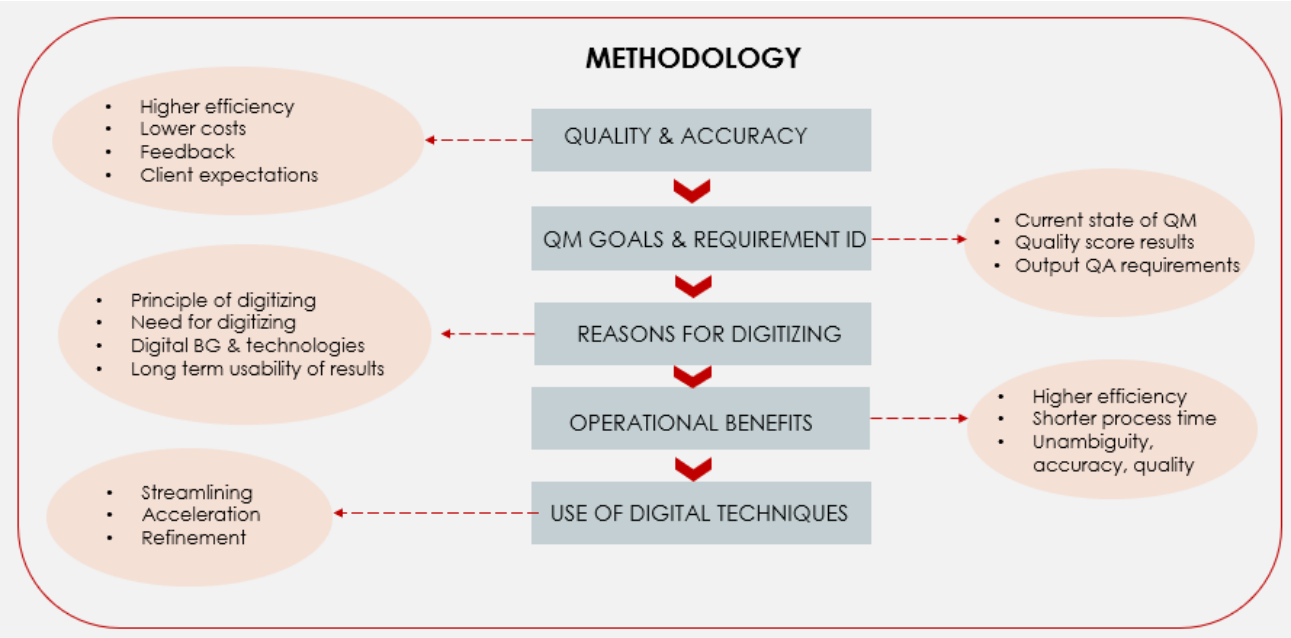


Fig 2.8 RP –3: Methodology

2.6 RESEARCH PAPERS SUMMARY

Table 2.2 Summary of Research Papers

S.No	THRUST AREA OF JOURNALS | LOCATION	SUMMARY OF RESEARCH	TOOLS/TECHNIQUES USED	TAKE AWAYS
1	QMS | India	• Poor planning major contributor for failure • Client satisfaction should be important • Supplier testing essential than site inspection of raw materials	• Questionnaires • Interviews • Weighted Average	• Process approach needed • Aspects of QMS to focus on
2	Critical factors in QM| India	• Consequences of poor quality • Middle management play important role • Top management crucial for enhancing quality further	• Questionnaire survey • SPSS software	• Process approach needed • Essence of other journals • Critical factors affecting success of QM • Critical factors affecting failure of QM
3	Digitizing QM | Czech	• Extend knowledge of project team → efficient, higher quality production • Increase in productivity	• Digitization	• Benefits of digitisation • Process of doing digitization • Reinstate need of digitalization

CHAPTER 3
CASE STUDIES

3.1 NET CASE STUDIES

3.1.1 Net Case Study – 1

A case study: effective implementation of quality control system in building construction
V. G. Salunkhe, A. N. Pinate, R. S. Alte, R. R. Gaikwad, Prof. U. J. Phatak | INDIA | 2018

Abstract
Attaining desired improvement of quality in major issue in construction sector. Human & material resources are expelled unnecessarily due to insufficient or non - existent/ unawareness of procedures relating to QM.

Quality control/ quantity assurance
Covers all the activities necessary to provide quality in the work to meet the project requirements. It involves establishing project related policies procedure, standard, training, guidelines and system necessary to produce quality.

- Provides protection through early warnings of both internal and external Problems
- Minimizes alterations, omissions, or faults sometimes leading to disputes and conflicts.

Present scenario
- **ISO** defines international standards in subjects like designing, testing production, delivery and service. The ISO 9000 series encompasses two standard Types - *Quality assurance* and *Quality management.*
- **TQM** is a broader concept focusing on customer ‘s requirements, and activities involving Quality Control
- Today Indian Companies are facing high competitor with companies worldwide inflame of globalization and cognizance.

Case study steps
Construction companies in *Pune* city
- Observations on checklists of material and quality
- Applied improved or modified checklists
- Observe the improvement obtained in terms of time, quality and economy

Questionnaire survey
- 256 questionnaires to site - engineers, contractors, builders of different construction
- 15 - 17 response from them as below.

TQM FIELD APPLICATION About 34% of firms have successfully implemented TQM. Awareness (workers & contractor) insufficient at larger proportion profit and losses are not met as per targets.	**TRANSIENT NATURE OF WORKERS.** About 73% of workers are transient to work. Seek employment near by to their home, site may be located at new place making them irrelevant to relocate. Contract basis relationship must be developed in order to maintain workforce.	**DISREGARD TOWARDS TQM** It has been observed that 15% of people on site consider TQM as an irrelevant method to be adopted in sites, especially minor sites.
BARRIER Language barrier is a minor problem for interacting. Also, insufficient material availability is about 48% at sites due to long distance	**DEVELOPMENT** 72% workers said that by programming training workshops, education can be provided thus boosting quality. 15% quality can be implemented by conducting quality field tests.	**FINACIAL STATUS** About 30% said financial status is responsible for accelerating the work progress.
MATERIAL QUALITY Around 90% people regard necessity of maintaining quality as an important factor.	**QUALITY CONTROL AND QUALITY ASSURANCE** About 95% crowds on the site believe that quality is very essential to achieve economy as well as guarantee	**CONCLUSION** Quality Control System benefits in terms of customer satisfaction, economy, time factor, etc.

Fig 3.1 Net Case Study 1: Highlights

3.1.2 Net Case Study – 2

Case study on quality assurance system in construction
Vikas Patel1, Brijesh Singh, P N Ojha, Amit Sagar | INDIA | 2021

About the projects

- 30 construction projects were selected from NCR
- Construction cost between 3-5 Crores
- Data was collected - quality and management related aspects.
- Structures such as school buildings, community hall, hostel block etc.

For an effective QA:

- Determine if expected quality standard met.
- Examine the quality of the ongoing & completed work
- Ensure that the material used meets project quality standards.
- Issue a report of acceptable work & substandard work.
- Track the corrective work & issues
- Examine the quality control methods
- Review processes, practices & procedures
- Identify possible areas for change

Conclusion

- For nearly 13% of the projects quality assurance is just satisfactory which is point of concern, keeping in view the lapses in quality system of various parameters, the Quality Assurance System of the projects were categorized as poor.

The major negligence:

- With mix design,
- Storage of materials,
- Work practices used during construction
- Availability of equipment's at the site.

Quality is an essential element for sustainability and consumer satisfaction. The high cost of the infrastructures makes it necessary to ensure the quality of the finished structure.

3.2 LIVE CASE STUDIES

3.2.1 Live Case Study 1 - HCL, Madurai

Fig 3.2 HCL Madurai: Campus View

- Location: ELCOT (the electronics corporation of Tamil Nadu limited) Madurai, TN
- Total site area: 6.75 acres
- Total built up area: 6,00,000 sq. Ft. (approx.)/ 55,750 sqm approx.
- Total nos. Of seats: 4,865 seats (11.5 sqm/ person)
- No. Of towers: 3
- No. Of floors: b+g+4 floors (tower 2 & 3), g+2 (tower 1)
- FSI: 1.43
- Ground coverage: 39 %
- Construction start date: march, 2016
- Phase 1 (tower 1) completion: September, 2016
- Phase 2 (tower 2 & 3) completion: July, 2018
- Major clients: MERK, Deutsche bank, Johnson & Johnson, Baxter etc.

Consultants:

- **Architect/ Structural/ MEP:** C R Narayana Rao architects & engineers Pvt ltd
- **Project coordinators**: CBRE
- **Landscape consultant:** Dhruva landscape architects

About the Project

This 6.75-acre campus was driven by a green mission with a goal for energy savings from the very start. Midrise buildings using half of the permitted FSI with interlinked courtyard. This zero-discharge facility has invested in state of the art BMS systems. Though active certification was not sought, all major decisions were influenced by how the correct design could lower energy consumption. Architectural decisions such as placement of staircases encourage walking. Natural light permeates all interior spaces.

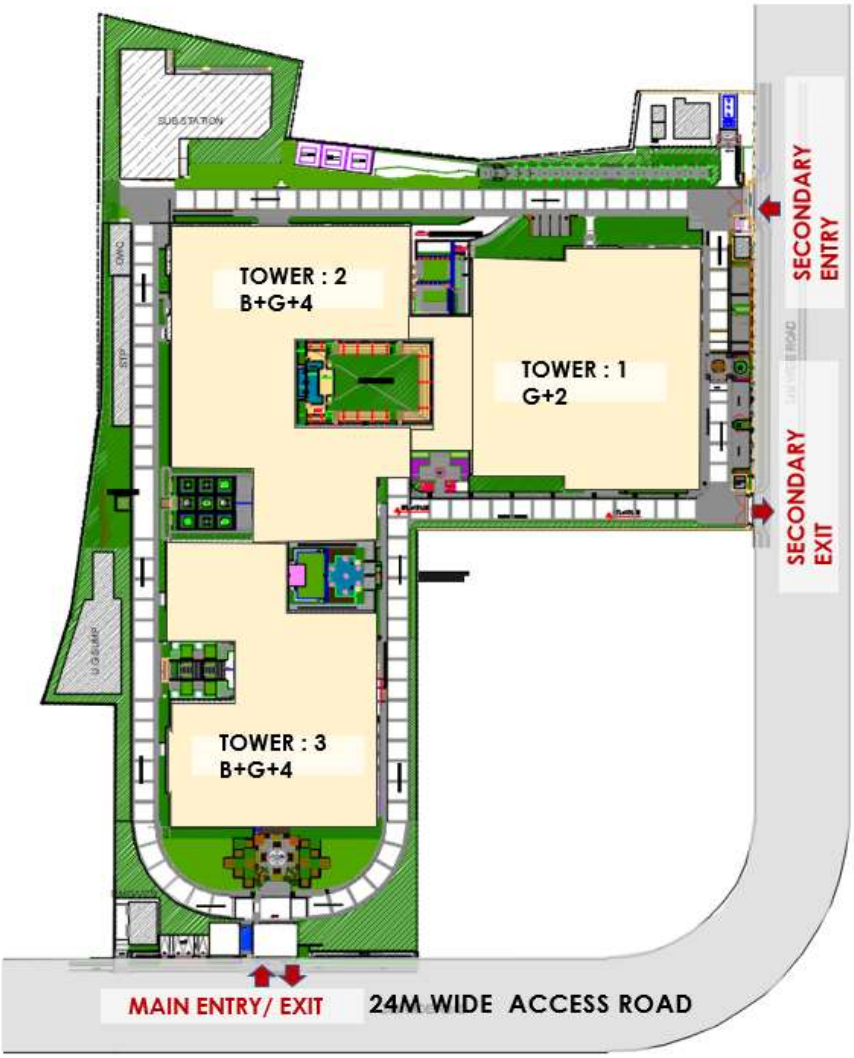


Fig 3.3 HCL Madurai: Site Plan

3.2.2 Live Case Study 2 – IT Park, Chennai

Fig 3.4 IT Park, Chennai: View

- Location: Pallikarnai, Chennai
- Type: greenfield development – it park
- Client: k. Raheja corp.
- PMC: CBRE south Asia Pvt. Ltd
- Contractor: SPCL (Shapoorji Pallonji & company private limited)
- Architect: Natraj & Venkat architects
- Peer review consultant: design tree service consultants, Bengaluru
- Built up area: 34,72,988 sq. Ft.
- Scope of work:
    - Civil works - structure & finishes,
    - MEP - common area services,
    - External development & road work

Total plot area: 536224 sq. ft. (12.31 acres)
Total nos. Of blocks: 3

Block 1

- 2 Basement + Stilt + Upper stilt 1, 2 & 3. (Parking space) +13 Upper Floors (Office Space)
- Floor to floor height (office): 3.90m
- Overall height: 68.80m (till terrace)

Blocks 2 & 3

- 3 Basement + Stilt + Upper stilt 1, 2 & 3 (Parking space) + 13 Upper Floors (Office Space)
- Floor to floor height (office): 3.90m
- Overall height: 68.80m (till terrace)

AREA DETAILS

Table 3.1 IT Park, Chennai: Area Details

Block	Built-Up Area (SFT)	Carpet Area (SFT)	Leasable Area (SFT)
Block - 1 (2B + S + 3US + 13)	**15,44,677**	**8,70,065**	**11,15,468**
BASEMENT 02	1,10,255.65	-	-
BASEMENT 01	80,170.27	-	-
STILT	80,191.80	-	-
UPPER STILT - 1	71,182.33	-	-
UPPER STILT - 2	80,191.80	-	-
UPPER STILT - 3	80,191.80	-	-
TYPICAL LEVELS - 4F to 16F	10,42,493.40	8,70,064.91	11,15,467.86
Block - 2 (3B + S + 3P + 13)	**9,68,689**	**5,15,542**	**6,60,951**
BASEMENT 03	62,032.93		
BASEMENT 02	60,386.04		
BASEMENT 01	46,769.58		
STILT	46,887.98		
PARKING LEVELS - 1F	42,829.96		
PARKING LEVELS - 2F	47,092.50		
PARKING LEVELS - 3F	47,092.50		
TYPICAL LEVELS - 4F TO 16F	6,15,700.80	5,15,541.78	6,60,950.94
Block - 3 (3B + S + 3P + 13)	**9,59,621**	**5,12,270**	**6,56,756**
BASEMENT 03	60,525.97		
BASEMENT 02	60,525.97		
BASEMENT 01	46,500.48		
STILT	46,640.41		
PARKING LEVELS - 1F	42,916.07		
PARKING LEVELS - 2F	46,834.16		
PARKING LEVELS - 3F	46,834.16		
TYPICAL LEVELS - 4F TO 16F	6,08,844.13	5,12,269.55	6,56,755.84
Total Structure	**34,72,988**	**18,97,876**	**24,33,175**

Fig 3.5 IT Park, Chennai: Typical Floor Plan

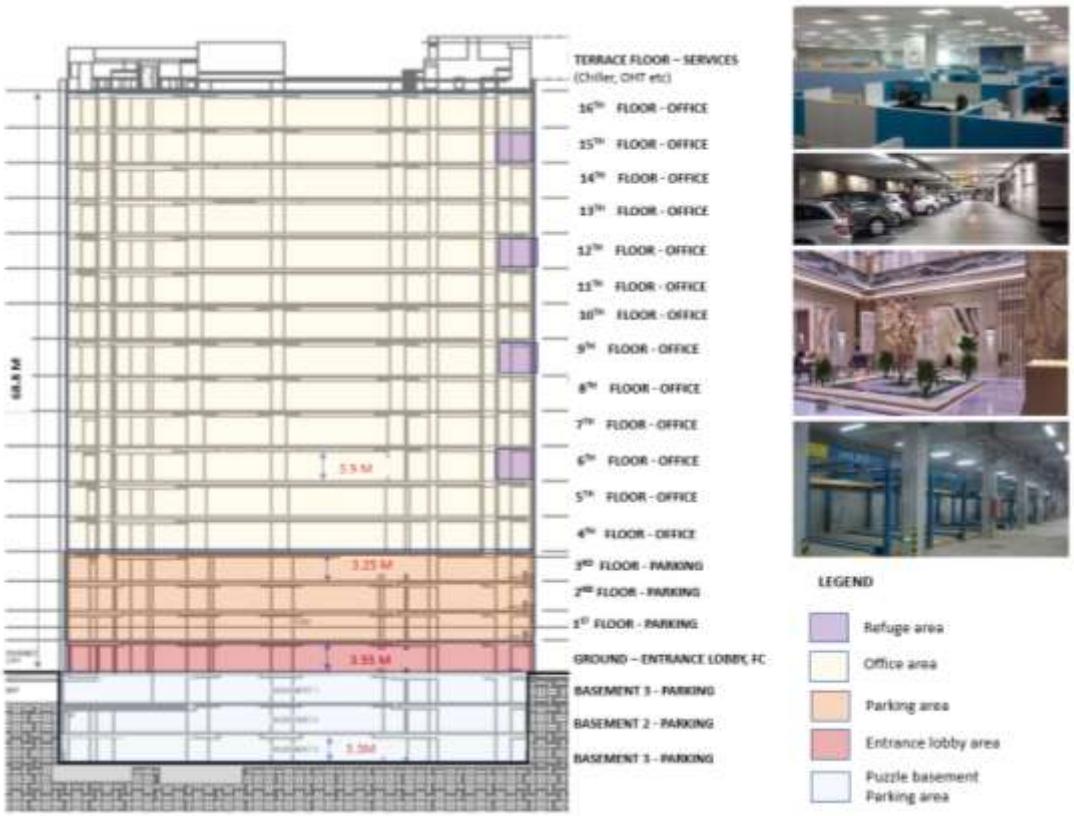


Fig 3.6 IT Park, Chennai: Typical Section

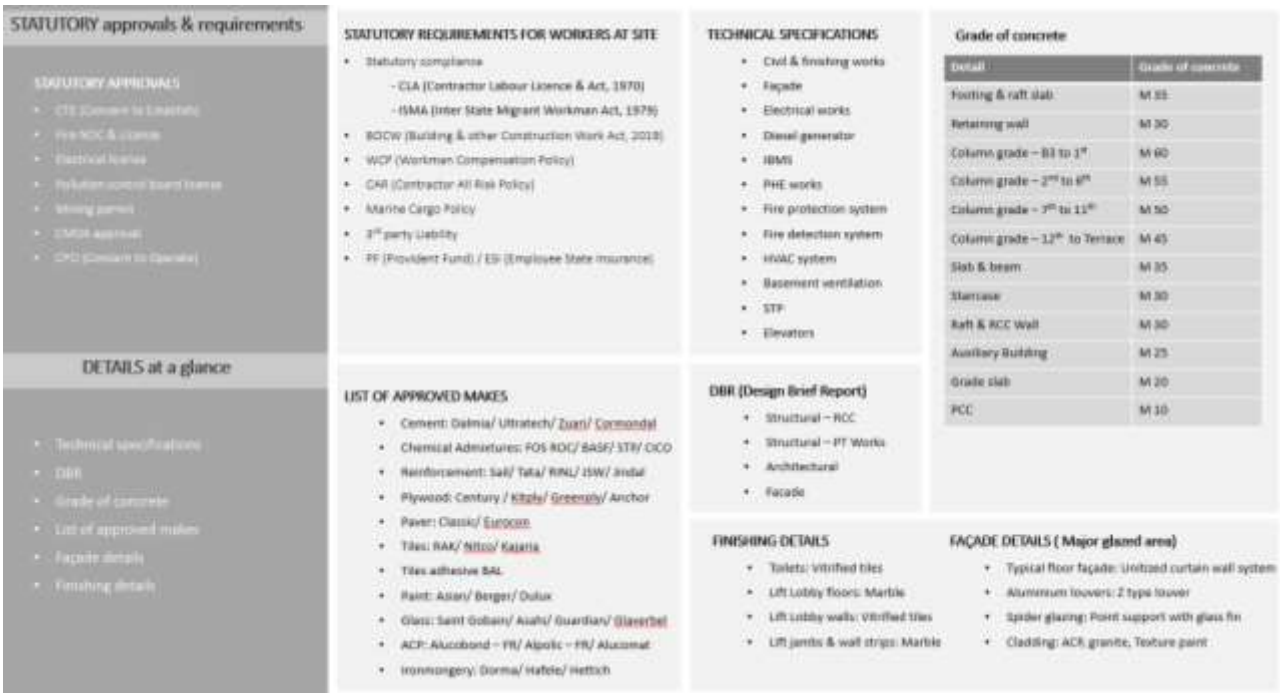


Fig 3.7 IT Park, Chennai: Statutory Approval & details

Fig 3.8 IT Park, Chennai: Essential Documents & Details

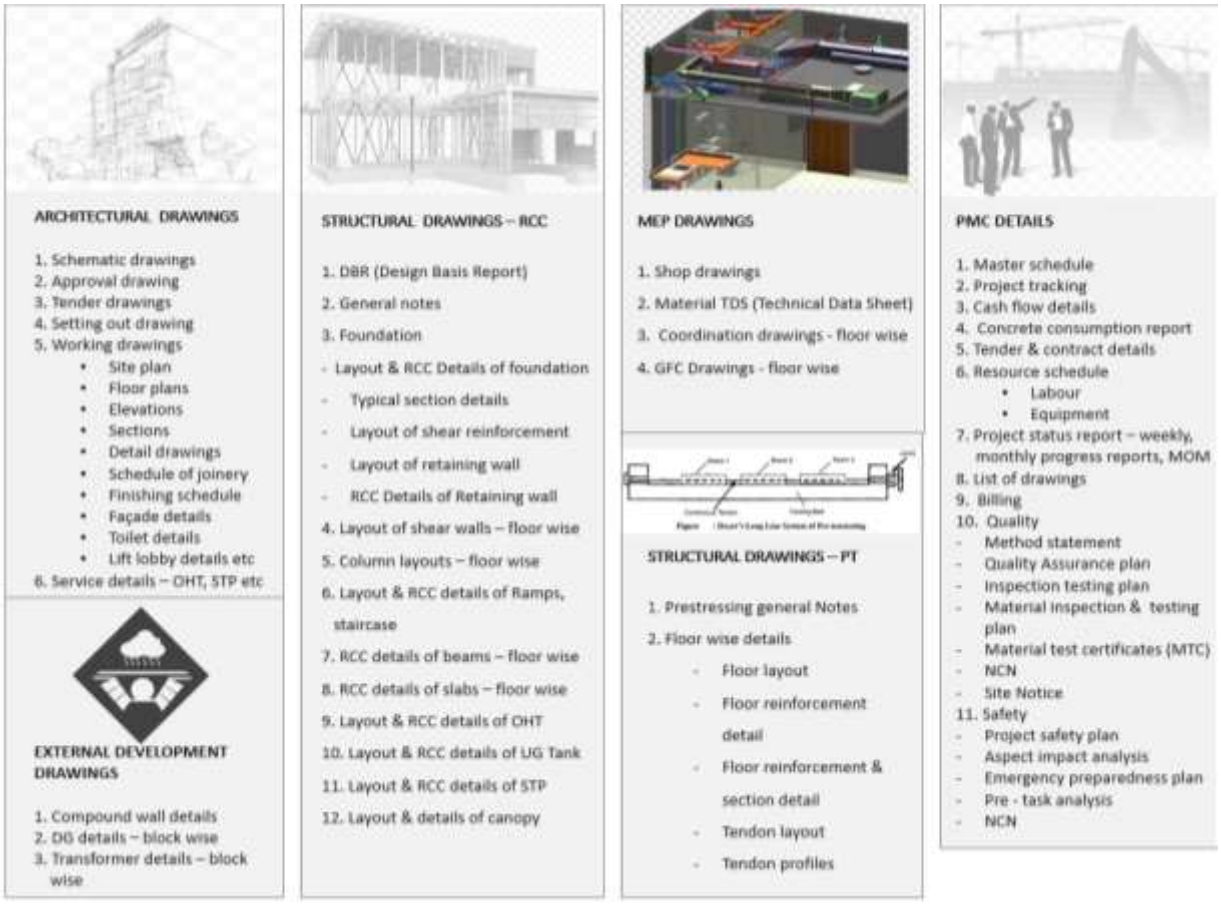


Fig 3.9 IT Park, Chennai: Essential Drawings & Details

Quality Management Plan

- **Work method statement**

For some of the activities:

- Light weight block masonry
- Crack treatment on RCC slab
- Whitewash
- Excavation
- Anti - termite treatment
- Formwork
- Reinforcement
- PCC
- Pour card
- After concreting
- Block masonry
- External plastering
- Internal plastering
- Tiling etc.

- **Scope**
  - Detailed & clear procedure to understand & implement by all concerned

    Employees & sub - contractors
- **References**
  - Technical Specifications
  - Relevant GFC drawings
  - Relevant IS Standards
  - Relevant HSEM procedures
  - Site work activity checklist
- **Control measures**
  - HSE Procedures

    Use of PPE's

    General Housekeeping
- **Work Methodology**
  - Before application steps
  - During application steps
- **Inspection procedure**
  - Check for latest GFC
  - Check for availability of material required for whitewashing
  - Check for availability of tools, tackles & machinery for white wash
  - Check for PT tendon Low profile marking with red paint
  - Check for second coat
  - Check for MEP services completion
  - Check for final coat of white wash

- **Resources available – Material/ Plant & Equipment**
  - Roller or Brush
  - Lime powder for white wash
  - Cleaning tools
- **Health & safety hazard assessment**

  Identified possible hazards are as follows:

  - Lack of Attentiveness, knowledge & fitness
  - Fall of materials or person

  All HSE requirements are followed in accordance with safety plan & policies:

  - Signages & barricades requirements are identified and implemented
  - Area lighting will be provided for night works
  - First Aid box will be provided at the site office
  - Good housekeeping shall be ensured

Fig 3.10 IT Park, Chennai: Method Statement – Whitewash

Table 3.2 IT Park, Chennai: Checklist - Whitewash

S.No	Description	YES	NO	NA	Date	Contractor	PMC/ Client	Remarks
	Referred to approved work method statement for painting							
1	Are all the safety norms being covered as per HSEM process							
2	Is the mock up approved							
3	Is the white wash area free from dead mortar, dirt, dust, algae, grease etc (masking tapes at joints/ corners)							
4	Check for rectifications of surface defects if any							
5	Is the PT Low Profile tendon marks identified							
6	Check for application of first coat & evenness/ uniformity of the first coat							
7	Check for PT Low Profile Tendon marking completion for the planned area							
8	Check for Application of second coat & evenness/ uniformity of the second coat							
9	Check for MEP work clearance for final coat							
10	Check for application of Final coat & evenness/ uniformity of the final coat							

Table 3.3 IT Park, Chennai: MIR

DATE	MIR NO	DESCRIPTION	SUPPLIER	QUANTITY (Nos.)	ACCEPTED/ REJECTED/ HOLD
24.11.21	1426	Solid Block 8"	Sri Sabari Fabs	600	Accepted
26.11.21	1431	Solid Block 150mm	Sri Sabari Fabs	500	Accepted
26.11.21	1432	AAC Block 150mm	The Metal Powder Company Ltd.	800	Accepted
23.11.21	1429	AAC Block 150mm	The Metal Powder Company Ltd.	800	Accepted

Table 3.4 IT Park, Chennai: MTP

S.NO.	MATERIAL	APPROVED MAKES	TYPE OF TEST	TEST REQUIRED	SPECIFICATION	ACCEPTANCE CRITERIA	FORMAT OF RECORDS	TESTING FREQUENCY		RESPONSIBILITY	
								IN HOUSE LAB TEST	3RD PARTY LAB TEST	CONTRACTOR	PMC
1.	Coarse aggregate	-	Physical test	Sieve analysis	IS 383 IS 2386 (PART 1)	As per IS 383, table 7	Internal lab test report & 3rd party test report	Weekly once	Once initial per source	check	Random
				Water absorption	IS 383 IS 23866 (PART 3)	As per IS 383, 2016, table 3		Monthly once			
				Specific gravity	IS 383 2386 (PART 3)	As per IS 383, 2016, table 3					
				Bulk density	IS 383 2386 (PART 3)	As actual					
				Moisture content	IS 383 2386 (PART 5)	As actual		Daily basis			
				Flakiness& elongation index	IS 383 2386 (PART 1)	As per IS 383, 2016, not exceed 40%		Monthly once	N/A		
				Soundness test	IS 383 2386 (PART 5)	Aggregate value shall not exceed 12%		N/A	Once initial per source	Review	review
				Aggregate Impact value	IS 383 2386 (PART 4)	Aggregate impact value shall not exceed 45%		Monthly once		Check	random

Material Testing Plan (MTP) For:

- Water
- Cement OPC 53 grade
- Cement PPC
- Fly ash
- M Sand
- Coarse Aggregate
- Chemical admixtures
- Hardened & fresh concrete
- Reinforcement Steel
- Soil (Backfilling, subgrade & Embankment)
- Plywood for shuttering
- Concrete blocks
- AAC blocks
- Tiles
- Paver blocks
- Glass
- Waterproofing material
- Expansion joint material
- Granites & marble
- Façade etc

Table 3.5 IT Park, Chennai: ITP

S.No	Activity	Inspections & tests to be conducted	Mode	Site Engineer/ in charge	QC Engineer	PMC	Acceptance criteria	Record
1	Survey works	a. Survey instrument calibration	Site inspection	M	M	M	To be calibrated	Report
		b. Boundary & building setting out i) Benchmarks, reference pillars, Closing of traverse, Coordination		M	M	M	As per drgs.	Checklist
		c. Alignment, levels		M	M	M		

NOTE: All finishing activity mock - up will be done & same get approval from PMC before proceeding the activity
LEGEND: M - Mandatory, R - Random, W - Witness

Inspection & testing plan (ITP) for:

- Survey works
- Excavation
- Rock Anchoring
- Anti – termite Treatment
- PCC
- Water proofing
- Backfilling
- Raft, Slab, Wall, Column
- Post tensioning works
- Curing
- Block work masonry
- Plastering
- Painting
- Tiling
- Granite works
- Structural Steel, MS Handrail, SS Handrail works
- False ceiling
- Doors & Windows
- Façade work etc

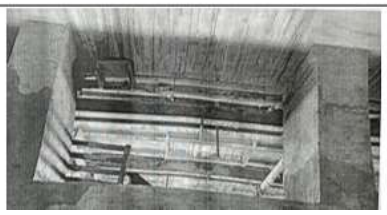
NCN (Non - Conformance Notice)

- Following item(s) is/ are in non – compliance with the Contract Documents.
- Corrective action is to taken immediately.
- If applicable, until the corrective action is completed, no monies may be paid for the item(s) and the cost of all corrective action shall be borne by the Contractor as per the provisions of the Contract.

- Attachments:
  - Photographs
  - Site Notes
  - MOM's
  - Other references

Block: Block 2	**Level:** 6th floor	**Grid:** Grid between 40 – 27 & L to P
Drawing Ref:		**Specification Ref:**
NC Description: Soffit beam noticed with very poor finish, more honeycomb, no proper alignment, shuttering sheets are stuck inside concrete. This needs to be rectified properly.		
PMC Suggestion: Rectification to be done at the earliest as per approved methodology.		
CONTRACTOR'S CORRECTIVE ACTION PROPOSAL: 1. Honeycombing rectified as per our methodology 2. Will ensure cleaning of shuttering boards & proper compaction of concrete & regular toolbox to be given to work force.		

- Photo of the NC



- Photo after corrective action

NCN closed after reviewing the corrective action

Fig 3.11 IT Park, Chennai: Typical NCN Detail

WEEKLY QUALITY REPORT – 1/12/21

Issues

- Many rectification works are pending on east side of the building

- In Steel yard – Steel in contact with soil and getting rusted
- Proper steel stacking required

1. NC Status:

S. No	Description	NC No	NC Issued on	No of days open	Status
1	Cracks - stilt floor (Non Tower area)	48	23-11-2020	352	Open
2	Water entering in to basement (Block 3)	103	21-08-2021	81	Closed

2: Site Note:

Open Site Notes					
S. No	Description	Site note No	SN issued on	No of days open	Site Note status
1	De shuttering not completely done	111	01-06-2021	127	Open

Fig 3.12 IT Park, Chennai: Weekly Meeting Detail - QM

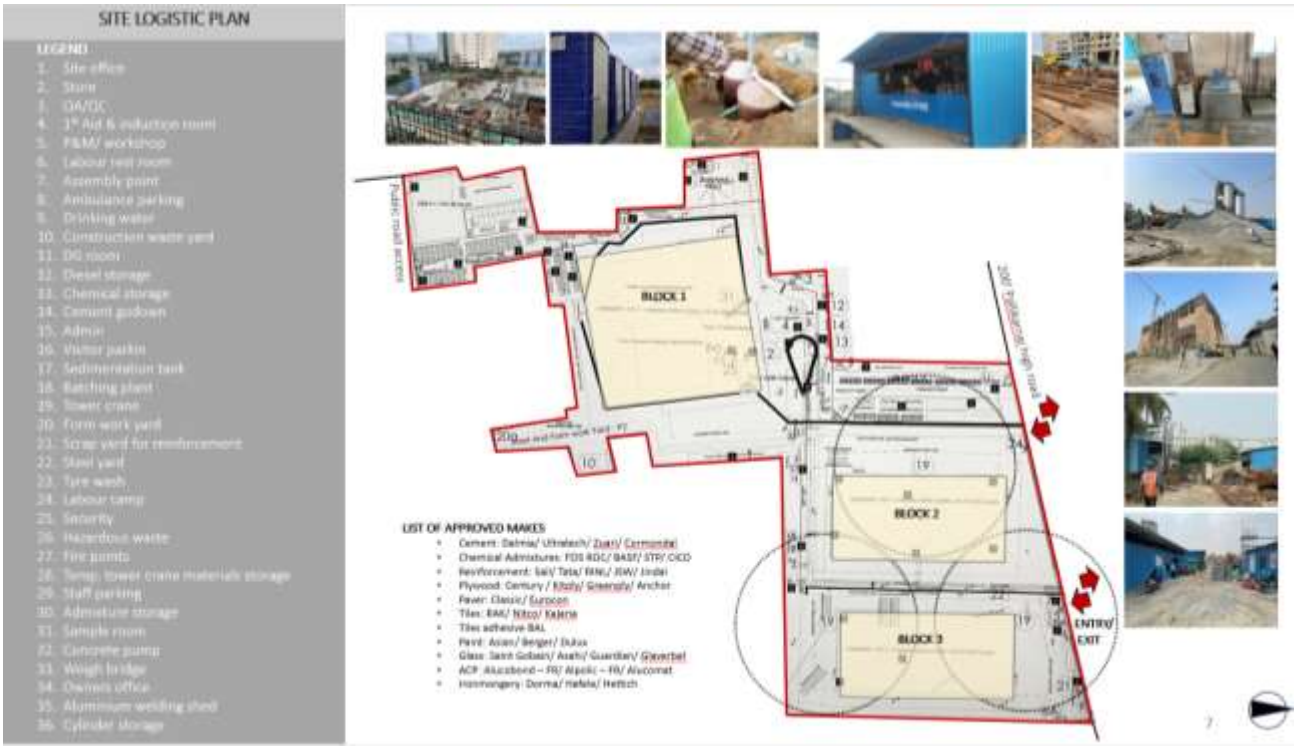


Fig 3.13 IT Park, Chennai: Site Logistic Plan

Fig 3.14 IT Park, Chennai: Overview of Schedule

Fig 3.15 IT Park, Chennai: Activity Sequence on Typical Floor

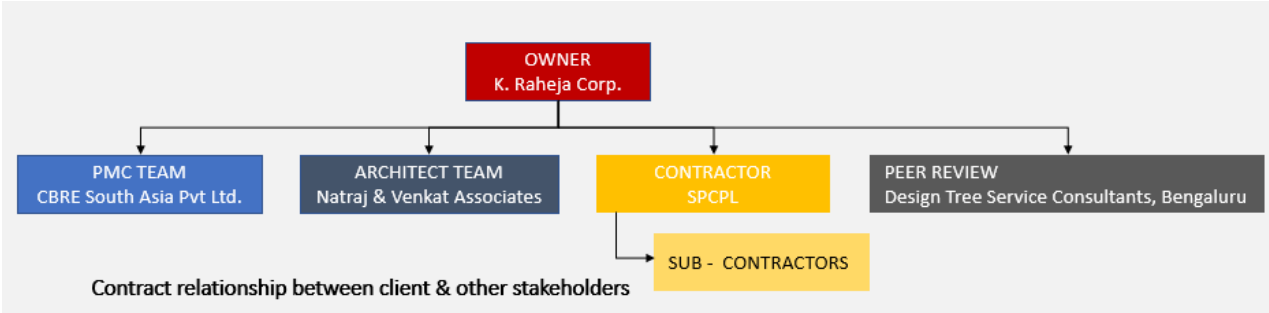


Fig 3.16 IT Park, Chennai: Contract Detail

CHAPTER 4
ANALYSIS & RECOMMENDATIONS

4.1 MINDMAPPING

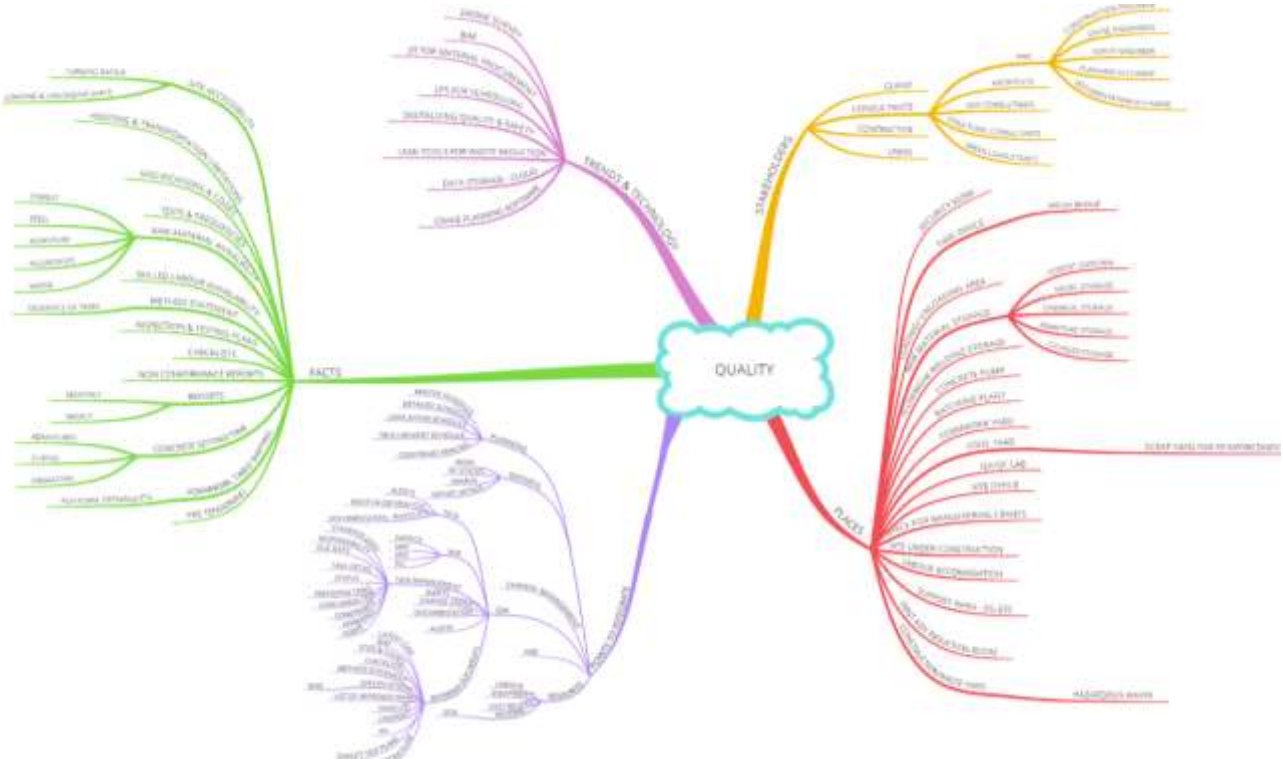


Fig 4.1 Mind mapping - QM

4.2 UNSTRUCTURED INTERIEWS WITH STAKEHOLDERS

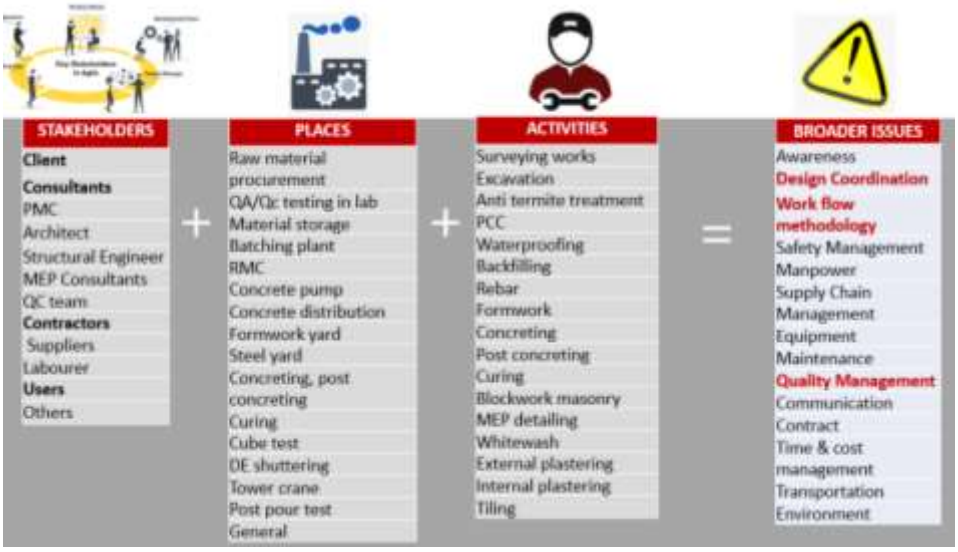


Fig 4.2 Big picture – Stakeholder Interviews

4.3 REBAR RELATED

Fig 4.3 Mind mapping – Rebar

Table 4.1 MTP – Reinforcement Steel

MATERIAL	APPROVED MAKES	TYPE OF TEST	TEST REQUIRED	SPECIFICATION/ RELEVANT IS CODES	ACCEPTANCE CRITERIA	FORMAT OF RECORDS	TESTING FREQUENCY	
							IN HOUSE LAB TEST	3RD PARTY TEST
Reinforcement steel	i) SAIL ii) TATA iii)RINL iv) JSW v) JINDAL	Physical test	Rolling margin	IS 1786 :2008	IS 1786, table 3 - Physical properties, IS 1786, Table 2 Cl 6.2 & 7.2.2 - Tolerances on nominal mass	Rolling margin register, 3rd party test report, MTC	Every Lot	Once initial each dia 1 sample & every 200MT, each dia 1 sample
			0.2% proof strength	IS 1786 :2008, IS 1608: 2005	IS 1786:2008, Table 3 & 4		N/A	
			Elongation %	IS 1786 :2008, IS 1608: 2005			N/A	
			Bend test	IS 1786 :2008, IS 1599: 2012			N/A	
			Rebound test	IS 1786 :2008			N/A	
			Tensile strength	IS 1786 :2008, IS 1608: 2005	IS 1786 - 2008, table 3 & 4		N/A	
		Chemical test	C,S,P, C equivalent	IS 1786 :2008	IS 1786, Cl 4.2 - Chemical composition	3rd party test report	N/A	Once initial for each dia & every 6 months each dia 1 sample

Fig 4.4 Site Images – Rebar process

Table 4.2 A3 Design Thinking – Rebar

ACTIVITY	SITE REFERENCE IMAGE	WHAT DID YOU HEAR	WHAT DID YOU OBSERVE	KEY CHALLENGES
Rebar		• Incorrect cutting/bending of bars • Incorrect dia, shape, dim, no's, ID • Unclean bars • Incorrect fixing of bars • Latest drawings not followed • Additional rebars near openings • Incorrect spacers, covers etc. • Junctions details incorrect • Delay in procurement	• Preceding activities not followed properly • Improper sequencing of activities • Real time tracking essential • Issues in SCM • Inefficient document management	• Digitizing QM • Proper work flow methodology • Proper pre - task scheduling • Efficient procurement

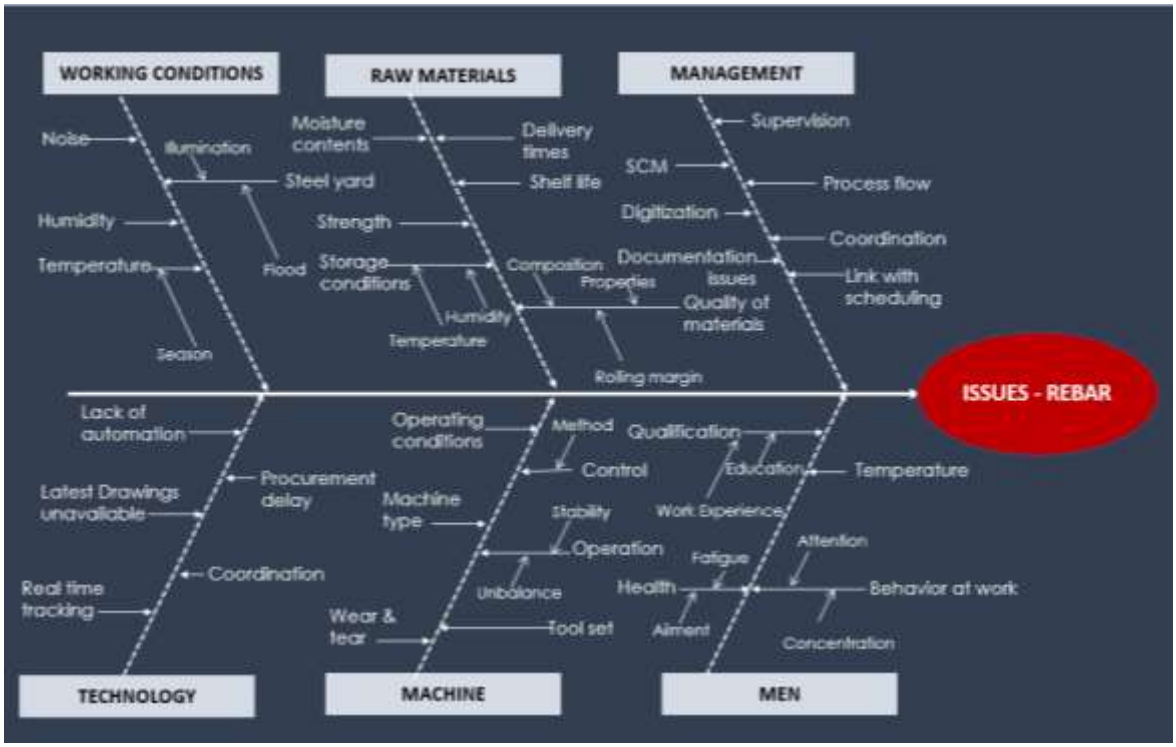


Fig 4.5 Fishbone – Rebar process

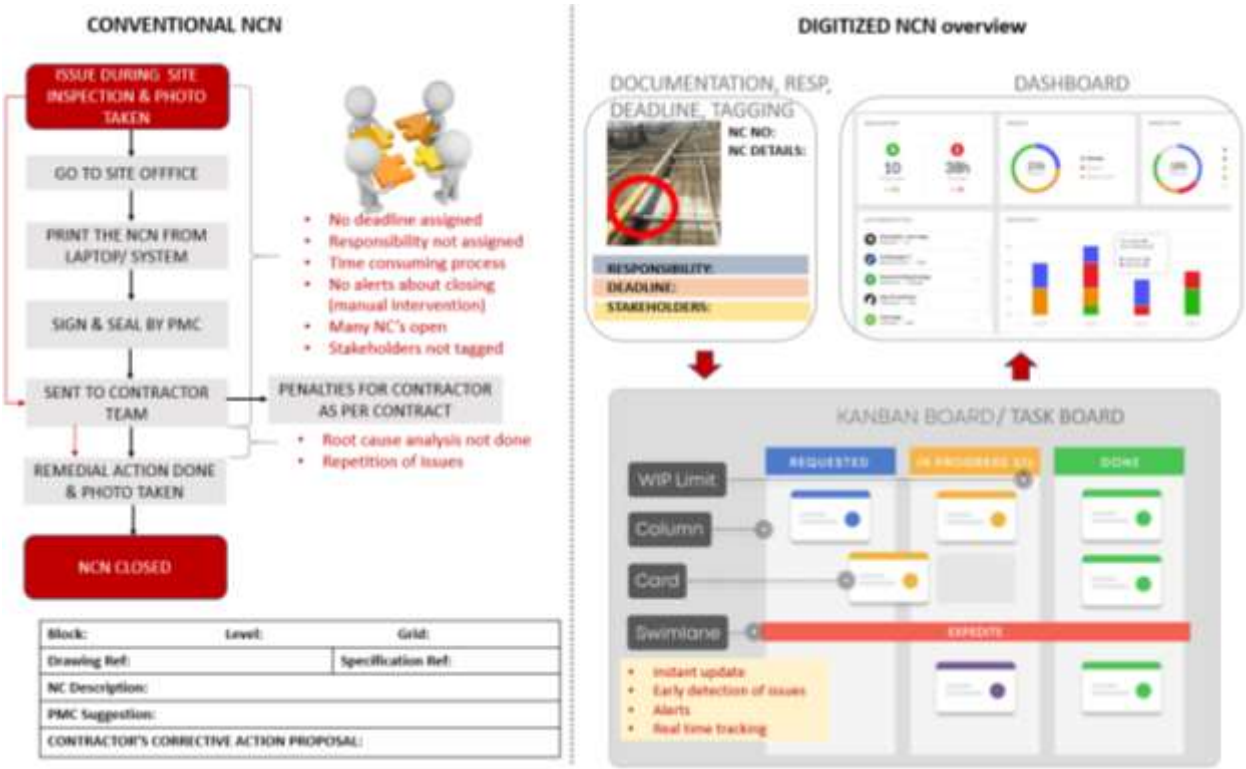


Fig 4.6 Conventional & Digitized NCN

4.4 CONCRETING RELATED

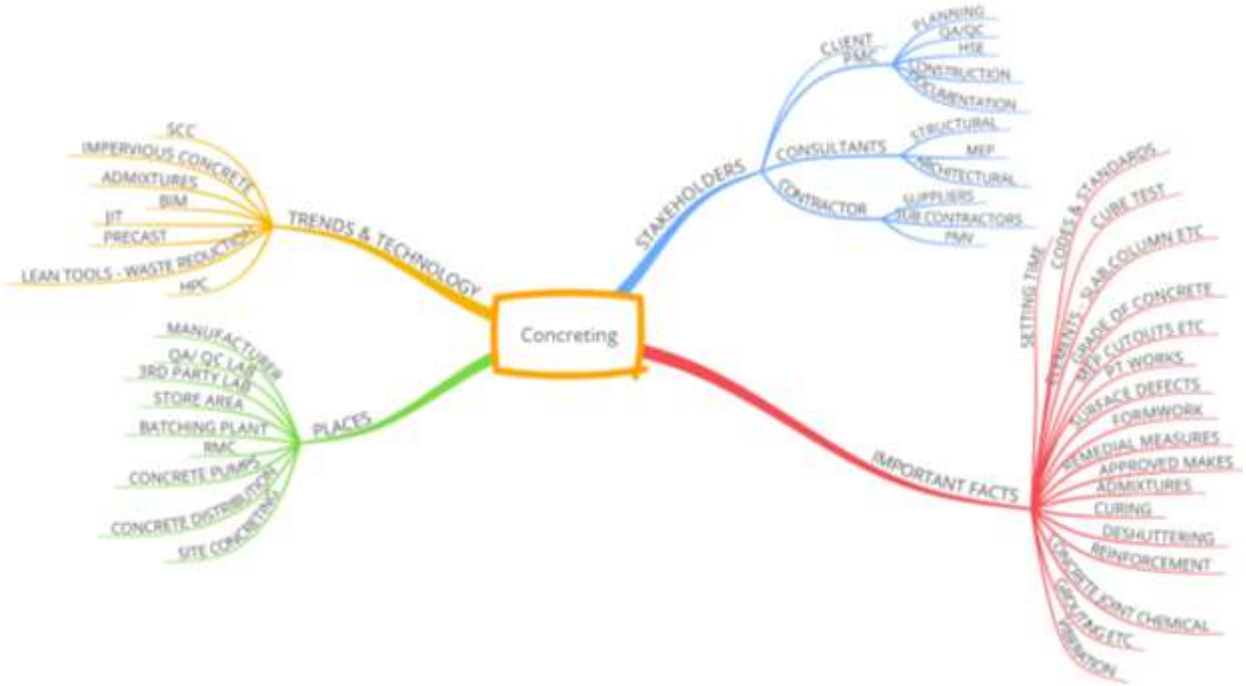


Fig 4.7 Mind mapping – Concreting

Table 4.3 MTP – Cement

MATERIAL	APPROVED MAKES	TYPE OF TEST	TEST REQUIRED	SPECIFICATION/ RELEVANT IS CODES	ACCEPTANCE CRITERIA	FORMAT OF RECORDS	TESTING FREQUENCY	
							IN HOUSE LAB TEST	3RD PARTY TEST
Cement OPC 53 grade	i) Dalmia	Physical test	Fineness by sieve	IS 12269 - 53 Grade, IS 4031 (part 5)		Internal test report	Monthly once	Once initial & each source for every 6 months - 3rd party
	ii) Ultratech		Normal consistency	IS 12269 - 53 grade, IS 4031 (part 1)			Monthly once	
	iii) Zuari		Setting time					
	IV) Coromandal		i) Initial	IS 12269 - 53 grade, IS 4031 part 5			Monthly once	
	v) Ramco		ii) Final					
			Soundness	IS 12269 - 53 grade			N/A	
			i)Le chat expansion unaerated	IS 4031 part 5				
			Compressive strength 3 days	IS 12269 - 53 grade, IS 4031 part 5			Monthly once	
			7 days					
			28 days					
			Specific gravity	IS 12269 - 53 grade, IS 4031 part 6				
		Chemical test	Magnesia	IS 4032	6% Max	3rd party test report	N/A	Once initial & each source for every 6 months - 3rd party
			Sulfuric Anhydride		3 % Max			
			Loss on ingnition		5 % Max			
			Insoluble residue		4 % Max			

Table 4.4 A3 Design Thinking – Concreting

ACTIVITY	SITE REFERENCE IMAGE	WHAT DID YOU HEAR	WHAT DID YOU OBSERVE	KEY CHALLENGES
Concreting		• Improper access to pour • Incorrect formwork/ reinforcement • Unapproved design mix • Preceding activities not completed • Mechanical equipments for post concreting not ready • Non - preparation of old & new concrete joint Insufficient manpower & materials	• Preceding activities not followed properly • Improper sequencing of activities • Real time tracking essential • Issues in SCM • Inefficient document management	• Digitizing QM • Proper work flow methodology • Proper pre - task scheduling • Efficient procurement
Post concreting		• Presence of surface finish issues - honeycombing • Misalignment of surface, cracks • Presence of undulations • Visible reinforcement • Improper curing • Casting, curing, DE shuttering details unavailable Back propping not as per approved details		
Curing		• Not kept for sufficient days • Damaged Tarpaulin/ Gunny bags • Improper methodology		

Fig 4.8 Site Images – Concreting

4.5 OVERALL

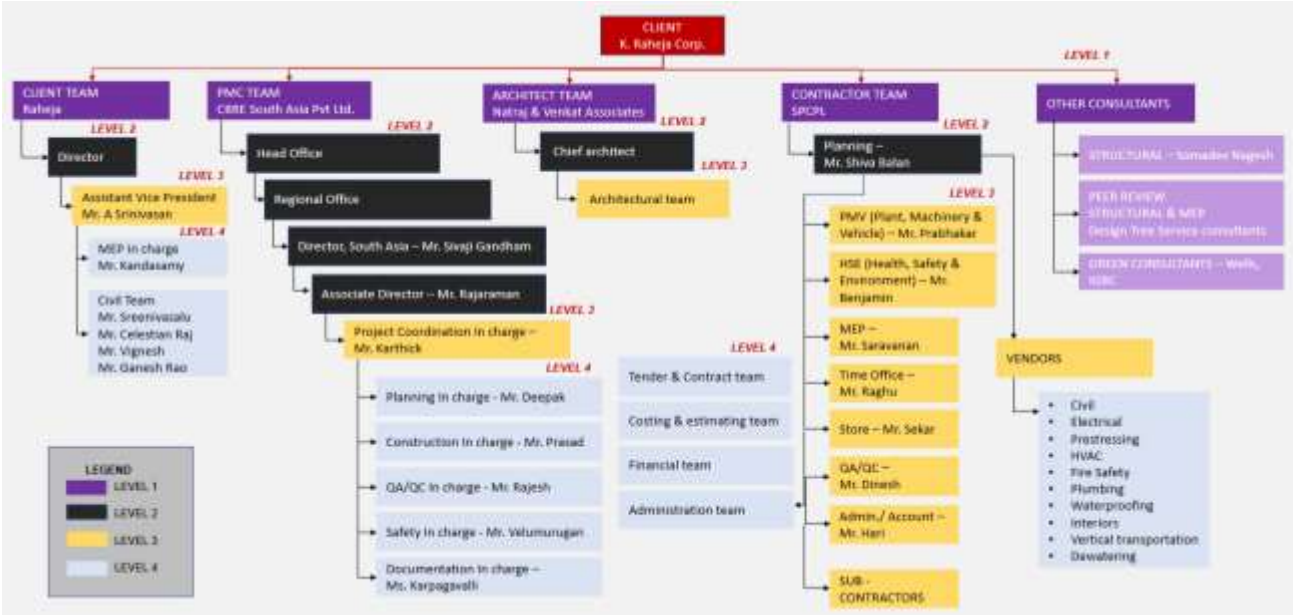


Fig 4.9 Project Team Organizational Chart

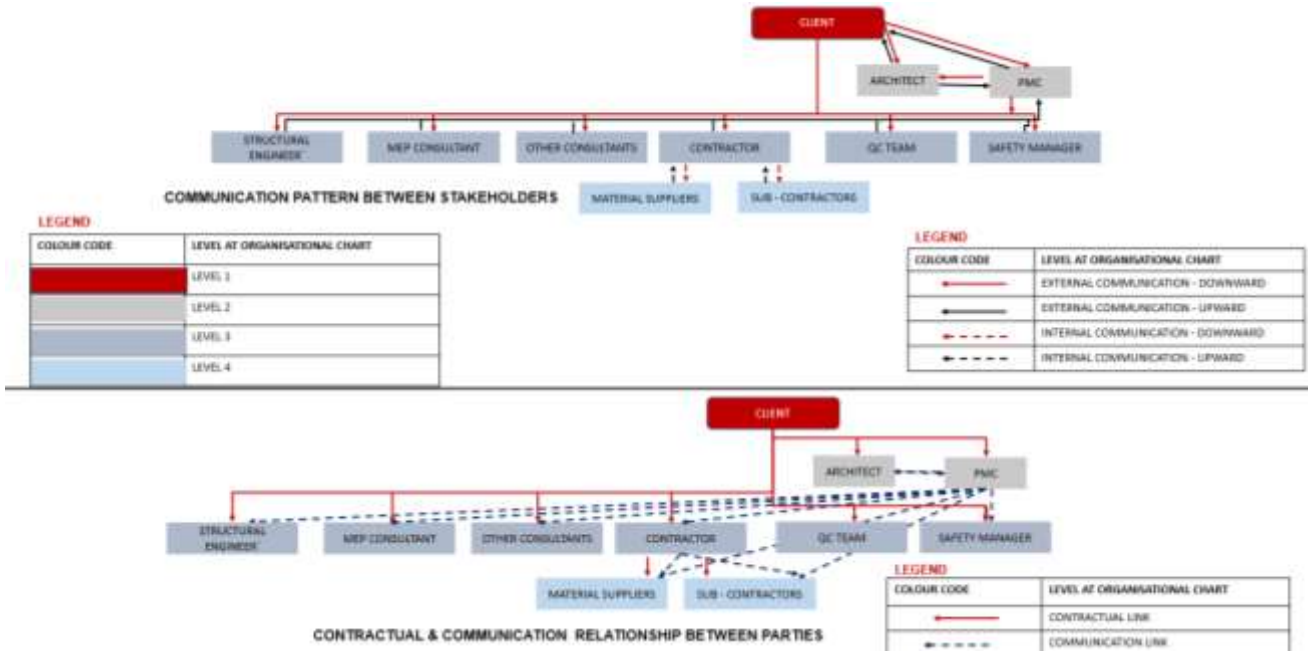


Fig 4.10 Project Contractual Relationship

4.6 QUALITY TOOLS

INVOLVED | NOT INVOLVED

	CONCEPTUALIZATION	PLANNING	ESTIMATION	CONTRACT	DESIGN	COST CONTROL	PROCUREMENT	TESTING	STORES	PROCESSING	EXECUTION	CLOSE OUT
CLIENT												
PMC												
PLANNING IN CHARGE												
QA/QC												
HSE												
CONSTRUCTION ENGINEER												
DOCUM. IN CHARGE												
ARCHITECT												
STRUCTURAL CONSULTANT												
MEP CONSULTANT												
CONTRACTOR												
SUB – CONTRACTOR												
SUPPLIER												

Fig 4.11 Stakeholder involvement at various stages

0 – 5 SCALE (0 being least important & 5 maximum important)

	CLIENT	PMC	PLANNING IN CHARGE	QA/QC	HSE	CONSTR. ENGINEER	DOCUM. IN CHARGE	ARCHITECT	STRUCTURAL CONSULTANT	MEP CONSUTANT	CONTRACTOR	SUB-CONTRACTOR	SUPPLIER
CLIENT	-	5	3	4	3	4	2	5	3	3	4	1	1
PMC	5	-	5	5	5	5	4	4	4	4	5	3	3
PLANNING IN CHARGE	3	5	-	4	3	5	4	3	3	3	4	2	2
QA/QC	4	5	4	-	4	4	4	0	4	3	4	3	3
HSE	3	5	3	4	-	4	4	0	1	0	4	3	3
CONSTRUCTION ENGINEER	4	5	5	4	4	-	4	3	3	3	4	3	3
DOCUM. IN CHARGE	2	4	4	4	4	4	-	4	4	4	4	2	2
ARCHITECT	5	4	3	0	0	3	4	-	4	4	2	0	2
STRUCTURAL CONSULTANT	3	4	3	1	1	3	4	4	-	4	4	2	2
MEP CONSULTANT	3	4	3	0	0	3	4	4	4	-	4	1	1
CONTRRACTOR	4	5	4	4	4	4	4	2	4	4	-	5	5
SUB – CONTRACTOR	1	3	2	3	3	3	2	0	2	1	5	-	4
SUPPLIER	1	3	2	3	3	3	2	2	2	1	5	4	-

Fig 4.12 Stakeholder communication matrix – Broad level

	CLIENT	PMC	ARCHITECT	STRUC. CONSUL.	MEP CONSUL.	GREEN & INTERIOR CONSUL.	CONTRACTOR	QUALITY CONTROL	SAFETY MANAGER	CONTRACT TENDERING TEAM	COSTING & ESTIM. TEAM	CONTRACTOR	SITE ENGINEER	DOCUMENT ATION TEAM
Implementation of the method statement	C	R/A	C	C	C	C	I	C	C			C	A/R	I
Ensure key personnel aware of spec & method statement	I	R/A	C	C	C	C	C	C	C		I	C	R	I
Ensure all resources available	I	R/A					C	C	C	C	C	I	R	
Ensure work carried as scheduled	I	A/R	I	I	I	I	C				I	C	R/A	I
Available at site full time for the execution of works as per schedule & specification	I	R					R	R	R		I	R	A/R	
Responsible for effective monitoring , implementation & documentation of QA/QC procedures	I	R	C	C	C	C	R	A/R	R		I	R	R	C
Responsible for accepting/ rejecting concrete		R		C			C	R/A				R	A/R	I
Responsible for performing all checks, taking slump/ tests		R		C			C	R/A				R	A/R	I
Responsible to overall quality control & inspection		R		C			C	R/A				R	R	I
Ensure all survey as per approved drawings		R	I	I	I		R					I	R/A	
Ensure setting out & levelling done using necessary equipments		R	I	I	I		R					I	R/A	
Site relates survey work		R	I	I	I		R					I	R/A	
Responsible for safety aspects	I	R		C			C	C	R/A			R	A/R	I
Overall tolerance plan		R/A	C	R	C	C	C	R/A	C			R	R	I
Coordination of overall project	C	A/R					R					R	R	

R – RESPOSIBLE – Person working on activity
A – ACCOUNTABLE – Person with decision authority
C – CONSULT – Key stakeholder included in decision/ activity
I – INFORM – Needs to know of decision or action

Fig 4.13 RACI Matrix – 1

	CLIENT	PMC	ARCHITECT	STRUC. CONSUL.	MEP CONSUL.	GREEN & INTERIOR CONSUL.	CONTRACTOR	QUALITY CONTROL	SAFETY MANAGER	CONTRACT TENDERING TEAM	COSTING & ESTIM. TEAM	CONTRACTOR	SITE ENGINEER	DOCUM ENTATION TEAM
Architectural drawings	I	C	A/R	C	C	C	I	I	I	I	I	R	C	I
Ensure final drawings executed	I	R/A	C	C	C	C	R	I		C	C	R/A	A/R	I
Scheduling	C	R/A	C	C	C	C	C	C	C	C	C	R/A	A/R	I
MEP drawings	I	C	C	C	A/R	C	I	I	I	I	I	R	C	I
Landscape & Interior drawings	I	C	C	C	C	A/R	I	I	I	I	I	R	C	I
Project meetings	C	A/R	C	C	C	C	C	I	I			C	C	C
Costing & estimation	C	R	C	C	C	C	C	C	C	C	A/R	R	I	I
Tender & contract document preparation	C	R	C	C	C	C	C			R/A	C	C		I
Boq preparation	C	R	C	C	C	C	C	C	C	R/A	C	R	I	I
Specifications preparation	I	R	C	R/A	C	C	C	C	C	R/A	C	R/A	I	I
Maintaining bank guarantees, statutory documents (ESI, PF etc)	I	C					R			C		I	C	R/A
Maintain records of payments, invoices etc	I	C					R			C		I	C	R/A
Casting sequence	I	R/A	C	C/R	C	C	R	C	C		C	R/A	R	I
Site access planning & resource planning	C	R/A					R	C	C		C	C	R	I
Preparation of method statement	I	R	C	R/A	C	C	C	C	C	I	C	R/A	I	I
Weekly status update to client	C	R/A				I	C				I	C	R	C
Project status report	C	R/A	I	I	I	I	C				I	C	R	C
Record keeping of site test results, rejections etc	I	C		I			R	C	C	C	I	I	C	R/A

R – RESPOSIBLE – Person working on activity
A – ACCOUNTABLE – Person with decision authority
C – CONSULT – Key stakeholder included in decision/ activity
I – INFORM – Needs to know of decision or action

Fig 4.14 RACI Matrix – 2

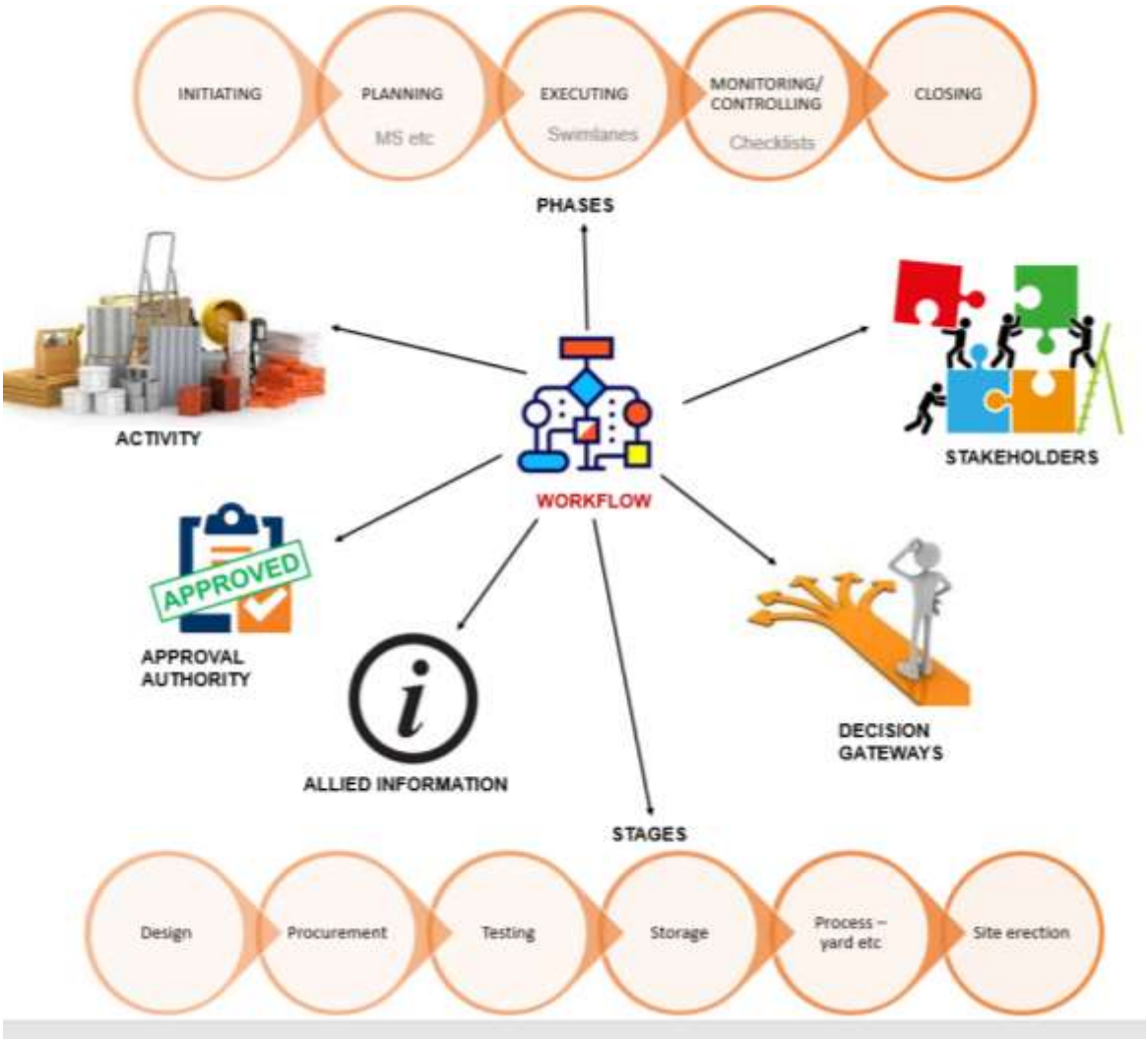


Fig 4.15 Concept of the Swim lanes

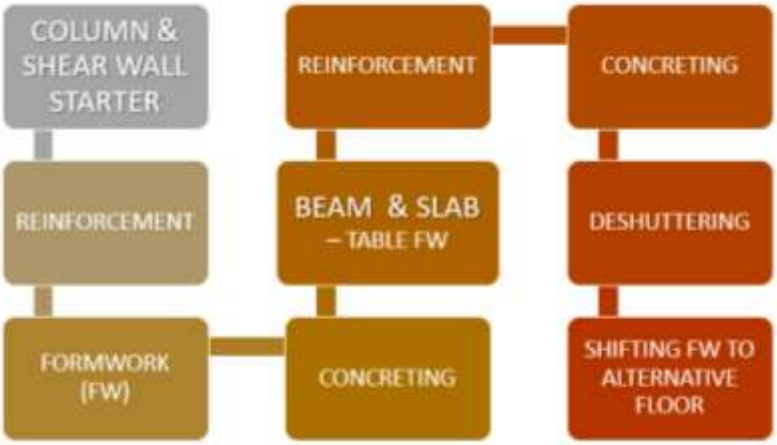


Fig 4.16 Big picture of the Swim lanes

Fig 4.17 Process Highlight – Rebar, FW & Concreting

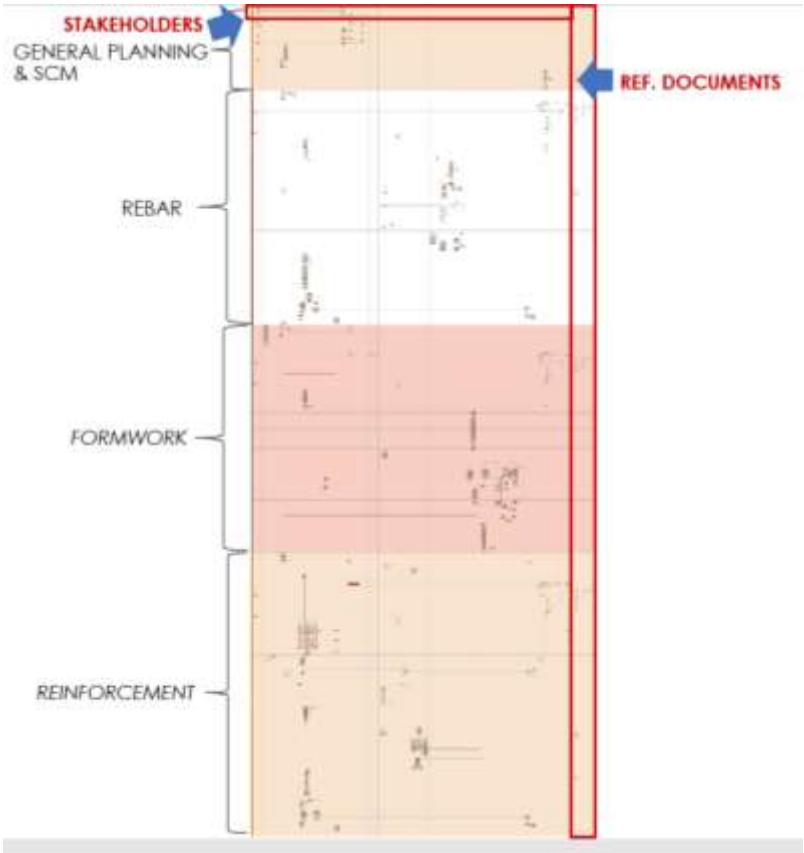
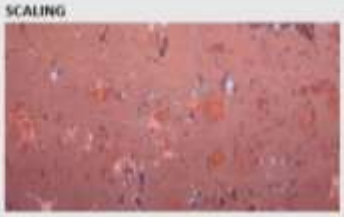
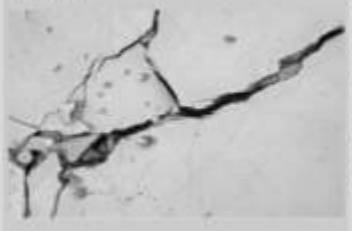


Fig 4.18 Overall Swim lane

4.7 CORRECTIVE MEASURES

Table 4.5 Corrective Measures

S.No	Common defects	Possible causes	Recommendations
1.	DISCOLORATION	A. If there are sudden changes to the cement material, B. If the finishing operations are rushed C. If calcium chloride is added. All concrete ingredients must comply with IS Standards	A. Specify with the ready-mix supplier your tolerance levels B. Prepare a uniform subgrade C. Wait until all the water has evaporated before finishing the concrete D. Avoid hard troweling on the exterior surface
2.	SCALING 	A. Occurs when the concrete surface breaks off and keeps peeling away. B. Scaling could also occur if non-air entrained concrete is exposed to freeze-thaw cycles, C. Due to inadequate concrete strength D. Due to inadequate curing procedure.	A. Use a low slump-air (6 to 7 percent) in the entrained mix B. Wait till water has been evaporated from the surface C. Do not use salt or other chemicals during the winter season
3.	CRAZING	A. Occurs when the surface shows several interconnected fine cracks B. Or when the cement paste comes up to the surface and shrinks. Although the concrete strength probably is not affected, cracks will show up when the slab is damp.	A. Cure the concrete in a timely manner B. Use a moderate slump concrete without bleeding and segregation C. Do not finish concrete until all water has evaporated D. Do not dust dry cement on the surface while water is present E. Do not sprinkle water over the concrete while finishing it F. If the weather could produce high evaporation rates, spray some water onto the subgrade, so it will not absorb the water from the concrete mix
4.	CRACKING 	A. Cracking can be the result of one or a combination of factors, such as drying shrinkage, B. Due to thermal contraction, C. Due to subgrade settlement, D. Due to applied loads. In the case of a wall, if a crack is not structural, or not too wide (the acceptable crack width is subjective but it could range from 1/16" to 1/4"), or isn't leaking water, it should be considered acceptable.	A. Install concrete joints accordingly by sawing, forming or tooling a groove B. Place, finish and cure concrete accordingly depending on the weather conditions C. Do not finish concrete if it has not finished bleeding D. Do not overwork concrete surface E. Avoid rapid drying conditions or use a set retardant admixture F. Minimize the mix water content by maximizing the size and amount of coarse aggregate and use low-shrinkage aggregate G. Grouting to be done as per MS
5.	CURLING	A. Occur when there is a difference in both temperature and moisture of the top and bottom surface. B. When the slab of the surface becomes unsupported from the base.	A. Use proper curling techniques B. Place concrete joints accordingly C. Use low water content or use water reducing admixtures D. Use the largest possible aggregate size E. Ensure proper bonding when applying thin topping mixes F. Use enough, not excessive, amount of steel reinforcement in the slab
6.	HONEYCOMBING & EXCESSIVE PINHOLES	A. Poor concrete compaction due to ineffective vibration B. Due to rebars congestion C. Leakage from the formwork	A. Proper compaction method should be adopted & carried out. B. Concrete mix design & workability should be reviewed & adjusted when needed C. Vibrators can be used to attain better compaction D. Rebar congestion can be alleviated by having larger rebars or increasing sectional dimensions of elements where possible E. Simplify reinforcement layout & to minimise rebar congestion F. Defective mould forms & accessories should be repaired or replaced to prevent leakage

4.8 HOW RE- ENGINEERING PROCESS FLOW HELPS

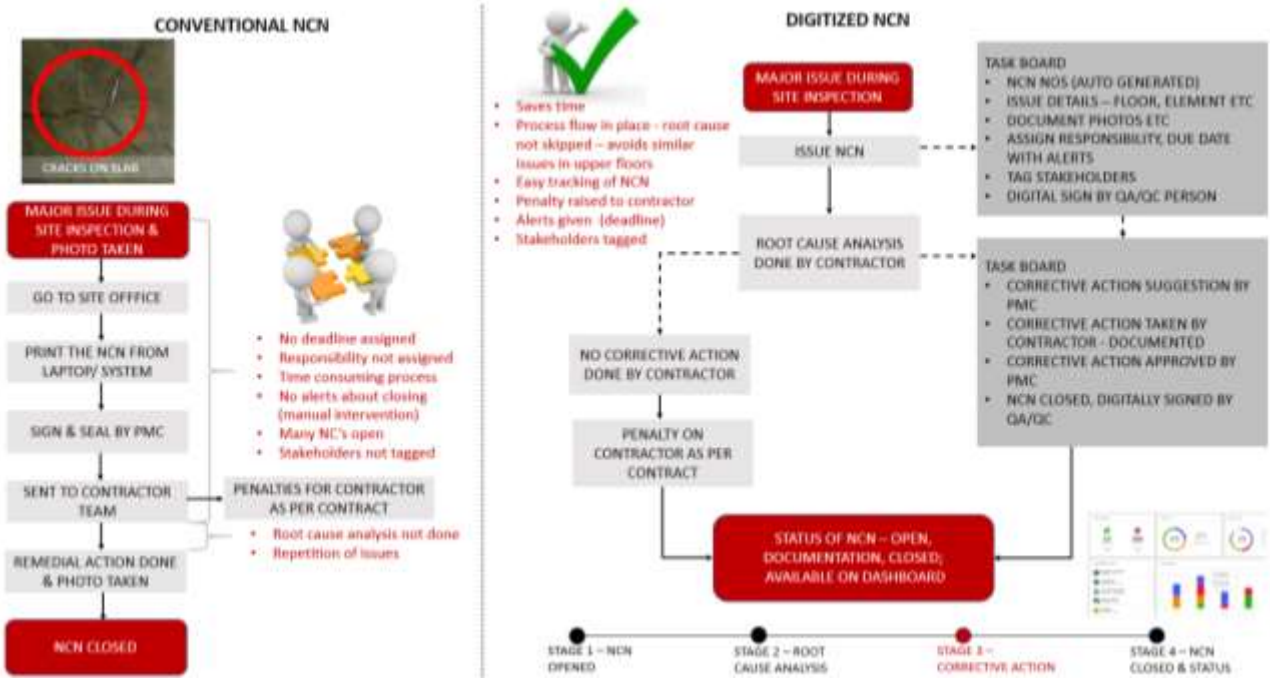


Fig 4.19 Conventional NCN v/s Digitized NCN

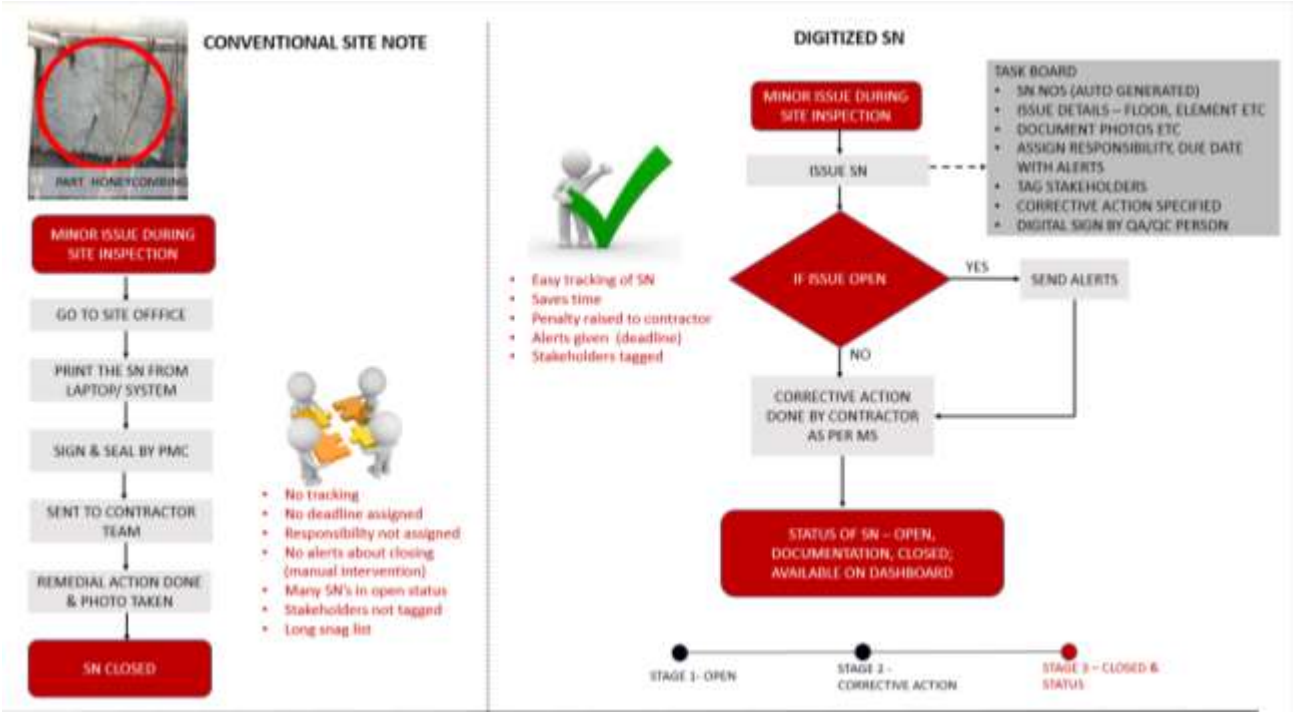


Fig 4.20 Conventional SN v/s Digitized SN

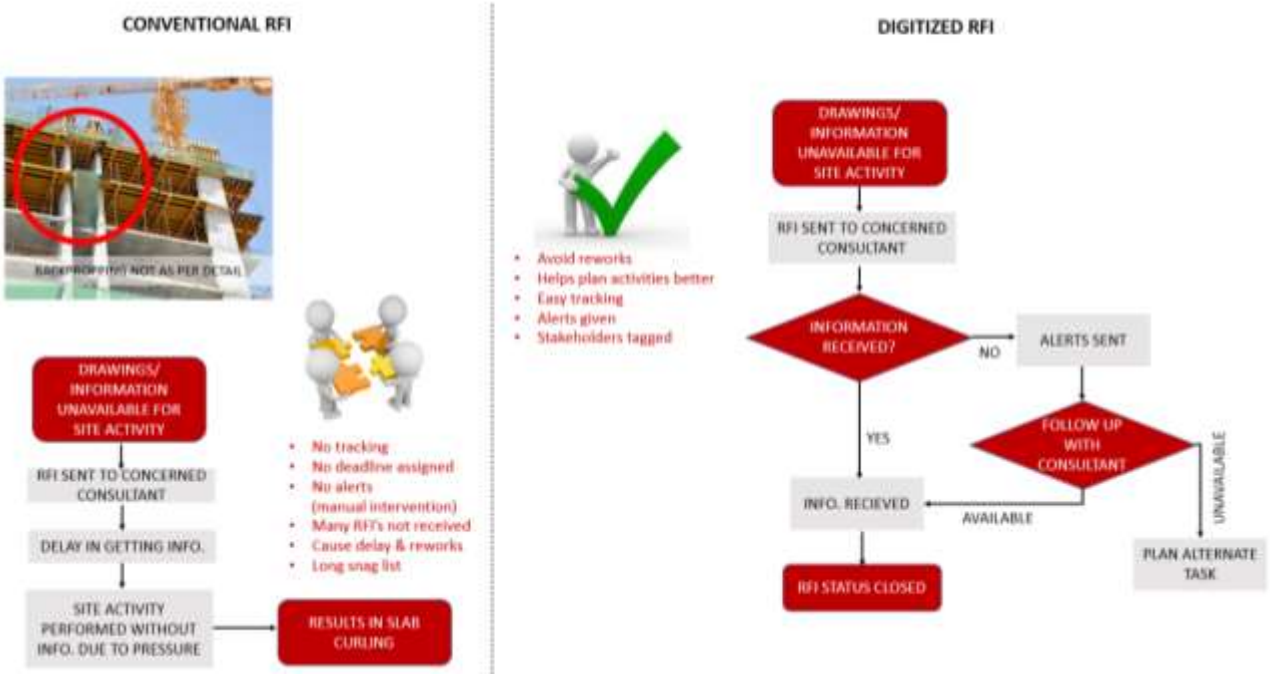
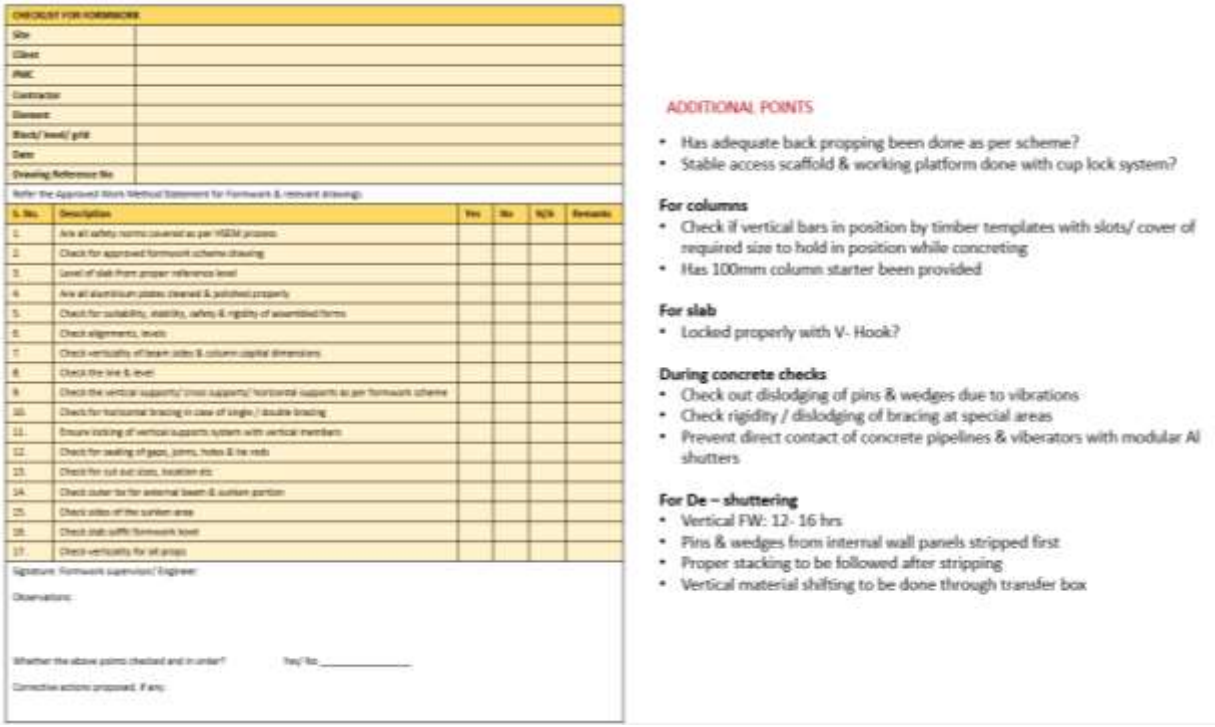


Fig 4.21 Conventional RFI v/s Digitized RFI

Fig 4.22 Conventional v/s Digitized Quality Audit

4.9 RECOMMENDATIONS – TOOLS & TECHNIQUES

4.9.1 Checklists



CHECKLIST FOR FORMWORK

Site	
Client	
PMC	
Contractor	
Element	
Block/ level/ grid	
Date	
Drawing Reference No	

Refer the Approved Work Method Statement for Formwork & relevant drawings

S. No.	Description	Yes	No	N/A	Remarks
1.	Are all safety norms covered as per HSEM process				
2.	Check for approved formwork scheme drawing				
3.	Level of slab from proper reference level				
4.	Are all aluminium plates cleaned & polished properly				
5.	Check for suitability, stability, safety & rigidity of assembled forms				
6.	Check alignments, levels				
7.	Check verticality of beam sides & column capital dimensions				
8.	Check the line & level				
9.	Check the vertical supports/ cross supports/ horizontal supports as per formwork scheme				
10.	Check for horizontal bracing in case of single / double bracing				
11.	Ensure locking of vertical supports system with vertical members				
12.	Check for sealing of gaps, joints, holes & tie rods				
13.	Check for cut out sizes, location etc				
14.	Check outer tie for external beam & sunken portion				
15.	Check sides of the sunken area				
16.	Check slab soffit formwork level				
17.	Check verticality for all props				

Signature: Formwork supervisor/ Engineer

Observations:

Whether the above points checked and in order? Yes/ No_____

Corrective actions proposed, if any:

ADDITIONAL POINTS

- Has adequate back propping been done as per scheme?
- Stable access scaffold & working platform done with cup lock system?

For columns

- Check if vertical bars in position by timber templates with slots/ cover of required size to hold in position while concreting
- Has 100mm column starter been provided

For slab

- Locked properly with V- Hook?

During concrete checks

- Check out dislodging of pins & wedges due to vibrations
- Check rigidity / dislodging of bracing at special areas
- Prevent direct contact of concrete pipelines & viberators with modular Al shutters

For De – shuttering

- Vertical FW: 12- 16 hrs
- Pins & wedges from internal wall panels stripped first
- Proper stacking to be followed after stripping
- Vertical material shifting to be done through transfer box

Fig 4.23 Additional points – to improve existing FW Checklist

ADDITIONAL POINTS

- Check if cover block is of more grade than concrete poured
- Cover block spacing should be 1m to 1.5m depending on the rebar unit weight
- Check adequate nos. of chairs every 1m or shorter to the support the weight of the top mat
- Cover as following:

  Columns: 40mm
  RCC Walls, Beams: 30mm
  Slabs: 25mm
- Has consultant approval been given for tack welding?
- Are crossing bars tied with annealed 0.9mm twisted steel wire

For columns & walls

- Check if vertical bars in position by timber templates with slots/ cover of required size to hold in position while concreting
- Has 100mm column & wall starter been provided?

For slab

- Has Table FW been checked ?
- Special attention given to reinforcement details in

  Sunken slabs
  Inverted beams
  Floating columns
  Cut outs

CHECKLIST FOR REINFORCEMENT

Site	
Client	
PMC	
Contractor	
Element	
Block/ level/ grid	
Date	
Drawing Reference No	

Refer the Approved Work Method Statement for Reinforcement & relevant drawings

S. No.		Description	Yes	No	N/A	Remarks
1.		Are all the safety norms being covered as per HSEM process?				
2.		Is the bar bending schedule prepared & approved?				
3.		Check for correct cutting, bending of bars as per BBS				
	a.	Bar Diameters				
	b.	Shapes of bars				
	c.	Dimension of bars				
	d.	Number of bars				
	e.	Identification tags				
4.		Check for cleanliness of bars				
5.		Check for correct fixing of bars. Is it as per construction drawings?				
	a.	Relative position of bars, spacing of bars				
	b.	Covers to reinforcement				
	c.	Provision of chairs/ spacers				
	d.	Lap length & location of laps				
	e.	Fixation & fixing of couplers				
	f.	Check for stirrups at beam/ column/ drop panel junctions				
6.		Check for satisfactory tying of c/f with binding wire				
7.		Check for provision of dowel bars				
8.		Check for type of binding wire & gauge				
9.		Check for fixing of master ring above column at the slab level				
10.		Check the construction joint location rebar details are provided as per GFC drawing				
11.		Check location of services conduits & additional rebars at opens				

Fig 4.24 Additional points – to improve existing Reinforcement Checklist

CONCRETE CHECKLIST/ POUR CARD	
Site	
Client	
PMC	
Contractor	
Element	
Block/ level/ grid	
Date	
Drawing Reference No	

Refer the Approved Work Method Statement for concreting & relevant drawings

S. No.	Description	Yes	No	N/A	Remarks
1.	Are all safety norms covered as per HSEM process				
2.	Check for proper access to the pour				
3.	Check for formwork, reinforcement approval to be concreted. Is it OK?				
4.	Check whether the concrete is as per approved mix design				
5.	Check for the completion of preceding activities – fixing of inserts & embedment & service conduits etc				
6.	Mode of concrete – Pump/ Manual				
7.	Check whether location of expansion joints are as per drawings?				
8.	Is the sequence of concreting decided & explained to all concerned?				
9.	Check for readiness of mechanical equipments during concreting				
10.	Check for cleanliness of pour area				
11.	Are protective covers against rain provided?				
12.	Check whether sufficient material & manpower are available?				
13.	Preparation of old & new concrete joint				
14.	Check availability of sufficient no. of cube moulds, slump cones & other required quality apparatus?				
15. a.	Mode of concreting (Mixer m/c, Batching plant, RMC).				
b.	Grade of Concrete				
c.	Total quantity of concrete				
d.	Date & time of concreting				

Signature: Formwork supervisor/ Engineer:

Observations:

Whether the above points checked and in order? Yes/ No _____

Corrective actions proposed, if any:

ADDITIONAL POINTS

- Check Batching plant report
- Has samples been sent for cube test & slump test
- Check if Slump test result has been recorded
- Concreting done layer wise?

Preceding activities

- Adequate needle viberators available?
- Arrange lighting for night works
- Arrange tarpaulin sheets in case of rains
- Barricade cuts outs
- Adequate power backup facilities
- Arrange tremie pipe for vertical concreting

Checks for construction joint works

- Ensure shear key before & after concreting for proper bonding

Fig 4.25 Additional points – to improve existing Pour - card Checklist

CHECKLIST FOR POST CONCRETING	
Site	
Client	
PMC	
Contractor	
Element	
Block/ level/ grid	
Date	
Drawing Reference No	

Refer the Approved Work Method Statement for Concreting & relevant drawings

S. No.	Description	Yes	No	N/A	Remarks
1.	Are all safety norms covered as per HSEM process				
2.	Any surface defects observed?				
3.	Alignment of surface found correct?				
4.	Any undulations observed?				
5.	Any voids observed due to improper compaction				
6.	Check for the vertical members rebar position & cover				
7.	Embedded reinforcement visible				
8.	Date of casting written on member				
9.	Proper curing arrangement available?				
10.	Back propping provided as per approved methodology				
11.	Check the TOC levels & recorded				
12.	Date of casting				
13.	Date of de shuttering				

Cube Register Cube ID	Avg. Compressive Strength (N/sq.mm)	
	7 days	28 days

Signature: Formwork supervisor/ Engineer:

Observations:

Whether the above points checked and in order? Yes/ No _____

Corrective actions proposed, if any:

Fig 4.26 Post - pour Checklist

Fig 4.27 Concrete repair works - Checklist

4.9.2 List of Recommended Tools & Techniques

Table 4.6 Recommendations – Tools & techniques

Task	Issues	Recommendations
SITE ERECTION	• Inadequate/ Incorrect quantities delivered • Elements delivered at improper time • Lack of storage space	JIT (Just in Time)
MODELLING	• Lack of 3D softwares, site issues	BIM (Building information modelling)
SCHEDULING	• Improper resource planning • Inefficient planning system, • Constraints not taken into account	LPS (Last Planner System)
SCM	• Late material order placement • Unavailable storage space • Unavailability of materials • Improper layout planning • Lack of real time tracking • Inefficient inventory management	• Cisco Systems • Amazon blockchain technology
ID (FW & REBAR BUNDLES)	• Tagged incorrectly • Lack of technology • Cause reworks & delays	RFID/ Barcoding
DATA STORAGE	• Data not retrieved remotely	Cloud based storage - easy access
CRANE PLANNING, SCHEDULING & OPERATION	• Capacity required at working radius when lifting. • Sufficient cranage to safely rotate panels • Is there sufficient ground stability for cranes entering site • Compliance with 'No-go zone' clearances and rules. • Use of certified riggers • Crane schedule not planned	Software – Cranetime etc
WASTE REDUCTION	• Wastage of cost, time, resource • Environmental issues • Improper disposal	Lean tools

4.9.3 For Quantitative improvement

- **Quality control tools – FMEA** (Failure Mode & Effect Analysis) - **template**

Is a systematic, proactive method for evaluating a process where & how it might fail & to assess the relative impact of different failures to identify the parts of process that are most in need of change. Has the following advantages:

- Highly structured technique for failure analysis
- Quantifies severity, occurrence & detection likelihood of failures

Used by the military, aerospace, Automotive, tech, Food industry.

Table 4.7 FMEA Template

TEMPLATE 1: FMEA - ACTUAL

Project Name: Product Name: ID:			Team: Approved by:				Document No: Original Date:	
Function or process Step	Failure Type	Potential Impact	SEVERITY	Potential Causes	OCCURANCE	Detection Mode	DETECTION	RPN
Briefly outline function, step or item being analysed	Describe what has gone wrong	What is the impact on the key output variables or internal requirements?	How severe is the effect to the customer?	What causes the key input to go wrong?	How frequently is this likely to occur?	What are the existing controls that either prevent the failure from occurring or detect it should occur?	How easy is it to detect?	Risk Priority Number = (SEVERITY * OCCURANCE* DETECTION)
Formwork	Leakage	Cause honeycombing	10	Lack of sufficient form releasing agents, Poor compaction, Damaged formwork	2	Pre pour inspection	3	60

TEMPLATE 2: FMEA REVISED

Project Name: Product Name: ID:			Team: Approved by:				Document No: Revised Date:	
Recommended actions	Responsibility	Target date	Action Taken	Revised SEVERITY	Revised OCCURANCE	Revised DETECTION	Revised RPN	
What are the actions for reducing the occurrence of the cause or improving the detection?	Who is responsible for the recommended action?	What is the target date for the recommended action?	What were the actions implemented? Now recalculated the RPN to see if the action has reduced the risk					
Addition of adequate form releasing agents, Proper compaction Discard or repair moulds	QA/QC in-charge	From immediate effect	Strict supervision of techniques & checklists Training to the labours involved	4	2	3	24	

4.9.4 For Continous improvement

- **A3 Sheets**

Table 4.8 A3 sheet Template - Empathize

A3 SHEET - EMPHATIZE

DESCRIPTION OF PROJECT/ WORK/ ACTIVITY/ TASK: Typical high rise building					AUTHOR: Monisha Martin		DATE: REV NO:	TITLE: Raw material procurement
STAKEHOLDER NAME:	ACTIVITY	ROLES & RESPONSIBILITY	WHAT DID YOU HEAR	WHAT DID YOU OBSERVE	KEY CHALLENGES	PROBLEMS	EXPECTATIONS	REMARK
• Client • PMC • EBP • Procurement team head • Vendor • Contractor	Raw material procurement	Procurement team	• Substandard raw material • Improper inspection of materials • Payment issues from client • Improper planning • Improper supply chain management • Logistics issues - transportation etc. • Periodic checking of ground water if used	• Improper supply chain management • Lack of proper testing • Delay due to lack of automation	• Implementation of efficient SCM • Proper testing & storage of raw materials • Checklists to be followed	• Lack of timely coordination • Lack of automation	• Supply of good quality raw materials • Timely supply • Efficient coordination	
PROBLEM DEFINITION: Lack of coordination & transparency, Lack of proper SCM, delay in procurement, inadequate testing & checking of raw materials								

Table 4.9 A3 sheet Template – Solution

TEMPLATE 4 : A3 - SOLUTION

A3 SHEET – SOLUTION SHEET				
DESCRIPTION OF PROJECT/ WORK/ ACTIVITY/ TASK: Typical High Rise Building	**AUTHOR:** Monisha Martin	**SUPPORT TEAM:** ERP, PMC, Client, QC, Procurement team	**DATE:**	**TITLE:** Raw material procurement
ACTIVITY NO. & NAME: Raw material procurement		**OVERALL PROBLEM STATEMENT** Lack of coordination & transparency, Lack of proper SCM, delay in procurement, Inadequate testing & checking of raw materials		
THE PROBLEM (TO BE SOLVED): • Lack of timely coordination • Lack of automation		**THE USERS/ STAKEHOLDERS** ERP, team, PMC team , Client team, QC team, Procurement team, Vendors, Contractors		
THE USER PAIN POINTS THE USER PAIN POINTS / NEEDS ARE Pain points: Inefficient SCM, Lack of supervision Need: Proper work flow methodology		**THE SOLUTION** OUR SOLUTION WORKS LIKE THIS Proper work flow methodology – better coordination, transparency, avoid delay Strict supervision, testing		
THE IMPACT THE BENEFITS OF THE SOLUTION IS • Proper coordination • Transparency & work flow • Reduced delay • Good quality raw materials	**THE ACTORS** OUR SOLUTION INVOLVES • Structural consultant - Specifications etc • PMC – Coordination & collaboration • ERP team – Planning & coordination, check availability as per approved makes • Client Team – Timely Approval • QC team – Proper checking & testing	**THE COST** THE SOLUTION NEEDS INVESTMENT FOR **OVERALL COST & TIME FRAME**		**THE REVENUE** OUR SOLUTION GENERATES PROFIT BY **WORK METHOD – QUALITY, SAFETY & PRODUCTIVITY**

Table 4.10 A3 sheet Template – Solver

TEMPLATE 5 : A3 - SOLVER

A3 SHEET - SOLVER						
PROJECT TITLE Typical high rise building		**CLIENT NAME**		**AUTHOR** Monisha Martin	**SUPPORT TEAM** ERP, team, PMC team , Client team, QC team, Procurement team, Vendors, Contractors, DC	
ACTIVITY NAME & NO. Raw material procurement				**DATE:** **REV. NO:**	**TITLE:** Raw material procurement	
STAKEHOLDERS ERP, team, PMC team , Client team, QC team, Procurement team, Vendors			**COUNTER MEASURE**	**DESCRIPTION**	**BENEFIT**	**SUPPORT**
CURRENT CONDITIONS • Improper supply chain management • Lack of proper testing • Delay due to lack of automation **PROBLEM** • Implementation of efficient SCM • Proper testing & storage of raw materials • Checklists to be followed		**CHALLENGES/ ASPIRATIONS** • Supply of good quality raw materials • Timely supply • Efficient coordination	Swim lanes integrating all the stakeholders RACI Matrix for coordination	Efficient workflow give way for automation which is more transparent, integrates all the stakeholders involved	• Proper coordination • Transparency & work flow • Reduced delay • Good quality raw materials	ERP, team, PMC team , Client team, QC team, Procurement team, Vendors, Contractors,
GOALS/ TARGETS • Proper coordination • Transparency & work flow • Reduced delay • Good quality raw materials	**DEPENDENCIES** Successor – Design work **CONSTRAINTS** Unavailability of materials Price escalation **COMMITMENT**	**RESOURCES** Procurement team ERP team **PRODUCTIVITY**	**DELIVERABLE** Good quality raw material within the timeframe planned	**TIMELINE** 3 weeks ahead of slab casting	**RESPONSIBILITY** ERP QC team	**REVIEW** Feedback after implementation
REASON ANALYSIS • Lack of proper coordination • Lack of efficient work flow			**CHECK** Testing **ACT – LEARN – IMPROVE** Feedback & method of improvement & continuous learning			

4.9.5 For Quality Scheduling improvement

Table 4.11 Look ahead Schedule (4 weeks) - Template

TEMPLATE 6 : LOOK AHEAD SCHEDULE (4weeks)

TASK	WEEK 1		WEEK 2	WEEK 3	WEEK 4
Column Rebar	Activity ID	CR2-4	Activity ID	Activity ID	Activity ID
	Activity Name	Column Rebar	Activity Name	Activity Name	Activity Name
	Location	2nd floor, Grid: 5	Location	Location	Location
	Element Name	C10,C11,C12,C13	Element Name	Element Name	Element Name
	Qty	4 Nos	Qty	Qty	Qty
	Resources	Rebar labour, Helper, Crane Operator	Resources	Resources	Resources
	Resp. Person	Rebar In Charge	Resp. Person	Resp. Person	Resp. Person
	Predecessor	Column Starter	Predecessor	Predecessor	Predecessor
	Successor	Column Formwork	Successor	Successor	Successor
	Checklist		Checklist	Checklist	Checklist
Info.	GFC DWG		GFC DWG	GFC DWG	GFC DWG
	BBS		BBS	BBS	BBS
	RFI		RFI	RFI	RFI
	Method Statement		Method Statement	Method Statement	Method Statement
Resources	Labour		Labour	Labour	Labour
	Equipments		Equipments	Equipments	Equipments
	Material		Material	Material	Material
	Space		Space	Space	Space

Table 4.12 Weekly plan - Template

TEMPLATE 7: WEEKLY PLAN

Weekly plan: 7th March, 2022 – 13th March, 2022											
S. No	Task Description	Make ready needs	Resp. Person	Stakeholders	Weekly plan						
					Mon	Tue	Wed	Thu	Fri	Sat	Sun
1.	Steel Procurement	MTC, MIR 3rd Party Lab Report MTP	Contractor procurement team	QA/QC In charge, Client, PMC, Time Office	Steel procurement initiation		• Rolling Margin test • Send for 3rd party testing			Get results of 3rd party testing	
2.	Stripping of slab formwork	Back propping scheme, Tools	Formwork In Charge	QA/QC In charge, Construction In Charge	De shuttering, Casting date, Curing Quality Inspection	Back propping, Remedial measures					

4.9.6 Mobile Application UI (User Interface)

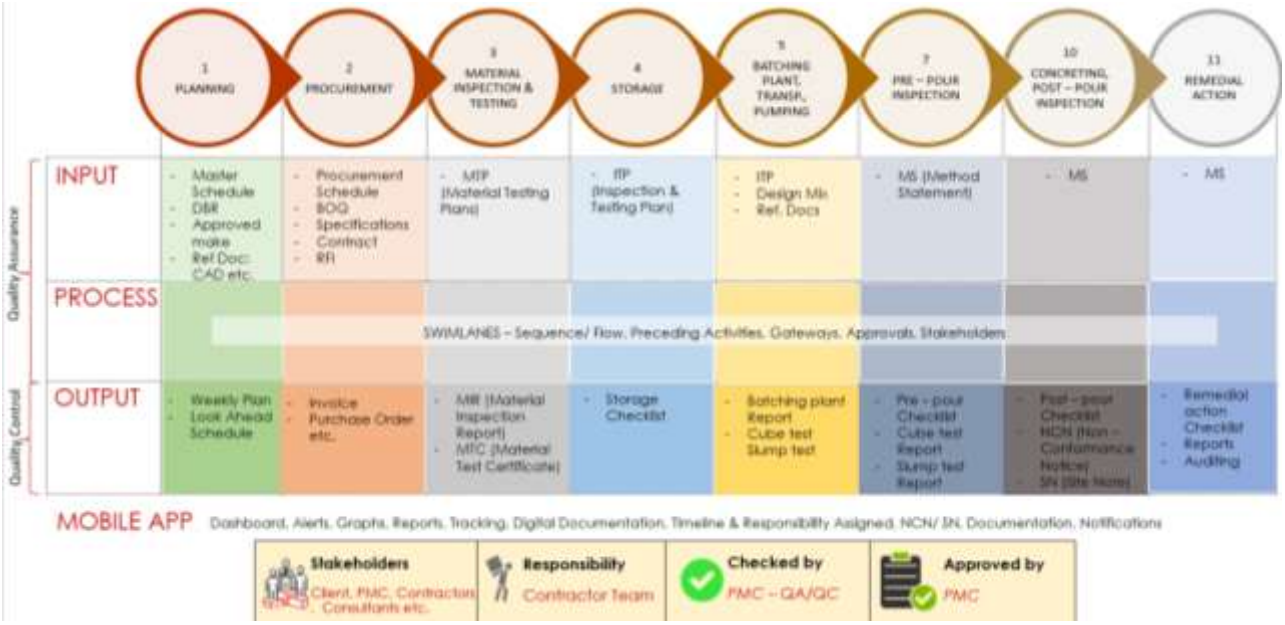


Fig 4.28 Mobile App Concept - Concreting

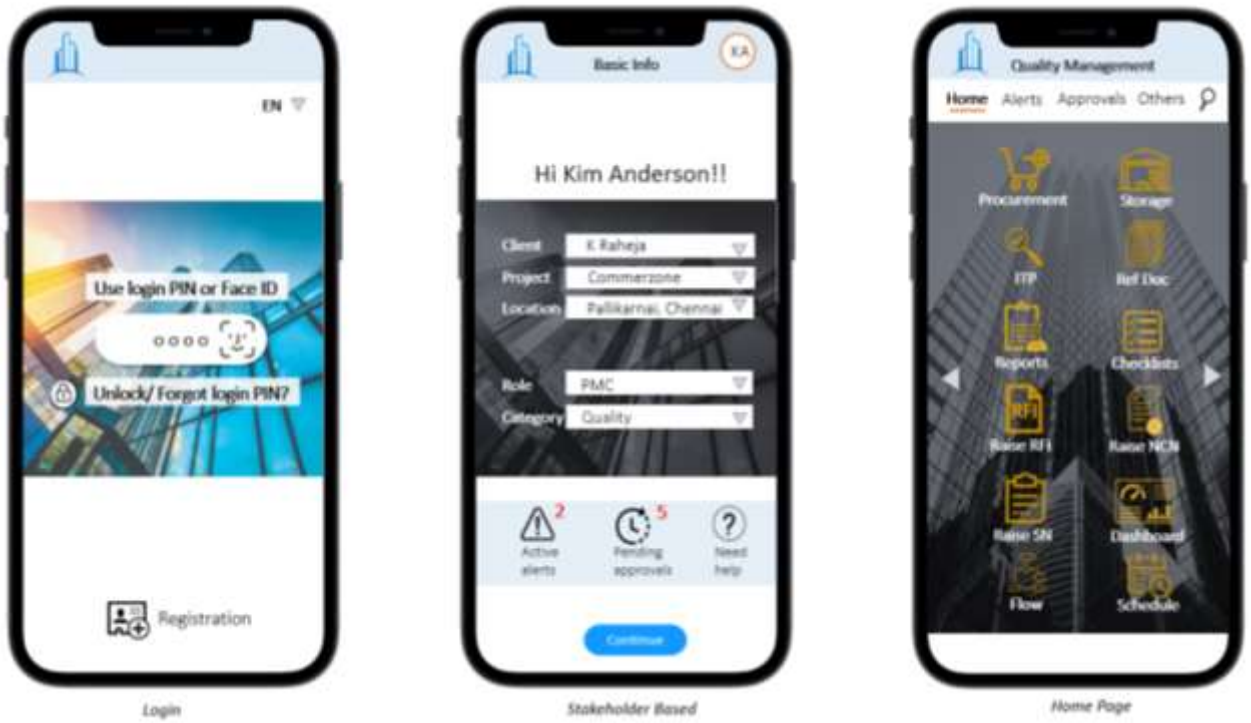


Fig 4.29 Mobile App UI - Login

Fig 4.30 Home Page - Overview

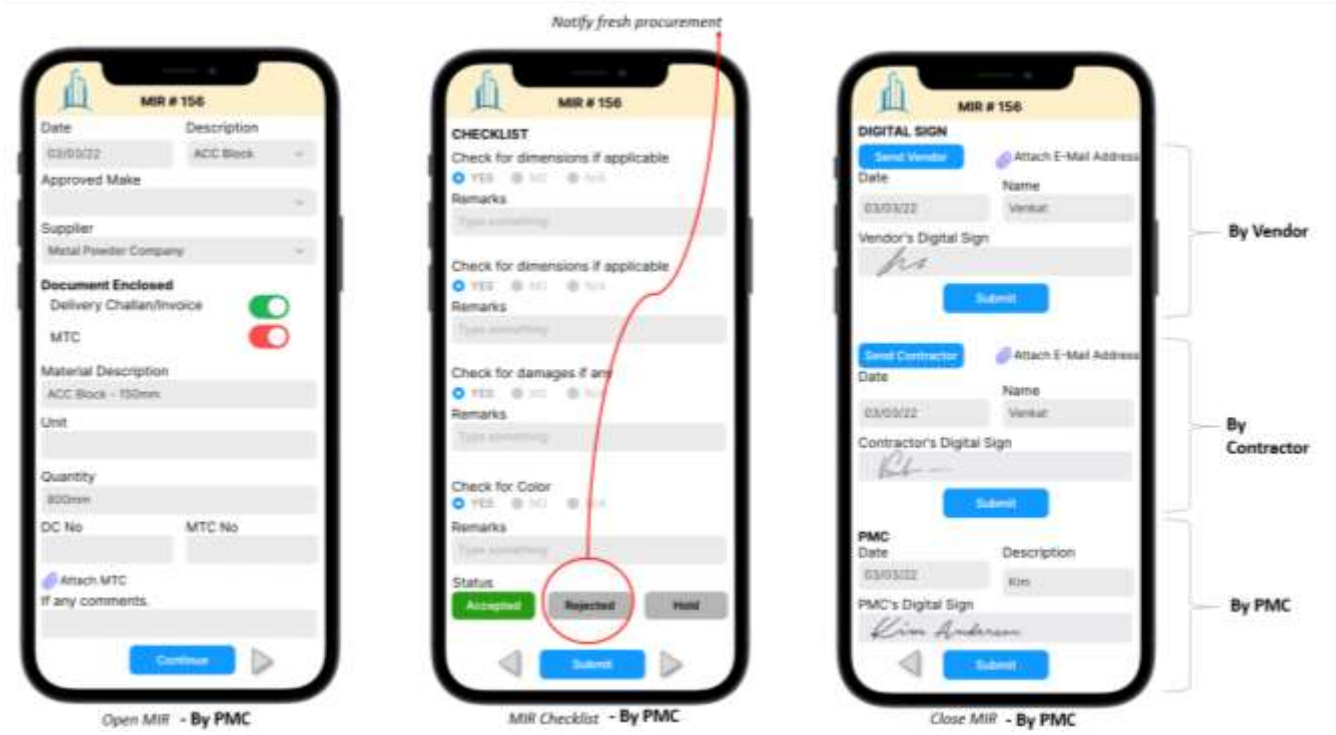


Fig 4.31 Mobile App UI – MIR Process

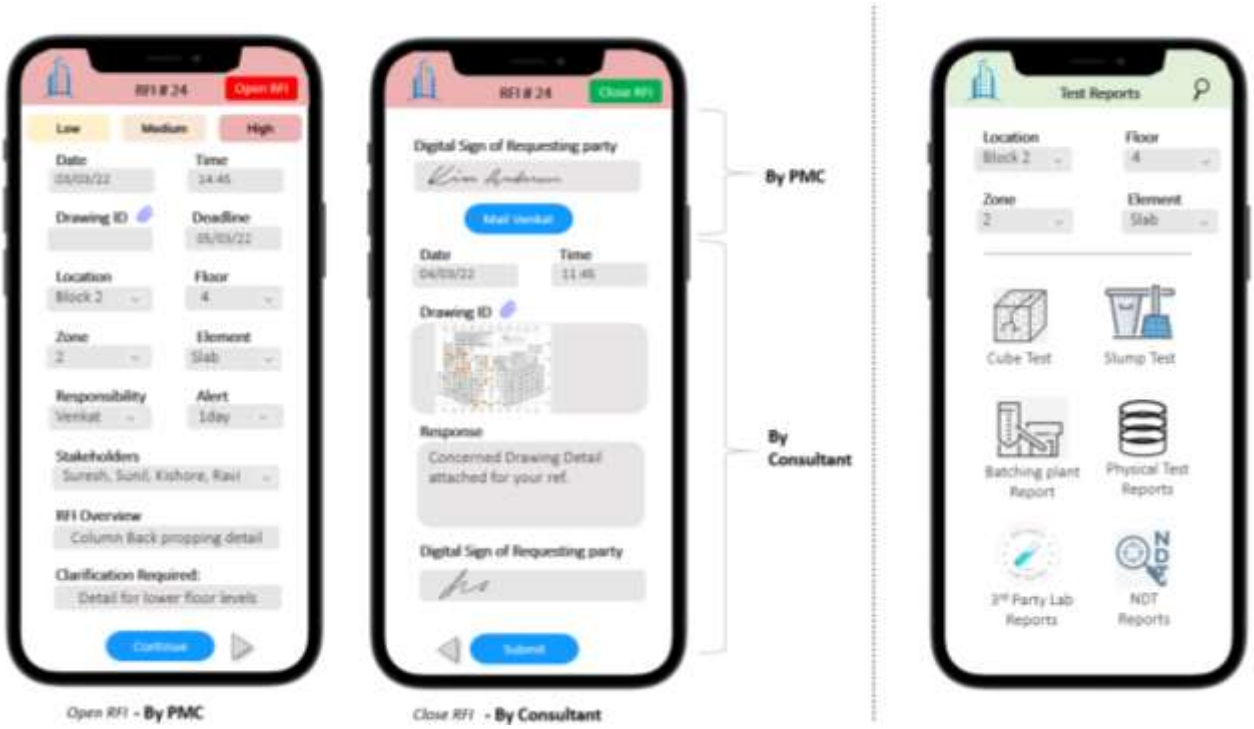


Fig 4.32 Mobile App UI – RFI & Tests Process

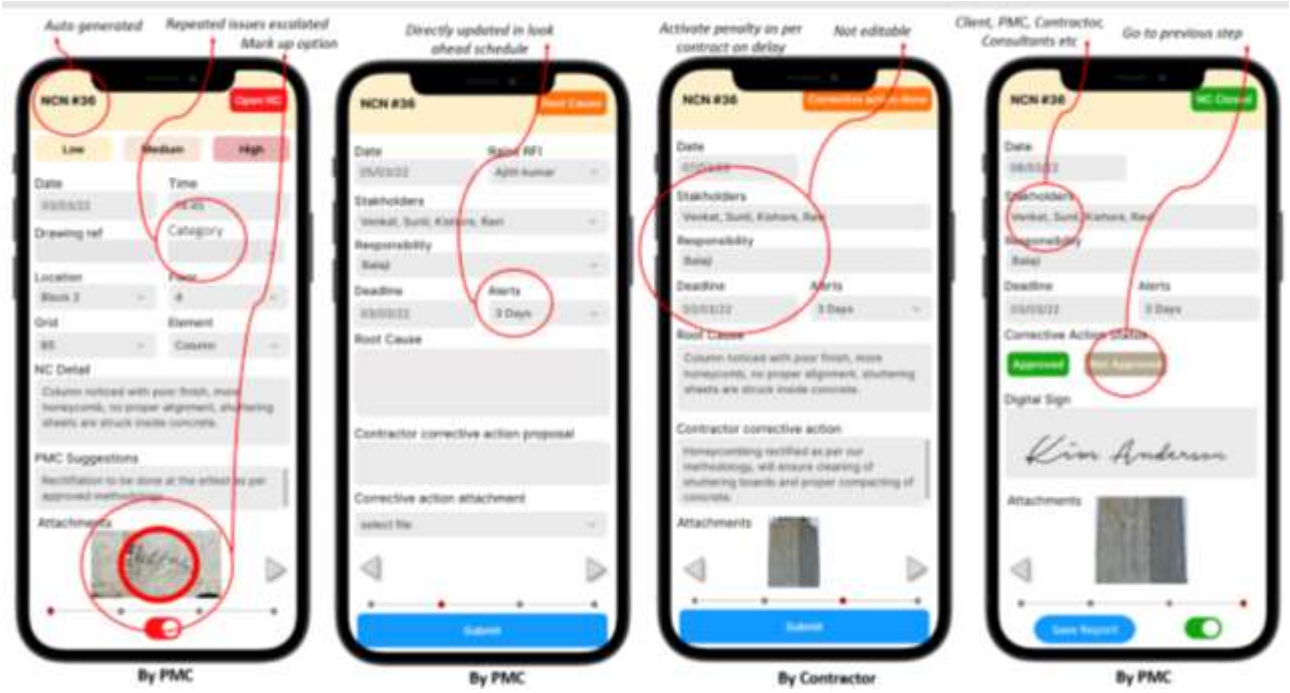


Fig 4.33 Mobile App UI – NCN Process

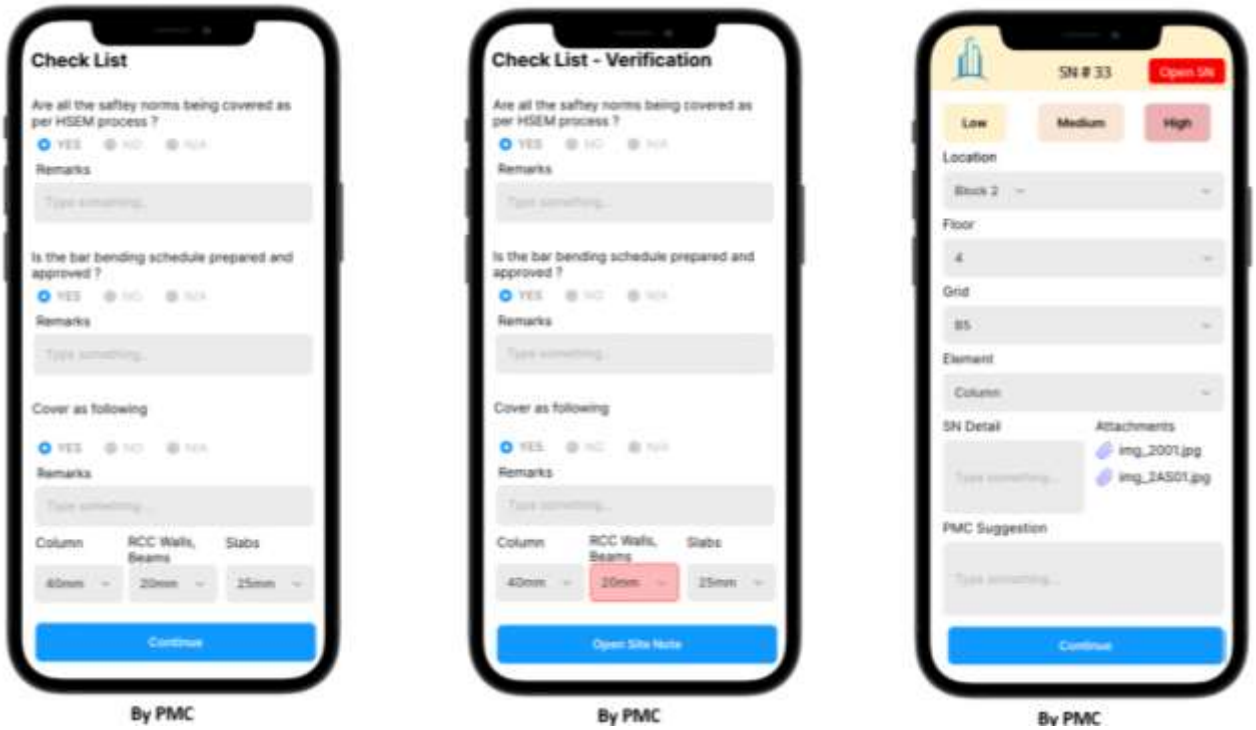


Fig 4.34 Mobile App UI – Checklist to SN Process

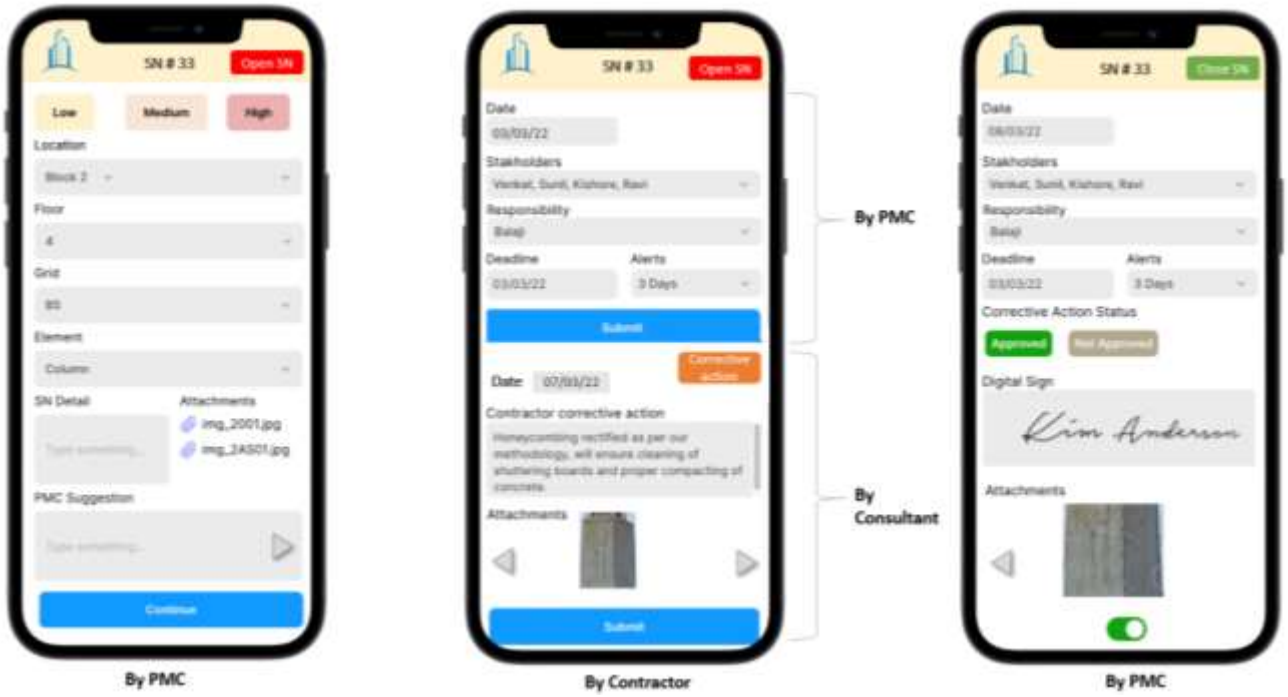


Fig 4.35 Mobile App UI – SN Process

Fig 4.36 Mobile App UI – Dashboard

Fig 4.37 QM Digitization Action Plan using Mobile

CHAPTER 5
SUMMARY & CONCLUSION

5.1 CONCLUSION

The cost & size of upcoming construction projects has gone up exponentially. Large scale construction projects & infrastructural projects are now very common. Continous monitoring during construction is often a laborious task for the stakeholders. Conventional Quality management system proves to be inefficient & ineffective. Decision making often is time consuming. There is an immediate need for a change in scenario with respect to quality management.
This instigates the use of technology to bridge the existing gaps. This will enable increased transparency with constant monitoring at various stages during execution through continuous improvement. It proves beneficial for all the stakeholders. Critical issues pertaining to the quality management have been re-engineered through appropriate tools & techniques. The study also proposes workflow methodology & mobile application UI which bridge the existing gaps in the system after design thinking process along with RACI matrix.

Many benefits to applying workflow automation to quality management systems:

- Bring all the stakeholders together
- Enables quick & easier decision making
- Avoids repetitive errors
- For see issues & mitigate accordingly
- Reduced snag list
- Complete audit trail of actions and activities
- Enforced oversight and compliance rules at every stage & proceed only on approval
- Consistency of processes with exception handling
- Centralized governance
- Reduced training time
- Capacity for continuous improvement
- Cost savings by redeployment of human staff to functions that require manual intervention

5.2 ACHIEVEMENT OF OBJECTIVES

5.2.1 To identify & examine the issues in the current scenario

The A3 thinking based on the Plan – do – check – act cycle, a powerful way of thinking developed by Toyota - A3 report had been used to define problems, suggest solutions and recommended for further recording the results of improvement activities. The various issues like awareness, coordination, work flow methodology, quality management etc were identified & for certain of these aspects, tools have been identified for mitigation as shown below:

5.2.2 Propose efficient workflows

The aim was mitigating the core issue - lack of proper workflow methodology by use of swim lanes, integrating various stakeholders involved for the various stages commencing from the sales work sequence, estimation, contracts, technical, design, supply chain management, procurement, stores, production, logistics, installation & recommendation for waste management.
It gives a holistic big picture of the process with the reference documents & tagged data needed specifically stage wise which is the essential first step towards quality management. This provides an algorithm to further develop into a BPM by automating like in automotive industries. By implementing digital solutions, such as workflow automation, manufacturers improve product traceability while retaining accurate quality data. Quality & transparency is becoming a customer expectation.
(REFER: Swim lanes)

5.2.3 Get all stakeholders involved

The lack of coordination is another issue that has been alleviated by use of various communication matrices – communication patterns between stakeholders, defining the contractual relationship between them, their involvement in various stages, communication matrix & by using RACI (Responsible, Account, Consult, Inform) matrix.

5.2.4 To reduce reworks

The use of inspection plan, checklists, corrective measures & task wise recommendations have been arrived at with both use of technology & tools. These reduce reworks thereby save time which is indispensable to any construction.

5.2.5 Propose a Mobile Application UI mitigating the issues faced

The mobile app is both user friendly & stage specific, offers transparency, traceability, easy auditing, reduced meeting time for the stakeholders involved. Has crucial features like assigning responsibility, deadline with alerts & notifications which are all remotely accessible.

5.3 CONTRIBUTION OF THE STUDY

Firstly, various issues in the current precast construction scenario have been identified & listed under broad categories with solutions for some of the key aspects. Similarly, the other remaining issues can be taken up for further study and solutions can be arrived at for the same.
Secondly, the proposed swim lanes provide a big picture view of the process at a glance giving opportunity to plan & schedule comprehensively integrating all the key stakeholders involved thereby promoting efficient work flow, coordination & transparency by tagging of stakeholders & associated documents.

Thirdly, it defines the roles & responsibilities of the various stakeholders in form of matrices for better planning of the communication channels which is currently lacking.
Lastly, it provides the inspection plans, checklists for various stages with corrective measures giving a comprehensive approach towards quality management with recommendations & Mobile Application UI (User Interface) combining technology & tools.

5.4 SCOPE FOR FUTURE STUDY

Table 5.1 Future study - VSM

S.NO	THRUST AREA OF FURTHER STUDY	OBJECTIVES
1	VSM (Value Stream Mapping)	• Productivity study • Streamline production process • Optimize project delivery & completion • Waste reduction

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