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# Exploration and Analysis of New Technology and its Adoption in Indian Construction Industry

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***Abstract:*** The goal of this research is to find the barriers to the use of advanced technologies in the construction sector and bring awareness about the usage of technology that assists the construction sector. The first goal of this paper is to learn about the most recent technology in use. The second goal is to rank the obstacles that prevent adoption and identify them. The third goal is to briefly address these barriers. The paper includes a list of the factors that prevent the use of these breakthroughs. A conducted literature review aids in identifying the technology as well as the usage-related obstacles. This research helps the organizations to concentrate on these barriers in order to counter the issues by them. Literature review and questionnaire survey approach was used to carry out the research work and AHP analysis was carried out to rank the barriers. The last part of the report deals with the conclusion, recommendation, and future scope of the work.

***Keywords*** **– Advanced Technologies, Construction Sector, Barriers, AHP Analysis**

## 1.INTRODUCTION

The introduction chapter consists of five sections with background being the first section of the study, then followed by problem statement in the second section, objective being elaborated in the third section, some light thrown on the methodology in the fourth section and the final section deals with the significance of the study.

### 1.1.Background

In the 17th and 18th centuries, as modern science advanced, so did the construction industry. Engineers were able to experiment with a wide range of materials thanks to scientific marvels, and the industrial revolution in the 19th century and these developments changed the way buildings were made.

Industrialization and digitization has taken a rapid pace in construction sector, it is estimated that by 2035 the majority of buildings all over that world will be constructed by use of industrialized construction as the manufacturing and construction industry merge. But the fact is that construction sector is among the least

digitized sector as all of its process being repetitive and labour intensive. All the project are unique in their own way. The other major constraints of a project are time, cost, quality, and safety. A study by Mc Kinsey on construction project has revealed that large projects extend the completion time by 20% and over budgeted by 80%. In order to meet the requirements and for a project to be successful in terms its constraints one should be aware of the advancements in this sector and the future of construction and design will require all its project stake holders to adopt to new technologies, skills, processes.

A report on the state of digital transformation in construction in India by International Data Corporation IDC states that 66% of the India companies have stated that industrialization and digitization is a key priority to sustain the market. 72% of the companies are in their initial stages (stage 1 or 2) for digitization and the fact is that only 3% of the companies are successful in their digitalization journey.

**1.2.Problem statement**

Economic growth, a continuous competitive advantage, and the completion of landmark projects all depend on innovative goods, technology and management strategies. Some experts have the general impression that the construction business is slow to adapt and that innovation is hard to come by. When the construction sector is compared to other industries, where the introduction and adoption of new technology and products have been widespread over the past several decades, this view can occasionally result. Despite significant technological innovation and growth, the construction sector has been slow to fully exploit these developments.

In comparison to other sectors, the construction industry is falling behind in terms of technical advancement and digitization. Because of a variety of reasons, construction companies are reluctant to utilise cutting-edge technology.

The use of technology in the construction sector has many benefits, but there are also challenges and impediments to overcome. There are barriers related to technology, finance, psychology, and processes. Considering the pace of digitization and industrialization in construction sector the need to address these issues is a vital part, without these factors being addressed it becomes difficult for the organizations to sustain the market and it becomes difficult for the organizations to complete the projects within the constraints.

**1.3.Objectives**

Finding the obstacles to the adoption of technical developments in the construction industry is the main goal of this study. The research was conducted using a hybrid research technique, and the results were validated for the same.

Studying the evolution of the construction industry in terms of materials, methods, technology, and practises was the first step in the research process. The necessity for automation in the construction industry was then

examined. With the aid of a questionnaire survey, this study first looks at the many technologies utilised in the construction industry. Some technology was chosen for the study based on percentage criteria that is obtained from the survey form. This involved determining the benefits and drawbacks of employing this specific technology in the construction industry like precast, lean construction, modular construction, BIM, exoskeletons, AR and VR. At the second stage with the use of a literature research, different barriers to the adoption of technology in the construction sector were discovered and classified them into technological, financial, psychological and process barriers. In the final stages of the study AHP analysis was used to rank these barriers accordingly. Third is to provide a brief solution to address these barriers. For the future scope this work can be used by the researchers to find solutions to these barriers in detail.

### 1.4.Methodology

In order to determine the present trends in the construction sector and to analyse the evolution of the industry, exploratory investigations were carried out early on in the research. In order to grasp the current situation regarding the trends and to choose specific themes for the advancement of the research activity, an analytical study using a questionnaire was done once the trends had been identified. To learn more about the chosen themes' tendencies, thorough studies were conducted on each.

We conducted a literature review later in the study to determine the obstacles preventing the implementation of these technologies. AHP analysis was done to rank the barriers after a questionnaire was put forward.

### 1.5.Significance of the study

Due to numerous concerns, including pandemics, inflation, project complexity, etc., the construction sector has recently focused more on sustainable ways of project execution. Every industry has benefited from technological improvements, and the construction business is no exception. In order to sustain the market by using technology, it is highly important for construction enterprises to become aware of it and the benefits of using it like it can reduce the stress on workers, it can financial advantages, quality construction can be achieved in required time.

## 2. LITERATURE REVIEW

A thorough analysis of the literature consulted for the study is provided in this chapter. The evolution of construction industry is depicted in the first section of this literature review. The second section of the literature review examines the most recent technological advancements used in the construction sector and their advantages and disadvantages. The causes and constraints of these developments in the construction industry are discussed in the third section.

### 2.1. Evolution of construction industry

The history of construction can be dated back to many thousands of years, tracking the history of construction is tricky as there is no clear definition of what construction actually is and it is as old as human history. Humans manipulated there surrounding environment to protect them from various factors like climate,

predators etc. The construction industry from then evolved in stages starting from the stone age to present 21st century construction. The construction industry now has been transformed in to a whole new standards in terms of materials, machinery, technology and practices used. In general the evolution of construction industry can be termed into four categories i.e material wise, height and space utility, technology and equipment used and interior built environment of the places.

**Table 1 : Construction industry evolution**

| Sl.no | Age | Period | Material used | Technology/ Tools |
|---|---|---|---|---|
| **1** | Neolithic age (stone age) | 9000 BC – 5000 BC | Stones, leaves, animal skin, mud. | Chisel made with bones, stones, stone axes, bone hammer etc. |
| **2** | Copper age and bronze age | 5000 BC – 3100 BC | Mud bricks, straw, stone bricks. | Tools made from bronze and copper, saw, axes, sledges, rollers. |
| **3** | Iron age | 1200 BC – 50 BC | Steel, wood, stone bricks. | Tools made from alloys of steel and copper. |
| **3.1** | Mesopotamia construction | | Mud bricks (burnt), stone of regular shapes, glazed bricks. | Sewage drains, pithed walls, drawings made on clay plates. |
| **3.2** | Ancient Egypt construction | | Sun baked bricks, masonry stones. | Ramp, levers for lifting heavy blocks, window and doors, scaled drawings, plywood, rope trusses, |
| **3.3** | Ancient Greece Construction | | Fired bricks with lime mortar, stone tiles, masonry units connected with metal clamps. | Beam-column method, surveying, lifting trusses. |
| **3.4** | Roman Construction | | Hydraulic lime mortar (cement), form work, dual | Plumbing, glass for windows, water mill, |

| | | | | |
|---|---|---|---|---|
| | | | wall technology, concrete, bronze roof tiles. | saw mill, paved roads, timber cranes |
| **4** | Medival Construction | 600 - 1000 AD | Timber, burnt tiles, stone walls, | Timber roof buildings, stone barrel vaults, gothic architecture, pile driver. |
| **5** | Renaissance | $13^{th}$ – $14^{th}$ Century | Iron, terracotta tiles, timber. | Design philosophy, dome construction. |
| **6** | Modern Construction | $17^{th}$ Century | Glass, iron for structural members, rubble stones, cut bricks. | Line gauge, plumb line, spirit level, carpenters square, drafting compass. |
| **7** | Modern Construction | $19^{th}$ – $21^{th}$ Century | Advancement in all materials, different types of cement, bricks, steel etc. | High rise, modular construction, prefabrication, use of drones….. |

### 2.2. Latest advancements in the construction sector

A total of 43 advancements were identified through the initial literature that has been carried out, these were then classified under 4 main categories i.e. technology, methods, equipment, practice as mentioned below.

Table 2 : Category wise representation of advancements

| Sl.no | Category | Advancements |
|---|---|---|
| 1 | Technology | Robotics , AR & VR, drone usage, BIM, IoT, Machine learning, block-chain, digital twins, AI, cloud based collaboration tools. |
| 2 | Method | Prefabrication, 3D printing, green materials, twin wall methodology, modular construction. |
| 3 | Equipment | Exoskeletons, bricklaying machines, robotic total stations, welding robots, auto plaster machines, launching machines, excavators. |
| 4 | Practise | Lean construction, offsite construction, sustainable construction, safety in construction, value management, supply chain management, whole life costing. |

**2.3. Theoretical study about the various technology in construction industry :**

The papers from journal of (IOSR Journal of mechanical and civil engineering, Ain Shams Engineering Journal, SHSCRC University of Johannesburg) a practical framework for adopting lean construction technique and measuring lean performance and to assess the use of lean Construction practices to efficiency improve productivity and performance of the construction industry. The main finding of these papers is that In India alone , there have been a lot of projects which are stalled on ground like inventory , half way produced it consumed a lot of cost , time and unsatisfied customer. There are lot of reasons for delay in delivering the projects in time. Poor undertaking of wastages produced during the process and reasons of delay in construction industry led the management in a situation of losing business. Key measures taken into consideration for lean approach such as waste minimization, just in time approach , value based approach , continuous improvement , Quality management system and Agility towards required change. The adoption of Lean manufacturing principles to the construction is an innovative approach for managing and improving construction processes by reducing cost and maximizing value considering customer demands.

The papers regarding precast from (IJERT , Autodesk report, Journal of construction engineering, technology and management) deals how to analyse time and cost for precast projects in comparison with conventional method of construction. Precast technology is one such move which is expected to enhance the productivity of the construction process, thereby, optimizing the requirement of resources on the site, reducing waste generation and resulting in a faster delivery of the projects. While internationally precast technology is considered as a mature technology, in India, it is not widely utilized, despite the advantages. Precast concrete construction plays a major role in the era of modernism and contemporary architecture. The application of precast methods can lead to the efficient utilization of resources and also reduces the time duration and cost of construction. The papers of 3D modular house say this construction is the type of prefabricated construction based on applying 3D blocks produced offsite in advance. Their use has a number of advantages: assembling speed; high quality control at a plant; work safety as the time of high-altitude works shortens; testing and rapid introduction of new technologies at the plant; decrease of noise level and the amount of construction waste at a construction site that has a good impact on the environment, etc. They determine the durability of modular homes, the advantages and disadvantages of modular construction.

The literature study regarding the modern construction methods determine the various trends in the construction industry and mention their advantages and disadvantages. To state the importance of these trends and they can be implemented to complete the project in an economical way. In the increasing demands of construction, quality and eco-friendly construction leads the construction industry worldwide to use or adopt new and more efficient methods and materials for construction purpose. The modern methods of construction (MMC) are defined as those which provide an efficient product management process to provide more products of better quality in less time.

The Main Objective of the papers related to AR & VR was to enhance stakeholder engagement, design support, Project planning, monitoring, safety, Training. The proposed AR based communication contributes

to filling an important research gap in the remote diagnosis context regarding improvements on object and procedure awareness of AR-based remote collaboration. Visualization methods of the available authoring tools do not incorporate the potential uncertainties associated with the geometric and semantic information of building elements. Using AR and VR for design support are that it is very difficult to translate the changes made using the AR and VR systems into BIM models, and that it is not possible to archive AR and VR outputs for later review or to record the experiences that the user had in AR and VR environments To Reducing the costs of maintenance tasks. Reducing the risk of accidents that may occur Improving time taken to complete a task . Improving the communication between technicians and experts 4Reducing experts' expenses for traveling to remote sites the ability to overlay spatially meaningful information on the 3D space allows the AR technology to be a promising option to support knowledge-intensive work. The multi-LOD meta-model facilitates managing the building information throughout the different stages. It makes it possible to formally specify the required information, including a description of the potential vagueness.

The ideology of the papers of exoskeletons was to understand the subjects' body postures when they are performing basic material handling work, and base on the posture study, a passive mechanism exoskeleton system was developed to demonstrate that robotic physical interventions facilitate posture correction in material handling work. To enhance the current wearable technology with the latest technology application, by seeking to identify and review the effect of MSDs to the construction and manufacturing workers and the current thru wearables technology in construction industry through literature review and journal article, to propose a new innovation idea on improving the health and safety in the construction and manufacturing industry, and to evaluate the marketability of the proposed innovation product to the potential user. In order to include within-subject comparisons of exoskeleton use with and without it, repeated measures type experimental designs were used in all research evaluating exoskeletons. The amplitude of the EMG was used to measure physiological factors such as muscle activity (i.e. effort) in the back, shoulder, arm, and leg regions.

### 2.4. Background study about the barriers to adoption of technology

According to (Hindaal Khan, Mr. Mohd Zeeshan Khan) the main objective of these papers was to identification of barriers to successful implementation of modern methods of construction and also categorize the barriers in implementation of modern methods of construction in Indian construction industry sector. The long distance between the factory and the site, the high initial cost, the high tax burden, a lack of resources, a lack of coordination between engineers and workers, a severe shortage of skilled workers, a lack of capital, a lack of market demand, heavy equipment, and an increase in the duration of the project's quality are some of the obstacles that modern construction methods have had to overcome. Modern construction methods have the following advantages: they save time, reduce waste, improve quality, reduce site disturbance due to MMC, require fewer workers, reduce health and safety risks, lower project costs, improve workability, increase strength, and are easy to construct. Simple construction is also advantageous. This thesis also revealed that

modern construction techniques reduce construction time, receiving a mean rating of 3.85 out of 5. As a result of this thesis, we also learned that modern construction methods produce high-quality products, with a mean rating of 4.01 out of 5. With a mean rating of 3.68 out of 5, this thesis also revealed that these modern construction methods are value for money. We also learned from this thesis that these modern construction methods are long-lasting, with a mean rating of 3.35 out of 5.

According to (Mansur Hamma-adama*1, 2 , Tahar Kouider1 , Huda Salman1 1Robert Gordon University) the main objective of these papers was to identification of barriers to successful implementation of BIM Adoption and also categorize the barriers in implementation of BIM Adoption in Indian construction industry sector. Clients' interest in the use of BIM in their projects, awareness of the technology among industry stakeholders, cooperation and commitment of professional bodies to its implementation, proof of cost savings by its adoption, cultural change among industry stakeholders, government support through legislation Efficiency and Reform Group, collaborative procurement methods are the drivers for the implementation of BIM Adoption in the construction industry. Lack of expertise within the organizations, expertise within the project team, a lack of standardization and protocols, a lack of collaboration among stakeholders, high investment costs, legal issues surrounding ownership, IP & PI insurance, a lack of infrastructure, a lack of government policy, industry cultural resistance, a lack of additional project finance to support BIM, resistance at the operational level, the unwillingness of team members to share information, and a Return on Investment (ROI) issue are the obstacles to the adoption of BIM in the According to the study, the established obstacles and drivers ought to be considered essential when developing an efficient BIM adoption framework. The obstacles should all be removed, and drivers should be encouraged, motivated, and instigated. To gain a deeper understanding of the obstacles to BIM adoption in the industry under investigation, additional in-person (interview) research is required. Additionally, periodic evaluation of the most important obstacles and drivers is essential as the industry becomes more aware of the BIM. By providing an in-depth understanding of barriers and drivers from the perspectives of adopters and non-adopters, as well as their strengths of influence from the two groups and combined influence to adoption of BIM in the Nigerian construction industry, this study adds to the body of knowledge.

The main objective of the paper by (Palak Sachdev) was to identification of barriers to successful implementation of modular construction and also categorize the barriers in implementation of modular construction in Indian construction industry sector. A building is constructed using three-dimensional units or modules, which are then assembled and produced in a manufacturing plant, in modular construction. The logistics and assembly aspects of modular construction are also included. These aspects are properly coordinated through planning, integration, and communication. An analysis technique has been proposed for quantitatively evaluating modular construction methods using cost per square foot of construction and qualitatively evaluating them by listing the advantages of each method and considering the trade-offs between them. For multi-story commercial projects, this method makes it possible to evaluate the cost-effectiveness of the two construction methods in a way that could be useful as a tool for making decisions. According to the conventional method, the building will cost Rs. 1100-1150 per sq. ft. In contrast, the modular method's building costs are estimated at Rs. 800-850 per sq. ft. The study answered the question and came to the

conclusion that the modular construction method is slightly more cost-effective than traditional construction, saving up to 30% of the total cost for this case study and the circumstances that were presented.

According to (Shyam Sunder Sharma, Pankaj Pandey (2020) , Devaki M.P (2014) , Ayodeji Emmanuel Oke,Clinton Aigbavboa ) The main objective of these papers was to identification of barriers to successful implementation of lean construction and also categorize the barriers in implementation of lean construction in Indian construction industry sector. Lean manufacturing implementation obstacles include high investment costs, a lack of financial backing, workers who are not prepared to accept changes on the shop floor, unqualified management, a shortage of skilled labour, and a lack of knowledge of the advantages of lean manufacturing. Lack of awareness of the need to embrace lean construction has been recognised as the key impediment to using lean concepts in India's construction industry. Supply chain uncertainty, the propensity to use conventional management, Issues with culture and human attitudes (mind-set problems) Top management's lack of commitment and the workforce's non-participative management style. Lean construction must be successfully implemented for there to be a sufficient level of dedication and knowledge among construction stakeholders, including comprehending the underlying concepts. Due to the perception of the practice's complexity, stakeholders should receive lean construction training. The training programme should include subcontractors and focus more on application than ideas.

According to (Alan Verghese Ittyeipe, Anu V. Thomas (2021), M Arif, D Bendi, A Sawhney (2012). Chris I. Goodier, Alistair G. F. Gibb 2015). The main objective of these papers was to identifying the various barriers to the promotion and growth of PCC on for buildings. Cost issues, Project delivery and supply chain, Design issues, Awareness and Knowledge, Policies and Regulation, Social climate, Market demand, and so forth, have been categorised into six categories. Studying the importance of these obstacles in the Indian construction industry is necessary, and identifying the main obstacles to PCC on adoption can assist policymakers in coming up with the best solutions. Therefore, the development of PCC on in India might be facilitated by the execution of appropriate steps to overcome the obstacles with the integration of diverse stakeholders. On the other hand, draw attention to the fact that participants do not see lower initial costs and more customization as being significant advantages in the Indian context. This can be due to the lack of knowledge and expertise needed to implement and design building projects employing off-site building. The majority of respondents agreed that while introducing alternative technologies in India's building industry, time, cost, and quality must all be taken into consideration.

According to (Juan Manuel Davila Delgadoa, Lukumon Oyedelea, Peter Demianc , Thomas Beach, Jacqueline Schmitta, Jochen Bonigb ,Thorbjorn Borggrafea Gunter Beitingerb , Jochen Deusea.2017) The main objective of these papers was to identification of barriers to successful implementation in construction industry. The early expenditures of putting an AR system in place can drive up the costs of the projects because it is a relatively new idea. The project's decision-makers would have a negative reaction to an increased cost.

The main goal of AR applications is to overlay virtual information on top of real world objects. AR applications need to create the perception that simulates that virtual and real entities coexist in the same space with an adequate spatial alignment of real and virtual entities, without proper registration, this perception is compromised. Nowadays Smart devices allow user to implement AR-based applications with mobility and others head mounted displays like the Daqri Smart helmet and HoloLens are aiming to provide a mobile solution for the manufacturing and construction industry. The development of user-friendly applications that stick to the right prototype of context-awareness and pervasiveness is an important barrier for implementing pervasive AR solutions, with the field of AR , the AEC industry's size and diversity, businesses should think about creating applications expressly for it.

According to (Dilruba Mahmud, Sean T. Bennett, Zhenhua Zhu, Peter G. Adamczyk , Michael Wehner, Dharmaraj Veeramani and FeiDai.2022) The main objective of these papers was to identification of barriers to successful implementation in construction industry. Barriers The prices of exo products can currently range from $5000 to $100,000 and hence are not affordable for workers to purchase for their use. If a business wishes to supply exos to every employee, the initial investment needed to buy exos may be too high. In addition, there is an extra charge for regular maintenance of exos to guarantee worker safety. Even if a business were to buy exos for its employees, there is a chance that certain employees could be hesitant or even refuse using this new technology. As a result, businesses are reluctant to invest in exos.

Exos testing, implementation, and maintenance require specialists with specific knowledge and experience, which the industry now lacks in sufficient numbers. The use of exos in the construction sector is hampered by the scarcity of competent workers.

As there are no clear assignments for the mandatory use of exos in construction companies, staff (contractors and engineers) are reluctant to spend time on trials as they are already swamped by their daily duties.

### 2.5. Barriers identified

- Limited knowledge about the technology in management, clients.
- Lack of training and prerequisite knowledge and R&D knowledge.
- Limited knowledge of scientists, designers, providers and suppliers.
- Lack of infrastructure.
- Lack of government policies, society regulations.
- Increase in cost of skilled labour.
- Limited value addition.
- Huge cost of procuring the equipment.
- Limited suppliers and skilled workers or unavailability of the new technologies.
- I appropriate marketing of the advancements.
- Complexity and durability of the technologies.

- Lack of inter organizational expertise.
- Lack of communication and data transfer.
- Lack of technical demonstration, maintenance.
- Inadequate design fee to support innovations.
- Lack of funds or budget or high cost of the technologies.
- High cost of setting up the equipment.
- Lack of budget for training the workers.
- High salary for skilled workers.
- Lack of leadership towards digital innovations.
- Low knowledge management and transfer of knowledge.
- Lack of collaboration and team work.
- Complexity in the technologies, computer of high configurations.
- Complexity in 3D modelling and slow data processing of he models.
- Inflexible building codes and in sufficient standardization.
- Fear to change.
- Fear of losing conventional knowledge, failures, profit loss.
- Dear of new market changes, process changes.
- Lack of trust in the new advancements.

### 2.6. Classification of barriers

The identifies barriers were grouped into 4 categories based on the similarity between them. All these barriers were compiled into categories such as technological barriers, financial barriers, psychological barriers and process barriers.

| Sl.no | Category | Barriers |
|---|---|---|
| 1 | Technological | Lack of awareness on latest equipment or computers |
| | | Lack of interest in the knowledge of digital technology |
| | | Lack of training resources in technology |
| | | Lack Insufficient skills in the technology |
| 2 | Financial | High cost of setting up equipment |
| | | Unwillingness of firm to spend a large amount on digital tools |
| | | Lack of insufficient R&D budget |
| | | Inadequate financial support for innovation |
| 3 | Process | Mobility of software to handle complex geometry |
| | | Lack of knowledge on legal procedure challenges of using new technology |

| | | |
|---|---|---|
| | | Lack of computers with high configuration to support new software like BIM |
| | | Difficulty in execution /Operations |
| | | Lack of interest in adopting new technologies in an ongoing projects, especially in loss making projects |
| 4 | Psychological | Fear of increase in total project costs |
| | | Preferences of using conventional methods |
| | | Lack of open mindset towards new technology |
| | | Lack of psychological assurance |

## 3. RESEARCH METHODOLOGY

This chapter of the report provides details about how the research was carried out like the journals used, details of questionnaire surveys, sampling of data, respondents, research methodologies, analysis and validity of the data collected.

### 3.1. Research Purpose

Prior to developing the approach, the research's goal should be established. The goal of this project was to conduct analytical investigations about technical breakthroughs and identify the obstacles preventing their implementation in the construction industry. The scope of the study lies according the summary of the report by Autodesk - Industrialized construction in academia that construction industry becomes industrialized and digitalized by 2035, but in reality only few companies are successful in this journey. Through this research we obtained knowledge about the evolution of construction industry, latest technology used, barriers holding them back, ranked the barriers using AHP analysis.

### 3.2. Research approach

The research is a combination of both qualitative and quantitative approach the initial part of the research follows a qualitative approach as it allows generation of data and understand the real life scenarios. The research was carried by detail literature review and followed by questionnaire survey. The final part of the research followed both qualitative and quantitative approach where literature review was done and analysis of the findings were done using AHP analysis.

To rank the barriers its really necessary to get the data that is relevant to the present scenarios and from qualified persons, so data sampling was done where the required responses were segregated in the first survey and the second questionnaire was floated only to selected people.

### 3.3. Theoretical assumptions during research

It is necessary to take the research's theoretical presumptions into account. They make up one's presumptions about the phenomena and their impact. As a result, the technologies with the highest and lowest percentages were utilised for the study based on the information gathered from the questionnaire survey. Additionally, certain analytical information from other study articles was directly used the main basis for the research was social constructivism. Social constructivists delve into people's reality and experiences, and the researcher relies on participant perceptions.

### 3.4. Method

We used both a qualitative and quantitative method for the research, as was already described. In order to accomplish the goal of this study, we first reviewed 22 publications and referred various website from different journals published over the last four years in order to discover major advancements in the construction business. After identifying the innovations, we divided them into groups such technology, method, process, and equipment before launching a questionnaire survey to determine which innovations are the most well-known and obscure.

At the later stages of the study we again performed the second round of literature review where 20 publications and websites were used for reference to find out the barriers and drivers for the selected advancements and in general.

### 3.5 Selection of papers and websites

A wide range of sources are available on advancements and barriers to the implementation them in construction industry which includes journals, websites, magazines, ppts etc. The articles used for the study are obtained from national and international journals listed below which are obtained from science direct, research gate, ASCE. Some key words were used to find the journals like technological advancements, barriers , drivers, evolution of construction industry in the titles, abstracts and keyword sections. As we were working on technological advancements most of the papers were selected which were published in last 3-4 years.

### 3.5.1. Framework against which the articles were analysed

| | Factors | Attributes |
|---|---|---|
| Content | Research stream relevance | Technological advancements, barriers to implementation, evolution of construction sector. |
| | Country, region, level | National, international, organization level |
| | Project life cycle phase | Design, construction, post construction |
| Article Type | Source of information | Reviews, case studies, websites, surveys |
| | Contribution of articles | Statistical analysis, general insights, model analysis. |
| Author | Background | Research scholars, professors, management of organizations, academicians, students. |

### 3.6 Design of questionnaire surveys

A total of two questionnaire surveys were used for the purpose of the study where the first questionnaire was designed on the basis to find out the most known and unknown technology. The second questionnaire was designed to rank the barriers and determine their significance. These were used as a part of quantitative analysis of the data for research purpose.

### 3.6.1. 1st Questionnaire Survey on trends in construction industry

This consisted a total of 10 questions which includes the name, occupation, awareness about the advancements where three option were given and multiple selection options were given for the categories technology, methods, equipment and practice.

1. Name :
2. Industry : Civil engineering / architecture / other
3. Work experience : 0-1 / 1-2 / 2-3 / >4 years
4. Age group :
5. Occupation : UG / PG / employee / business
6. Aware of latest trends : Expert / some extent / may be / not yet all
7. Technologies known/ using : None/ AR / VR / drone Usage / robotics / BIM / O T / machine learning / digital twins.
8. Methods known/ using : None / prefabrication / 3D printing / green materials / modular construction / twin wall technology / precast.
9. Practises known / using : None / lean construction / offsite construction / sustainable sustainable construction / value management / whole life

costing.

10. Equipment known / using : None / exoskeletons/ brick laying machines / auto plaster machines / rovers and laser scanners/ robotic total stations / auto plaster machines.

**3.6.2. 2nd Questionnaire Survey on barriers to adoption of new technology and practices in construction industry.**

This survey consisted a total of 12 questions which includes the list of barriers and details about the respondents.

1. Name :
2. Location :
3. Years of experience :
4. Type of projects : Infra / residential / commercial
5. Technology used : None/ AR / VR / drone Usage / robotics / BIM / O T / machine learning / digital twins.
6. Methods used : None / prefabrication / 3D printing / green materials / modular construction / twin wall technology / precast.
7. Machinery used : None / exoskeletons/ brick laying machines / auto plaster machines / rovers and laser scanners/ robotic total stations / auto plaster machines.
11. Practices used : None / lean construction / offsite construction / sustainable sustainable construction / value management / whole life costing.
12. Technological barriers : Lack of awareness on latest equipment / Lack of training resources in technology / lack of insufficient skills in technology lack of interest in knowledge of technology.
13. Financial barriers : Inadequate finance support for innovation / lack of sufficient budget For R&D / high cost of setting up equipment / Unwillingness of firm to spend more on advancements.
14. Psychological barriers : Lack of open mind-set to new technology / lack of psychological assurance / preference of using conventional methods / fear of increase in total project cost.
15. Process barriers : Lack of computer configuration / mobility of software to handle Complex geometry / lack of knowledge on legal procedure challenges of using new technology / lack of interest in adopting new technology / Difficulty in execution and operations.

### 3.7 Data sampling techniques used for survey 1 & 2

Initially the 1st questionnaire was circulated among various institution and organizations, a total of 175 responses were obtained. After the forms have been closed the data has been reduced to 112 responses as it was filtered base on the criteria set by the research team. The criteria that has been followed was the respondent should be related to civil and allied branches or working in organizations related to civil engineering and allied. The second survey was circulated only to well know persons working in reputed organizations as the data that is to be collected to be accurate a total of 13 responses were collected to perform the AHP analysis.

## 4. DATA ANALYSIS AND FINDINGS

This chapter represent the findings of the questionnaire surveys, analysis of demographics and the AHP analysis that has been carried out to rank the barriers.

### 4.1 Analysis of demographics of 1st questionnaire

Total number of respondents – 175

Number of respondents after reduction according to criteria set – 112

#### 4.1.1. Age group

| Age group | Responses | Percentage |
|---|---|---|
| 20-25 | 78 | 69.6% |
| 26-30 | 15 | 13.4% |
| 31-35 | 9 | 8% |
| 36-40 | 6 | 5.4% |
| >40 | 4 | 3.6% |

#### 4.1.2. Occupation

| Occupation | Responses | Percentage |
|---|---|---|
| Post Graduate | 59 | 52.7% |
| Under Graduate | 19 | 17% |
| Employee | 16 | 14.3% |
| Businessman | 2 | 1.8% |
| PHD | 6 | 5.4% |
| Assistant Professor | 3 | 2.9% |
| M.Tech | 2 | 1.8% |
| Graduate | 1 | 0.9% |

| | | |
|---|---|---|
| MSC in Environmental | 1 | 0.9% |
| AECOM CONSTRUCTION PVT LTD | 1 | 0.9% |

### 4.1.3. Industry

| Industry | Responses | Percentage |
|---|---|---|
| Civil Engineering | 102 | 91.1% |
| Architecture | 6 | 5.4% |
| Construction Mgmt | 1 | 0.9% |
| Computer Science Engineering | 1 | 0.9% |
| Mechanical engg | 1 | 0.9% |
| Electronics engg | 1 | 0.9% |

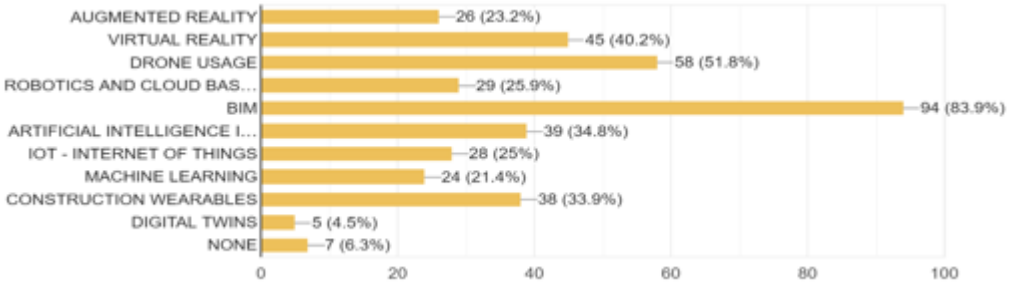
### 4.1.4. Work Experience

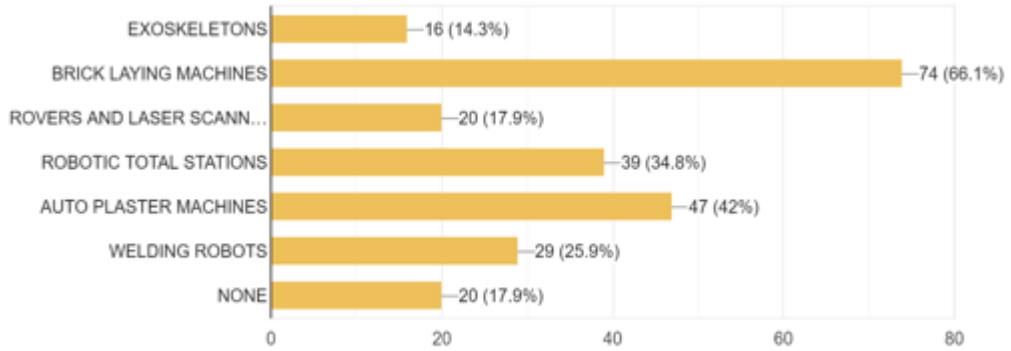
| Working expereince | Responses | Percentage |
|---|---|---|
| 0-1 Yrs | 66 | 58.9% |
| 1-2 Yrs | 14 | 12.5% |
| 2-3 Yrs | 16 | 14.3% |
| >4Yrs | 16 | 14.3% |

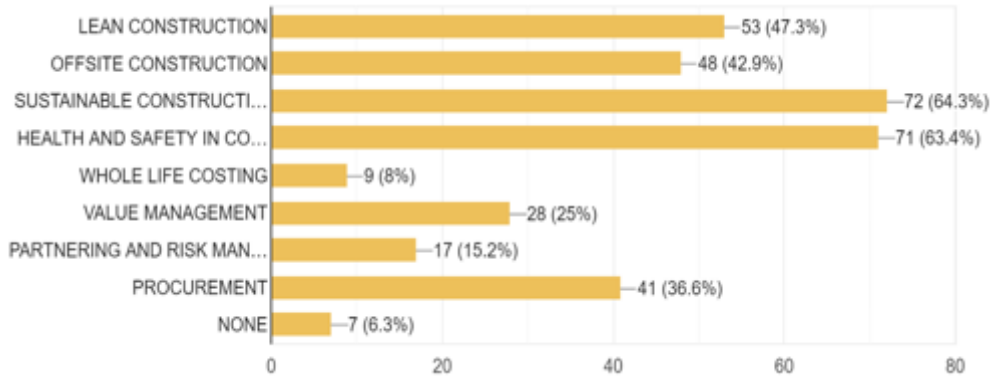
### 4.1.5. Awareness

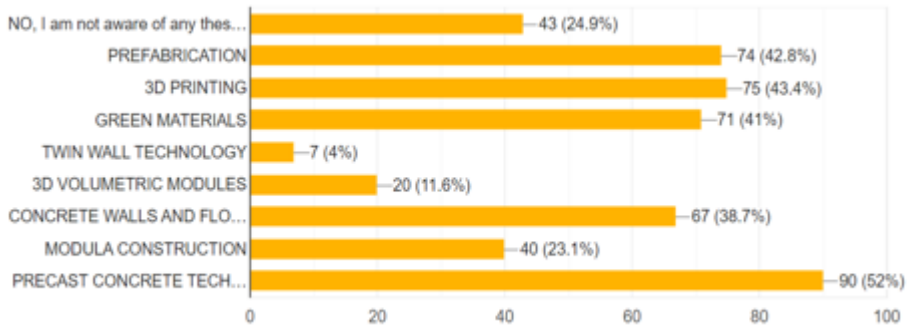
| List | Responses | Percentage |
|---|---|---|
| Expert | 1 | 0.9% |
| Some extent | 75 | 67% |
| May be | 33 | 29.5% |
| Not yet all | 3 | 2.7% |

Graphical representation of technology, methods, practices, equipment.




### 4.2. Analysis of demographics of 2nd Questionnaire

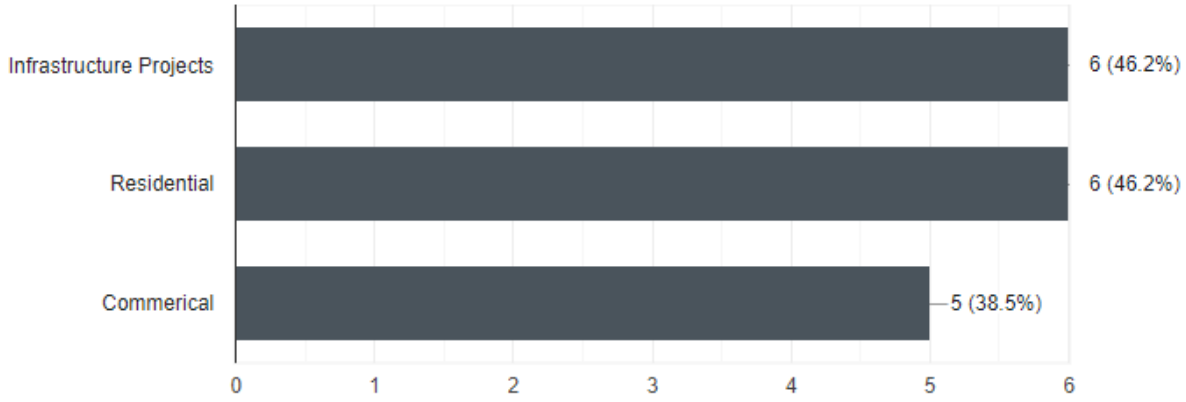
The questionnaire was sent to selected people from reputed companies with sufficient work experience.

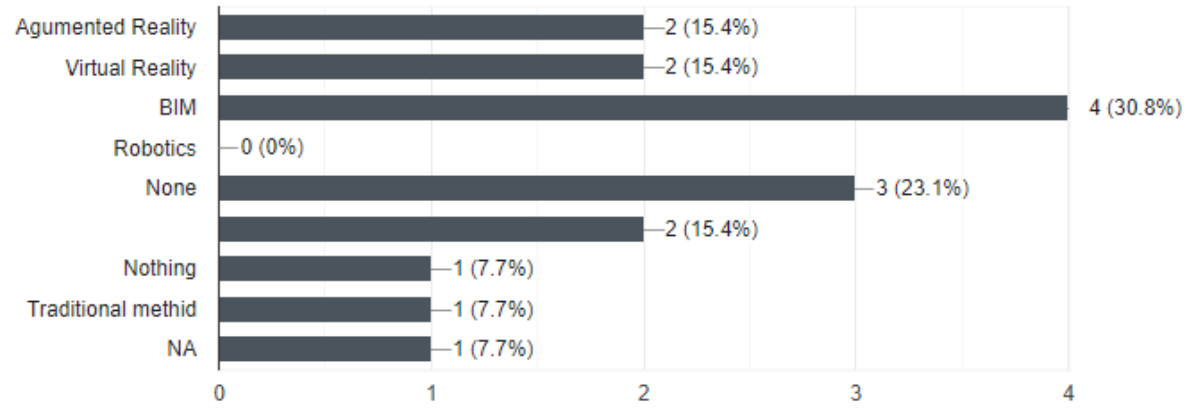
Organizations of the respondents :

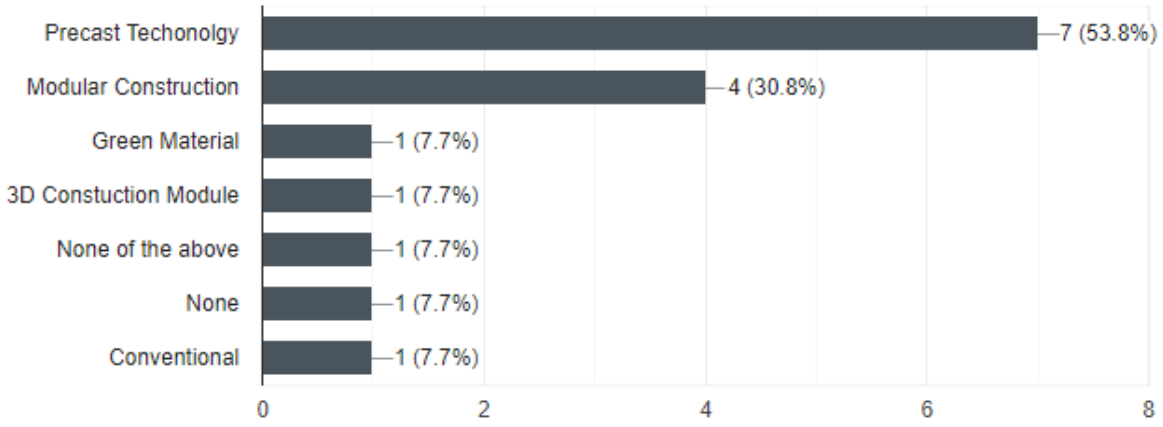
- ANJ Turnkey Projects Pvt. Ltd.

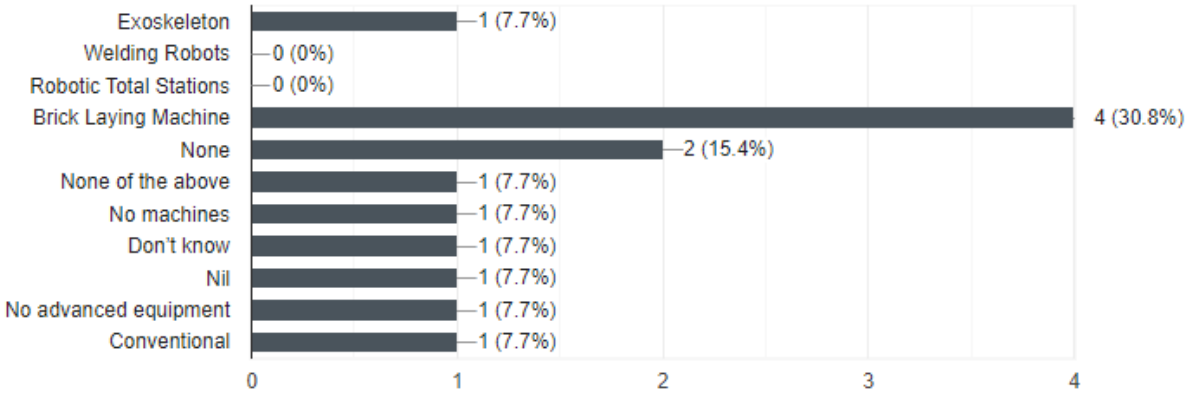
- SN Consultants
- L & T Heavy Civil Infrastructure
- AACP Infrastructure Systems Pvt Ltd
- Kalpataru Power Transmission Ltd
- Mahaveer group
- Bangalore smart city limited
- EPMCR
- CCR CONSTRUCTIONS
- GS infra Pvt Ltd
- Arham Constrotech Pvt Ltd
- Indian Institute of Technology Bombay
- NICE Constructions

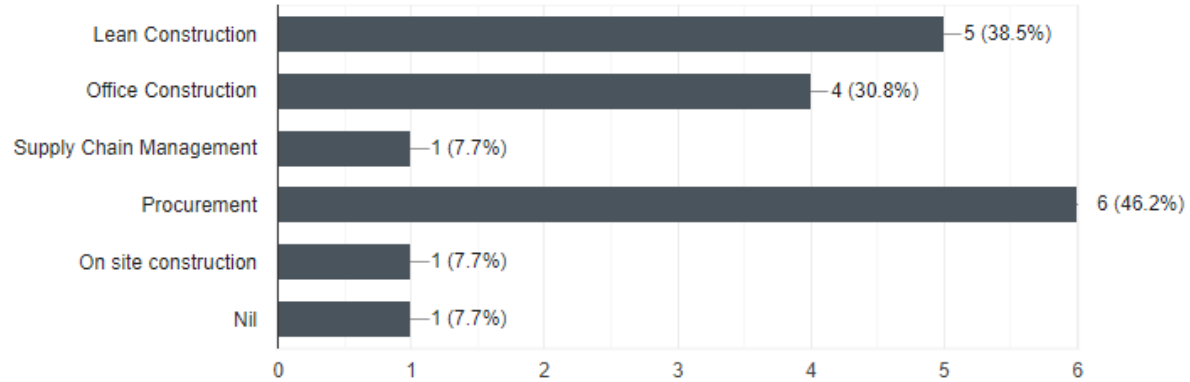
Graphical representation of nature of projects , technology, methods, process, equipment and categories of barriers

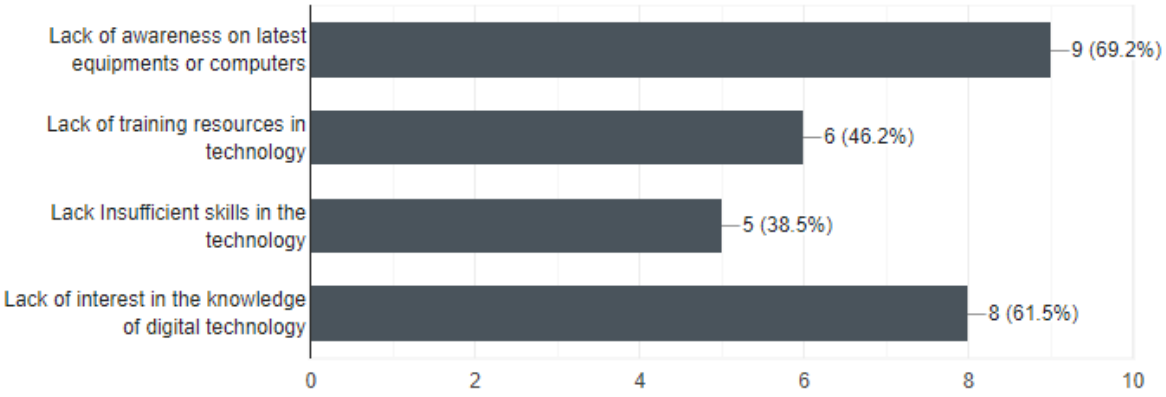


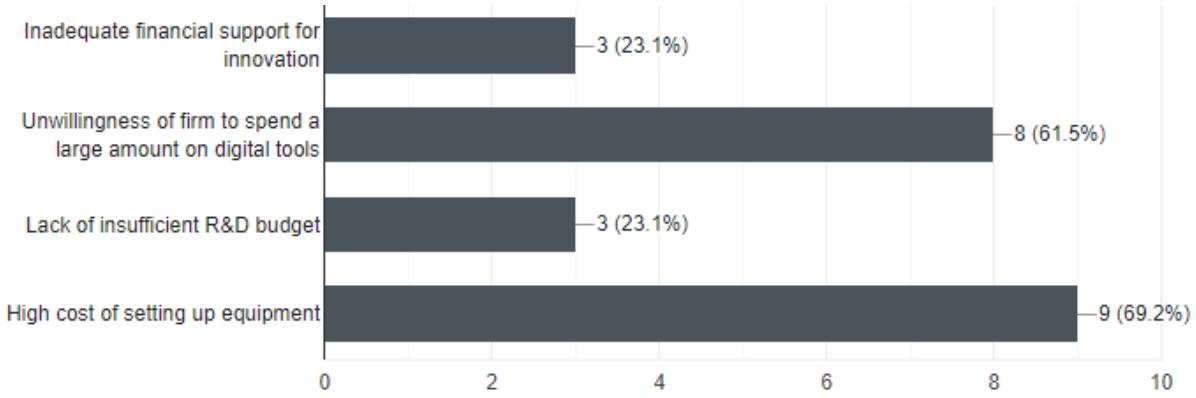



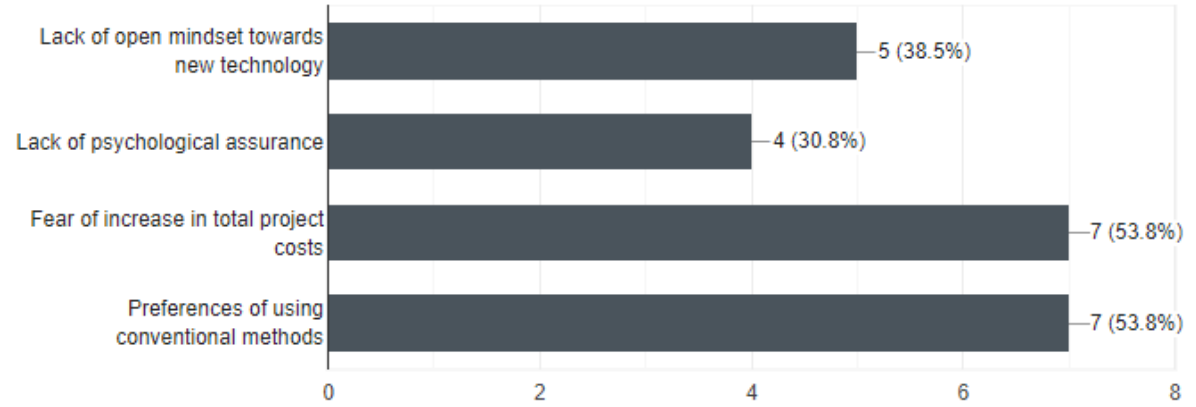

Precast Techonolgy
7 (53.8%)
Modular Construction
4 (30.8%)
Green Material
1 (7.7%)
3D Constuction Module
1 (7.7%)
None of the above
1 (7.7%)
None
1 (7.7%)
Conventional
1 (7.7%)
0
2
4
6
8

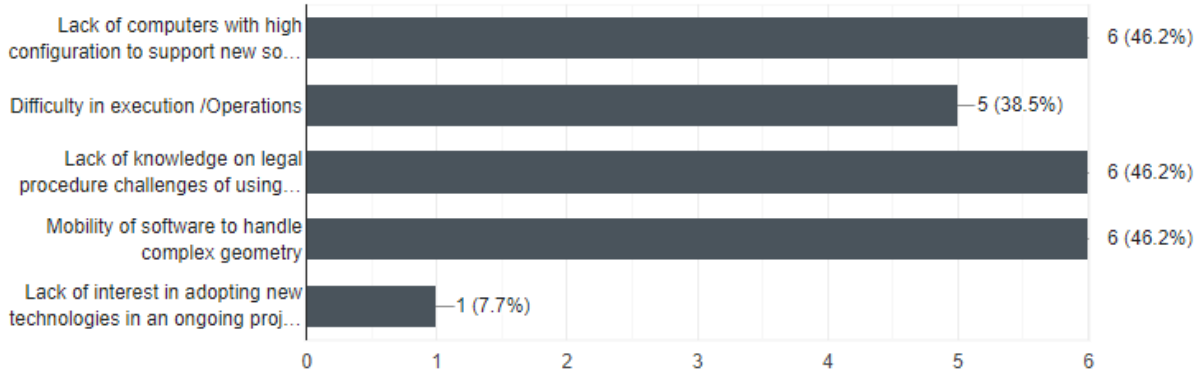

Exoskeleton
1 (7.7%)
Welding Robots
0 (0%)
Robotic Total Stations
0 (0%)
Brick Laying Machine
4 (30.8%)
None
2 (15.4%)
None of the above
1 (7.7%)
No machines
1 (7.7%)
Don't know
1 (7.7%)
Nil
1 (7.7%)
No advanced equipment
1 (7.7%)
Conventional
1 (7.7%)
0
1
2
3
4


Lean Construction
5 (38.5%)
Office Construction
4 (30.8%)
Supply Chain Management
1 (7.7%)
Procurement
6 (46.2%)
On site construction
1 (7.7%)
Nil
1 (7.7%)
0
1
2
3
4
5
6


Lack of awareness on latest equipments or computers
9 (69.2%)
Lack of training resources in technology
6 (46.2%)
Lack Insufficient skills in the technology
5 (38.5%)
Lack of interest in the knowledge of digital technology
8 (61.5%)
0
2
4
6
8
10




**Concept of AHP Analysis**

Making decisions is crucial when it comes to envisioning a bright future. Your choice now will determine whether your future and that of future generations will be peaceful or violent. But there are many difficulties involved in making decisions in company or at work. Making the best decision is probably the most difficult task today. When a person must manage a variety of viewpoints before making a choice, it becomes extremely challenging for him/her to choose the best course of action.

The **Analytic Hierarchy Process** is one such well-known methodology that is known for making difficult judgements simple. AHP will be very effective in offering appropriate answers for your problems, from problem structure to evaluation to decision-making.

The goal of Analytic Hierarchy is to create a comprehensive structure for the issue, highlighting various objectives and potential solutions.

There won't be just one right choice offered to you; rather, there will be many!

**Important Fact**

For the alternative selection issue with multi-level hierarchical structure, an AHP that incorporates both language evaluations and numerical values will be described. When choosing the best option from a list of viable options, AHP uses the ideas of fuzzy set theory and hierarchical structure analysis. Van Laarhoven and Pedrycz (1983) put forth the first AHP technique, which uses fuzzy numbers with triangle membership functions to explain fuzzy comparison judgement. The fuzzy priority of comparison ratios with trapezoidal membership functions were discovered by Buckley (1985). The method of van Laarhoven and Pedrycz was expanded by Boender et al. (1989), who also created a more reliable method for normalising local priorities. A novel approach was put forth by Chang (1996) using triangular fuzzy integers and For the paired comparison scale of the AHP and the synthetic extent values of the pairwise comparisons, respectively, extent analysis method.

**Approaches -**

It is among the best approaches to carry out a project you embark on. The various steps that an AHP goes through include:

**1.Initial Problem Structure**

Here, the choice problem and aim are defined. The next step is to identify and organise the decision criteria and related alternatives.

**2. The main practises of this stage of AHP are evaluation**

Judgements of the relative value of the various alternatives on each choice criterion and the evaluation of the relative importance of decision criteria. Later, it centres on the grouping of the judgements and the investigation of the judgements' inconsistencies. Using the Analytic Hierarchy Process to reach a consensus on a choice has numerous advantages.

**3. Option**

In this step, the weights and priorities of various alternatives and criteria are calculated. The process also involves performing a sensitivity analysis

**Benefits of using AHP analysis** –

- AHP is the greatest option because it can take into account the relative importance of many aspects or options.
- For any given problem, AHP offers a straightforward and highly adaptable model.
- AHP offers a straightforward decision-making process that helps the decision-maker reach accurate conclusions.
- During the decision-making process, both quantitative and qualitative information as well as subjective or objective considerations are crucial.
- This approach allows for the listing or organisation of any level of specifics about the core emphasis.
- The overview of the primary concern or the issue can be simply stated in this fashion.

AHP analysis to rank the barriers to implementation in construction industry

Category and list of barriers

**Technological barriers**

- Lack of awareness on latest equipment or computers [ TB1]
- Lack of training resources in technology [ TB2]
- Lack Insufficient skills in the technology [ TB3]
- Lack of interest in the knowledge of digital technology [TB4]

**Financial barriers**

- Inadequate financial support for innovation [ FB1]
- Unwillingness of firm to spend a large amount on digital tools [ FB2]
- Lack of insufficient R&D budget [ FB3]
- High cost of setting up equipment [ FB4]

**Psychological barriers**

- Lack of open mind-set towards new technology [ PB1]
- Lack of psychological assurance [PB2]
- Fear of increase in total project costs [PB3]
- Preferences of using conventional methods [PB4]

**Process barriers**

- Lack of computers with high configuration to support new software like BIM [ PRB1]
- Difficulty in execution /Operations [PRB2]
- Lack of knowledge on legal procedure challenges of using new technology [PRB3]
- Mobility of software to handle complex geometry [PRB4]
- Lack of interest in adopting new technologies in an ongoing projects, especially in loss making projects [PRB5]

Ranking of barriers

Technology barriers

| | | |
|---|---|---|
| TB1 - 9 | | TB1 – 9/28 - 0.32 |
| TB2 – 6 | [ 9+6+5+8] = 28 | TB2 - 6/28 - 0.21 |
| TB3 – 5 | | TB3 – 5/28 - 0.17 |
| TB4 - 8 | | TB4 – 8/28 - 0.28 |

**Priorities of ranking barriers in technology**

| Ranking priorties | Barriers | Description |
|---|---|---|
| 1 | TB1 | Lack of awareness on latest equipments or computers |
| 2 | TB4 | Lack of interest in the knowledge of digital technology |
| 3 | TB2 | Lack of training resources in technology |
| 4 | TB3 | Lack Insufficient skills in the technology |

Financial BARRIERS

FB1 - 3 FB1 – 3/23 - 0.13

FB2 – 8 [ 3+8+3+9] = 23 FB2 - 8/23 - 0.34

FB3 – 3 FB3 – 3/23 - 0.13

FB4 - 9 FB4 – 9/23 - 0.39

**Priorities of ranking barriers in financial**

| Ranking priorties | Barriers | Description |
|---|---|---|
| 1 | FB4 | High cost of setting up equipment |
| 2 | FB2 | Unwillingness of firm to spend a large amount on digital tools |
| 3 | FB3 | Lack of insufficient R&D budget |
| 4 | FB1 | Inadequate financial support for innovation |

Pyschological BARRIERS

PB1 - 5 PB1 – 5/23 - 0.21

PB2 – 4 [ 5+4+7+7] = 23 PB2 - 4/23 - 0.17

PB3 – 7 PB3 – 7/23 - 0.30

PB4 - 7 PB4 – 7/23 - 0.30

**Priorities of ranking barriers in pyschological**

| Ranking priorties | Barriers | Description |
|---|---|---|
| 1 | PB3 | Fear of increase in total project costs |
| 2 | PB4 | Preferences of using conventional methods |
| 3 | PB1 | Lack of open mindset towards new technology |
| 4 | PB2 | Lack of psychological assurance |

Process BARRIERS

PRB1 - 6 PRB1 – 6/24 - 0.25

PRB2 – 5 [ 6+5+6+6+1] = 24 PRB2 - 5/24 - 0.20

PRB3 – 6 PRB3 – 6/24 - 0.25

PRB4 - 6 PRB4 – 6/24 - 0.25

PRB5 – 1 PRB5 – 1/24 – 0.04

**Priorities of ranking barriers in process**

| Ranking priorties | Barriers | Description |
|---|---|---|
| 1 | PRB4 | Mobility of software to handle complex geometry |
| 2 | PRB3 | Lack of knowledge on legal procedure challenges of using new technology |
| 3 | PRB1 | Lack of computers with high configuration to support new software like BIM |
| 4 | PRB2 | Difficulty in execution /Operations |
| 5 | PRB5 | Lack of interest in adopting new technologies in an ongoing projects, especially in loss making projects |

## 5. CONCLUSION

The main objective of this study was to validate on barriers to adoption of new technology and practices in Indian construction industry , we have successfully met this objective as we have received respondents from big construction firms . Based on barriers of 4 categories which are technology, financial, psychological and process. From that we identified barriers challenges of each category in Indian construction firm. After identifying barriers challenges , we validated on ranking barriers by using AHP analysis , before drawing conclusion of AHP analysis , we would to discuss on understanding of AHP analysis. AHP is a analytic hierarchy process where it helps for organizing and analyzing complex decisions . The main advantage of using AHP analysis is where you can converts these evaluations into numbers , which can be compared to all possible criteria and also these numbers represent the most desired solutions based on all user's values. By using AHP analysis, we conclude most of the Indian construction firm facing lack of awareness on latest equipment , lack of training resources as well as relevant skills in term of technology. Coming to Financial, they are unwilling to spend large amounts on digital tools, high-cost equipment. If you look at psychological point of view , they are lacking on having open mind to adopt new technology due to that they still preferred conventional methods . On process barriers , many Indian construction firm complained that they are lacking of computers with high configuration to support new software like BIM and also mobility of software to handle complex geometry .

Based on the results, we would like to give recommendations on how can Indian construction firms can overcome barriers issues on adoption of new technology and practices in construction industry.

The use of conventional management ideas is a tendency. People normally do not like to interfere with processes that have been in place for a long time, but with the current construction boom, it is imperative that the construction sector recognize the high level of waste produced of all aspects by industry and the need to reduce it. This can be done by educating all of the company's managers and employees on the advantages of adoption of new technology and practices in construction. Workshops comparing adoption of new technology and practices in construction to conventional construction processes and outlining on adoption on latest construction trends. It is necessary to create appropriate measurements to ensure that current technology and practices are used by practitioners.

Current technology and practices can help the company save a significant amount of money on expenses; thus, managers should push it. Managers ought to adapt to the times and emerging technologies. This can be accomplished by implementing new waste minimization policies, changing organizational culture, and working with suppliers and subcontractors to ensure that they adhere to current construction practices and technology.

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