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Advances in Civil Engineering Materials: The Case of DPWH-Aurora District

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Abstract

This study aimed to know the usability of modern technologies and other advancements in science to facilitate the choice of materials in the DPWH Project in the District Office of Aurora. More specifically, it answered the following: (a) standard processes involved in the procurement of materials in the DPWH-Aurora; (b) advances in civil engineering materials; and (c) plan of action to facilitate the usability and utilization of these advances in civil engineering materials. The descriptive research method was used in this study, which entails collecting, analyzing, categorizing, and tabulating information about current situations, practices, beliefs, processes, trends, and cause-and-effect relationships before providing adequate and accurate interpretations of the information with or without the aid of statistical techniques. Within the scope of the study, Aurora has ten engineering offices: eight municipal engineering offices, one provincial engineering office, and the District Office of the Department of Public Works and Highways. The findings revealed that the civil engineers often employed the standard processes involved in the procurement of materials in the DPWH-Aurora while they often managed to establish advances in civil engineering materials in different projects. It was concluded that the need for a cost estimation approach that incorporates all estimation components from both kinds, including estimator-specific, design-specific, and project-specific aspects, is critical. It was suggested that Project Engineers should be utilizing common benchmarks that could aid in categorizing, grouping, and ranking cost estimation projects.

Keywords: Material Advances; Civil Engineering; Infrastructure; DPWH.

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1. Introduction

The goal of advances in civil engineering is to create machine components that assess human thought processes and reflect them in reality. Applications for artificial intelligence have recently been developed in a variety of engineering fields, including civil engineering. Artificial intelligence will become more prevalent in engineering fields over the next few years, according to the rapidly growing body of research on the subject. The use of artificial intelligence techniques in civil engineering is the main topic of this special issue. The foundation of this special issue is primarily hybrid artificial intelligence research in the areas of structural engineering, construction management, hydrology, hydraulic engineering, geotechnical engineering, environmental engineering, transportation engineering, coastal and ocean engineering, and building materials. This special edition also includes review articles that discuss applications of artificial intelligence in the field of civil engineering.

Technology development is essential for overcoming obstacles in construction projects. Numerous civil engineers have emphasized the need of adopting these technologies to improve the performance of construction projects. The building sector faces a variety of difficult problems that go beyond technological limitations. These issues serve as the driving force behind the use of smart solutions to these challenging issues. For instance, using intelligent strategies to handle problems like choosing the most competent prime contractor, projecting project performance at various stages, evaluating the danger of cost overruns, or running past a proper plan may put numerous contractors at more risk. The field of civil engineering has recently started to view artificial intelligence (AI) solutions as the best approach for dealing with hazy and confusing problems.

In the case of the Department of Public Works and Highways in the District Office of Aurora, engineers believed that civil engineering is an ever-changing industry. People have watched the discipline of civil engineering change from using only concrete to designing and constructing everything from bridges to buildings as a result of technological improvements. With the help of automated machinery and 3D printing, civil engineers are no longer restricted to designing on paper while sitting at a desk; instead, they are using both their hands and minds to move around a construction site. Hence this study on the Advances in Civil Engineering Materials: The Case of DPWH-Aurora District.

1.1 Conceptual Framework

This study is anchored with the concept of Advances in Civil Engineering Materials. High-quality papers on a variety of subjects about the characteristics and functionality of civil engineering materials can be found in Advances in Civil Engineering Materials. Characterization includes things like chemical make-up, nanostructure, and microstructure; physical qualities include things like stiffness, strength, and fracture behavior; constructability includes things like construction techniques, quality assurance, life cycle analysis, and sustainability; and durability includes things like durability. Papers may present modeling or experimental investigations based on in-lab or out-of-door observations. Particularly appreciated are papers that discuss the sustainability of engineering materials or how materials affect the sustainability of engineering structures.

For civil engineering to advance over the ages, there had to be a constant battle between the materials that could be used, the spans or heights that could be reached, the active loads, and the natural forces of water, fire, wind, and earthquakes. Construction work enhances the standard of living for people, but it also has a substantial negative influence on the environment. Energy is needed and greenhouse gases are produced during the manufacturing of construction materials. The constant demand for quick house delivery in developing nations is frequently met by the promotion of low-cost or economical building technology and materials. There is potential to transform how we build and renovate buildings thanks to new high-tech materials. They bring value through improved functionality and performance. The development of energy-efficient procedures and the use of discarded or recycled materials during production can reduce the carbon footprint of construction materials. In a changing climate, durability presents new issues that new materials can assist overcome.

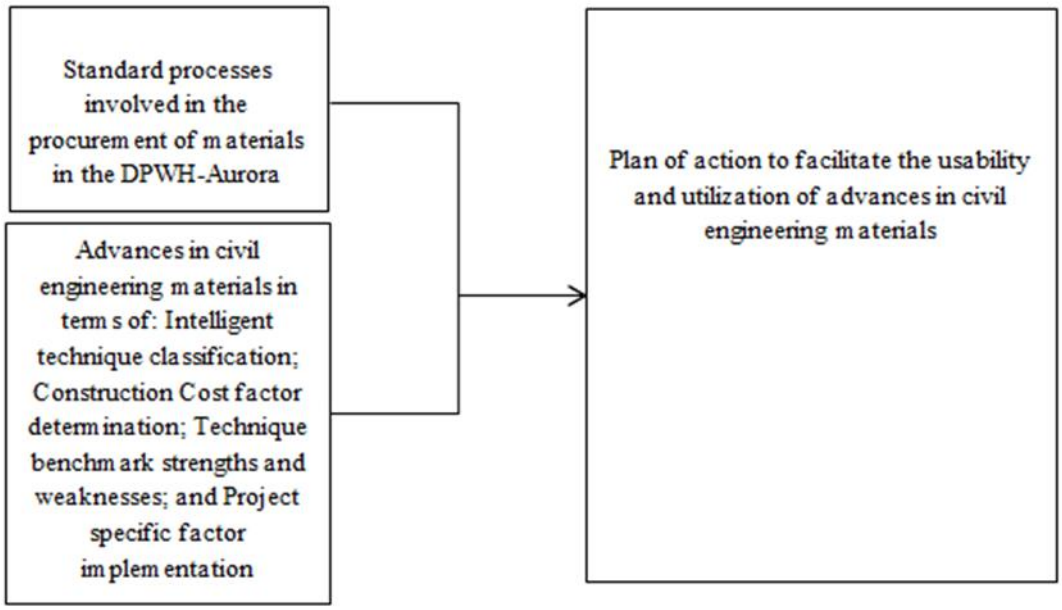

Figure 1: Paradigm of the Study.

2. Materials and Methods

This study aimed to know the usability of modern technologies and other advancements in science to facilitate the choice of materials in the DPWH Project in the District Office of Aurora. More specifically, it answered the following questions:

1. What are the standard processes involved in the procurement of materials in the DPWH-Aurora:
1.1. Preparation of Project Procurement Management Plan (PPMP);
1.2. Pre-procurement conference;
1.3. Advertisement / Posting;
1.4. Application for Eligibility / Expression of Interest;

1.5. Eligibility evaluation, including notification of eligible and ineligible bidders;
1.6. Issuance of bid documents;
1.7. Site inspection;
1.8. Pre-bid conference;
1.9. Submission / Opening of bids;
1.10. Bid Evaluation;
1.11. Post-qualification;
1.12. BAC Deliberation and Approval of Resolution of Award;
1.13. Contract Preparation and Approval; and
1.14. Issuance of Notice to Proceed?
2. How may the advances in civil engineering materials be described in terms of:
2.1. Intelligent technique classification;
2.2. Construction Cost factor determination;
2.3. Technique benchmark strengths and weaknesses; and
2.4. Project-specific factor implementation?
3. What plan of action may be proposed to facilitate the usability and utilization of these advances in civil engineering materials?

2.1. Scope and Coverage

This study is only limited to the usability of modern technologies and other advancements in science to facilitate the choice of materials in the DPWH Project in the District Office of Aurora. It includes the responses on the first sets of variables in Standard processes involved in the procurement of materials in the DPWH-Aurora along Preparation of Project Procurement Management Plan (PPMP); Pre-procurement conference; Advertisement/Posting; Application for Eligibility/Expression of Interest; Eligibility evaluation, including notification of eligible and ineligible bidders; Issuance of bid documents; Site inspection; Pre-bid conference; Submission/Opening of bids; Bid Evaluation; Post-qualification; BAC Deliberation and Approval of Resolution of Award; Contract Preparation and Approval; and Issuance of Notice to Proceed. The second sets of variables are Advances in civil engineering materials in terms of Intelligent technique classification; Construction Cost factor determination; Technique benchmark strengths and weaknesses; and Project specific factor implementation.

2.2. Significance of the Study

This research was focused on the findings regarding the usability of modern technologies and other advancements in science to facilitate the choice of materials in the DPWH Project in the District Office of Aurora. This study was very significant to the following people:

Administrators. The study's findings will serve as a wake-up call for them to enhance, update, and revise their current competencies in civil engineering to cope with globalization.

Instructors/Professors. They will be given insights and an understanding of how to fulfill industry demands by adjusting and upgrading their teaching methods and instructional materials.

Researchers. The findings of this study will offer them information and knowledge about the strengths and limitations of current civil engineering capabilities, from which many researchable concerns will be uncovered and further explored in the pursuit of truth and knowledge.

Civil Engineering Students. This study will make them aware of the importance of developing their skills and competencies early to be ready and equipped for the actual world of work in the engineering profession.

Civil Engineers. This study will assist students in fulfilling the needs of the period, notably in satisfying the expectations for the globalization of the civil engineering profession for easy employment in the United States or elsewhere.

Curriculum Planners. This research will help them develop a more comprehensive and effective civil engineering program in the future.

Policy-Makers. This study will give them a clear picture of civil engineering education in the province, allowing them to develop educational plans and policies that will make them more responsive to the demands of the time by instilling quality education and excellence, both of which are desperately needed in the global arena of education.

Community. This will raise community knowledge of the state of civil engineering competencies and their employability, encouraging children to enroll in this course.

2.3. Design

The descriptive research method was used in this study, which entails collecting, analyzing, categorizing, and tabulating information about current situations, practices, beliefs, processes, trends, and cause-and-effect relationships before providing adequate and accurate interpretations of the information with or without the aid of statistical techniques. Based on a thorough analysis of the phenomenon, the descriptive technique offers a broader and deeper understanding of the phenomenon. This method is very tenable in the present study since it stressed present conditions, specifically on the advancements in science to facilitate the choice of materials in the DPWH Project in the District Office of Aurora.

This study was conducted in the Province of Aurora which is composed of eight municipalities. The researcher confirmed project monitoring and coordination throughout the municipal engineering office. It is easier for him to access the target responders as an engineer detailed at the District Office. Within the scope of the study, Aurora has ten engineering offices: eight municipal engineering offices, one provincial engineering office, and the District Office of the Department of Public Works and Highways.

2.4. Respondents and Sampling

A total of 110 respondents will be included in this study. The subject of the study will be based on the number of engineers available/present in the different Engineering Offices in Aurora on the day of the data gathering. For more convenience, the Slovene formula will be used to select the respondents. The total number of engineers in the national and local offices in the province of Aurora is 151. The sample size (n), given the population size (N), and the margin of error (e), is calculated using Slovene. It uses a formula to estimate sampling size that is based on random sampling. The computed sample is 110. The following is the breakdown of respondents from each office:

Table 1: Distribution of Respondents.

Office	Number of Engineers	Sample Size	Percentage Distribution
MEO-Baler	16	12	10.6%
MEO-San Luis	12	8	7.9%
MEO-Maria Aurora	15	11	9.9%
MEO-Dingalan	9	7	6.0%
MEO-Dipaculao	15	11	9.9%
MEO-Dinalungan	7	5	4.6%
MEO-Casiguran	11	8	7.3%
MEO-Dilasag	9	6	6.0%
PEO-Aurora	19	14	12.6%
DPWH-Aurora	38	28	25.2%
Total	151	110	100.0%

Following the administration of the questionnaire to the respondents, revisions, and improvements will be made based on the feedback from the pre-test. A permit to perform this study will also be obtained from the District Engineer concurrently with the drafting of the questionnaire. The researcher will ask for assistance from the Head of Office to efficiently facilitate its administration among the respondents. Following approval of the request to carry out the study, the questionnaire will be distributed to the pre-identified respondents. It will be directly administered to the responders by the researcher. Fully accomplished questionnaires will be immediately retrieved and checked to ensure that all items are answered.

The data will be tabulated and will be analyzed in terms of their statistical meanings and significance. The following statistical tools will be used corresponding to the problems of the study.

For the statement of problem numbers 1 and 2, the weighted mean will be used to obtain the responses of the engineers.

Weight	Interval	Description
1	1.00-1.80	Never
2	1.81-2.60	Seldom
3	2.61-3.40	Sometimes
4	3.41-4.20	Often

5	4.21-5.00	Always

3. Results

Table 2: Standard Processes involved in the Procurement of Materials in the DPWH-Aurora.

Item	Statement	WM	VI	
1.	Preparation of Project Procurement Management Plan (PPMP)	3.59	Often	4
2.	Pre-procurement conference	3.32	Sometimes	11
3.	Advertisement/Posting	3.50	Often	7
4.	Application for Eligibility/Expression of Interest	3.31	Sometimes	12
5.	Eligibility evaluation, including notification of eligible and ineligible bidders	3.18	Sometimes	14
6.	Issuance of bid documents	3.62	Often	2
7.	Site inspection	3.57	Often	5.5
8.	Pre-bid conference	3.25	Sometimes	13
9.	Submission / Opening of bids	3.64	Often	1
10.	Bid Evaluation	3.42	Often	9
11.	Post-qualification	3.60	Often	3
12.	BAC Deliberation and Approval of Resolution of Award	3.48	Often	8
13.	Contract Preparation and Approval	3.35	Sometimes	10
14.	Issuance of Notice to Proceed	3.57	Often	5.5
AWM		**3.46**	**Often**	

Legend: Weighted Mean (WM); Verbal Interpretation (VI); Rank (R); Average Weighted Mean (AWM)

The process of acquiring or receiving products, services, or works from an outside source is known as procurement. Researching, choosing, ordering, and paying for the raw materials needed to build a building or other structure is known as material procurement. Any sort of procurement entails finding and choosing suppliers or vendors, haggling over terms and costs, and awarding contracts. The supply chain management practice of direct procurement is crucial, and its effects on an organization's bottom line can be substantial. To make the greatest choices for their organization, companies must carefully weigh all of the relevant aspects. Although the phrases procurement and purchase might be used interchangeably, they have different meanings. Purchasing is the act of buying products or services, whereas procurement is a more comprehensive phrase that includes sourcing, negotiating, and contract management in addition to purchasing.[1]

When purchasing materials, several aspects need to be taken into account, such as price, availability, and delivery time. To receive the maximum value for their money, organizations must strike a balance between these elements. When buying materials, price is frequently the main factor to take into account. [2} said that companies aim to pay as little as possible for the goods and services they want. It is crucial to evaluate costs from several suppliers, bargain for the best deal, and use strategic sourcing.

When buying materials, quality is yet another crucial factor. Quality is important because it influences how well the materials or items being purchased perform. For instance, even if a construction company purchases wood that is of a lesser grade than needed for a stable structure, it will be unable to offer its consumers a high-quality result. [3] also claimed that companies like to buy products that adhere to their

standards and specifications. For the quality they want, they might have to forgo some savings. Businesses may benefit from having an advantage over rivals as a result.

Another key aspect to think about is how quickly the materials will be delivered. Businesses want to make sure that the supplies they require arrive on schedule. If the suppliers are spread out throughout the nation or the globe, this may be difficult. To control expectations and include anticipated delivery dates in your vendor contracts, it's critical to have a solid understanding of the supply chain. The procurement of materials is a crucial component of direct procurement since it ensures that companies can locate and acquire the raw materials required to maintain their operations. Effective material procurement also lessens the likelihood of supply chain interruptions brought on by shortages [4].

A considerable portion of the time, procurement operations are also in charge of making sure that products are purchased at the most affordable costs, which can result in significant cost savings for the business. Additionally, it can aid in gaining a competitive advantage because some suppliers might grant larger orders with better conditions. The best technique of procurement for an organization will rely on the kind and quantity of products needed as well as the company's preferences and budget. Direct, indirect, and internet procurement are a few popular techniques.

Everything that the project will purchase is listed in the Project Procurement Management Plan (PPMP), which is divided into categories for products, services, and infrastructure. The PPMP has two key functions: (a) it acts as a roadmap for the procurement and contract implementation processes and is a crucial source of information for procurement monitoring; and (b) it is a key tool for resource and financial management, giving the procuring entity the flexibility to make the best use of limited resources. Only if the proper plan is in place can a business excel in the procurement department [5]. The next stage is to create a complete plan based on the organization's information and whereabouts once you have realized the crucial function that the procurement process plays in the process.

A procurement management strategy outlines the requirements for a specific project as well as the processes that must be taken to enter the final contract. The procedure is necessary to acquire the goods or services that the company deals in is referred to in this context as the specific project. Everything about procurement, including the things to be bought, contracts, the approval process for contracts, cost estimation, and decision criteria, is spelled down in the plan. [6] stated that estimating the project's funding requirements is essential before submitting a bid through the procurement process. For future reference, it is important to compare and analyze elements such as net present value analysis, capital budgeting, and cost-benefit analysis when estimating.

Overall, the project's structure is determined by the procurement management strategy. Throughout the project, it can serve as a guide for the organization and relevant stakeholders. A procurement management plan is always adaptable and may be changed to reflect changes occurring within the firm or in the environment, improving more efficient business operations. A sound procurement strategy always creates opportunities for cost, time, and effort savings that lead to corporate compliance. This is so that a plan may properly outline the project from beginning to end. Additionally, it guarantees that everyone engaged comprehends each step from the beginning to the end [7].

A task, its start date, end date, and budget are all clearly stated in the project schedule. The work must be divided into distinct tasks for various responsibilities, including those of outside contractors, vendors, and suppliers of service providers. Vendor management is a crucial step in the procedure. It aids in ensuring that the vendors' work is satisfactory. [8] stated that techniques for vendor control should be included in a plan that explicitly states the declaration of results and references.

Pre-qualifying the vendors you want to collaborate with is essential after putting up the vendor control measures. You can decide whether they meet your requirements based on their prior work, the descriptions of the project team, your work process, etc. The roles of the individuals needed to make the process work smoothly are specified in a procurement management plan. The function of project managers, technical managers, contract managers, operational managers, and lawyers is clearly defined, and their work boundaries are established. When dealing with a variety of partners, there is always a significant degree of risk. Each project should have a risk profile in a procurement management plan that includes the project's risk level, risk tolerance, degree of information, contracts, policies, and reviews [9].

Legal jurisdictions should always be addressed in a procurement management plan. It serves to link the project together and inform stakeholders of their work so they can respond appropriately. The terms of payment, modalities, and methods should always be included in a procurement management plan depending on the project. To prevent future disputes and problems, it is crucial to include this element. Plans are continually created while taking various future restrictions and presumptions into account. It could comprise normative requirements, timelines, environments, geographical settings, physical circumstances, levels of quality, or security. A procurement plan aids in the definition of the strategies based on the project's risk, cost, price, and market conditions. It aids in defining the components used in the entire process [10].

The project's lifeblood is its stakeholders. By including them in the process, a procurement management plan allows one to connect with numerous suppliers and vendors. In exchange, they will offer the best services, ultimately making one happy. This specification related to the many components engaged in the process is laid out in a proper procurement management strategy. [11] said that giving deadlines for the project's implementation, identifying the people in charge, and describing what needs to be done all at once is helpful. Every stage of the procurement process requires monitoring and evaluation. It is essential to be aware of the work's progress and to document it for future use.

Any estimate of the cost of construction should be based on specific factors, such as the project's kind, material costs, potential design and scope revisions, the site's characteristics, the project's size, the type of customer, and the tendering process. [12] To compare the various cost estimation proposals, they have presented these elements as a standard. Construction project cost estimates are impacted by a variety of factors. These characteristics can be divided into two separate groups: (i) factors specific to estimators, and (ii) factors specific to designs and projects.

One of the three parties—contractor, consultant, or owner—can serve as the cost estimator. Cost estimates may contain cognitive biases or inaccuracies under the estimator's training and experience. In many instances, the cost estimator makes choices based more on the potential profits or losses of an endeavor than on the actual results of the choice. [13] Additionally, the individual estimator may alter cost following top regional techniques, which vary from nation to nation. This article will concentrate on design and project-specific aspects

as a result.

[14] Project size, kind, ground conditions, client type, material costs, potential design and scope revisions, duration, tendering process, and contract type are some of these considerations. The next sentences go into further depth about these elements' definitions and how they relate to cost estimating. The number of laborers and project size, measured in square feet or meters, are strongly correlated. The cost estimation of some goods, however, may have some biases and grow more reasonable as the number of laborers rises (for example, job scheduling or production rate estimation). Numerous empirical research has been done on how project size affects cost estimation. A good choice of technology, equipment, and labor procedures is necessary while completing a specific sort of project. However, this may restrict the kind of materials that can be used and the number of crew that can be hired, which will have an impact on the project's budget. [15] Project types can be categorized into several different groups. Building construction, special-purpose construction, heavy construction, highway construction, infrastructure construction, and industrial construction are the six main categories of construction projects. The state of the ground should be one of the first issues addressed in any building project before inviting bids. The contractor should still estimate the cost despite not knowing the state of the ground; however, if the assumption is incorrect, this will result in extra charges for poor ground conditions. [16] The parameters of the contract and the behavior of the bidders are mostly influenced by the client type because each construction project has unique client ideas, roles, and objectives. According to Drew and colleagues there are seven different categories of clients: (1) the government; (2) the housing authority; (3) other clients from the public sector; (4) large developers; (5) large industrial, commercial, and retailing organizations; (6) medium and small industrial, commercial, and retailing organizations; and (7) other clients from the private sector.

Table 3: Advances in Civil Engineering Materials in DPWH-Aurora.

Item Statement	**WM**	**VI**	**R**
Intelligent technique classification			
Machine Learning (ML) System	3.35	Sometimes	4.5
Knowledge-Based Systems (KBS)	3.46	Often	3
Evolutionary Systems (ES)	3.56	Often	2
Agent-Based Systems (ABS)	3.60	Often	1
Hybrid Systems (HS)	3.35	Sometimes	4.5
Construction Cost factor determination			
Project Size	3.60	Often	2
Type of Project	3.57	Often	3
Ground Conditions	3.50	Often	4
Type of Client	3.28	Sometimes	7
Material Costs	3.42	Often	6
Design and Scope	3.46	Often	5
Duration	3.64	Often	1
Technique benchmark strengths and weaknesses			
Open	3.52	Often	3
Selective	3.57	Often	1.5
Negotiated	3.45	Often	4
Two-Stage	3.18	Sometimes	5
Serial	3.57	Often	1.5
Project-specific factor implementation			
Client Needs	3.45	Often	2.5

Project Cost	3.44	Often	4
Completion Time	3.54	Often	1
Qualification	3.45	Often	2.5

Legend: Weighted Mean (WM); Verbal Interpretation (VI); Rank (R); Average Weighted Mean (AWM)

The timing of material selection, the kind of materials used, and their accessibility to the local market all show a statistically significant impact on building project cost estimates. Any methods used to precisely estimate the material cost would reduce wastage and increase the major project's cost and time benefits because materials can account for up to 70% of the project construction cost. Additionally, the amount of material needed must be precisely calculated based on the drawing and is independent of the work method or crew performance. [17] However, depending on the laborers' productivity and working style, this element can vary significantly.

[18] The client has more control over the design and building process, depending on their level of skill. To meet the standards demanded by the customer, many project types necessitate that the client selects a design firm to plan and oversee the project phases.

There are five different tendering procedures, including (i) Open Tendering. Local advertisements are used to solicit contractors to submit bids for a contract. (ii)Selective Tendering. The type and size of the contract, as well as the contractor's dependability, are taken into consideration while inviting bids. (iii) Negotiated Tendering. A variant of this is a cost-reimbursement contract, which may be utilized when completion time is more crucial than cost (iv) Two-Stage Tendering. At the design stage, it is utilized to bring in a contractor who may inform the architect of any issues with the building's design. Unit pricing would be negotiated based on the initial bid. (v)Serial Tendering. A typical (notional) bill of quantities is used as the foundation for inviting bids from a predetermined list. [19] The chosen contractor typically offers the lowest bid and agrees to sign several contracts to complete the work at the rates listed in the hypothetical bill of quantities. Choosing one of the aforementioned strategies essentially aims to reduce any additional customer risk. The customer must strike a balance between four factors to achieve this goal: (i) client needs; (ii) project cost; (iii) completion time; and (iv) qualification of the tender to complete the task.

A system that can learn from data is what is referred to as a machine learning (ML) system. In general, the major advantages of ML are (i) the capacity to handle ambiguity, (ii) the capacity to work with incomplete data, and (iii) the capacity to assess novel situations using knowledge gained from precedent situations. On the other hand, ML's primary flaw is its lack of technical explanation, which means that it lacks access to causes independent of the choice. A black box choice falls within this category. However, the most popular ML techniques in construction management are the support vector machine (SVM) and artificial neural network (ANN). [20] The approaches for construction cost estimation that are based on ML are examined in the paragraph that follows.

Structured questionnaires from several tunnel construction sites served as the foundation for this study's data collection technique. The primary flaw in this study was that some construction cost elements were disregarded. An ANN model for the price of building a roadway was introduced by Wilmot and Mei. Price of labor, price of

material, price of equipment, the quantity of pay item, contract duration, contract location, a quarter in which the contract was let, annual bid volume, bid volume variance, number of plan changes, and changes in standards or specifications served as the foundation for cost estimation in this study. [21] This work's significant contribution was that it took into account every important factor. However, the data collection procedure used for training and evaluating the findings, as well as the validation of the suggested approach, were not adequately described. The ANN approach for forecasting seismic retrofit construction costs was suggested. Although this concept is presented as an evaluation tool, it may also be used as a cost estimation technique. The technique was created using information from completed building construction projects. A database compiled from many studies that were conducted during extensive earthwork activities on the construction site of one of the biggest chemical plants served as the foundation for the development of this model. But nothing is said about how the results are validated before they are presented.

One created a hybrid prediction model for cost performance of commercial building projects that combines principal component analysis (PCA) with a support vector regression (SVR) predictive model. The pre-project planning phase was defined using pertinent factors. Based on data from construction projects that were finished within three years of the study's start date, they created their dataset. It created a least squares support vector machine-based cost estimation at completion technique. One construction company gathered the data sets from reinforced concrete construction projects [22].

Any method that applies logical principles to arrive at the required conclusions falls under this category. The key benefits of KBS are (i) their capacity to justify any outcome and (ii) their straightforward techniques (i.e., how simple it is to create KBS). The disadvantages of KBS, on the other hand, are (i) the time required for rule acquisition and (ii) the difficulty of self-learning. The most widely utilized methods in KBS are the expert system and case-based reasoning. [23] The quantity of cases chosen has a significant impact on case-based reasoning's correctness. KBS has recently been integrated with other methods to address the self-learning process's limitations. However, the section of this paper that discusses hybrid systems will go into greater detail about this blend.

Case-based reasoning was suggested as a method for creating conceptual and strategic estimations for construction budgeting. For planning public roads, a cost prediction model was suggested. Additionally, it utilized a genetic algorithm to optimize the rough-set model and rough-set theory to regulate the data collecting. Since the authors included a case-based reasoning component in their cost estimation, their work was categorized as KBS. Using CBR, [24] created a cost-estimating model. Using a genetic algorithm, this research eliminates the uncertainty in selecting the appropriate scenario. It concentrated on building national bridges. How the results were validated, though, was not revealed.

A knowledge-based risk mapping tool was created to determine the costs of multinational building projects. The necessary information and cost calculation criteria were gathered from the literature [25]. Expert interviews were used as part of the validation process to obtain input on the created tool. By automating the process of looking for the best work items, it presented an ontological inference process for estimating building costs. A nondominated sorting genetic algorithm was used to solve, and calculate the overall cost, time, and resources for

construction projects [26].

A class of intelligent systems known as evolutionary systems (ES) is those that continuously optimize using heuristics. It is thought that the fundamental drawback of ES is that because the findings of ES are produced using particular heuristics, it is very difficult to generalize them. The primary driving force for researchers' adoption of ES is their capacity to resolve challenging and uncertain challenges. However, the ES method helps in finding the right answer. Evolutionary systems are typically utilized as optimization techniques where there are multiple solutions. As one of the main branches of artificial intelligence, agent-based systems (ABS) simulate the behavior and interactions of free-floating agents to evaluate how these activities affect the system as a whole. The biggest obstacle in ABS is generalizing the retrieved results [27].

A group of methods combined to address a particular issue is referred to as a hybrid system (HS). Typically, researchers use HS to get around the shortcomings of the separate approaches. Due to the lack of computing tools that could facilitate its implementation, HS implementation could be difficult. A hybrid conceptual cost-estimating approach for sizable mixed-use building projects was also put forth by [28].This proposal used a hybrid methodology that combined statistical analysis, CBR, and database methodologies [29].

4. Conclusion

The research gaps that have been identified from this survey, as per the findings of this report, are as follows. The need for a cost estimation approach that incorporates all estimation components from both kinds, including estimator-specific, design-specific, and project-specific aspects, is critical. No project has made every material advancement in order. A standardized validation procedure that may be utilized to assess the degree of accuracy of a cost estimation project is needed. Many projects struggle with a lack of scientific justification for the outcomes, or more specifically, a lack of technical explanation of how the outcomes have been accomplished.

To close the gaps that have been discussed, further research directions for cost estimates are suggested.

(a) By making cost estimation recommendations that promote the acquisition of human competence, the construction cost estimation is released from the need for human dependability. The more effective method that could take the place of human expertise is a computerized expert system. On the other hand, knowledge management models and methods will help create computerized management systems free of humanitarian restrictions. Capturing and dealing with estimator-specific elements should be the major objective of knowledge management systems. The first approach for the future is to encourage academics and business leaders to use knowledge management systems in construction projects.

(b) The second direction for the future is to support industry professionals and researchers in developing an integrated construction cost prediction system that aims to achieve all the design and project-specific elements that have been described. This will lead to the development of cost-estimation projects based on every design and project-specific factor.

(c) Giving a scientific basis for the cost estimating ideas based on empirical data would explain how the

estimates function and explain the biases of the estimators. To boost the level of confidence in any suggestion, include scientific support for it. Additionally, offering scientific support makes it easier to trace the specifics of the cost estimation process, increasing transparency. Last but not least, offering scientific support improves maintainability.

(d) Formulating a general rule of thumb in the absence of accessible alternative cost estimation techniques. establishing a common baseline for evaluating the projects' level of accuracy in terms of construction cost estimation. Using information from prior attempts, a database may be built to achieve this. The known value of this database should also be included by any future cost-estimating models, as it provides a useful baseline for the accuracy of those models' cost estimations. Cost-estimating projects could be categorized, grouped, and ranked using common benchmarks.

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