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Optimization of Construction Management: Leveraging Modern Methods in Sustainable Construction and Lightweighting

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Abstract

Sustainability and project management are interrelated concepts that are highly significant in today's world. Sustainability is an emerging necessity in the fields of construction management, project management, and engineering. Optimizing construction management is particularly important in the construction industry today, drawing significant attention. With advancements in technology, there is an urgent need to adopt modern methods to achieve sustainable construction and lightweight designs. The rapid growth of urbanization in metropolitan areas brings with it a multifaceted set of challenges, including increased traffic congestion and environmental degradation. These challenges are inherently linked to the rising demand for engineering projects, particularly civil engineering initiatives. Construction management is a key area within the broader architecture industry that encompasses a variety of activities related to building and the associated management processes. A range of methods has been proposed to address the challenges faced in engineering projects of various sizes. These methods can be categorized as intelligent techniques, generally referred to as "smart techniques." Construction engineering management encompasses a wide range of activities, including pre-design, planning, construction, operation, and maintenance. Addressing these research gaps will contribute to a deeper understanding and more effective application of intelligent methods in construction. This paper examines the optimization of construction management, focusing on the use of modern techniques in sustainable and lightweight construction. The main objective of this research is to identify and analyze modern tools and techniques that can enhance the efficiency and sustainability of construction projects.

Keywords: construction management, project management, structural optimization, sustainable construction, lightweight construction, modern methods.

1- Introduction

Optimizing construction management is of great importance, especially in sustainable building and lightweight construction, which benefit both the environment and the economy. The use of modern methods in this field can lead to improved efficiency and cost reduction. Construction management is one of the key factors in the success of building projects. Given the environmental and economic challenges, the adoption of modern and sustainable methods has become essential. During the processes of urbanization and industrialization, greenhouse gas emissions have contributed to global warming, which in turn leads to climate change. In this context, the construction engineering industry plays a crucial role in promoting sustainable development. Today, society values speed and efficiency. In situations where the lightweight and purity of structures are of utmost importance, technical consequences can become so significant that they dictate architectural designs. This is where close collaboration between architects and structural engineers, or the presence of an engineer skilled in both architecture and structural design, becomes crucial for a seamless and integrated design process. Construction management, as a complex process, requires innovation and the use of new technologies. Implementing modern methods in construction not only enhances project efficiency but also contributes to environmental preservation. Therefore, this article emphasizes the positive features of structural design, such as lightweight construction, structural integrity, avoidance of internal complexities, cost reduction, diversity in creative works, and the creation of visually appealing architectural forms.

2- Statement of the problem

This article is a descriptive-analytical piece that examines the most modern methods of sustainability in optimizing construction management within architecture. It analyzes various types of lightweight structures and concludes by highlighting the necessity of incorporating these methods into architectural practice.

3- Research Method

The research method of this article is entirely descriptive. It describes issues related to sustainable architecture and the current conditions. Additionally, it employs a library research method, utilizing previous studies on sustainable architecture to emphasize the necessity and importance of using lightweight structures for streamlining and optimizing construction management.

4- Research Background

Construction management, as both a scientific and practical discipline, focuses on improving construction processes and reducing project costs and timelines. In recent decades, this field has undergone significant transformations due to advancements in technology and innovative methods. Research shows that the implementation of modern technologies, such as Building Information Modeling (BIM), can enhance efficiency, reduce waste, and improve collaboration among project teams. Sustainability in architecture and construction management optimization indicates that this field has received significant attention in recent decades. The concept of sustainability involves creating structures that not only meet current needs but also reduce negative environmental impacts and help preserve resources for future generations. In the context of sustainability in architecture, characterized by a holistic and interconnected approach, three fundamental topics are considered: economy, human society and culture, and the environment. This perspective does not examine these areas in isolation but rather focuses on the relationships and interactions among them. Public belief holds that the social dimensions of sustainable development should carry the same weight and importance as its environmental goals. This is because the concept focuses less on abstract characteristics and more on the specific needs of individuals and their qualitative responses to places. Sustainability typically encompasses three dimensions (or pillars): environmental, economic, and social. Many definitions emphasize the environmental aspect. This can include addressing key environmental issues such as climate change and biodiversity loss. (Davoodi, Mandana & Akhlaghdoost, Shahed, 2024).

Therefore, it can be stated that sustainable architecture refers to design and construction methods that contribute to sustainability by utilizing local materials, implementing energy-efficient designs, and minimizing waste during construction. In the past, architects selected architectural forms that suited the climate, which was itself a sign of their consideration for sustainability. In construction management, multi-criteria decision-making (MCDM) approaches have been used over the past decades to address issues related to engineering projects, especially when data is limited. MCDM is a potential technique for handling complex decision-making problems. This method considers various criteria to analyze a problem and then provides solutions using diverse indicators in ambiguous and uncertain environments. Multi-criteria decision-making methods in construction management can be effectively combined with intelligent methods to address the multidimensional challenges associated with engineering projects. The synergy of these two approaches provides a robust framework for tackling the various issues and considerations that arise in these projects.

Considering the various characteristics and complexities of projects, the research gaps in this area can be summarized as follows:

1.The emphasis on construction management methods in the academic literature presents a limitation. Some studies focus exclusively on construction management techniques without adequately addressing the potential contributions of intelligent techniques in the management of engineering projects.

In the examination of intelligent techniques, the judgments of experts have been overlooked; and 3. There is an excessive emphasis on specific stages of the project, such as particular phases in engineering projects.

2. Therefore, we have conducted a comprehensive review that integrates expert judgments with objectively measured data processed through intelligent techniques for engineering projects. The innovation of this review lies in its emphasis on the extensive application of intelligent techniques at all stages of the life cycle of an engineering project. This analysis emphasizes the comprehensive integration of intelligent techniques across various conditions, from scenarios with limited data to those with abundant data. Furthermore, as the project advances to the engineering construction phase, the volume of data significantly increases, necessitating a shift toward data-driven approaches. Construction sites are becoming real data producers, generating real-time information about project progress and quality control.

5- sustainable construction

Sustainable construction means using recyclable and renewable materials in building projects while minimizing energy consumption and waste production. Its primary goal is to reduce harmful impacts on the environment. Sustainable construction principles are based on three main concepts:

- Resource Efficiency: The use of natural resources in an efficient and sustainable manner, ensuring that these resources are not jeopardized for future generations.
- Pollution Reduction: Decreasing the emission of pollutants into the environment, including air, water, and soil pollution.
- Quality of Life Improvement: Enhancing the quality of life for residents and users of buildings, including aspects of health, well-being, and safety.

5-1- Benefits and Importance

There are numerous benefits for the environment, economy, and society. Some of these benefits include:

5-1-1- Reducing Environmental Impacts

Reducing environmental impacts can help decrease greenhouse gas emissions, air and water pollution, and the destruction of natural habitats.

5-1-2- Lower Operating Costs

Sustainable buildings typically have lower operating costs compared to traditional buildings, as they consume less energy and fewer resources.

5-1-3- Increased Property Value:

Sustainable buildings tend to have a higher value than traditional ones because they are more attractive to buyers and renters.

5-1-4- Enhanced Health and Well-being:

Sustainable buildings can improve the health and well-being of residents and users, as they offer better air quality and use fewer toxic materials.

6- Importance of Optimization in Construction Management

Every construction project has specific goals that must be achieved. It is worth mentioning that, in many cases, these goals may conflict with one another. In such situations, the construction manager plays a crucial role. They are responsible for clarifying the given objectives and preventing costly issues that could disrupt the normal progress of the project. Project management offers numerous advantages, including:

6-1- Improved Productivity

Project management helps streamline processes, optimize resource allocation, and minimize waste, leading to increased efficiency and productivity.

6-2- Risk Reduction

Project managers identify and manage potential risks, implementing preventive measures to effectively mitigate them.

6-3- Stakeholder Satisfaction

Clear communication, regular updates, and adherence to the project timeline and budget enhance stakeholder satisfaction.

6-4- Cost Control

Project management techniques such as budgeting, cost estimation, and tracking help control expenses and prevent cost overruns.

6-5- Quality Assurance

Project managers ensure that projects meet quality standards by implementing quality control measures and conducting thorough testing. (Borhani Zarandi, Roghieh, 2024).

7- Modern Methods in Construction Management

7-1- Building Information Modeling (BIM)

Building Information Modeling (BIM) is a digital representation of the physical and functional characteristics of a building. It enables architects, engineers, and contractors to collaborate more effectively, reduce errors, and enhance efficiency. Additionally, it facilitates the creation of virtual models that can be used for simulation, analysis, and visualization. BIM data can be used to represent the entire lifecycle of a building, from inception and design to demolition and reuse of materials. Spaces, systems, products, and more can be displayed in relative scale to each other and, in turn, to the entire project. By marking conflicts, it helps prevent creeping errors during various stages of development and construction.

7-2- Lean Construction

Lean construction is a method aimed at reducing waste in the timeline by finding ways to maximize productivity and efficiency. This approach is similar to value engineering and applies lean manufacturing principles to construction. With lean construction, projects are completed faster, costs are lower, and productivity is maximized at every stage of the lifecycle. Lean construction could be the future of the construction industry. Its most significant advantage is the reduction of production waste through decreased resource usage and increased capacity for innovation. In modern construction methods, using new and more sustainable materials can lead to more efficient project execution. Lean construction can help minimize process waste, optimize resources, and ultimately increase profitability.

7-3- Internet of Things (IoT)

The Internet of Things (IoT) refers to a wide range of objects and devices in our environment that are connected to the internet. These can be controlled and managed through applications available on smart phones and tablets. The use of the Internet of Things (IoT) in the construction industry aids in the collection of precise and up-to-date data. This data can lead to improved decision-making and project management. By utilizing sensors and smart devices, the project's status can be monitored at any moment, allowing for quick responses to any issues that arise.

7-4- Lightweight Construction

Today, in many countries with a rich and powerful construction and architectural industry, architecture and structure complement each other beautifully. With the continuous advancements in technology and modern sciences, the pursuit of creating aesthetically pleasing and sustainable works that meet the quantities and qualities of both an artistic creation and a robust structural indicator is undeniable. This integration not only blurs the distinction between structural design and architectural expression but also represents a strong approach to optimizing the use of time, space, and energy. Structure is a fundamental aspect of establishing space in architecture. The ability to bear and transfer loads, along with the inherent functions of a structure, plays a crucial role in architecture, ultimately leading to the formation of the building's main framework .

Structure and architectural design are inseparable, whether in a simple shelter or an enclosed space for worship or commerce. In any case, buildings are made from materials and must be resilient and stable against natural forces such as weight, wind, and fire. (Davoodi, Mandana & Fotuhi, Ehsan, 2023) Lightweight construction refers to the use of materials and techniques that reduce the weight of structures. This not only helps decrease transportation and construction costs but also enhances the stability and safety of the buildings. The use of innovative materials such as composites, steel and wooden panel structures, lightweight concrete, trusses, space frames, and tension structures are among the effective methods in lightweight construction.

7-4-1 Lightweight Concrete

As an efficient and sustainable material, lightweight concrete can be beneficial in constructing lightweight, resilient, and cost-effective residential structures. Due to its insulating properties, lightweight concrete helps maintain a balanced temperature and reduces noise from the outside environment. This quiet atmosphere contributes to lowering stress and anxiety in individuals, fostering a sense of security and tranquility within the space. (Ansari Samani, Azam & Davoodi, Mandana, 2024).

Features of Steel and Wooden Panel Structures
Lightweight and portability: These structures are easily transportable and installable, reducing construction time.
Durability and strength: Steel has high resistance and is durable against weather conditions, while wood acts as an excellent thermal insulator.
Environmental compatibility: The wood used can be sourced from sustainable resources, and steel has a high recyclability.
Flexibility in design: These structures allow for diverse designs and can easily change shape or expand.
Low maintenance costs: Due to the durability of the materials, they require less maintenance.

Table1: Features of Steel and Wooden Panel Structures. (۶)

7-4-2- Trusses

A truss is a structural framework composed of triangular shapes, which support loads through a network of interconnected members. In a truss, the members experience only axial forces tension and compression, while shear and bending are minimized. Although some bending stress might occur due to friction and distributed loads, it is generally considered alongside axial forces in practical analyses .

The triangle is the fundamental geometric unit because it maintains its shape without altering side lengths, unlike other polygons such as rectangles, which can be unstable. When a cable is stretched between two fixed points, the horizontal forces are balanced by the supports. If one support is hinged and the other is a roller, the system may become unstable, as the roller support can only react to vertical forces, while horizontal forces could cause movement. (Davoodi, Mandana & Fotuhi, Ehsan, 2023)

7-4-3- space-efficient structures

A space efficient structure is a three-dimensional truss system with spans that extend in two directions, and its members are subjected only to tension or compression. While the term "frame" accurately refers to structures with rigid connections, "space structure" is commonly used for both pinned and rigidly connected structures. Most space structures are composed of uniform, repeatable modules with parallel layers above and below, similar to the upper and lower elements of a truss. Space efficient structures can utilize various shapes, including the half octagon (tetrahedron), quadrilateral (triangular pyramid), and all polygons, extensively in buildings. In addition to covering large spaces with horizontal roofs, this system can also be used for other areas such as walls and sloped or curved roofs. As long as the geometry of space structures allows for the use of various shapes, half-octagons (tetrahedrons), quadrilaterals (triangular pyramids), and all polygons are extensively used in buildings. Besides covering large spaces with horizontal roofs, this system can also be applied to other sections such as walls and sloped or curved roofs. (13)

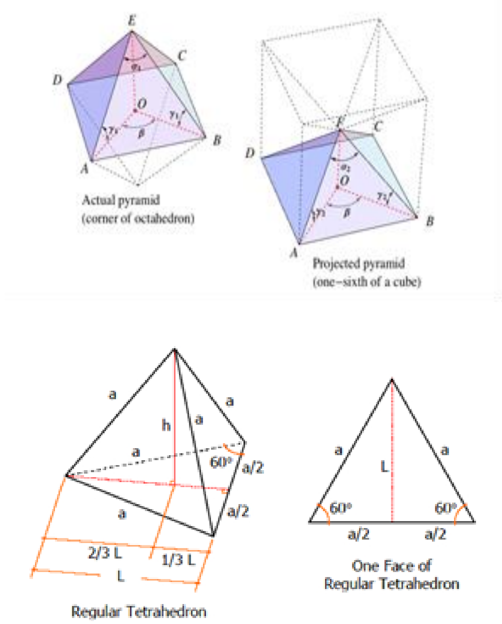

Figure 1: Module Common geometries for space-efficient structures. (13)

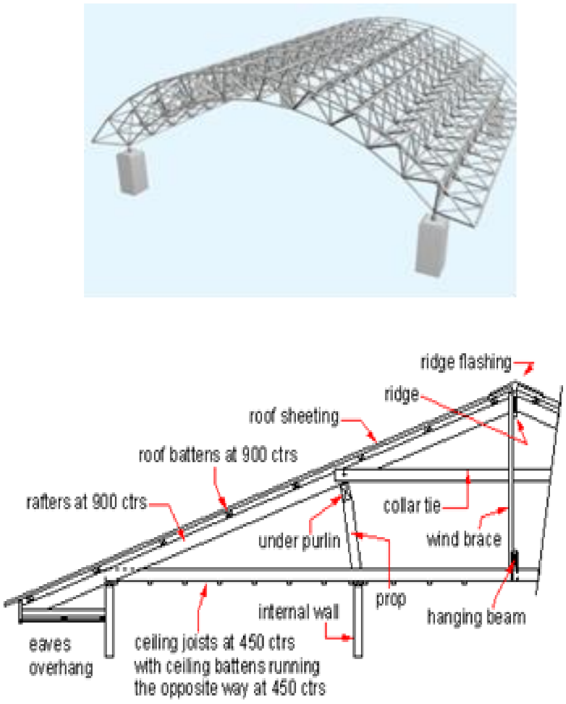

Figure 2: Comparison of space-efficient structures with truss and purlin systems. (a) Space structures are three dimensional and can withstand forces in two or more directions. (b)In comparison, truss and purlin combinations are essentially two-dimensional and can only bear loads in one direction.(13)

7-4-4- Tent structures

Horst Berger, one of the engineers involved in the design of a large number of recent tent structures, writes: Despite the great progress of construction materials and technology in recent years, there is a fundamental lack of understanding of the design and behavior of tent structures among most architects. The temporary nature and vulnerability are combined with the words shell and tent to obscure the fact that such structures are safer and more reliable than many traditional systems. Because they are practically very light and provide an integrated and flexible waterproof shell. The complexity of tent structures, including the state of lines and curves, hides the simplicity of the behavior of this structure, which is based on tension and curvature, and its ability to carry loads. This simplicity of form creates a visible shell. In tent structures, architectural form and structural function are the same. As a result, building engineering and architecture are inseparable and understanding the structure's behavior is an essential tool in the design of this type of structures. Due to the myopic relationship of visual appearance and structural behavior, it is not difficult to understand such a concept for using this system. (13)

7-5- Agile construction

Agile is a repetitive, flexible, and "process-oriented" approach that helps project managers achieve better results. Being part of an agile team means you can effectively manage unforeseen circumstances. Whenever a change or modification is necessary, the agile process incorporates these changes based on a review of completed activities. This is the most adaptable method available among project management methodologies. Whenever a client has a new request or the team encounters a fresh idea, you can easily implement the necessary changes.

7-6- Smart Construction

Smart construction is a new construction model that is deeply integrated with next-generation information technology and designed to cover the entire lifecycle of an engineering project. This approach facilitates the digitalization of the design process, the industrialization of construction, and the modernization of management. It acts as a leading pathway to accelerate transformation and enhance the construction industry, bringing about fundamental changes in production methods. The goal of smart technology is to enhance the comfort of occupants, reduce energy consumption, lower operational and maintenance costs, improve security, and extend the lifespan of related equipment and facilities.

The framework for using smart techniques in construction management encompasses the life cycle of engineering projects and addresses the unique challenges posed by data dynamics, complexity, uncertainty, and diversity. Construction design is typically based on the specific characteristics of a project; in other words, the planning of construction, allocation of labor resources, and budgeting for an engineering project cannot simply be applied to other projects without modifications. Instead, lessons learned from previous engineering projects, including both successful and unsuccessful experiences, provide guidance for decision-making by project managers.

8- Construction Management

It can be said that this type of management is a professional service that supports the proper progress of a project by effectively managing planning, costs, quality, safety, time, and performance. The goal of construction management is to meet the client's needs and deliver a practical and economical project. The construction manager provides direct oversight of the entire project for the client. The primary goal of construction management is to closely monitor and control the processes of a project in terms of quality, cost, and time. This involves a wide range of responsibilities and encompasses various topics. For this reason, the construction manager plays a crucial role in a project. The duties and responsibilities of construction management include:

- Determining the budget and estimating costs–
- Planning the work schedule–
- Selecting the appropriate construction methods and strategies for the project–
- Maintaining a good and close relationship with clients–
- Negotiating contract agreements with staff and other project stakeholders–
- Ensuring the safety and protection of workers on-site–
- Collaborating with multiple project consultants–

9- Smart techniques in Construction Engineering Management (CEM)

This section elucidates methodologies for Multi-Criteria Decision-Making (MCDM), research areas related to intelligent techniques, and the application of advanced methodologies in underground space exploitation (USE). MCDM techniques can be utilized to address various problems in CEM related to fuzzy and uncertain environments. Fuzzy set theory was originally developed to resolve and simulate the intrinsic vagueness of the cognitive procedures of human beings. Membership functions and corresponding fuzzy numbers are the basic elements for decision-making.

10- Multi-Criteria Decision Making

MCDM is regarded as a smart technique in CEM due to its ability to handle complex and multidimensional decision problems effectively. Using MCDM methods, decision-makers can systematically evaluate and prioritize different alternatives based on the determined criteria. This approach allows decision-makers to make informed choices that optimize multiple objectives simultaneously. Thus, MCDM serves as a smart decision-making method in CEM by providing a structured framework for navigating complex decision scenarios and achieving optimal solutions.

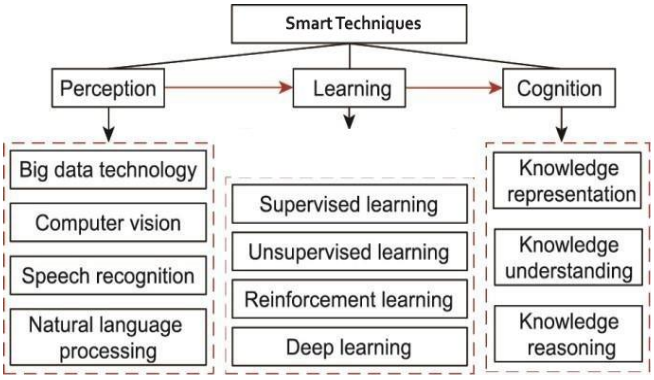

Diagram1: Smart Techniques.

11- Challenges and Obstacles

In recent years, the construction and premature demolition of buildings have incurred substantial costs. The significant energy consumption and the overwhelming volume of waste and construction debris resulting from the demolition of unstable structures have posed serious environmental challenges for many societies, particularly in large cities. This situation exists even as building systems and construction technologies rapidly evolve alongside advancements in other scientific fields, allowing for the use of diverse, practical, and flexible systems in architectural design, especially in structural engineering .

Despite significant advancements in construction management, challenges persist. Issues such as the reluctance to adopt new technologies and a lack of necessary skills in the workforce still exist. Additionally, these challenges can be attributed to resistance to change, the need for training, and investment in new technologies. To overcome these challenges, a comprehensive approach and close collaboration among all stakeholders are necessary. Despite the advancements made, research indicates that education and the development of managerial and technical skills are essential to address these challenges effectively.

12- Conclusions

The use of modern methods in construction management not only aids in optimizing processes but ultimately leads to sustainable and efficient building practices. These innovations aim to achieve ambitious goals, including carbon neutrality and sustainability. They not only transform the execution methods of construction projects but also reshape the long-term environmental and social impacts of these projects. Optimizing construction management through modern methods can help achieve sustainable and economic goals in the construction industry. The use of innovative technologies and modern approaches not only enhances project efficiency but also contributes to environmental preservation and the improvement of quality of life. To reach these goals, collaboration and information exchange among all stakeholders and professionals in the industry are essential. Construction management is a field recognized for its dynamic and evolving nature. In this area, projects take shape in a lively environment influenced by technological advancements, regulatory changes, and shifting economic landscapes. Managing construction and engineering projects requires a high level of adaptability to ensure that projects are successfully completed. Project managers must confront complex challenges such as tight deadlines, budget constraints, and unforeseen obstacles while staying informed about the latest innovations in construction technology and sustainable practices. The dynamic nature of construction management requires a proactive approach to problem-solving, effective communication, and strategic decision-making to address the multifaceted challenges present in this industry. By guiding the phases of planning, design, engineering construction, operations, and maintenance, data-driven decision-making techniques facilitate increased efficiency and enhance sustainability.

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