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Cost Optimization of Construction Projects by Using Advance Methods and Advanced Materials

Prof. Yogita Fulse[1], Aniket R. Zolekar[2]

[1]Assistant Professor, [2]M Tech Construction Management,
[1,2]Department of Civil Engineering, School of Engineering and Technology,
Sandip University, Nashik, Maharashtra, India

ABSTRACT

Construction industry could be considered as a very important sector for development all over the World and the construction cost is the most important element in it. The construction project can vary from extremely profitable to barely worth it and sometimes end up costing the contractor more than what he or she is getting paid to complete it. In construction industry the aim of project control is to ensure the projects finish on time, within budget and achieving other project activities. Time and cost are two main concerns which increase importance of cost reduction techniques. Reduction of cost of construction is a constant goal for construction industry. One way of reducing construction cost is to develop innovative technologies as well as methodologies to increase productivity. This study was carried out to identify the factors affecting construction cost. The factors were identified based on case studies and market surveys. In this paper, we have studied different techniques for optimization. To minimize the construction cost and duration at each phase is important. It is a need to meet the present day requirements and to complete the project within the estimated time, cost, and available resources. Mainly affecting the factor on cost of project is delay in project and material. Several methods have been developed and applied to analyze the time-cost problems, but they can optimize only one parameter. Various low cost material also suggested for optimizing the cost of project along with maintaining the quality and strength of the project. Also various mathematical method and software based models studied for optimization. This study centers on assessing the cost of construction project and compare the construction cost with the optimized cost of the same building by using advance construction techniques and materials. Outcomes of cost study suggest that the construction cost of residential building project is reduced by 20-30%, 10-20% in infrastructural projects and 25-35% in industrial projects than the construction cost.

KEYWORDS: *Construction, Cost Reduction, Value Engineering, Cost, Value, Project, Cost Optimization Techniques, Cost Reduction Techniques, Advance methods, Advance Material, Material Management, etc*

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1. INTRODUCTION

The construction industry is considered one of the most resource-intensive industry sectors in the global economy and is often exposed to several risks such as resource scarcity, availability, and prices of globally traded commodities. Decreasing the power of assets used in construction is, in this way, critical for expanding industrial and economic resilience.

In general, there are three sectors of construction: buildings, infrastructure and industrial. Building construction is usually further divided into residential and non-residential. Infrastructure, also called heavy civil or heavy engineering, includes large public works, dams, bridges, highways, railways, water or wastewater and utility distribution. Industrial

construction includes offshore construction (mainly of energy installations), mining and quarrying, refineries, chemical processing, power generation, mills and manufacturing plants.

There are also other ways to break the industry into sectors or markets. For example, Engineering News-Record (ENR), a US-based construction trade magazine, has compiled and r Engineering News-Record (ENR), reported data about the size of design and construction contractors. In 2020, it split the data into nine market segments: transportation, petroleum, buildings, power, industrial, water, manufacturing, sewer/waste, telecom, hazardous waste, and a tenth category for other projects. Engineering News-Record (ENR) used data on transportation, sewer, hazardous waste and water to rank firms as heavy contractors.

The Standard Industrial Classification and the newer North American Industry Classification System classify companies that perform or engage in construction into three subsectors: building construction, heavy and civil engineering construction, and specialty trade contractors. There are also categories for professional services firms (e.g., engineering, architecture, surveying, project management).

A. Building Construction

Building construction is the process of adding structures to areas of land, also known as real property sites. Typically, a project is instigated by or with the owner of the property (who may be an individual or an organisation); occasionally, land may be compulsorily purchased from the owner for public use.

I. Residential Construction :-

Residential construction may be undertaken by individual land-owners (self-build), by specialist house-builders, by property developers, by general contractors, or by providers of public or social housing (eg. local authorities, housing associations). Where local zoning or planning policies allow, mixed-use developments may comprise both residential and non-residential construction (eg. retail, leisure, offices, public buildings, etc).

Fig -1: Residential Construction

Residential construction practices, technologies, and resources must conform to local building authority regulations and codes of practice. Materials readily available in the area generally dictate the construction materials used (eg. brick versus stone versus timber). Costs of construction on per square meter (or per square foot) basis for houses can vary dramatically based on site conditions, access routes, local regulations, economies of scale (custom-designed homes are often more expensive to build) and the availability of skilled trades people. Residential construction actually addresses the housing needs of society. Housing construction takes many forms: individual homes, apartments, condominiums, townhouses, and prefabricated units like modular and manufactured homes. Individual homes are classified as single-family dwellings. Apartment condominiums and townhouses are all referred to as multi-family dwellings.

II. Non-residential Construction :-

Depending upon the type of building, non-residential building construction can be procured by a wide range of private and public organisations, including local authorities, educational and religious bodies, transport undertakings, retailers, hoteliers, property developers, financial institutions and other private companies. Most construction in these sector s is undertaken by general contractors.

Fig -2: Non-residential Construction

This act of the industry primarily addresses the needs of commerce, trade and government and makes up about a third of the total construction market. This is the category that includes banks, schools, office buildings, hotels, shopping malls, religious facilities, basketball stadiums, theatres, universities, amusement parks, hospital, courthouses, government buildings, and other facilities where people gather. These projects may range in size from small medical office to large high-rise office buildings to state-of-the-art biotechnology facilities. The building cost are significantly higher than with residential construction, and the project duration is much longer. It is not uncommon for commercial project last three years or more.

B. Building Construction

Civil engineering covers the design, construction, and maintenance of the physical and naturally built environment, including public works such as roads, bridges, canals, dams, tunnels, airports, water and sewerage systems, pipelines, and railways.

Fig -3: Infrastructure Construction

Some general contractors have expertise in civil engineering; civil engineering contractors are firms dedicated to work in this sector, and may specialize in particular types of infrastructure. Infrastructure is composed of public and private physical structures such as roads, railways, bridges, tunnels, water supply, sewers, electrical grids, and telecommunications (including internet connectivity and broadband access). In general, infrastructure has been defined as "the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions" and maintain the surrounding environment. Especially in light of the massive societal transformations needed to mitigate and adapt to climate change, contemporary infrastructure conversations frequently focus on sustainable development and green infrastructure. Acknowledging this importance, the international community has created policy focused on sustainable infrastructure through the Sustainable Development Goals, especially Sustainable Development Goal 9 "Industry, Innovation and Infrastructure".

C. Industrial Construction

Fig -4: Industrial Construction

Industrial construction includes offshore construction (mainly of energy installations: oil and gas platforms, wind power), mining and quarrying, refineries, breweries, distilleries and other processing plants, power stations, steel mills, warehouses and factories. Industrial construction is a specific form of building that requires expert training and highly experienced workers who can multi-task**.** Many industrial construction companies are large, multi-national firms. Projects are run by a bevy of managers, engineers and architects.

2. CONSTRUCTION PROCESS

Some construction projects are small renovations or repair jobs, where the owner may act as designer, paymaster and laborer for the entire project. However, more complex or ambitious projects usually require additional multi-disciplinary expertise and manpower, so the owner may commission one or more specialist businesses to undertake detailed planning, design, construction and handover of the work. Often the owner will appoint one business to oversee the project (this may be a designer, a contractor, a construction manager, or other advisor); such specialists are normally appointed for their expertise in project delivery, and will help the owner define the project brief, agree a budget and schedule, liaise with relevant public authorities, and procure the services of other specialists (the supply chain, comprising subcontractors). Contracts are agreed for the delivery of services by all businesses, alongside other detailed plans aimed at ensuring legal, timely, on-budget and safe delivery of the specified works.

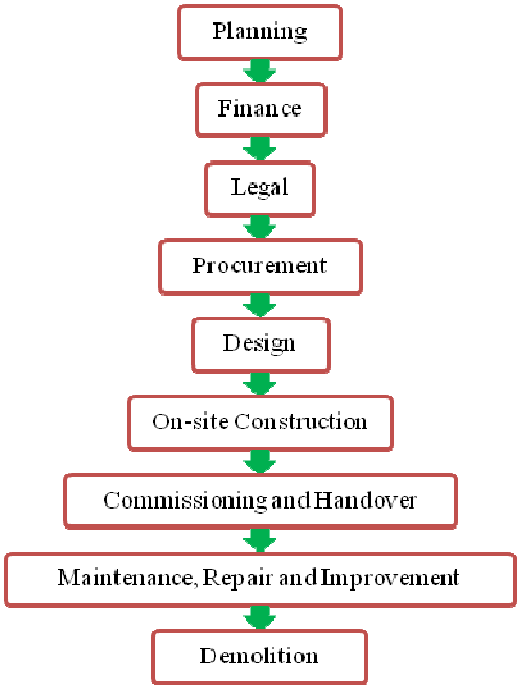

Fig -5: Construction Process

A. Construction Cost

Expense incurred by a contractor for labour, material, equipment, financing, service utilities etc. plus overheads and contractors' profit. Cost of land, architectural design, fee of consultant and engineer are not construction costs. Construction costs form part of the overall costs incurred during the development of a built asset such as a building. Very broadly, construction costs will be those costs incurred by the actual construction works themselves, and on some projects may be determined by the value of the contract with the main contractor.

In addition, the contract is likely to allow for the contract sum to be adjusted as a result, for example, of variations to the works, claims for loss and expense, or fluctuations (a way of dealing with inflation on large projects that may last for several years). It is because of these unknowns that clients are advised to hold a contingency. As a result, what is considered the actual 'construction cost' of a project must be clearly defined and may not be finally determined until well after the actual construction works have been completed. This is true, even if a contract is described as having a 'fixed price' or 'guaranteed maximum price'.

B. Factors Affecting Construction Cost

A. Similar Construction Projects
B. Construction Material Costs
C. Labour Wage Rates
D. Construction Site Conditions
E. Inflation Factor
F. Project Schedule
G. Quality of Plans & Specifications
H. Reputation of Engineer
I. Regulatory Requirements
J. Insurance Requirements
K. Size and Type of Construction Project
L. Location of Construction
M. Engineering Review
N. Contingency

3. RESEARCH METHODOLOGY

In many construction projects, project managers and contractors find difficulties like poor planning of project, poor material, labour shortages, increased cost of material, delays in deliveries, wastage of material, over budgeting, unexpected weather changes, lapse in management and control, loss of material, poor communication etc. This result into cost and time overruns conflicts in project. So there is need to study costs included in projects and to identify cost reduction or cost control techniques for carrying construction projects effectively. Reduction of cost of construction is a constant goal for construction industry. One way of reducing construction cost is to develop innovative technologies as well as methodologies to increase productivity. Due to cost reduction techniques cost of project is managed so that contractor does not suffer losses while carrying different activities of projects. The principal aim of this study is to optimize cost of construction projects.

A. Aim of the Study

India is a country where every family dreams of staying in the house they own. But with the current increase in land costs, construction material prices and labour charges, it is becoming difficult for middle class families to fulfill their dream of living in their own homes. So I thought of putting forward some conclusion that can be helpful for such families to build the house of their dreams. Reduction of cost of construction is a constant goal for construction industry. One way of reducing construction cost is to develop innovative technologies as well as methodologies to increase productivity.

B. Objectives of the Study

1. To study different construction projects with respect to cost and material, this includes residential project, infrastructure project and industrial project.
2. To minimize total cost of construction projects with respect to different factors. (Direct cost and Indirect cost).
3. To study cost reduction methods and advance materials for construction projects.

4. To compare cost of projects before and after using advance methods and materials.

C. Need of the Cost Optimization

The optimization of cost is necessary as it could minimize the total cost of project. This optimization in cost helps to achieve the greatest benefit.

D. Methodology of the Study

The different phases of this project of work are shown in the following diagram. The figure simply describes the experimental strategy of this study step by step.

A. Review the existing literature for cost optimization of construction projects,
B. Select different construction projects for conducting study with respect to cost and material,
C. Study the different factors which are responsible for increasing cost of construction projects,
D. Study of direct and indirect cost for reducing total cost of construction,
E. Study of different cost reduction techniques and advance materials,
F. Comparative analysis of different projects with respect to cost,
G. Interpretation of results and conclusion.

E. Different Projects for Case Studies

Table -1: Overview of the Investigated Projects

Sr. No.	Project	Description	Location
1	Residential Project	Prangan Residential Flat Project (G + 20 Residential Building)	Nashik
2	Infrastructural Project	Chatrapati Shivaji Maharaj Uddanpul	Nashik
3	Industrial Project	Industrial Shed, Sinnar MIDC	Sinnar

F. Cost Reduction Techniques

There are various cost effective techniques of construction. Many of them are also energy efficient and easily adoptable. Since India is a developing country, the economy haves importance. There is a need for the adoption of strong, durable, environment friendly, ecologically appropriate, energy efficient and yet cost effective materials and appropriate technologies in construction. In construction project reduction in cost can be achieved by some of the following techniques:

1. Value Engineering
2. Material Management
3. Budgetary Control
4. Cost Optimization Techniques
5. Cost Reduction Techniques at site

4. DATA COLLECTION AND ANALYSIS

A. Project 1 : Residential Project

"Prangan" is an ongoing premium 2BHK and 3BHK residential flats project. This residential project "Prangan" consists of two wings namely 'Wing A' and 'Wing B'. Both wings are same, so for our study, we take 'Wing A'. "Prangan" residential flat project consists of G + 20 floors over 36 lifestyle amenities.

Table -2: Technical Data of Residential Project

Name of Project	Residential Project
Description	"Prangan" Residential Flat Project ("A" Wing)
Location	"Prangan", 4th Ave, Serene Meadows, Gangapur Road, Nashik – 422 013
No. of Floors	G + 20 Floors
Odd Floors	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21
Even Floors	2, 4, 6, 8, 10, 12, 14, 16, 18, 20
Carpet Area	Odd Floor : 1026 sq. ft. (95.36 sq. m) Even Floor : 1023 sq. ft. (95.04 sq. m)
Usable Area	Odd Floor : 313 sq. ft. (29.05 sq. m) Even Floor : 289 sq. ft. (26.83 sq. m)
Built-up Area	Odd Floor : 2365 sq. ft. (219.79 sq. m) Even Floor : 2158 sq. ft. (200.55 sq. m)

Table -3: Construction Cost of "Prangan" (Wing A) Residential Project

Total Carpet Area	**21516 sq. ft. (1996.63 sq. m)**
Total Usable Area	6333 sq. ft. (588.57 sq. m)
Total Built-up Area	47595 sq. ft. (4423.33 sq. m)
Construction Cost	1500/- per sq. ft.
Total Cost	1500 x 47595 = 7,13,92,500 INR Seven Crore Thirteen Lacs Ninety Two Thousand and Five Hundred

Construction costs form part of the overall costs incurred during the development of a built asset such as a building. Very broadly, **construction costs** will be those costs incurred by the actual construction works themselves, and on some projects may be determined by the value of the contract with the main contractor.

Fig -6: 3D View of Prangan Residential Flat Project

However, the construction contract may include costs that might not in themselves be considered literal **construction costs** (hard costs), such as fees, profits, overheads, and so on. Many projects will also include costs that it is not possible to determine when the construction contract is awarded (such as prime cost sums and provisional sums), and there may be construction works that are awarded by the client outside of the main contract. There are some other charges like scrutiny fees, construction development charges, ancillary charges, cess charges, drainage charges, tree plantation charges, land development charges etc. are not considered in construction cost. It is because; our objectives are to minimize Cost Construction Projects by using Advance Construction Techniques and Materials.

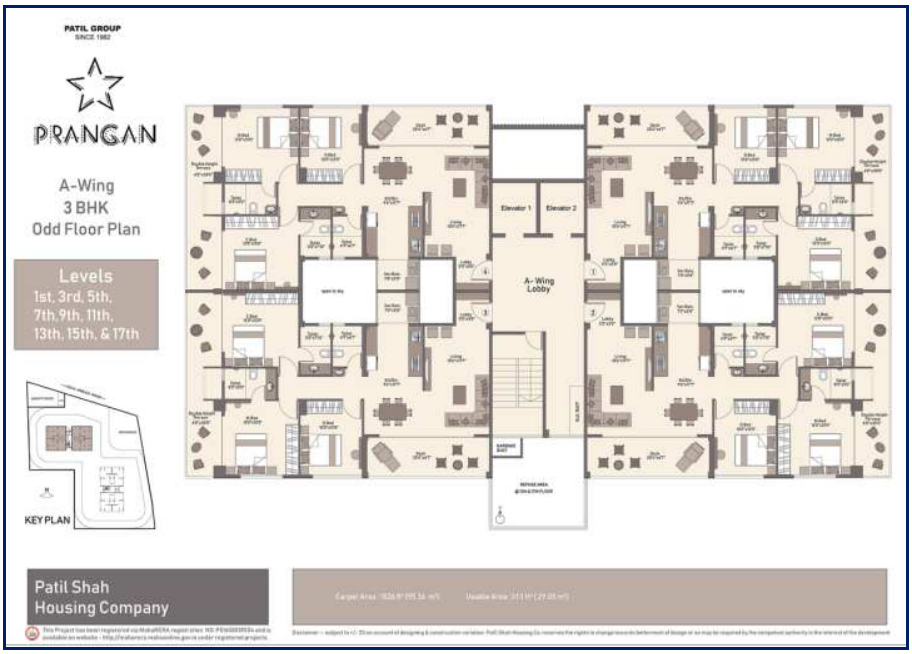

Fig -7: Floor Plan of "Prangan" Residential Flat Project (Odd Floor)

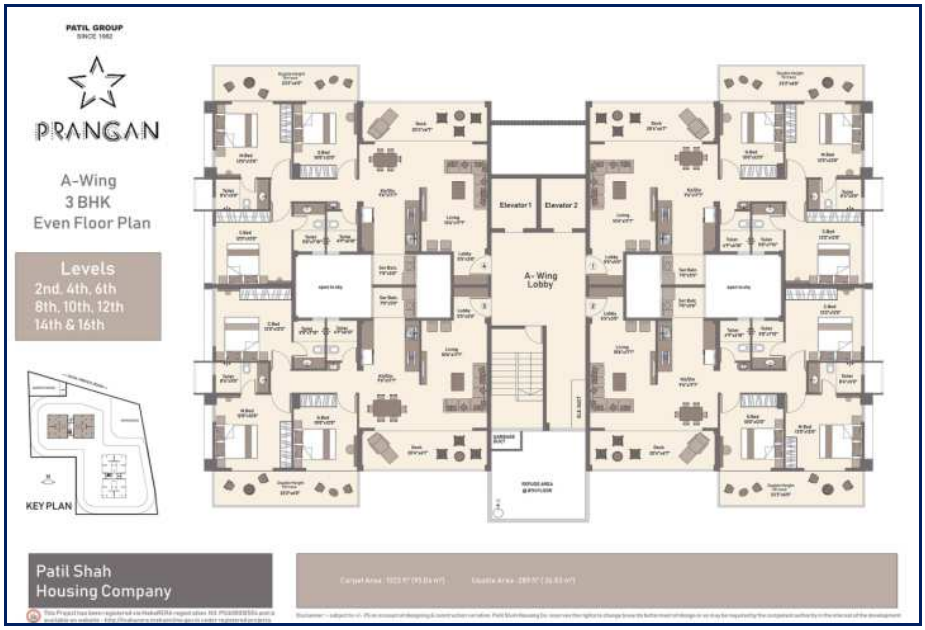

Fig -8: Floor Plan of "Prangan" Residential Flat Project (Even Floor)

B. Project 2 : Infrastructural Project

Chatrapati Shivaji Maharaj Uddanpul is in Nashik city, Dwarka area and located on National Highway 3 (India). It starts from Pandavleni caves and ends near Panchavati Stadium, it is India's first externally strutted segmental box girder bridge used over 2100 and having capacity of 100 Ton each and India's Second Longest road bridge. It was approved by Atal Bihari Vajpayee in 2002.

Table -4: Technical Data of Infrastructural Project

Name of Project	Infrastructural Project
Official Name	Chatrapati Shivaji Maharaj Uddanpul
Location	Nashik
Carries	4 lanes not allowed for pedestrians, bicycles, Motor-Cycles, and Auto Rickshaws.
Characteristics	
Maintained by	Ashoka Buildcon, Larsen & Toubro, National Highways Authority of India
Material	Steel
Total length	14 Km.
Width	120 ft.
Height	70 ft.
Clearance above	20 ft.
Clearance below	20 ft.
Constructed by	Ashoka Buildcon and Larsen & Toubro
Statistics	
Daily traffic	50,000 vehicles
Toll	Free both ways in City.

Fig -9: Chatrapati Shivaji Maharaj Uddanpul, Nashik

Table-5: Construction Cost of Chatrapati Shivaji Maharaj Uddanpul, Nashik

Total Length	16 km
Cost of Construction per km	25,00,00,000/-
Total Cost	4,00,00,00,000 INR (Four Hundred Crore Rupees)

C. Project 3: Industrial Project

Table -6: Technical Data of Industrial Project

Name of Project	**Industrial Project**
Official Name	Amruta Industries, Sinnar Industrial Shed, Sinner MIDC
Location	B-24, Sinnar Taluka Industrial Co. Opp Etate Ltd, Sinnar, Maharashtra
Length	40 m (131.23 ft)
Width	15 m (49.21 ft)
Plan Area	40 m X 15 m = 600 sq. m (131.23 ft X 49.21 ft = 6457.83 sq. ft)

Fig -10: Amruta Industries, Sinnar

Table -7: Construction Cost of Amruta Industries, Sinnar

Plan Area	40 m X 15 m = 600 sq. m (131.23 ft X 49.21 ft = 6457.83 sq. ft)
Cost of construction per sq. ft	240/- Rs.
Total Cost	6457.83 X 240 = 15,49,879 INR (Fifteen Lacs Forty Nine Thousand Eight Hundred and Seventy Nine Rupees)

D. Cost Reduction Programme

Cost reduction aims at improvement of human efforts. In a business organisation several persons are engaged in diverse activities. It may be a short-term or long-term under special problems such as reduction in profit, specific inefficiencies in certain spots (or fall in production). A special cost reduction programme is geared into action to meet the situation and improve the position. Long-term cost reduction plans improve major reductions in costs and may involve capital expenditure.

Briefly, a programme of cost reduction consists of the following:

A. Numerous centres or points where costs are incurred are located and grouped according to departmental responsibility.
B. Each such point or group or points is then submitted a value analysis scheme to determine whether optimum efficiency has been achieved in its performance or whether there is a norm for cost reductions.
C. Suitable techniques are, therefore, applied to reduce costs. No cost reduction programme can be effective unless a joint effort is made by all the departments concerned and the plan is linked with responsible management. Allocation of responsibility of the various cost reduction levels of management is an important requirement for control of cost reduction of the operation and spheres under his control.
D. The programme for cost reduction should be clearly defined and responsibilities delegated. Thus, each executive should be aware of his role in the over-all scheme of cost reduction and of the function he has to perform.

E. Tools and Techniques of Cost reduction Programme

The various techniques and tools used for achieving cost reduction are practically the same which have been suggested for cost control.

Some of these are:

1. Budgetary control,
2. Standard costing,
3. Standardisation of products and tools and equipment's,
4. Simplification and variety reduction,
5. Improvement in design,
6. Material control,
7. Labour control,
8. Overhead control,
9. Production planning and control,
10. Automation,
11. Operation research,
12. Market research,
13. Planning and control of finance,
14. Value analysis,
15. Quality measurement and research,
16. Cost benefits analysis.
17. Contribution Analysis

F. Effective Ways to Reduce Material Cost

1. Substitute Lower Cost Materials Where Possible
2. Reduce Waste
3. Eliminate Unnecessary Product Features
4. Negotiate, Negotiate, Negotiate
5. Leverage Suppliers
6. Buy Need, Not Potential
7. Trade Time for Discounts
8. Buy Bargains
9. Transform Buyers into Suppliers
10. Barter Finished Goods for Raw Materials
11. Provide Warehouse and Distribution Services
12. Offer Quick Payment for Lower Prices
13. Enter Into Cooperative Purchase Agreements to Gain Buying Muscle
14. Negotiate Long-Term Supply Agreements

G. Advance Construction Materials

1. Durable Concrete
2. High Performance Concrete
3. Self–compacting Concrete (SCC)
4. The Use of Mineral Admixtures
5. Fly Ash
6. High Volume Fly Ash Concrete (HVFA)
7. Ground Granulated Blast Furnace Slag (GGBFS)
8. Condensed Silica Fume (CSF)
9. Ternary Blends
10. Cement Silos
11. Durability Enhancing Products
12. Hydrophobic Concrete Waterproofing System
13. Reinforcement
14. Ternary Blended Cements
15. Photo-catalytic Cement
16. Insulated Concrete Form (ICF)
17. Exterior Self–leveling Concrete Topping
18. Carbon Dioxide (CO_2)
19. Corrosion Inhibiters for Reinforced Concrete
20. Coarse Aggregates for Concrete

21. Recycled Aggregates
22. Lightweight Aggregates
23. High Performance Lightweight Concrete
24. Self–curing, Shrinkage-free concrete
25. Advanced Composite Reinforcement
26. Application of Nano Technology

H. Advance Construction Techniques

1. Precast Flat Panel System
2. 3D Volumetric Modules
3. Flat Slab Construction
4. Precast Cladding Panels
5. Concrete Wall and Floors
6. Twin Wall Technology
7. Precast Concrete Foundation
8. Concrete Formwork Insulation

I. Cost Optimization by Using Advance Construction Techniques and Materials

The problem of cost optimization is actually the lack of knowledge and inadequate planning for the implementation coupled with the poor management of construction resources. General methods that are used by Builders for cost optimization methods are as follows:

1. Comparison with a cost standard.
2. Subdivision by detail.
3. Integration with other functions.

The availability of qualified experts is the main problem faced by Builder in optimizing the costs of construction projects. Project managers/ civil engineers don't have cost Reconcile approach they do not prepare Cost control documents for their Projects that's why they don't have expertise in Cost optimization.

1. As per study, 20-30% cost can be optimized in residential projects by using advance construction techniques and materials.
2. 10-20% cost can be optimized in infrastructural projects by using construction and demolition waste materials.
3. In industrial projects, 25-35% cost can be optimized by using Pre-Engineered Buildings.

Table -8: Cost Optimization of Different Projects

Sr. No.	Description	Construction Cost	Optimizing Cost
Project 1	Prangan Residential Flat Project (G + 20 Residential Building)	7,13,92,500 INR	5,35,44,375 INR
Project 2	Chatrapati Shivaji Maharaj Uddanpul	4,00,00,00,000 INR	3,40,00,00,000 INR
Project 3	Industrial Shed, Sinnar MIDC	15,49,879 INR	10,84,915 INR

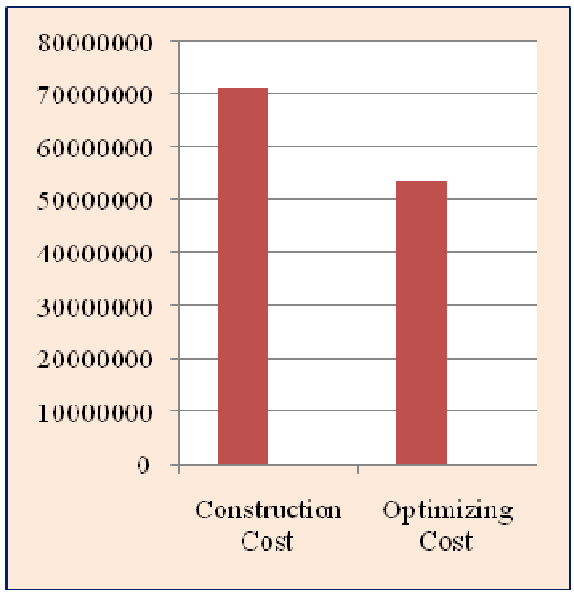

Chart -1: Cost Optimization of Residential Project (Project 1)

Contour Crafting technology can also be used for cost optimization of construction projects. Contour crafting is a building printing technology being researched by Behrokh Khoshnevis of the University of Southern California's Information Sciences Institute (in the Viterbi School of Engineering) that uses a computer-controlled crane or gantry to build edifices rapidly and efficiently with substantially less manual labor. It was originally conceived as a method to construct molds for industrial parts. Khoshnevis decided to adapt the technology for rapid home construction as a way to rebuild after natural disasters, like the devastating earthquakes that have plagued his native Iran.

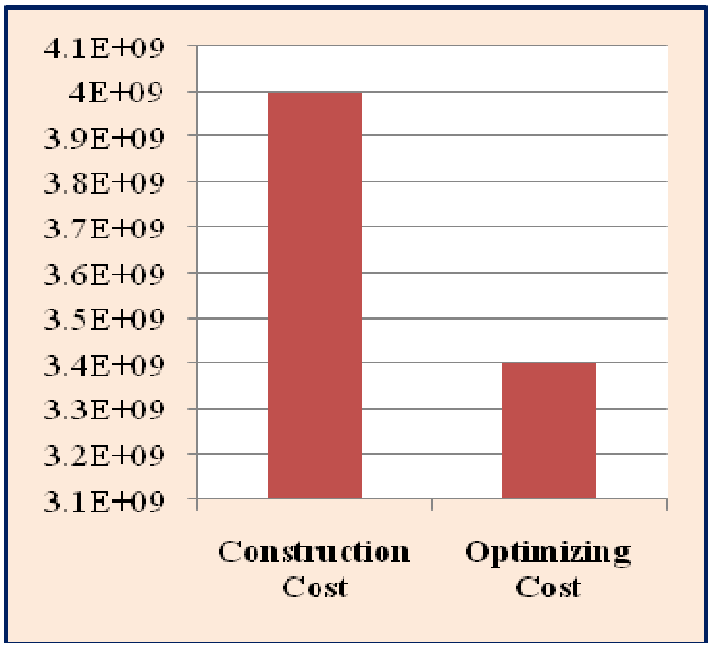

Chart -2: Cost Optimization of Infrastructural Project (Project 2)

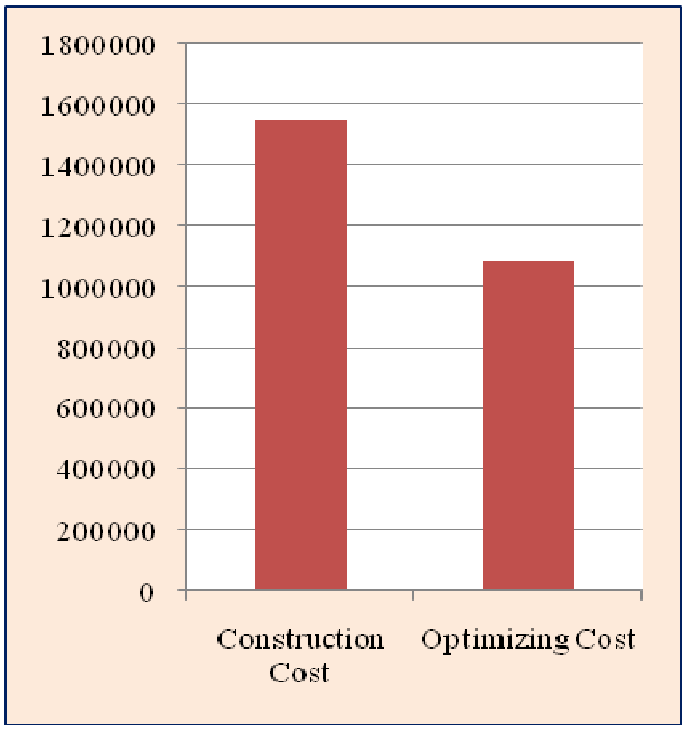

Chart -3: Cost Optimization of Commercial Project (Project 3)

4. CONCLUSIONS

In this paper, we have studied different techniques for optimization. To minimize the construction cost and duration at each phase is important. It is a need to meet the present day requirements and to complete the project within the estimated time, cost, and available resources. Mainly affecting the factor on cost of project is delay in project and material. Several methods have been developed and applied to analyze the time-cost problems, but they can optimize only one parameter. Various low cost materials also suggested for optimizing the cost of project along with maintaining the quality and strength of the project. Also various mathematical method and software based models studied for optimization. This study centers on assessing the cost of construction

project and compare the construction cost with the optimized cost of the same building by using advance construction techniques and materials. Outcomes of cost study suggest that the construction cost of residential building project is reduced by 20-30%, 10-20% in infrastructural projects and 25-35% in industrial projects than the construction cost. The current research has multiple limitations. First, the study was conducted based on a single building construction project, thus it is difficult to generalize the findings of the study for other projects. Small sample size also compromised the statistical validation of the study. Second, the remedies of cost reduction were based on previous studies, as the study team was unable to interview people involved in the project. Third, in this study, only construction cost was compared. If the total life cycle costs are compared then there might be an offset for the projects. Finally, the study excluded the schedule information of the project because of data unavailability. Future research should address all these issues to analyze the cost and time of the building construction projects.

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