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Mechanization and Automation in Construction

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ABSTRACT: Industrialization has shown a strong ability to lower costs, increase quality, and make complicated items accessible to the great majority of people. However, it has not yet been applied to the construction industry as a whole. Moving towards industrialization through mechanization and automation in the construction sector is one approach for addressing issues in the construction industry such as performance, productivity, the environment, and health and safety, as well as frequent delays and cost overruns. The current research aims to analyse the constraints in the implementation of mechanization and automation on Indian construction industry. From the analysis it is observed that the most significant and frequently occurring constraints in the implementation of these technologies on site is the perception of industry professionals that these technologies acquire high cost in purchasing, implementing, updating and maintaining. After obtaining the critical constraints a framework is developed to measure cost effectiveness of mechanized and automized technologies in comparison to manual work practices to improve safety, productivity and quality standards in construction. Conclusions are established on the profit gained by machine as well as its economic viability. The proposed framework can be utilized by constructors to measure cost effectiveness of machine in comparison to manual work practices before investing in them.

Keywords: Mechanization, Automation, Industrialization, Implementation constraints, Benefits, CostEffectiveness

I. INTRODUCTION

There are five degrees of industrialization that have been recognized. Prefabrication, mechanization, automation,robotics, and reproduction are the terms used to describe these processes(Richard, 2005). Moving towards industrialization through M&A in the construction sector is one approach for addressing issues in the construction industry such as performance, productivity, the environment, and health and safety, as well as frequent delays and cost overruns(Vidushi, et al., 2022). Time is money in the building sector. Contractors could expect projects to be completed sooner when employing M&A because it is faster than work operations done by human (Kamaruddin et al., 2021). As per M.Warisa, Mohd. Shahir Liew and others (Waris et al., 2014) M&A is widespread in developed countries and many manual procedures are getting superseded due to expansive and scarcity of skilled labour whereas it is not widespread in developing countries like India. Sinceconstruction is one of the most important sectors in terms of investment, employment, and GDP contribution in both emerging and developed nations. (Kamaruddin et al., 2016), it is momentous for developing countries like India to keep up with fast growing trends of M&A in order to remain competitive in the current global market. The majority of prior research into construction M&A technologies has concentrated on software and hardware development, and the use of design or planning software for the early phases of construction (Mahbub, 2008). To compete effectively amid rising globalization, market competitiveness, and technology improvements in the twenty-first century, the construction sector requires effective construction organizations, effective construction procedures, and creative building methods (Mahbub, 2008). In this context (Basu et al., 2017), revealed the aspects of innovation pertaining to the automation in the building construction sector wherein, the concepts have been integrated with the sustainability as well highlighting the relevant performance indicators (Basu et al., 2019).

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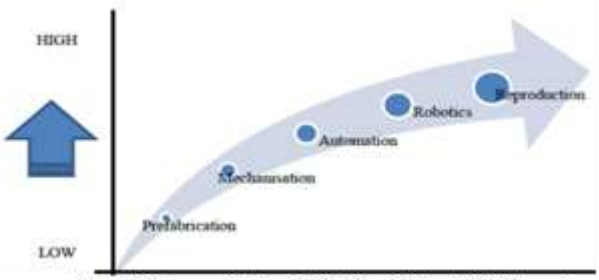

Figure 1 Degree of Industrialization, (Richard, 2005)

The aim of the research is toanalyse the constraints in the implementation of mechanization and automation on Indian construction industry. Four objectives have been framed to achieve the it-

1. To assess the constraints of implementing mechanization and automation in Indian traditional construction industry through literature.
2. To validate the identified constraints of implementing mechanization and automation in Indian construction industry through case study.
3. To analyse these constraints to obtain the critical implementation constraints of mechanization and automation through questionnaire surveys.
4. To propose suitable framework to mitigate the critical constraints.

II. LITERATURE REVIEW

2.1 Definitions

Prefabrication can be defined as-

- The word starts with ‘pre’, which means ‘before’ or ‘elsewhere’. In the construction sector, prefabrication specifies building (in a factory) components or full modules very similar to the ones done on a traditional construction site, very often using the same procedures and the same materials (Richard, 2005).
- A process of manufacturing that takes place at a specialized facility, in which different materials are joined to form a component part of the ultimate installation (Kamaruddin et al., 2018)

Mechanization can be defined as-

- Method of employing mechanical equipment in the performance of a job. (Kamaruddin et al., 2016).
- The act of using modern technology to operate machinery, generally including electrical hardware (Mahbub, 2008).
- Machines are being introduced into a production process (Kapliński et al., 2002).
- When machinery is used to reduce a laborer's burden (Kamaruddin et al., 2018).

Automation can be defined as-

- The use of automated tools totally replaces the labor-intensive operations. Although the industrial engineer and programmer are the key players and a 'supervisor' is still present (Richard, 2005).
- Self-regulating procedure involving the use of programmable equipment to complete a set of tasks (Kamaruddin et al., 2021).
- Usage of automated tools totally replaces the labor-intensive operations (Kamaruddin et al., 2018).

Robotics can be defined as-

- The ability of the same multi-axis flexible tooling to execute a variety of operations on its own (Kamaruddin et al., 2018).
- Field that bridges the lines between artificial intelligence and mechanical engineering. It's about making robots, which are programmable devices having mechanical actuators and sensory organs that are connected to a computer (Mahbub, 2008).

Reproduction can be defined as-

- The research and development of new methods has the potential to greatly simplify the manufacturing process (Kamaruddin et al., 2018).
- The goal of reproduction is to reduce the time spent on repeated linear activities that are trademarks of the artisan technique, such as hammering wood studs, laying bricks, and so on (Richard, 2005).

Prefabrication is more concerned with the location of the manufacturing process whereas the next three degrees of industrialization i.e., mechanization, automation and robotics are concerned with duplicating the conventional methods by shifting the responsibilities from the artisan/worker to the mechanical plants. The difference between mechanization, automation and robotics in the sophistication of technology application. Automation goes beyond mechanization in that the process is not only

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supported by machines, but these machines may also function in accordance with a programme that controls their behaviour. Robotics would be the furthermost sophisticated and progressive application, with task-specific, specialized robots doing distinct jobs on simplified construction technology.

2.2 Evolution of the Industrial Ages: Industry 1.0 to 4.0

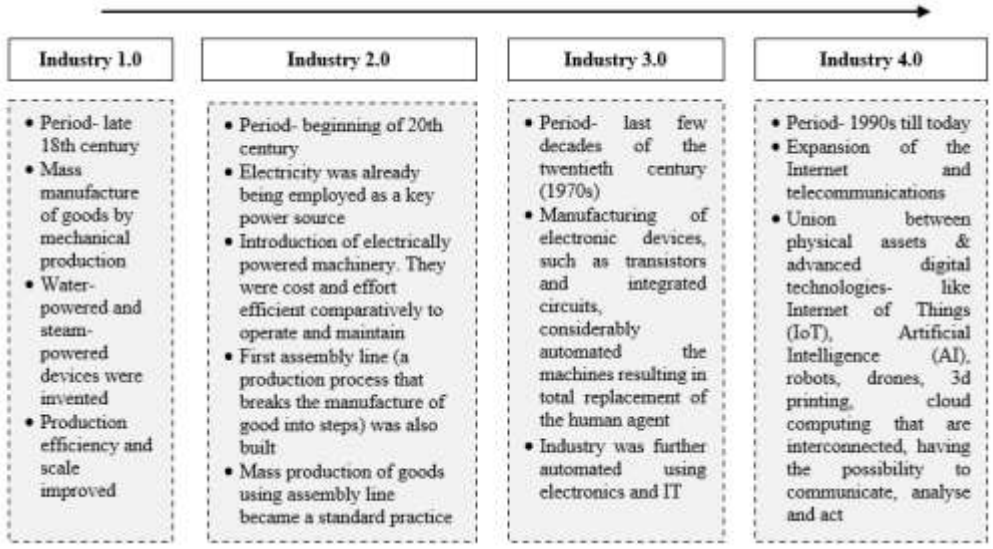

Figure 2 Evolution of the Industrial Ages

In India improvements in productivity, safety, and quality during the last few decades in other industries like manufacturing, have reached a new level of effectiveness in terms of implementing new technology such as automation using electronics and IT (entered into Industry 3.0). The use of emerging technology in the construction industry to fully automate or mechanize construction operations remains restricted, particularly for on-site activities as a result of which we are struggling somewhere near 2.0.

2.3 Range of Mechanization and Automation Application in Construction

The scope of M&A technology application in construction may be quite extensive, including all stages of the construction life cycle, from initial design through actual construction of the structure, Design**,** Planning, Scheduling, Estimating and Costing**,** Project Management and Total Construction Systems**,** On-site Construction Operations**,** Dismantling or Demolition**.** The spectrum of M&A technologies used in diverse stages of construction differs depending on their sophistication and technological application, but in general, construction work activities and processes will be identified as barrier variables0020(Kapoor, et al., 2022). As a result, the focus of this study will be confined to constraints to implementation of M&A technologies during the construction phase.

2.4 Benefits of Mechanization and Automation in Construction

1. **Increase safety on site:** Construction workers are frequently exposed to a variety of risks that come with working on a construction site. Despite the fact that numerous techniques to preventing accidents have been used, the figure shows that more progress must be made quickly (Hamid et al., 2019).
2. **Less dependency on labour/Reduce foreign labour:** According to Martinez (Martinez et al., 2008), the activity has a direct relationship to the operator, which eliminates issues with quality and repetitiveness of work carried out.Resolving foreign labour workforce issues, improving product quality, minimizing the volume of material consumed in finishing projects, and promoting a better perception of the construction industry, which is currently known to be dirty, low quality, and dangerous, are some of the perceived impacts and achievements that will have a significant impact on the application of M&A. (Nik Fatma Arisya Nik Yahya, 2020).
3. **Speed up the construction time:** M&A made the activities increases the speed of construction. It is also strengthened by removing the human factor's limitations from

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the equation (Rashid et al., 2019). A study conducted by (Martinez et al., 2008) utilizing a automated machine to weld 1m steel 2mm thick saves a significant amount of time. It takes around 600 seconds to complete by manual metal arc welding, and 7 seconds to complete by laser welding. According to industry case studies, homes built using M&A may be built 30% faster and for 25% less money (Rashid et al., 2019).

4. **Higher accuracy:** By using M&A in construction, it is possible to achieve a better level of consistency and precision than skilled labour(Divyesh Joshi, 2015).
5. **Reduce Construction wastages:** According to Rashid (Rashid et al., 2019), the Waste & Resources Action Plan UK (WRAP) discovered savings through the use of M&A as a consequence of waste reduction.Traditional techniques waste 10% to 20% of the raw material; however, with more advanced M&A construction may generate the same assets with half the waste (Rashid et al., 2019).According to Mi Pan (Pan et al., 2018) waste resulting from concrete can be reduced from about 51.47% to 60%. and the waste of steel bars can be reduced from about 35% to 55.52%. It shows that M&A approaches can catalyst in the efficient use of materials in many ways.
6. **Reduced Re-works:** By removing the human factor's limitations from the equation (Rashid et al., 2019) M&A technologies reduces re-works as re-works occurs as a result of human errors.
7. **Reduce Overall Cost:** Labor costs may also be decreased since the M&A system requires fewer operators (Rashid et al., 2019).The reduction in the cost of human labour and the decrease in material loss, among other factors, reduce the cost of the operation (Martinez et al., 2008).This can be explained the fact that construction done using M&A technologies is less likely to suffer from cost blowouts caused by unknown factors such as the weather. According to industry case studies, homes built using M&A may be built 30% faster and for 25% less money (Rashid et al., 2019).
8. **Clients Satisfaction:** Client satisfaction is determined by the amount of time, cost, and the quality of the work (Yunus et al., 2016). By approaching M&A in construction provides uniform quality with higher accuracy than that provided by skilled worker (Divyesh Joshi, 2015). Also, timeline of the project can be reduced.
9. **Increase productivity:** M&A may also increase productivity and job efficiency while lowering costs (Divyesh Joshi, 2015). Reduction of costs, mostly due to the decrease in work load per task, and eliminating or cutting down the need to use scaffolding, security system and additional transport equipment (Nik Fatma Arisya Nik Yahya, 2020).
10. **Increase quality of work done:** By approaching M&A in construction activities, it can deliver uniform quality with higher accuracy than that provided by skilled worker (Divyesh Joshi, 2015) which lead to reduce poor workmanship problems. M&A will improve the working environment by reducing traditional manual work to a bare minimum, allowing workers to be relieved of uncomfortable work positions while also eliminating complaints about noise and dust associated with tasks such as surface removal, cleaning, and preparation (Divyesh Joshi, 2015).
11. **Increase Site Cleanliness:** As the use of M&A technologies in construction brings machinery and automatic robots into picture and reduces workman on sites ultimately encouraging site cleanliness (Musa et al., 2015).
12. **Sustainable approach:** M&A contributes to sustainability by reducing waste, increasing environmental and construction site cleanliness, improving quality control, and promoting a safer and more organized construction site (Musa et al., 2015). Furthermore, sustainability entails innovation and the use of modern construction methods through industrialization, such as M&A. Using M&A to advance the sustainabilityagenda may also be extremely beneficial because it can provide significant advantages to organizations (Mohammad, 2013). The sustainable approach pertaining to the mechanization in construction is pertinent and vital in terms of adaptive reuse of the buildings (Sreekumar, et al., 2022).
13. **Advantage during global pandemic:**The global Corona virus epidemic has had a significant impact on the global building sector. Transportation limitations, social distance, and lockdowns have affected the labour, material, and financial supply chains, causing delays and increasing expenses. Because of the near physical proximity of the work, civil construction is particularly vulnerable to such pandemics. Also, there are several inadequacies of present construction

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processesand the increasing need for better quality, which also enhances research and development of new methodologies and processes(Singh, et al., 2022)

14. **Provides flexibility to designers:** Buildings must be constructed within the constraints of known building methods, and the incorporation of new technology into those processes introduces new parameters and opportunities for architects (Brown, 1989).
15. **Improving Image of Industry:**Because the construction sector is currently viewed as dirty, low-quality, and unsafe, using M&A technology in construction might assist to improve public impression of the business (Kamaruddin et al., 2016).

2.5 Inferences of Literature Review: Implementation Constraints of M&A Technologies

As compared to technologies used for on-site operations, the usage of software for designing, planning, and other tasks has become highly popular and widely available. Many hurdles were found as a result of the literature reviews, and the following are some of the most significant:

1. **High cost in purchasing and implementing:** Cost would be a crucial consideration in determining whether or not to adopt a new technology (Nik Fatma Arisya Nik Yahya, 2020). The cost of purchasing and implementing the techniques is so high that only companies with a high turnover and strong market competitiveness can afford them (Sadique & Mahesh, 2016). Mechanized Construction process may demand increased investment cost at the initial stages of projects due to procurement of expensive equipment (Khan et al., n.d.).
2. **Expensive for operating, updating and maintaining:** Cost considerations should encompass not just the purchase price of M&A technologies, but also the cost of maintaining them to ensure that they can increase overall efficiency and production (Divyesh Joshi, 2015). The acquisition and maintenance of technology requires large costs/financial commitments in order to implement M&A (Mahbub, 2008).
3. **Limited resources available to medium and small sized firms:** When compared to small and medium businesses, larger companies can afford to invest in new technologies. They also lack the necessary skilled labour to deal with the new technology (Sadique & Mahesh, 2016). Because of the high maintenance costs, most developers, especially smaller companies, refuse to invest in such expensive technology. Small businesses struggle to implement automation since their money is insufficient to acquire automation technologies in proportion to their turnover.
4. **Fragmentary nature of the construction industry (multi-point responsibility):** Construction processes deals with multi point responsibility so incorporating M&A technologies may create issues (Mahbub, 2008).
5. **Multiphase characteristic of construction process**: All construction procedures has its own characteristics. As a result, the same technologies cannot be employed at all times (Sadique & Mahesh, 2016). Construction is a diverse industry and one that has to cope with an almost unique set of circumstances on each project and site (Mahbub, 2008).
6. **Unique nature of construction sites:** Sites are often distinct and does not provide the same set of issues, but automation requires a controlled environment and work process (Mahbub, 2008).
7. **Availability of cheap labour:** The accessibility of cheap labour which balances the cost benefit of using M&A methodologies is a basic reason of the low acceptance in the past. As long as it is easy for the industry to find workers, labour rates will remain low and builders will find it unattractive to change into simplified solutions such as M&A construction (Din et al., 2012).
8. **Required for re-training worker:** M&A technology are complicated to use and understand. Workers are resistant to the M&A technologies because they are unfamiliar. Nowadays, there is need to train the workers to operate these techniques in proper manner (Nik Fatma Arisya Nik Yahya, 2020). According to Mahbub (Rohana Mahbub, 2012), low technology literacy of project participants/need for re-training of workers is also consider a barrier to implement the automation in construction industry.
9. **Knowledge awareness of key players:** The implementation of M&A is restricted by a lack of scientific and technical information among the stakeholders. It is quite certain that implementation of M&A concept is yet to be executed due to limited knowledge and awareness (Abdullah, n.d.).
10. **Locally unavailable:** A shortage of equipment and machinery is a significant major hurdle in the construction sector. Indian construction

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sector also facing a constraints to implement M&A as machineries are unavailable locally and technology difficult to acquire (Sadique & Mahesh, 2016). Also, there are many developers who rely with traditional construction method because these technologies are required to be imported from other countries (Rohana Mahbub, 2012).

11. **Incompatibility of the technologies with existing practices and current construction operations:** Mismatch of the M&A technologies with existing practices and current construction operations possess a major implementation constraint of using these technologies.
12. **Loss of human skills:** Laborers who have grown overdependent on machines have lost their artistic skills and initiative (Khan et al., n.d.).
13. **Rise in unemployment:** The employment of M&A technology to replace human labour limits the number of jobs available. This might worsen the situation in some nations where unemployment is severe. As a result, more industrialization may result in higher levels of unemployment. It's important to employ the right amount of industrialization. For optimum productivity, there has to be an optimal level of industrialization (Alinaitwe et al., 2006).
14. **Technology not easily accepted by worker union:** There is a potential that labour unions may challenge the use of M&A technology since it may result in a fall in employment rates. Apart from that, owing to the intricacy of M&A technology, workers have a hard time accepting new technologies (Sadique & Mahesh, 2016). Some research concludes reduction in the number of workers on site as a result of M&A systems used to help labourers do their jobs more efficiently (Richard, 2005).
15. **Level of workforce skill:** The use of technology in design and implementation has necessitated a major increase in knowledge and abilities. On-site designers and managers needed IT skills to plan and implement the usage of technologies provided by IT (Abdullah, n.d.).

III. CASE STUDY HIGHRISE RESIDENTIAL TOWNSHIP: GREATER NOIDA

3.1 Project Details

Project Details	
Location	Greater Noida
Typology	High-rise Residential Township
Architect	Gian P Mathur (GPM, India)
Structure Designer	E. Construct, U. A. E
Developer	Amrapali Group
Overall built-up area (Precast + CIS)	10 million sq ft
Built-up area planned in Precast	3.79 million sq ft
Basement, Ground & terrace work	Cast in Situ
Total precast concrete volume (m^3)	16000

Table 1 Project Details

Project includes 47 high-rise residential towers, 379 villas, commercial and institutional building. Residential towers are divided in to six typologies (series) from A to F with further classification as A1 to A7, B1 to B6, C1 to C12, D1 to D2, E1 to E8, and F1 to F12. After a lot of brainstorming and feasibility study, Series A, D, E & F were planned to be constructed by using precast construction technology. All towers of series A (2B+G+18 Floors), D, E1 & F (2B+G+24 Floors) rise about 60 m above ground with floor-to-floor height of 3.05m. A total of 3.7 million sq ft area was planned to be constructed with precast.To make the case easy to understand, this study will discuss the construction of series A having total seven towers. As of today, all the seven towers are completed. Each level has 12 units, each with a carpet area of around 430 square feet for a 1BHK. Because all of the units in Series A are similar, precast technology became a realistic alternative. Figure 6 depicts the general plan of a group housing project with high-rise towers, including one built utilizing precast concrete technology.

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Figure 1 Overall Layout Plan

3.2 Implementation of M&A in on-site Construction Activities

Variety of mechanized and automized methods and processes has been used on site during construction of the township. Some of the major M&A technologies has been listed here.

Earth Excavator- Excavators are large machines with a boom, bucket, and cab mounted on a rotating platform. The home is built on top of a track or wheeled under carriage. Hydraulic fluid is used to power the excavator's movement and operations, whether it's using rams or motors.

Figure 3 Earth Excavator,Tipper and Crane

Tipper- A tipper or dump truck is a construction vehicle that transports loose materials such as sand and gravel. A standard dump truck has a hydraulically powered open-box bed that is hinged at the back and can be pushed up to allow the contents to be placed on the ground behind the vehicle at the delivery site.

Cranes- A crane is a hoisting equipment with a winder wire ropes or chains, and sheaves that can raise and lower goods as well as move them horizontally. Cranes are frequently used in the construction sector to raise large materials, such as girders**.**

Concrete Pump- Concrete pumps are devices that transport liquid concrete from a concrete supply to a casting location.

3.3 Benefits Achieved using M&A on Site

1. **Speed up the construction time-** In 18 months, 7 towers with 2B+G+18 stories were built. Precast technology and mechanized and automated procedures made it possible.
2. **Increase quality of work done-** Superior quality & finish of construction is achieved as confirmed by the project manager. M&A of construction project improved overall productivity.
3. **Reduce Construction wastages-** Reduction in concrete & steel factor per sq ft of built-up area has been observed. The use of precast wall panels and cladding allows for the elimination of brickwork and plaster.
4. **Increase safety on site-** The advantages of this technology include the fact that workers are

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not exposed to flying sparks or extreme heat when operating these robots, making them handy for safety.

5. **Provides flexibility to designers-** Precast and M&A technologies allowed flexible design and longer clear spans in the non-tower areas like parking.

3.4 Inferences: Challenges and Constraints experienced while Implementing M&A Technologies

Following are the constraints/barriers conveyed by the professionals in interview.

1. **High cost in purchasing and implementing-** Mechanized Construction process demanded increased investment cost at the initial stages of projects due to procurement of expensive equipment.
2. **Lack of contractor expertise and competence manufacturer-** Low technology and machine literacy of project participants became one of the major barriers in implementation of M&A. The construction industry has shown a notable resistance to adopt new technologies. Lack of competent workforce with understanding of the precast industry, operation of various machineries, and erection, which was addressed via extensive training.
3. **Hesitation to adopt-**The major task was to construct a high-rise residential building using precast construction technology that eventually turned into a severe learning curve. It was tough to overcome people's natural resistance to change in building technique, as well as their patience and desire to try new things. Contractors were hesitant to implement M&A technology and prefer to stick to traditional building methods because they were already experienced with the traditional method, and the technology suits them well.
4. **Unavailability of codes and standards-** Several design, production & erection aspects of standard practices used abroad were needed to be modified to suit the Indian scenario. Although European and other standards were readily available for reference, the lack of IS codes was regarded critical. Only a few Indian standards were available to the designers from India.

Two new implementation constraints have been found from the case study i.e., lack of contractor expertise and competence manufacturer and hesitation to adopt M&A. All the implementation constraints identified from the literature (secondary sources) as well as from case study (primary source) are clubbed to form a comprehensive list and are classified into groups to better handling for further analysis.

Group. No.	Group Title	S. No.	Implementation Constraints
A	Economics and Cost	1	High cost in purchasing and implementing
		2	Expensive for operating, updating and maintaining
		3	Limited resources available to medium and small sized firms
B	Characteristics of the Construction Industry	4	Fragmentary nature of the construction industry (multi-point responsibility)
		5	Multiphase characteristic of construction process: diversity of construction tasks and work processes
		6	Unique nature of construction sites
		7	Availability of Cheap Labour
C	Technology	8	Required for re-training worker
		9	Knowledge awareness of key players
		10	Locally Unavailable
		11	Incompatibility of the technologies with existing practices
D	Human Factors	12	Loss of human skills
		13	Rise in unemployment
		14	Technology not easily accepted by worker union
		15	Lack of contractor expertise and

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			competence manufacturer
		16	Hesitation to adopt
		17	Level of workforce skill

Table 2 Implementation Constraints of M&A Technologies

IV. DATA COLLECTION AND ANALYSIS

4.1 Research Methodology

The impact of various constraints in implementing M&A on construction sites has been investigated using a questionnaire survey approach. The form of questionnaire contains three sections. Section 1: The first part of the questionnaire is targeted to gather data about the respondents.Section 2: The second part of the questionnaire is targeted to investigate level of implementation and development of M&A technologies. Section 3: The third part of the questionnaire is focused to investigate the influence of the identified constraints on the implementation of M&A on construction sites. A 5-point Likert scale was used for measuring of the level of effect of these constraints. Respondents simply equipped of implementation constraints of M&A on construction sites. As a result, each respondent could choose only one option for each constraint. The responses were to be based on the respondents' understanding, knowledge, and experience, rather than on any specific project. A Likert scale of 1-5 was used in the questionnaire.Data collected form survey was analyzed with the help of RII- Relative Importance index method and its reliability is checked with the help of Cronbach alpha.

4.2 Data Collection

Questionnaire survey was created on Google forms. A total of 100 questionnaires were sent to industry professionals through WhatsApp, LinkedIn & email. A total of 60 questionnaires are received back with responses, subsequent in a nearly 60% reply rate.

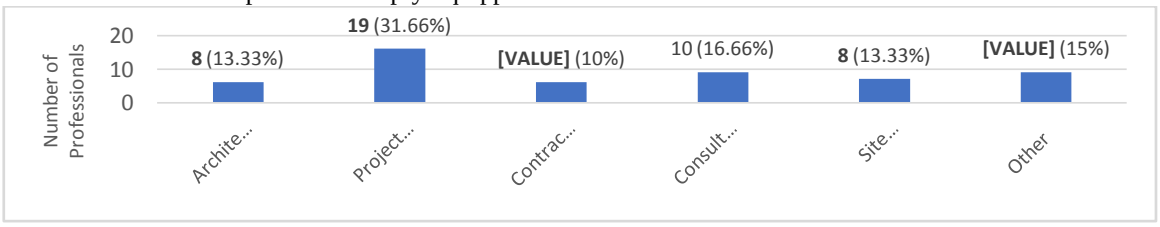

Figure 4 Area of Expertise

Experience of the respondents is diverse; we have obtained response from more than 15 years of experienced professional and also from less than 2 years of experienced professional.After filtering out by the area of expertise. We are considering 53 responses out of 60 total responses received. We are considering two construction managers in our analyses from 'other category of expertise' section.

4.3 Data Analysis

Relative Importance index is calculated for each constraint along with average RII of each constraint group. From the analysis, we can say that among 4 constraint groups, most critical one is Economic and Cost constraints followed by Technology related constraints then comes the Human Factor constraints and constraints related to industry characteristics has lowest average RII.

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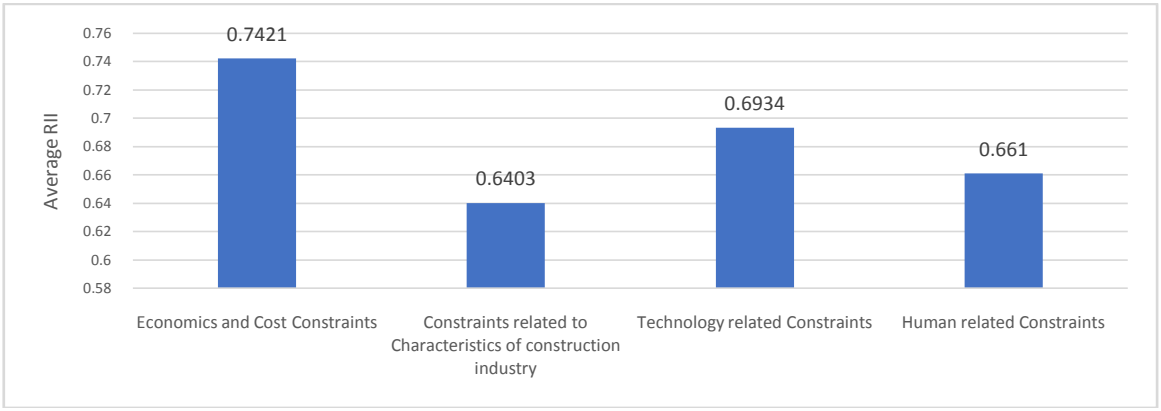

Figure 5Average RII of Constraint Group

It has been observed that majority of the respondents i.e., 43.28% are participating in residential construction projects and the least respondents i.e., 8.35% are participating in infrastructure construction projects. It is to be noted that respondents are provided more than one options to select in this question of the survey. Overall, it can be seen that mechanization and automation is utilized in every type of projects in India.

The majority 74% of Indian companies uses M&A. A more useful indication of usage is in looking at areas within which the technologies are used, as most companies may only use mechanization and automation in the design stage (in the form of design software such as Computer Aided Design). So, it is important to let respondents choose in which areas are these technologies most used by their company. India uses the technology across the board, with less usage in on-site construction compared to the design which shows the most usage. As per analysis it has been observed that in Design M&A application is used at maximum level, followed by Scheduling/Planning and least M&A is used in on-site construction activities.

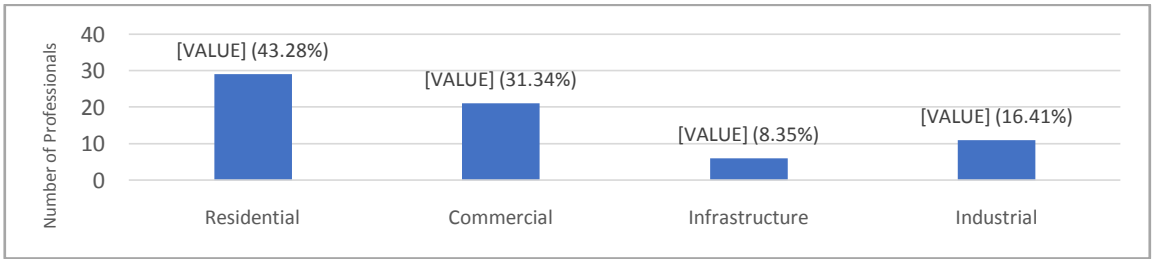

Figure 6 Type of Project

Areas	RII	Rank
Design	0.8453	1
Scheduling/Planning	0.7170	2
Costing/Tendering	0.5283	4
Project Management	0.6943	3
On-site Construction	0.4340	5

Table 3 Use of M&A in different Construction Areas

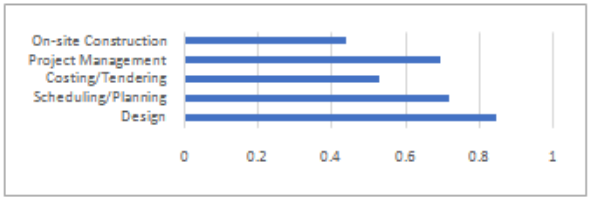

Figure 7Use of M&A in different Construction Areas

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To sum up, mechanization and automation is least adopted in painting and finishing works while most utilized in earthworks.

Construction Activities	RII	Rank
Earthworks	0.7245	1
Structural Steelwork	0.6604	3
Concreting	0.6830	4
Material Transportation and Building Assembly/ Lifting & Positioning of components	0.7094	2
Painting / Finishing	0.6377	5

Table 4 Use of M&A in Construction Activies

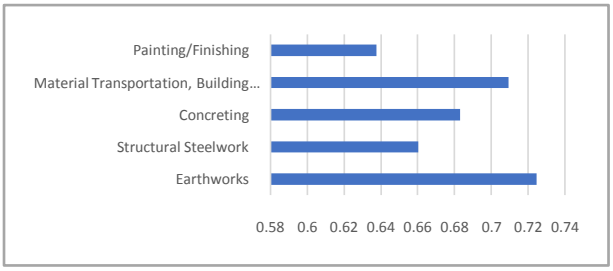

Figure8 Use of M&A in Construction Activies

4.4 Overall Ranking of Constraints

Respondents are asked to rate the occurrence of identified constraints (among- never, rarely, sometimes, mostly, always). Relative Importance index is calculated for each of 17 identified constraints.

Rank	Group Title	Constraints	RII
1	Economics and Cost Constraints	High cost in purchasing and implementing	0.7774
2	Economics and Cost Constraints	Expensive for operating, updating and maintaining	0.7358
3	Human related Constraints	Lack of contractor expertise and competence manufacturer	0.7283
4	Human related Constraints	Level of workforce skill	0.7170
5	Economics and Cost Constraints	Limited resources available to medium and small sized firms	0.7132
6	Technology related Constraints	Locally unavailable	0.7094
7	Human related Constraints	Hesitation to adopt	0.7094
8	Technology related Constraints	Knowledge awareness of key players	0.6981
9	Technology related Constraints	Incompatibility of the technologies with existing practices	0.6868
10	Technology related Constraints	Required for re-training worker	0.6792
11	Human related Constraints	Technology not easily accepted by worker union	0.6679
12	Characteristics of the Construction Industry	Unique nature of construction sites	0.6604
13	Characteristics of the Construction Industry	Multiphase characteristic of construction process: diversity of construction tasks and work processes	0.6566
14	Characteristics of the Construction Industry	Availability of Cheap Labour	0.6566
15	Human related Constraints	Loss of human skills	0.5925
16	Characteristics of the Construction Industry	Fragmentary nature of the construction industry (multi-point responsibility)	0.5887
17	Human related Constraints	Rise in unemployment	0.5509

Table 5 Overall Ranking of Constraints

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4.5 Inferences and Conclusion of Data Analysis

According to the results of an examination of 17 identified constraints included in a survey questionnaire filled out by various professional specialists in the field, the significant/critical implementation constraints of M&A are-

1. High cost in purchasing and implementing
2. Expensive for operating, updating and maintaining
3. Lack of contractor expertise and competence manufacturer
4. Level of workforce skill
5. Limited resources available to medium and small sized firms
6. Locally unavailable
7. Hesitation to adopt
8. Knowledge awareness of key players
9. Incompatibility of the technologies with existing practices
10. Required for re-training worker

From the analysis it becomes very clear that perception of the industry professionals that high cost in purchasing, implementing, updating and maintaining the M&A technologies are the most significant and frequently occurring constraints in the implementation of these technologies on site. A large percentage of labours in the building construction business have been dissatisfied with the excessively mechanized and automated approach. Furthermore, certain technologies have been discovered to be highly sophisticated and high-tech. This is because their use is so specialized that it necessitates highly qualified and skilled operators, resulting in a high total cost, regardless of whether it is manufactured locally or overseas(Seshadhri & Paul, 2018).

V. COST EFFECTIVENESS OF MECHANIZED & AUTOMIZED TECHNOLOGY

From the analysis it becomes clear that perception of the industry professionals that high cost in purchasing, implementing, updating and maintaining the M&A technologies are the most significant and frequently occurring constraints, which necessitates the assessment of cost effectiveness of M&A in comparison to manual work practices. For doing so a framework is required to be developed to perform economic analysis which can be utilized by constructors in determining whether the potential investment would be profitable or not.

5.1 Methodology

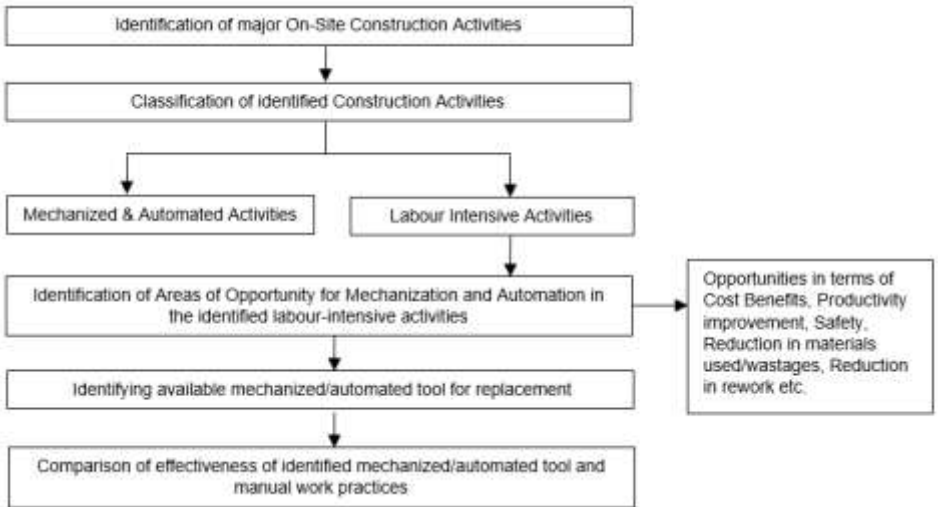

Figure 9 Methodology for Comparision of Cost Effectiveness

For obtaining the required data for comparing the mechanized/automated tools and manual work processes, methodology of conducting interviews has been adopted. Respondents has been asked to fill a form during the interview to obtain formulized results. Target respondents are contractors for this case. Total 6 local contractors are interviewed for data collection.

5.2 Identification of On-Site Construction Activities

Respondents have been asked to fill a form during the interview to obtain major on-site construction activities. They are Excavation, Backfilling, Reinforcement Cutting, Reinforcement Bending, Formwork, Concrete Batching and Mixing, Concrete Transportation, Concrete Placing, Material Transportation, Flooring, Masonry and Plastering(Yadav, et al., 2022).

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5.3 Classification of identified Construction Activities

To classify the above obtained activities among mechanized/automated activities and labour-intensive activities, respondents are asked to rate these activities on a Likert scale, where 5 indicates the most mechanized/automated and 1 indicates most labour intensive. Relative Importance index is calculated for each of 12 major on-site construction activities. The calculated RII result is shown in table below.

On-Site Construction Activities	RII	Rank
Excavation	0.8667	1
Backfilling	0.6000	7
Reinforcement Cutting	0.8667	1
Reinforcement Bending	0.5333	9
Formwork	0.6333	6
Concrete Batching & Mixing	0.7667	4
Concrete Transportation	0.8000	3
Concrete Placing	0.6000	8
Material Transportation	0.7333	5
Flooring	0.5333	9
Masonry	0.4667	11
Plastering	0.4333	12

Table 6 On-Site Construction Activites

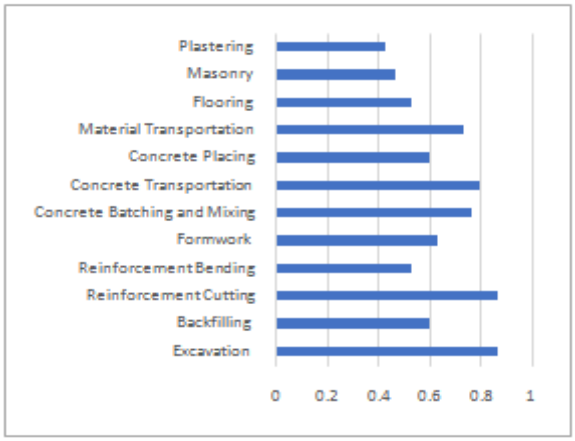

Figure 10 On-Site Construction Activites

From the analysis, we can classify the major on-site construction activities into mechanized/automated activities and labour-intensiveactivities. To summarize we can say that plastering, masonry and flooring are the most labour-intensive activities whereas excavation, reinforcement cutting, concrete transportation, and concrete batching and mixing are the most mechanized/automated ones.

Mechanized/Automated activities	Rank	Labour-Intensive activities	Rank
Excavation	1	Plastering	1
Reinforcement Cutting	1	Masonry	2
Concrete Transportation	3	Flooring	3
Concrete Batching & Mixing	4	Reinforcement Bending	3
Material Transportation	5	Concrete Placing	5
Formwork	6	Backfilling	6

Table 7 Mechanized and Labour Intensive Activites

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5.4 Areas of opportunity for Mechanization & Automation in the identified labour-intensive activities

In this section respondents are asked to mention the hinderances which they have faced in the labour-intensive activities on site which may result as an area of opportunity for mechanized/automated technologies. From the analysis following hinderances/gaps are found to be widely present in on-site construction activities.Major issues which occur very frequently while reinforcement mat preparation manually by labour is placement of reinforcement bars of proper sizes with required spacing and direction with appropriate binding. Manual mat preparation is time consuming and subject to errors and reworks.

1. Applying finishes on various interior surfaces manually with appropriate uniformity is another major challenge. Plastering and flooring are labour-intensive areas, where quality and productivity is required to be increased.

5.5 Identifying available Mechanized/Automated tool for Replacement

Once the primary quality, productivity and safety flaws/hinderances have been recognized, attempts are undertaken to search for mechanized/automated tools for replacement to prevent such hinderances. These hinderances can be considered as opportunities to promote M&A in Indian construction industry.

Opportunity-1: Manual Reinforcement Mat Preparation

Tool for replacement: Reinforcement Mat Equipment based on SCARA technology

Working: Initially this type of equipment was used in the manufacturing industry for picking, carrying in line assembly works in activities such as shifting of raw materials from one location to another in the factory. In construction industry this technology is used for automatic measurement, placement and binding of steel reinforcement bars for mat preparation of slabs, columns etc. using digital feed. The machine features a jointed arm that can do repeated operations. Magnetic finger grippers are utilized as end effectors for lifting and positioning rebar. Movement is accomplished via a crawler or a mobile vehicle placed on a track. The presence of a deck on the back allows for the deployment of sufficient rebar. Electricity is used to provide power. Tactile sensors are utilized to measure and compare rebar placement co-ordinates with digital input.

Reach of Equipment: 65ft to 100ft | Payload of Equipment: 0.2ton to 0.5ton

Figure 11 Reinforcement Mat Equipment

Opportunity-2: Applying finishes manually with appropriate uniformity

Tool for replacement: Interior/Floor Finishing Equipment

Working: This equipment is used to prepare flat uniform surfaces along with spraying of paints at a fast speed in comparison to manual spraying. It is capable of performing finishing activities in both horizontal and vertical surface at same instant. The use of tracks/wheels on this equipment also provides easy and rapid mobility, minimizing the time it takes to shift from one location to another. Concrete placement gun and finishing plate are employed as end effectors. Mobility is provided by a mobile vehicle with wheels. Material is delivered to the end effector via pumping through a tube. It is powered by an electric source. Tactile sensors are utilized in autonomous mobility for navigation and anti-collision capabilities.Reach of Equipment: 8ft to 14ft | Payload of Equipment: 50kg to 100kg

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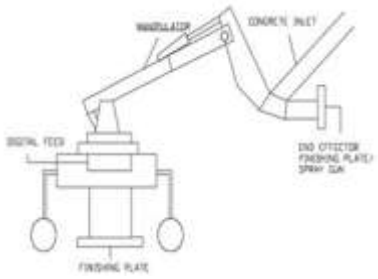

Figure 12 Interior/Floor Finishing Equipment

5.6 Development of Framework

The proposed framework can be utilized by constructors to measure cost effectiveness of machine in comparison to manual work practices before investing in them.

Framework for Economic Analysis of On-site Construction Activities				
Name of Construction Activity	Reinforcement Mat Preparation			
Notes	In the first step of framework all costs are calculated annually			
	Cost for labours in the first step is calculated total number of labours substituted by machine annually			
STEP-1	COSTS INVOLVED	Automated Machinery	Manual Labour	
	1 Initial Capital Cost	Acquisition Cost (Purchasing Cost can be used here which includes cost of parts, assembly, sensors etc.)	Wages of substituted Labour/year = Cost of labour/hour x 12 hours x 26 days x 12 months x No of Substituted Labour	
		Rs.	Rs.	
	2 Operating Cost	Cost required to operate the equipment per year	Total Cost of Insurance/per year for substituted labours (3000/year/labour)	
		Rs.	Rs.	
	3 Maintenance Cost	Breakdown or service cost of machine	Turnover cost for labour = cost that the company needs to pay to recruit new employees and train them to replace the previous employee who resigns	
		Rs.	Rs.	
	4 Rework Cost	Cost of rework done by machine (Ideally machines provides maximum quality so this section can be considered as Nil)	Cost of material wastage caused by rework done by substituted labours/year	Wages of labours for extra working hours for doing reworks
			Rs.	Rs.
		Rs.	Rs.	
	5 Productivity Cost gained	Work done/year by machine	Work done/year by substituted labours	
		Rs.	Rs.	
Notes	The above cost comparision is done keeping in mind the year-1 only, from the analysis it can be observed that automated machinery incur huge amount of cost in comparison with geting the work done by labour for first year of investment. This bring us to calculate payback and Rate on investment for the equipment for the above mentioned construction activity.			
STEP-2	VALUE ESTIMATION	$V = (KL - M - O + tP) \times \frac{(1+I)^n - 1}{I(1+I)^n}$	V= Rs.	
	Inputs Required			
	K	number of workers replaced		
	L	labour savings per year per one worker		
	M	maintenance cost annual		
	O	operating cost annual		
	t	tax reduction rate		
	P	initial purchase price		
	I	interest rate		
	n	economic life		
Notes	This method compares purchase price of equipment with the value of equipment to user i.e., present worth of net annual benefits desired over economic life.			
	KL can also be regarded as to total benefits gained using the equipment/annual saving generated by equipment.			
STEP-3	PAYBACK PERIOD	P = I / (L - E)	P = Years	
	Inputs Required			
	I	Total capital investment = Acquisition cost + Installation Cost + Training & Testing Cost		
	L	Annual labour savings generated by equipment, dependent upon the number of workers replaced by equipment		
	E	Total annual expenses for the equipment = Maintenance Cost + Operating Cost		
Notes	It is the length of time required for the owner to recover his initial investment in the equipment.			
STEP-4	RETURN ON INVESTMENT	$ROI = \frac{(S - E) \times 100}{I}$	ROI = %	
	Inputs Required			
	S	Annual savings generated by use of equipment		
	E	Total annual expenses for the equipment		
	I	Total capital investment = Acquisition cost + Installation Cost + Training & Testing Cost		
Notes	It gives the investor a simple method of determining whether the potential investment will meet his investment criteria before the investment is made. Based on it a decision can be obtained if implementing the process will give the desired results or not.			
STEP-5	CONCLUSION & SUGGESTION	Value Estimation	Payback Period	Return on Investment
	Construction activity & Equipment Name	Rs.	Years	%

Figure 13 Framework for Economic Analysis of On-site Construction Activities

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5.7 Economic Analysis of identified Mechanized/Automated tool

Once the mechanized and automated tools are identified and their working has been understood, an effort has been made to produce detailed economic analysis based on the performance of each equipment/tool to determine if it is viable to use the technology in the field of construction in order to get maximum advantages in terms of performance in many aspects such as time taken, material consumed, cost generated, and so on.

Reinforcement Mat Equipment

Costs Involved

Monetary terms (Rs.)	Automated machinery	Manual labour
Initial capital cost	62,00,000	7,86,240 (wages)
Operating cost	7,30,500	18,000 (insurance)
Breakdown/Maintenance/Service cost	3,00,000	20,000 (turnover)
Quality/rework cost	0	85,200
Productivity	76,79,000	55,46,000

Table 8 Reinforcement Tool Cost Comparison

Value Estimation

$$V = (KL - M - O + tP) \times \frac{(1+I)^n - 1}{I(1+I)^n}$$

$$V = \{(30,04,440) - 3,00,000 - 7,30,500 + 0.07 \times 62,00,000\} \times \frac{(1+0.1)^{10} - 1}{0.1(1+0.1)^{10}}$$

$$= \text{Rs.14,79,558/year}$$

Payback Period

$$P = I / (L - E)$$

$$P = 63,35,000 / (30,04,440 - 10,30,500)$$

$$= 3.209 \text{ years}$$

Return on investment

$$ROI = \frac{(S - E) \times 100}{I}$$

$$ROI = \frac{(30,04,440 - 10,30,500) \times 100}{63,35,000}$$

$$= 31.15\%$$

Interior/Floor Finishing Equipment

Costs Involved

Monetary terms (Rs.)	Automated machinery	Manual labour
Initial capital cost	51,00,000	3,70,656 (wages)
Operating cost	8,10,920	9,000 (insurance)
Breakdown/Maintenance/Service cost	3,00,000	10,000 (turnover)
Quality/rework cost	0	43,760
Productivity	29,95,200	18,72,000

Table 9 Finishing Tool Cost Comparison

Value Estimation

$$V = \frac{(KL - M - O + tP) \times (1+I)^n - 1}{I(1+I)^n}$$

$$V = \{(15,37,616) - 3,00,000 - 8,10,920 + 0.07 \times 51,00,000\} \times \frac{(1+0.1)^8 - 1}{0.1(1+0.1)^8}$$

$$= \text{Rs.7,21,531/year}$$

Payback Period

$$P = I / (L - E)$$

$$P = 52,00,000/ (15,37,616 - 11,10,920)$$

$$= 12.186 \text{ years}$$

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Return on investment

$$ROI = \frac{(S - E) \times 100}{I}$$

$$ROI = \frac{(15,37,616 - 11,10,920) \times 100}{52,00,000}$$

$$= 8.21\%$$

5.8 Final Cost Comparison and Suggestion

Automated Machinery	Value Estimation	Payback Period	Rate of Return	Suggestion
Reinforcement Mat Equipment	Rs.14,79,558/year	3.209 years	31.15%	Recommended
Interior/Floor Finishing Equipment	Rs.7,21,531/year	12.186 years	8.21%	Not Recommended

Table 10 Final Comparison

VI. CONCLUSION AND RECOMMENDATIONS

The predicted benefits of M&A are expected to have a favorable and significant influence on the culture of building practices. An important issue which is likely to influence the wider and successful implementation of M&A is the role that knowledge management plays in this regard. When respondents are asked to rate the specified mitigation measures in terms of their effectiveness, it is observed that reducing the costs of acquiring or buying M&A technologies and making them cheaper to operate and maintain is preferred by respondents followed by better training programmes for workers and encouraging greater standardization of construction products and processes.

The government's policies will have the greatest impact on the decision between traditional and mechanized and atomized methods for projects. If implementation of M&A technologies becomes mandatory by government for large projects then it can become easily applicable. For small and specialized structures, however, traditional building methods must be permitted to continue, but they must be supplemented with modern and effective mechanization and highly skilled labour. Hence, government policy should be enforced on the use of M&A and for standardization of construction products and operating procedures. Basically, M&A on construction sites would be feasible if there are the economics of scale. The role of government in establishing the policy for strategic level of implementation can be a significant impact on the issues. The incentives and promotion offered by statutory authorities and government policies are desirable through planning approval process whereby more floor areas are allowed to be built.

The thesis claims that economy development, nature of industry, perception of current conventional construction industry, stakeholder's readiness and research development are identified as issues and challenges of adoption of M&A which needs be looked upon along with the most significant and frequently occurring constraint which is the perception of the industry professionals that these technologies incur high cost in purchasing, implementing, updating and maintaining.

Although there is certain level of M&A already happening on ground in India construction sites. So, it is momentous to develop a framework to measure cost effectiveness of mechanized and automized equipment in comparison to manual work practices. This framework requires few inputs regarding cost acquired by machine and by labour performing any construction activity and as a result it provides whether the machine works better than manual labour in terms of cost or not. The proposed framework can be utilized by constructors to measure cost effectiveness of machine in comparison to manual work practices before investing in them.

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