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Applications of Optimization and Value Engineering Techniques for Foundations System of Buildings

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ABSTRACT

This paper seeks to give a literature review. That explored the benefits of using value and optimization techniques in the construction sector, namely the foundation systems of high-rise buildings. High-rise building foundations are part of the specialist design and construction industry. They oversee the design and construction and its continuous operation and upkeep. Therefore, when making key decisions concerning the foundations of high-rise structures, owners and builders must consider maximizing the balance of cost and function. Over the years, the notion of VE has grown and expanded greatly, and there are now various standards and associated documents. Many developed nations' building sectors have embraced the benefits of VE and fully used the technique. This article frames the breadth and numerous aspects of VE and optimization techniques in the modern structural engineering setting, especially for foundation systems in high-rise buildings, describes recent work on important subjects, and suggests probable future routes in research and implementation. It has been argued that optimization techniques are engineering techniques that aim to meet the requirements for performance, quality, integrity, reliability, and safety while achieving the lowest life-cycle cost. Optimization techniques reduce construction costs, save time, and streamline preliminary design in construction projects.

Introduction

In recent decades, significant public and private investment in the construction industry has led to the development of recommendations or guidelines for deciding the optimum foundation systems for high-rise buildings, thus reducing construction time and cost. In addition, recent decades have seen dramatic changes in structural engineering. However, there are presently no globally agreed guidelines for identifying variables, challenges, and knowledge gaps to create a decision-support system model. The most cost-effective foundation systems might be determined using optimization and VE approaches throughout the project's life-cycle cost (LCC) and the design phase. Not simply the initiatives indicated above, but any building, project, or asset may be subject to a value management strategy. Value management is a technique that may be utilized for construction sections or subdividing a project. Generally, more significant projects are better suited for value management since the cost of value management studies is more effective. However, VE has become widely used during the last seven decades. In the 1940s and 1950s, Lawrence D. Miles pioneered early VE approaches. Miles worked for General Electric Company as the Manager of Value Service. Miles, widely regarded as the father of VE, released Techniques of Value Analysis and Engineering in 1961 [1]. A management technique called VE is used to carry out a project's core functions as cheaply as feasible. Since it was first used in the 1950s, VE has developed into a standard practice for many government agencies, for-profit engineering companies, and contractors [2]. First, the project's cost is examined in the study when it is being created. Next, an already completed project or projected product is the subject of a value analysis (VA), which evaluates its value. Finally, the item is assessed to determine if it can be improved [3].

In 1982, the General Services Administration (GSA) adopted VM for the first time. VM provides several perks, ranging from financial rewards to boosting professional team spirit. It affects all project participants or stakeholders. Most demands may be addressed directly or indirectly via VM, resulting in satisfaction for all stakeholders. The conference proceedings, international journals, and several engineering databases were searched. Furthermore, Several industry best practices that might impact choosing the appropriate foundation systems for high-rise structures were assessed for their applicability to this study. [4].

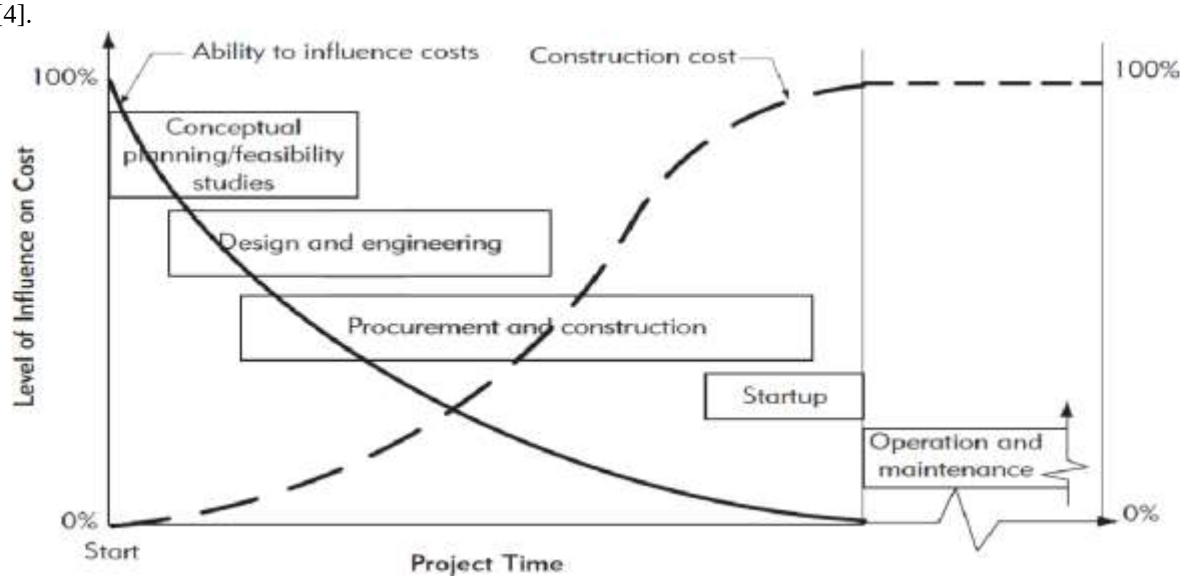

Fig 1 The importance of early project definition

[5]

The purposeful pursuit of higher profit margins and the most notable outcomes possible in each situation is known as optimization. To shorten the project's duration and lower its overall cost, time and money must be optimized. The most important value is achieved with the help of this time and cost optimization. Cost optimization reduces the costs associated with a project, from the first client concept to the project's completion and final on-site payment [6]. Optimization is applied in many science and engineering sectors, including structural engineering. Design objectives in structural optimization, for example, are structural criteria used to judge the soundness of a design, such as maximum stiffness, minimal life-cycle cost, minimum construction cost, and minimum weight [7]. Through investigating various design concepts, materials, and construction techniques, VE is used to examine project requirements to deliver the necessary functionality at the lowest LCC without jeopardizing the client's functional and financial goals; as shown in Fig 1, There are numerous ways to apply VE, even during construction. However, A greater return on time and effort is achieved if the tool is used early.

Poor knowledge and information can lead to poor value, mistakes, bad attitudes, reluctance to seek assistance, lack of time, outdated standards for measuring human interactions, and inaccurate information. As demonstrated in Fig 1, VE assists a project decision-maker in satisfying the customer's desire for cost efficiency in a short time, five options for improving VE:

- Increase the function's value while maintaining the ongoing cost.
- While keeping the original function lowers the cost.
- Enhance functionality or bill at a higher rate than necessary.
- Function and costs are reduced; the process generates more value than it costs.
- Cut costs while improving function.

Building and industrial construction projects are crucial to the success of VE instruments focused on the sector. This is generally the most challenging part of industrial and heavy projects, as demonstrated in Fig 1. VE focuses on[8];

- Quality improvement of projects,
- Saving money on projects,
- Promoting creativity,
- Removing redundant and expensive design components,

Although significant research has been completed with value engineering methods and decision-making, most of that work has been conducted in one country. Only limited joint research exists that crosses country boundaries, and that has happened primarily where the construction industries in those countries were similar. Much existing research aims to determine how VE affects industrial and construction projects.

Data Collection

To represent the use of VE on building projects, this evaluation is based on works in the field of VE that have been gathered from credible academic journals between 1990 and 2022. The journals are listed in the Engineering Index or Science Citation Index Expanded databases and have had a significant impact on VE. Two searches were carried out using Google Scholar, SCOPUS, and Web of Science as paper search engines. Numerous key terminology, such as optimization approaches, VE, foundations systems, design, construction, operation, building, civil engineering, and structural engineering, were utilized in the papers throughout the first phase of the research; of each study. Following two rounds of screening, 93 journal papers were chosen and divided into one main category. Two categories as second-level then focused on some techniques, which are as follows: (A) Applications of optimization techniques for foundation system proposed of buildings. (1) Traditional optimization techniques. (2) Advanced optimization techniques. (2.1) Genetic algorithms (GA), (2.2) Genetic programming (GP), (2.3) Artificial neural networks (ANN), (2.4) Support vector machine (SVM), (2.5) Particle swarm optimization (PSO), (2.6) Fuzzy system (FS), (2.7) Hybrid techniques, (2.8) Other's optimization techniques. This review comprises research publications from many journals covering various topics relating to optimization techniques or VE in foundation systems.

Applications of optimization techniques for foundation Systems Proposed for Buildings

Over the years, several foundation techniques have been applied to high-rise construction projects. The construction industry, especially high-rise buildings, consumes a substantial amount of time and money from both the public and private sectors. Thus it is crucial to ensure that both are used wisely in this vital sector. They are choosing the best foundation system for high-rise buildings. In 2013, Katzenbach presented the importance of enhanced geotechnical design and independent quality control using the 4-eye approach; early in the design process of a building, money is a crucial factor in decision-making. Given the current climate of global competition, cost containment is critical to maintaining high-quality levels when profit margins and market shares shrink (Katzenbach et al., 2013). Zhussupbekov asserted that calculating pile capacities and settlements require an accurate estimation of the geotechnical engineering and geological conditions of the ground. In addition, they reviewed Astana (the New Capital) and West Kazakhstan's geotechnical issues for high-rise structures and structures with distinctive architectural aspects (the Coast of the Caspian Sea) [10] line 1, integrating accurate measurement engineering data and numerical results, the dynamic response of the steel pipe pile foundation during deep neighborhood excavation. In their investigation, Yao and Yijun employed finite element analysis [11].

In 2018, Rabiei and Janalizadeh Choobbasti showed how improving the pile arrangement might provide design components with similar construction costs and the highest performance indices. The exact amount of construction materials would need to be consumed in order to reach the required degree of foundation performance, which might have economic and cost-saving consequences [12]. Shrestha presented an innovative application of piled-raft foundations for 130 m tall wind turbines in 2019 for various site conditions and geotechnical design optimizations [13]. Finally, to solve any problem, different optimization techniques are available. There are two major categories into which optimization techniques may be separated: classical and advanced optimization approaches.

Traditional optimization techniques

Traditional optimization strategies aid in the solution of issues involving continuous and different functions. These approaches assume that the function is differentiable twice in terms of design variables and continuous derivate. Furthermore, these analytical approaches employ differential calculus techniques to find the best spots. Traditional optimization strategies can handle issues with a single variable or numerous variables. Some examples of traditional optimization approaches are shown below [14].

- Linear programming method (LP)
- Non-linear programming method (NLP)
- Quadratic programming method (QP)
- Geometric programming method (GP)
- Dynamic programming method (DP)
- Decomposition techniques

In order to make decisions, make forecasts, estimate costs, and optimize processes, many academics have employed several techniques in the field of construction management. Comparative cost estimate, for instance, assumes a linear relationship between the final cost and the project's primary design elements. On the other hand, traditional cost estimation depends on blueprints and specifications [15].

Advanced optimization techniques

The designs, construction methods, and materials used in high-rise building foundation systems have all been improved by numerous research. For instance, several scholars have studied the structural effectiveness of diagrid systems, which are used for tall structures with complicated geometries, such as twisted, slanted, and free-form towers. The number of studies in this sector expanded practically dramatically, according to an analysis of 626 publications and theses by Ebid in 2021 that dealt with using artificial intelligence (AI) techniques in geotechnical engineering. Artificial neural networks (ANN) are the most commonly used (AI) methodology, and the correlation of soil and rock characteristics is the most studied topic, making up around 30% of the studies [16]. There are several optimization approaches accessible to handle any real-world problem. However, specific optimization strategies demand more time and repetitions and cannot generate optimal results. Advanced optimization approaches are based on the properties and behavior of biological, molecular, insect swarm, and neural systems. Newer and more complex optimization strategies are being developed regularly to deal with these real-world challenges, and some are listed below:

- Genetic algorithms (GA)
- Genetic programming (GP):
- Artificial neural networks (ANN)
- Support vector machine (SVM)
- Particle swarm optimization (PSO)
- Fuzzy system (FS)
- Hybrid techniques

Genetic algorithms (GA)

This method is based on something known as the survivors. First, it creates many random solutions known as "population." Then, based on past information, eliminate the incorrect responses. The good ones keep on and are recognized as survivors. Cross-selection and mutation are the operators. They aim to use the survivors to increase the population to obtain more precise solutions (survivors). The accuracy improves as the number of iterations rises. When the operators attain the desired level of precision, they come to a halt. Keys must be encoded as a genetic chromosome encoding the number of genes. Each of them contributes to the answer [16]. Current construction practices indicate that the design and materials greatly influence cost [17]. [18] a preliminary cost estimation model employing case-based reasoning and a genetic algorithm was presented to determine the weights of the essential building qualities for the early stages of a bridge-building project and determine the consequences of the critical building qualities for the early stages of a bridge-building project, a preliminary cost estimation model employing case-based reasoning and a genetic algorithm were presented. A weight estimation approach to produce a construction cost estimate model was anticipated to result in a more reliable model in the early phases. In 2012, The preliminary design stage examined the ideal conceptual design for piling foundations. The foundation is separated into modules using a modular approach, and the pile length, diameter, number, and layout identify each module. A design variable can be used to aggregate and represent modules having comparable properties. A minimum-cost optimization model with several design constraints based on Chinese code and a cardinality constraint is built to achieve simultaneous pile size and structure optimization. The model is solved using improved automated grouping genetic algorithms improved automatic grouping genetic algorithms; the model is translated to produce a design with ideal variables and ideal variable grouping. An accurate illustration shows the proposed approach's practical [19].

In 2013, Gan and Nguyen offered a genetic algorithm (GA) as a design tool for piles put on residential housing footings. The footing layout is encoded into an individual population that comprises pile position genetic information. The finest goodness of the complete fitness function will result in constructing a residential home footing plan. Using the design of a footing arrangement as an example, the current study's utility as a tool for making design decisions is demonstrated [20]. The objectives of this work were to explore the soil characteristics of three distinct foundation kinds using a k-means algorithm and to develop an algorithm model for optimizing the foundation types. The computed results show that the algorithm technique is reasonable and beneficial and provides a solid foundation design basis [21]. In 2018, Fatehnia and Amirinia employed GP and ANN applications to evaluate the bearing capacity of pile foundations [22]. In 2018, a revolutionary method for creating the best-stacked raft foundations was proposed based on a genetic-based evolution algorithm without requiring gradients. Two-goal functions under study are differential settlements based on structure serviceability and total weights of rafts and piles based on system cost. A search or optimization method based on natural selection is a genetically based evolution algorithm. According to the Darwinian theory of survival of the fittest, every generation generates more physically fit individuals.

The analysis of stacked raft foundations is based on the "hybrid" methodology put out by Clancy (1993), as well as a fundamental genetic algorithm developed by Goldberg (1989) as part of the development of a genetic algorithm (GA) based on the optimal design approach. The analysis of stacked raft foundations is based on the "hybrid" methodology put out by Clancy (1993), as well as a fundamental genetic algorithm developed by Goldberg (1989) as part of the development of a genetic algorithm (GA) based on the optimal design approach. Two piled raft foundation design examples—5 x 5 and 3 x 3 group piles—are examined to verify the efficacy of the recommended GA-based optimum design approach. In order to further explore the impact of important variables on the ideal design of piled raft foundations, parametric studies are conducted using the suggested optimal design technique (H. T. Kim et al., 2018). In 2020, Using the safety and serviceability standards of Indian Standard (IS) 456:2000, Chaudhuri determined the ideal cost of an isolated foundation. The cost of any small footing design is optimized for the first time using two adaptable optimization strategies. For the best design of any isolated foundations, two optimization techniques are developed in MATLAB: a constrained binary-coded evolutionary algorithm with a static penalty function approach and unified particle swarm optimization. On the total cost of footing, the set target function is founded. This includes the price of the formwork, steel, and concrete [24]. In 2021, Using SAP2000 by hand, Orhan and Taşkn produced three different building models. After converting the data to MATLAB, they used a genetic algorithm (GA) to improve the geometry-defining procedure iteratively. Therefore, the objective is to automate the best preliminary topology design for high-rise diagrid structures.

In addition, the feasibility of the best models is compared using complexity index parameters. Calculations show that ideal variable angle (VA) models are more effective than uniform angle (UA) models, for instance, in terms of the total weight of the diagrid shell. Comparatively speaking, UA models are more useful based on the complexity index values [25]. In 2021, Hikmat Haji & Mohsin Abdulazeez described Gradient Descent (GD), Adaptive Gradient (AdaGrad), Batch Gradient Descent (BGD), Adaptive Delta (AdaDelta), Maximum Adaptive Moment Estimation (AdaMax) Stochastic Gradient Descent (SGD), and Mini-batch GD, then made a comparison between optimization algorithms, including Momentum, Nesterov Momentum, Root Mean Square Propagation (RMSProp), Adaptive Moment Estimation (Adam) and Nesterov Accelerated Adaptive Moment Estimation (Nadam) algorithms, finally Work results show that Nadam showed a more excellent [26]. In 2021, Wang optimized the pile-anchor supporting structure of the bottomless foundation pit 2021 using the genetic algorithm and the safety factor calculation approach. This system compares the outcomes to the actual results while optimizing the design. The findings showed that the bottomless foundation pit supporting the structure's construction cost dropped from 6920 to 4760 yuan with improved design. It reduced project costs by around 32.5%, and the safety coefficient exceeded 1.25, satisfying China's technical standards for foundation pit support [27].

Genetic Programming (GP)

Consider one of its applications. GP is a subset of GA. The mathematical formula of GP is GA. Using (GA) in this calculation, Ebid utilized the original approach as an intermediary step in converting genetic form to mathematical form. After creating and encoding the first random solutions of formulae, this approach leverages the original one to fit the procedure best. The (GP) has spawned sub-techniques such as (LGP), (CGP), (GEP), and (MGEP) [16]. By researching the bearing capacity of footings over two-layer foundation soils, Moayedi made improvements in 2021. In order to change the linking weights and biases in forecasting failure likelihood, the Harris Hawk's Optimization (HHO) and Dragonfly Algorithm (DA) are utilized as multi-layer perceptron (MLP) prediction tools. You combine the HHO and DA metaheuristic algorithms as a first result, which boosts the MLP's effectiveness [26].

Artificial neural networks (ANN)

Consider one of the most effective (AI) strategies for success, speed, and accuracy. Neurons are specialized brain cells. This strategy imitates their link. The input layer, the first layer, the hidden layer, the intermediate layer, and the output layer, which is the last layer, are all layers in the brain. Each layer is connected by connections, which are made up of neurons. Each has its own "weight," which represents the strength of the bond. In "Back Propagation Training," each connection is assigned a weight based on prior information. There is just too much advancement and development in the (ANN). They are working to improve its accuracy and efficiency. Here are some of the outcomes: Bayesian Regression Neural Network (BRNN), Redial Basis Function Neural Network (RBFNN), Back Propagation Neural Network (BPNN), Feed Forward Neural Network (FFNN) [16][28]. Methods for optimal design and analysis of geotechnical engineering challenges are presented. It also provided an overview of several methodologies, such as optimization, artificial neural networks, and other evolutionary strategies. The breadth of these methodologies to assess diverse geotechnical engineering problems was quickly presented, leaving out significant specifics. Furthermore, it was suggested that researchers employ these approaches in the efficient and cost-effective design of foundations and earth structures with the advent of high-performance personal computers. It has been utilized successfully for a variety of geotechnical engineering challenges. ANN modeling provides an advantage over other system modeling methods [29]. Furthermore, an ANN technique encourages feedback, which may aid decision-makers in reaching the best answer [30].

In 2014, Letsios offered a structural optimization method that was used in two actual situations, one in London and the other in the UK, to assess the effectiveness of the suggested design formulation. Two design code specifications, Eurocode 7 and DIN 4014, were used to examine and finish the enhanced pile foundation designs. Additionally, compared to original solutions, optimum tactics might reduce construction costs by anywhere between 7% and 33% [31]. In 2017, Ranasinghe looked at the effectiveness of (RDC) on various types of soil and attempted to build a forecasting tool using the commonly utilized ANN artificial intelligence technology. Using the 4-sided, 8-tonne impact roller, the ANN models combine a database of ground density data from DCP testing with RDC (Ranasinghe et al., 2017). This report's applicability focuses on management and implementation in the construction industry. ANNs aim to make sense of the chaotic data through practical interpretation. Examine the use of ANNs in construction operations to forecast costs, risk, safety, tender bids, and labor and equipment productivity. Jassim filed a report in 2018 to investigate the broad and essential notion of artificial neural networks [33]. In 2019, Bagińska & Srokosz illustrated the possibility of employing Deep Neural Networks (DNN) to forecast the eventual bearing capacity of shallow foundations in cases when experimental data needed to train networks is insufficient [34]. In 2020, ANN can be utilized to attain this aim quickly. For network learning, data from physical and numerical models can be employed. One of the benefits of this technology is its quickness and ease of use. The model presented a multi-layer perceptron ANN. In this model, the input parameters pile diameter, pile length, and pile spacing may be utilized to determine maximum settlement, maximum differential settlement, and maximum raft moment. This model may generate a wide range of outcomes for optimal system selection in the required piled raft foundation. The neural network's results show that it can recognize stacked raft behavior. The offered approach provides an appealing solution while also improving the economics of the stacked raft foundation system design. This novel design strategy decreases the time spent on software analysis [35] [36]. Computer and software technology advancements have made new techniques to cost estimates. For example, if the structural system is constructed effectively, the overall cost of a multi-story residential structure can be significantly reduced. A basic computer model was built during the early design stage of high-rise buildings to propose the ideal composite flooring system. In the early stages of the design process, an ANN model can assist designers in making educated selections [37]. In 2021, a new ANNs model was presented, with the learning step accomplished by utilizing [38]. In 2022, Centrifugal pump optimization issues are often nonlinear and non-differentiable. The standard multi-objective particle swarm technique was changed to address this issue, which increased accuracy and searches time in the validation trials. The geometry of an industrial inline pump's impeller blades was adjusted using a modified algorithm and multi-layer ANNs to increase overall performance in various operating scenarios. In the parametric design of the blade geometry, the non-uniform rational B-spline was used, and 14 spline design variables were eventually used in the iteration. The efficiency of the part-load condition, nominal condition, and overload condition was chosen as the goal functions under the constraint of the computational head. Following optimization, a remarkable increase in efficiency was obtained in all three specified operating situations, and the association between the inflow conditions before the impeller and the performance of the inline pump was demonstrated [39], as shown in Fig 2

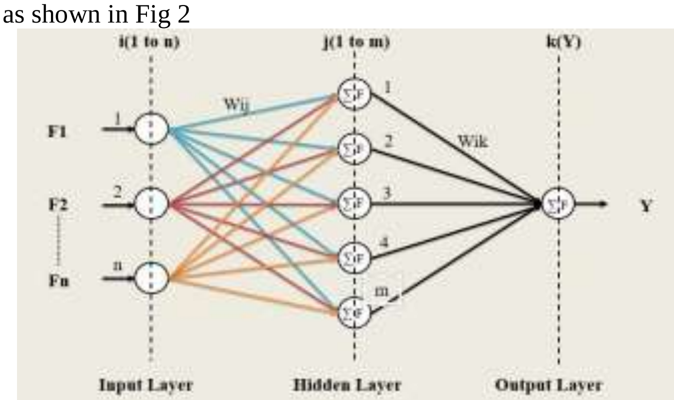

Fig 2 Typical structure of ANNs model with two hidden layers **[40]**

Support vector machine (SVM)

An (SVM) is used for regression and classification analysis based on statistical ideas. The primary strategy was to determine the optimal linear border between areas. Then, in a 2-dim space, classify the edges and margins. Then it improves by being more adept at coping with non-linear (radial and polynomial) boundaries. There is now a hybrid approach called (SVQR), which is a combination of (SVM) and (SVQR) (ANN), as shown in Fig 3 [16]. Developing ANNs ensemble and support vector machines classification models to forecast project cost and schedule success, with early planning status used as model inputs [41]. Applying AI and conventional approaches provide reliable project resource estimations, such as building materials [42]. For example, Viana, T. Haftka, and T. Watson used the multiple surrogate efficient global optimization (MSEGO) method in 2013, employing different surrogates to add many design sites at each cycle optimization cycle. MSE-GO is a low-cost alternative to using a single kriging model to add numerous points in each EGO cycle (computationally more expensive). MSEGO, on the other hand, is viable with multiple kriging cases [43].

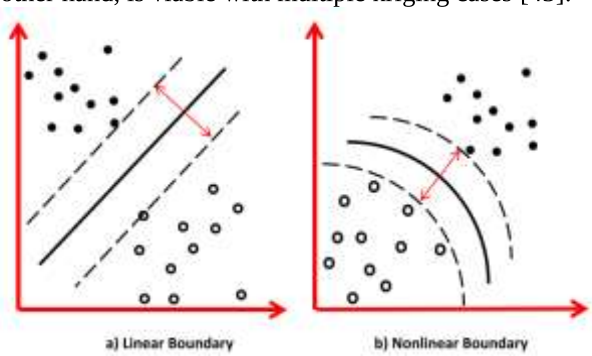

Fig 3: Support Vector Machine (SVM) in 2-dimensions space **[16]**

Particle swarm optimization (PSO)

Particle swarm optimization is a technique that simulates the behavior of a swarm of organisms while seeking food or any objective (PSO). This approach separates the solution into sections where each creature hunts for the optimal answer based on the pre-defined criteria. Depending on the creature's kind, each can communicate with the others to make each move better than the previous one until they reach the best one. After multiple rounds, all individuals will have found the best solution to the problem. They will not give up until they have found the perfect option. The general approach is (PSO). They create an excessive number of sub-methods, such as Ant Colony Optimization (ACO), Grasshopper Optimization Algorithm (GOA), Salp Swarm Algorithm, Artificial Bee Colony (ABC), and Crow Search Algorithm (CSA), Whale Optimization Algorithm (WOA), and Firefly Algorithm (FA). Their difference is how they communicate, locate food, and blend local and global directions [16]. The ability of the ant colony optimization (ACO) method to optimize piled-raft foundations is investigated in this work. The soil-pile interactions are considered by modeling the piles' side and tip capacities in the OpenSees platform utilizing nonlinear p-y, t-z, and Q-z springs. The Winkler springs beneath the raft are used to model the soil-raft interaction. The goal of the optimization issue is to reduce the volume of the foundation by using design factors such as the number, configuration, penetration depth of the piles, and thickness of the raft. The optimization issue is constrained by the side and tip forces of the piles, the pressure given to the underlying soil, and the total and differential motions of the foundation under the serviceability limit state. The results show that the ACO algorithm is a good tool for designing piled-raft foundations. Furthermore, the study's findings suggest integrating soil nonlinearity in the analysis (rather than a linear elastic soil model) might lead to a more cost-effective design for these foundation systems [44].

In 2020, The purpose of this work was to improve the Adaptive Neuro-Fuzzy Inferences System (ANFIS) for the estimation of friction capacity ratio (α) in driven shafts using two optimization strategies, namely, Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). Several studies have shown that ANFIS and AFIS are valuable methods for predicting engineering problems. However, optimizing ANFIS using GA and PSO in pile engineering has not been employed. The training data set was created from the full-scale results of the driven piles that were accessible. In 2020, The input parameters were pile diameter (m), pile length (m), relative density (Id), embedment ratio (L/D), both pile end resistance (qc), and base resistance at 10% base settlement (qb0.1) from CPT results, and the output was. A learning fuzzy-based technique was utilized in the MATLAB program to train the ANFIS model. The system was tuned by varying the number of clusters in the FIS and then using the GA and PSO optimization algorithms. The forecast was compared to field data from real-time monitoring. Consequently, excellent agreement was achieved, indicating the dependability of all offered models [45].

In contrast to expert system methodologies, fuzzy systems (FS) can deal with incomplete, erroneous, and faulty data (data). (FS) based on analytical and statistical techniques. This strategy is based on a concept known as "Membership Function." It is based on a supposition. According to this idea, each changing phrase has a probability distribution function. Ebid employed Boolean logical operators on the "Membership Function" of the generated inputs. The "fuzzifier" will do the first phase of "fuzzifying." The output is then sent into the "Interface Engine," which employs its algorithms by utilizing the "Rule base" and providing the best answer by "Defuzzifying" [16].

A synthesized fuzzy inference system was built and used as the primary component of the NFDSS by integrating fuzzy and neural network approaches. With its user-friendly GUIs, this neuro-fuzzy model was supposed to assist industry experts in selecting ideal RA techniques to accomplish efficient risk management and eventual project success while using PPP procurement models [46]. In 2021, Armaghani developed ANFIS-GMDH-ICA, a novel intelligence system methodology based on the adaptive neuro-fuzzy inference system (ANFIS)-group method of data management (GMDH) optimized by the competitive imperialism algorithm (ICA) for forecasting pile carrying capacity [47].

Hybrid techniques

Every "AI" technology has advantages and disadvantages. Researchers blended two or more courses to overcome and gain from its weaknesses. The three basic types of hybrid designs are sequential, auxiliary, and embedded. Sequential approaches use the outputs of the first one and feed them into the next one to create a better answer. Other processes use some information from the first approach, profit from it in the second, and solely use the output from the last procedure. Embedded means combining the techniques and employing them concurrently. The most often used hybrid approaches combine (ANN) and (FS). This approach is supposed to be efficient, quick, and effective.

Here is a list of some hybrid techniques:

- (FS) and (ANN)
- a multi-agent system (MAS) and cellular automaton (CA)
- (Bayesian) and (ANN)
- (FS) and (CA)
- (GA) and (ANN)
- (GA) and (Bayesian)
- (FS) and (GA)
- Case-based reasoning (CBR) and Rule-based systems (RBS)

In 2009, Chan described an automated optimum design technique for pile group foundations that use a hybrid genetic algorithm. The design method for piling foundations is size and topology optimization. The goal is to reduce the foundation's material volume, using the configuration, number, and cross-sectional dimensions of the piles and the thickness of the pile cap, as design factors. A fully stressed Design (FSD) approach to local search operator is introduced into a genetic algorithm (GA) to address two fundamental weaknesses of a GA, namely, large computing effort in searching for the optimal design and inadequate local search capabilities. A five-by-five pile group subjected to diverse loading situations is used to demonstrate the usefulness and capabilities of the suggested method. The proposed optimization technique is then applied to a large-scale foundation project to demonstrate its feasibility. The suggested hybrid genetic algorithm successfully decreases the volume of material consumption, and the outcome is consistent with the engineering assumption. The FSD operator has made significant progress in design quality and convergence rate. The difficulties faced when applying optimization approaches to the design of pile groups comprised of hundreds of heaps are explored [48].

In 2012, The modeling and optimization of floating raft systems were covered in this work. The floating raft system modeling is based on FRF-based sub-structuring synthesis, and optimization is based on a hybrid genetic algorithm that combines SA and GA. SA's design sensitivities are developed for the floating raft system and confirmed using FDM. The technique offers five-goal functions for stiffness optimization [49].

In 2017, Kulkarni Presented a hybrid method that integrated the ratio of the principal item estimation method with the adaptive neuro-fuzzy inference system for mining cost estimation data. The proposed method provided exceptional capability for mining estimation knowledge. A case study of residential building projects in China was done to show the suggested strategy. A neuro-fuzzy decision support system was created to aid the RA decision-making process in PPP projects [50]. In 2017, A high-rise structure was studied under diverse soil conditions. The foundation was developed for each situation. They could see the foundation offered based on varied soil holding capabilities for a single structure. Foundations are designed to support the base loads estimated by ETABS, and the related foundations are available in SAFE and soil-structure interaction. Each case's soil pressure and displacement are studied, and an optimal design is provided. The high-rise structure is developed based on prototype studies and offers the best foundation design [51].

In 2020, The eco-friendly raft-pile foundation (ERP) system was one of the most recently designed pile foundations, with original components sourced locally in Bakau. Many engineers are interested in making a precise prediction of its behavior. This research introduces three intelligent systems for predicting vertical settlement in ERP systems: adaptive neuro-fuzzy inference system (ANFIS), standard artificial neural network (ANN), and improved ANN model with genetic algorithm (GA). In this regard, a database comprised of 43 load-settlement outcomes derived from full-scale maintained load tests was created (PLT). It should be noted that the piles in this floating raft-pile system were subjected to vertical axial stress [52].

Other optimization techniques

In 1997, Valliappan, Tandjiria, and Khalili used two tactics 1997. A bi-point constraint approximation and a semi-analytical sensitivity approach have both been introduced. A raft foundation on a soil media was tested to support the suggested approaches. The results were then compared. The numerical results indicate that for non-linear analysis, the semi-analytical sensitivity technique is more effective than the Finite Difference method. Results from the bi-point approximation are comparable to those from solutions using finite elements [53]. In 1999, Valliappan, Tandjiria, and Khalili described how the design of a raft pile foundation system was optimized using the finite element method in conjunction with a structural optimization approach. The analysis considers the soil medium's and piles' nonlinear behavior. The sensitivity analysis is carried out using the approximate semi-analytical approach for optimization. The constrained approximation is simultaneously accomplished by merging extended Bi-point and Lagrangian polynomial approximation techniques. The problem's objective function is the cost of the foundation. The raft's thickness, cross-section, length, and several piles all play a role in its design. Maximum and differential displacement is set as restrictions. It has been demonstrated that the recommended method produces an ideal raft pile foundation design accurately and efficiently [54].

A high-rise structure is assessed on several characteristics, and the foundation is created for each situation. They could see the variance in the foundation produced by a variable angle of internal friction for a single building. The piles are used to decrease settling. The high-rise structure is planned, and the most suitable foundation design is chosen based on prototype investigations [55].

In 2000, this work expanded on prior research by examining the numerical assessment of stacked rafts and their advantages for a simple case design. The paper presents the results of a parametric and comparative analysis using numerical software created especially for groups of deep foundations subjected to general stress (vertical, horizontal, and moment loads). From both a technical and financial perspective, it is found that an optimization technique is suitable for enhancing the design of stacked raft systems [56]. In 2001, They described an efficient pile arrangement technique for reducing differential settling in piled raft foundations. The Mindlin theory describes a raft as a plate, soil, and piling as Winkler and linked springs. The approximate analytical approach described by Randolph and Wroth is used to determine the stiffness of piles. The Winkler spring constant is determined using the modulus of the subgrade response [57].

In 2001, The 425 references were for Eschenauer and Olthoff. The best topology and layout design of linearly elastic 2D and 3D continuum structures are highlighted, along with developments in these two methodologies. The usefulness of various techniques based on the mathematical-physical concepts of topology and layout optimization is illustrated by several examples. New topology optimization applications are discussed near the essay's conclusion [58]. In 2001, The optimal cost-revenue conceptual design for high-rise office buildings was described by Khajehpour as a computer-based computational approach. Pareto optimization, which decreases capital and operating costs while increasing income revenue for a specific construction project, is carried out using a Multi-Criteria Genetic Algorithm (MGA), subject to design constraints imposed by building codes and manufacturing requirements [59].

In 2002, In order to avoid the need for complex settling joints significantly below the groundwater level, Mossallamy described the stacked raft's new usage in foundations with significant load eccentricities or significantly diverse burdened sections of buildings. In order to confirm the design concept and show that the serviceability criteria were met, extensive measurements of the load transmission mechanism of stacked raft foundations were made both during and after construction. The geotechnical engineer's mission is to guarantee the building's serviceability requirements and foundation stability while considering the project's economics. The stacked raft foundation introduces a revolutionary geotechnical method for developing high-rise building foundations. It supports stability and serviceability in addition to high-level technical and financial optimization. For a safe and effective solution for foundations on highly compressible subsurface, a theoretical understanding of the impacts of structure-subsoil interaction, expert use of measuring techniques, and numerical modeling, combined with tried and verified implementation design, is required [60].

In 2006, A summary of recent new stacked raft applications in Germany was given by Mossallamy. The need for the fastest foundation-building time has become a severe technological problem due to the astonishing number of newly constructed and projected tall structures, notably in the Gulf Countries. The stacked raft can help achieve the required short construction time by maximizing the necessary piles. Additionally, the stacked raft foundation approach is appropriate for most subsurface conditions in Gulf nations [61].

In 2006, P. K. Basudha presented an optimal cost design of a rigid raft foundation while considering geotechnical and structural design issues. The cost of the raft foundation was chosen as the objective function, and the design criteria were enforced as side and behavioral constraints. The point is expressed as a simple mathematical programming problem. Many of the limits are non-linear, which is difficult with non-linear programming. The sequential unconstrained minimization approach using the penalty function method was among the conventional techniques. In this formulation, the restrictions are attached to the objective function via a penalty parameter to produce a composite surface, and unconstrained minimization is performed using Powell's conjugate direction search technique to decrease the penalty sequence described above. The system efficiently finds the rigid raft foundation's best cost analysis. Among the non-traditional approaches utilized was a genetic algorithm for a restricted optimization problem with a penalty parameter. The influence of soil characteristics on optimal analysis has been studied using parametric analyses. It has been discovered that the undrained shear strength does not affect the thickness of the raft foundation in saturated fine-grained soils. The best design for cohesionless soil is indifferent to the difference in value between (20^o - 30^o). The soil modulus of elasticity significantly impacts the optimal construction of a raft. The optimal cost is more sensitive to the settlement criteria than the bearing capacity criterion [62].

In 2007, numerous research types were applied to evaluate pile raft foundations' behavior. Calculations are made about the effects of pile length, pile distance, pile arrangement, and cap thickness under vertical or horizontal static and dynamic loads [63]. In 2009, Abdel Glil looked for an alternative foundation to solve the Port-Said settling problem. The stacked raft was investigated as a potential settlement reduction. To complete the work, normal soil stratification and attributes were evaluated. Back analysis was performed to validate the soil characteristics utilized in the study. Parametric research was conducted to investigate the behavior of a single pile, a pile group, a raft, and a piled raft under various variables and situations. Compared to a raft, the results show that a stacked raft is a better foundation solution at Port-Said. The research provided recommendations and illustrations for the stacked raft utilized in the Port Said region. The study also found that the best-piled raft elements for typical residential construction in Port-Said are 24 [m] pile length, 0.5 [m] pile diameter, and 2-3 [m] pile spacing. Compared to a raft, the best-stacked raft can reduce settling by 60-50% [64]. In 2010, Leung, Klar, and Soga conducted optimization studies of freestanding pile groups, and stacked rafts were given. In these studies, pile lengths were varied across the groups to enhance foundation performance. The evaluations' conclusions are applicable when the majority of the piles' carrying capacity is accounted for by frictional resistance. With the same amount of total pile material, an optimum design for the pile length may increase the foundation's overall stiffness and reduce the differential settlements that can lead to superstructure deformation and cracking. Less material is needed to reach the proper level of foundation performance, which translates the advantages of optimization into financial and environmental savings. Additionally, the reliability of the optimization benefits in the presence of construction-related unpredictability is addressed [65]. In 2011, The interaction between the superstructure, the pile raft foundation, and the foundation was shown to have distributed stress that was particularly big in the center and little at the edge using the calculation results from finite element models, according to Li, Yongle, Wang, and Yang. The differential settling led to the internal force in the raft and secondary stress in the top structure. By adjusting the foundation soil stiffness and the pile length, diameter, and distance, it was possible to examine the impact of shifting stiffness on differential settlement. According to the findings, the optimal pile raft foundation for a high-rise structure was designed by adjusting the pile arrangement and controlling the stiffness of the foundation soil [66].

In 2011, Guo performed a numerical analysis on a composite long-short pile foundation using FLAC3D. The distribution of axial force, neutral position, and penetration amount are examined using a sophisticated three-dimensional numerical model, together with the displacement and stress fields. Also carefully investigated are the effects of the long-short-pile composite foundation's essential parameters on pile-soil stress ratio and foundation settling. The proposed parameter values are then provided depending on the foundation settling control [67]. In 2011, A practical method for choosing the best design for reinforced concrete columns in a spring-mounted turbine generator foundation subjected to dynamic pressures from rotating gear was reported by Timac, Braut, and Igulic. Extensive finite element research suggests that columns may be efficiently represented individually, allowing for adopting more straightforward, analytical column models. The design seeks to prevent resonance between the foundation columns' first two natural frequencies and the generator's first harmonic excitation. The size of a column's cross-section, on the other hand, is a design variable. The results of the instance under investigation demonstrate that the optimization was successful since better column dimensions provide natural frequencies outside the critical frequency range [68]. The Firefly Algorithm (FA), a novel meta-heuristic optimization algorithm created recently, is used to discover the best design for tower-shaped buildings. The FA resembles the social behavior of fireflies, which use bioluminescence with varying flashing patterns to communicate and locate mates. In 2011, Ronagh proposed an adaptable FA that handles restrictions using the feasible-based technique. This strategy enhances convergence and is appropriate for costly optimization jobs such as large-scale structures. Three tower constructions are chosen to test the algorithm's performance. The findings outperform those found in the literature, confirming the validity of the suggested technique [69]. In 2012, After evaluating the impact of raft concrete strength and thickness on a raft foundation, an optimal design was provided using the FEM program ANSYS. This gave raft foundation design and calculation a theoretical underpinning [70]. In 2012, Multiple optimum loading design approaches for pile-raft foundations were looked at, and ANSYS was utilized to explore the interaction between piles and soil in high-rise structures. The findings showed that in the pile-raft foundation optimization design, the traditional pile layout was broken by the pile layout of outwardly weak and internally powerful piles, the side pile and corner pile were weakened, the pile foundation was deposited uniformly, the differential settlement was minimized, and forced state of foundation and superstructure were considerably improved [71]. The pile-raft foundation is popular in high-rise structures due to its great bearing capacity and little settling. People have been drawn to study and inquiry into the ideal construction of pile-raft foundations. Since the 1950s, there has been a lot of activity in the theory and implementation of pile-raft foundations. Optimum design research on pile-raft foundations has taken centre stage in recent years. A massive number of useful study results have been supplied. Many difficulties need to be explored and addressed in light of the effect variables on the pile-raft foundation ideal design [72]. In 2012It was noticed that using piles that aren't identical might enhance system performance in piled-raft foundations subjected to irregular loads. In addition to other useful factors, this parameter effect has been considered. A piled-raft foundation with different-sized piles was evaluated using the APRILS program. Mahmoudzadeh employed the finite element method and the finite layer technique to study piled-raft foundation systems and layered soil. The piles, raft, and soil interplay and their interactions have been examined as crucial system behavior components. Under non-uniform horizontal and vertical stress, it looked at how no similar piles interacted. They found that using non-identical heaps might improve system performance. When piling rafts that will be subjected to uneven vertical loading with notice of differential loading, piles of larger length should be put in the raft's center. In contrast, piles of bigger diameter should be placed in this region for horizontal loading [73].

In 2012, Izwan developed a direct-search computational approach based on the Complex Method of Box to determine the optimum reinforced concrete integrated footing design. The goal function includes the cost of excavation, filling, concrete, and foundation reinforcement, which is reduced during the optimization process. Design considerations include the footings' length, breadth, depth, and flexural reinforcement area, which is now a crucial element. The strength design technique complies with the necessary portions of the American Concrete Institute (ACI) standards and codes' explicit and implicit criteria, such as constraints on stresses and displacements and restrictions on footing dimensions. A computer application developed in the Visual Basic.NET (VB.Net) programming language is used to perform structural analysis, design, and optimize the connected footings. The strategy determines the appropriate response in terms of discrete variables. To analyze how the optimization strategy behaves, two numerical scenarios are solved. The findings highlight constructive design improvements and convergence rates [74]. In 2012, Eslami, Veiskarami, and Eslami presented two three-dimensional finite element analyses of linked and unconnected pile-raft systems carried out on three case studies: a 12-story Iranian residential building, an Indonesian twin tower with 39 stories, and Frankfurt, Germany's 256-meter-high Messeturm skyscraper. The assessments examine the impact of numerous features, such as pile spacing, embedment length, piling arrangement, and raft thickness, to enhance the design. The function of each parameter is also investigated. Finally, the comparison demonstrates that quick and easy 2D analysis yields results equivalent to lengthy and complex 3D analysis [75].

In 2013, Under vertical or horizontal static and dynamic stresses, the effects of pile length, pile distance, pile arrangement, and cap thickness were determined [76]. In 2013, An ideal design strategy was presented by Nakanishi and Takewaki for calculating the pile lengths of stacked raft foundations. By considering the raft-pile-soil interaction, the settling of the foundation is evaluated. Using Steinbrenner's equation simplifies the settlement analysis. While keeping the settling limitation in mind, the overall pile length is decreased. A complete, sequential linear programming technique combined with an adaptive step-length algorithm of pile lengths is used to solve the optimal design issue. The validity of the best solution and the accuracy of the simplified settlement analysis technique is investigated by comparing the actual measurement findings in existing stacked raft foundations [77].

In 2014, a finite difference in two dimensions In this inquiry, a numerical technique was applied. This numerical approach was confirmed using experimental data before analyzing the EPS functioning in the raft in a parametric study. The parametric research was developed to consider variations in the geofoam layer's density, thickness, and several stores. Comparing cases with and without replacement of the geofoam. Discussion of the numerical results led to conclusions [78]. In 2014, It provided a plan for enhancing pile length. In order to analyze the non-linear behavior of piles, a "cut-off" method was employed to limit the integral equation's capacity for piles while still taking into account their linear behavior. Nearby non-yielding piles take on heavier loads when some piles start to give (i.e., reaching their ultimate load capacity). A pile-square rigid raft system was used to demonstrate the effects of the recommended approach. The research found that the pile raft's stiffness decreased when the load cut-off was considered. The load cut-off strategy may improve the distribution of reactions for short piles in terms of their locations and lengths. A more economical solution than uniform piles would be the best design with a variety of heaps [79].

In 2015, The topology optimization method for constructing two-dimensional fundamental geotechnical structures was presented in this study. The SIMP approach is used to optimize the topologies of structures in terms of their deformational behavior during serviceability. The finite element analysis with the Abaqus standard is carried out via a hypoplastic constitutive model. In addition to the newly described topology optimization of strip footings, pile, and retaining walls, two boundary value issues are investigated. All outcomes are reviewed to provide an overview of topology optimization in basic geotechnical design [80]. In 2015, studies and analyses of the Pile-Raft System were critical, given the prevalence of tall structures and skyscrapers. Two strategies have been utilized to build a Piled Raft System. The load borne by the pile and raft foundations is not encumbered in the first technique. The second approach passes the major constraint to the soil via a raft foundation, and the pile is employed for settlement management. There are several issues with analyzing the Piled Raft System based on the interactions between the soil pile-raft. However, developments in computer science, memory sticks, and numerical approaches allow for examining various scenarios [81]. In 2015, Taghavi Ghalesari developed design criteria for the undrained behavior of a piled raft system based on an analysis of average and differential settlements, raft bending moment, and pile butt load ratio. The evaluation of raft settlements involved a series of three-dimensional finite element computations. The number of piles and raft thickness heavily influenced the average settling values for the stacked raft. In this case, cohesive soil pile design choices are discussed. The pile butt load ratio was decreased by increasing the pile spacing because it allowed a more uniform weight distribution between the piles [82]. In 2015, Mohamed and Austrell compared the cost and behavior of two foundation solutions: a stacked raft and a circular raft enclosed by a water tank. A soil profile recorded in the Gothenburg area of Sweden is utilized. The soil profile is used in the FE program Abaqus to assess the feasibility of employing various foundations on the stated soil type. Regarding settling and tilting, it is demonstrated that using a water tank encircling the usual circular raft for the real soil profile in the Gothenburg region has a positive impact. In terms of cost, an analysis was performed to assess the total foundation cost for a circular raft encircled by a water tank and a stacked raft. The novel foundation technique reduces foundation costs compared to stacked rafts with a pile length = of 28 m and a one-meter square pile. The impact of dynamic loads was also studied. The results show that the entire system successfully avoids resonance via rotor excitations by employing a circular raft surrounded by a water tank as a base [83]. In 2015, High-rise reinforced concrete buildings were the subject of Xiong & Calvo's effective optimization. The optimization technique divides the main Structure into four substructures: the floor system, vertical load-resisting system, lateral load-resisting system, and foundation system. Each subsystem is then improved by utilizing the design criteria specified in the building regulations. Because superstructure optimization impacts the foundation system, the vertical and lateral load-resisting system is the last to be addressed after reinforcing the floor [84]. In 2017, Shrestha, Ravichandran, and Rahbari offered the geotechnical design methodology for a piled-raft foundation for a hypothetical 130 m tall hybrid wind turbine tower exposed to a mean wind speed of 125 mph at a potential wind farm in Charleston, SC.

Additionally, parametric research was conducted to examine how random variable variation, such as wind speed and soil quality, may affect the outcome of the design (undrained cohesion in this study). Finally, a thorough design optimization was conducted using the material cost and the standard deviation of differential settlement as objectives. The design optimization results are shown graphically in a Pareto front, which may choose the best design given a performance criterion and cost cap [85]. In 2017, Leung proposed an analysis and optimization approach for pile group and piled raft foundations that connect superstructure stiffness with the foundation model via a condensed matrix defining the superstructure's flexural characteristics. This related approach is used in a multi-objective optimization algorithm that creates several optimal pile designs at various material amounts. The recommended method helps engineers to make knowledgeable foundation design decisions based on project economics and performance requirements [86]. In 2017, The ideal design of a multi-type-pile composite foundation should consider the constraint requirements of bearing capacity, settlement, and constraint stress condition of the main pile. The top load is reduced by the weight of the dirt between the piles, leaving the main pile to carry the remaining two-thirds of the weight. The first pile must be high [87]. In 2018, Huber focused on developing combination piled raft foundations (CPRF) under load and resistance uncertainty in our work. They created a unique optimization technique that considers the uncertainty of the load and resistance characteristics. This new technique is used in an exemplary case study of a mixed piled raft foundation to demonstrate the strength of the suggested approach [88]. In 2019, Teodosio constructed a prefabricated foundation using an improved waffle raft. The intended approach may be used in environments ranging from stable to extremely reactive, minimizing the requirement for on-site assembly and maximizing the building's efficiency, sustainability, and speed [89]. In 2019, Beleviius, Manas, and eok set out to illustrate the strategy utilized for the global optimization of grillage-type pile foundations, which incorporates the application of two highly advanced metaheuristics: AAGA and AGADS. The new optimization method that has been suggested surpasses the traditional AGA and GADS by utilizing the synergy of AAGA and AGADS. Minimizing compromised target functions include the maximum reactive force in piles and the maximum bending moment in coupled beams. A numerical examination of the domain of the aim function for various distinct foundation topologies demonstrates the practicality of a simple weighting strategy for the goal function. The size of connecting beams is handled concurrently with the optimization issue. To tackle the immediate problem, the original finite element software was used [90] [91].

In 2021, many academics looked at various aspects of the unconnected piled raft foundation (UPRF) system in the last two decades. A structural fill cushion is incorporated in this design between the raft and the concrete piles (PC) to transmit loads from the superstructure to the banks. They showed that UPRF might increase the raft's load-bearing share relative to concrete piles, producing a beneficial economic effect. The use of deep-mixed columns (DMC) and stone columns (SC) has increased. In several different constructions, they have successfully replaced concrete pile foundations. The use of SC and DMC in the UPRF system is examined in this article as a potential use. Column properties, including material, stiffness, spacing, embedment length, arrangement, and raft thickness, may impact UPRF system design parameters. El Kamash examined how these traits affect the effectiveness of the UPRF. Structural fill and EPS Geofoam were two other cushion solutions that were researched. Using 3D finite element models of a 16-story building on soft clay, the behavior of several UPRF foundation types buried in various soft clays was examined. A coupled hydraulic and mechanical model that used the Modified Cam Clay soil model was used to simulate soft soil [92]. 2020, In recent years, the static optimized design of piled raft foundations with variable stiffness has been widely used to save costs and improve the overall performance of building systems. However, due to the interaction between the soil, piles, and structure, midrise buildings supported by piled raft foundations in seismically active areas may experience changes in the dynamic properties of the soil-pile-structure system during an earthquake. Numerical simulations of a nuclear power plant on top of multilayered soil are used to investigate these factors. The article explains a numerical modeling strategy for simulating complex seismic soil-pile-structure interaction occurrences. Following optimization, it was found that the overall shear force on top of the piles and the raft's swaying is reduced. However, the displacement of the superstructure is essentially unchanged. The results of this study can aid engineers in choosing the right pile arrangement when assessing the seismic performance of a structure resting on soft soil [93]. In 2021, Asefa looked at how different pile designs and geometric elements affect the bearing capacity and settlement response of a combined pile-raft foundation system using FLAC3D software. Additionally, it was shown that examining the issue of stacked raft foundations is acceptable when employing zero-thickness interface elements to simulate the interaction between foundation system components [94]. In 2021, In this work, FLAC3D was used to model the raft foundation and deep-mixing columns, with the uniaxial and triaxial experimental testing used to estimate the mixing parameters. It is investigated how some features, such as the ideal area ratio of the column group to the raft and the effective length, diameter, and distance of the columns, behave in the loose sand of Firouzkouh. Following that, the optimization of column groupings is looked at, including length and arrangement. Lastly, a comparison is made between the concrete piling and deep-mixing columns [95].

In 2021, In order to provide a more reliable and affordable foundation, a piled mat cap and strip cap were finite elements approached using STAAD software. Using finite element analysis, the plate distribution region of bending moments and shear stresses was investigated; simultaneously, the design value of plate stress was analyzed using the compatibility of the element plate's deformation. The findings demonstrate that a single plate value is not indicative; a value averaged over nine plates (3x3 array) is more accurate. In this project, the strip cap surpasses the mat cap in terms of moment value and sheer value of the plate element; the strip cap was advised due to its excellent financial benefit [96]. In 2021, Cavalcante set out to investigate how the flexibility of the foundation and the soil affected the topological optimization of stacked constructions. The embedded pile group foundation and its interaction with the soil are described using a stiffness matrix technique, while the structure is modeled using standard finite elements. Direct continuity and equilibrium conditions are established at their touch, linking the design and its base. Topology optimization of the discretized piled form is carried out utilizing the Bi-directional Evolutionary Structural Optimization (BESO) method for various boundary conditions. Minimizing the stacked structure's compliance with the specified volume limitation is the objective of the optimization problem. The findings show that the achievable optimization goal and the optimal structural topology may be significantly impacted by the soil and pile flexibility [97]. In 2021, Dodigovi examined the viability of utilizing the genetic algorithm NSGA-II to optimize a reinforced concrete retaining wall buried in saturated silty sand. Using multi-objective constrained optimization, the cost was reduced while maximizing the overdesign factors (ODF) against sliding, overturning, and soil-bearing resistance. Additionally, the foundation's breadth and embedment depth were adjusted to account for a 5.0 m change in ground elevation. The method's performance was examined for two- and three-objective optimizations, showing that the number of objectives significantly influences the convergence rate. Additionally, it was demonstrated that proving a wall's resistance to sliding yields a lower ODF score than proving the wall's stability and soil-holding ability. As a result, they can be excluded from the definition of optimization issues. Therefore, an NSGA-II algorithm helps identify the best-retaining wall designs [98]. In 2022, Chuloh, Riyad, and Jihad described the goal of this research as being to analyze the unit technologies employed in the structural design of an impressive skyscraper and provide an optimum structural design technique. Case studies of certain iconic buildings in the United Arab Emirates created by renowned firms like SOM, AECOM, and Salama Structural Engineers are analyzed, along with the status of atypical skyscraper optimization technologies as a technique. The findings show that unit technologies for optimizing atypical structures may be separated into four stages: concept design, schematic design, design development, and construction documentation [99]. In 2022, During the early phases of the complete life cycle of structures, Shanshan, Elhegazy, and Elzarka sought to discover, examine, and rank aspects that influence decision-making for the best system in the construction business. To accomplish this, a statistically representative sample of Egyptian practitioners and experts was asked to participate in a structured questionnaire survey. There were 17 questions in the questionnaire, and they were broken down into three stages: feasibility assessment, planning, and design and engineering [100] [101].

Finally, ANN and its improvements account for roughly 48 percent of all AI techniques employed in the geotechnical area; the shares of Fuzzy systems, PSO, GP & SVM approaches are each about 8 to 12 percent, and the other techniques are utilized in combination. as shown in Fig 5 [102].

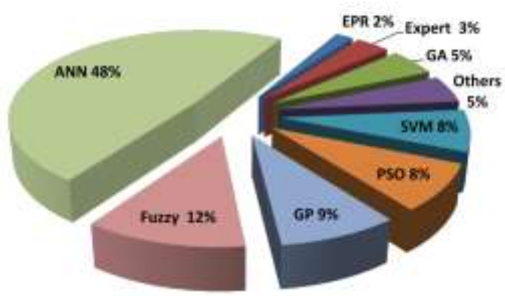

Fig 5 : Percentage of used AI Techniques [102]

Applications of Value engineering techniques for foundation Systems Proposed for Buildings

The definition of VE is engineering that meets performance, quality, reliability, and safety standards while providing the required functionalities at the lowest life-cycle cost. In 2014, In recent decades, Rana Nishant and Rana rapidly evolved while gaining from many innovations. They proceed. In his brief discussion of the different important structural form systems utilized in tall buildings, Siddhant emphasized the importance of each system to the functionality of these structures. The size of high-rise buildings has grown. Serviceability issues, including lateral wobbling, floor vibration, and occupant comfort, are getting more attention with more raised constructions [103]. One of the key success aspects of VE in achieving better project objectives is the providing pertinent input by multidisciplinary team members participating in critical decision-making discussions throughout the early phases of construction projects. The most often used stages or phases for the value management division are the pre-study, information, creative, evaluation, development, presentation, and post-study phases. The use of VE in public projects is difficult for less developed countries [104]. In 2021, Yanita and Mochtar responded and were asked to rate their opinions on 22 topics drawn from the literature in an empirical questionnaire survey that looked at Ghana's construction and consulting industries.Legal components (regulations) in Jakarta's (Indonesia) construction projects were researched for the main limiting reasons and their remedies for VE implementation [105]. Basha and Gab-Allah analyzed using VE ideas to choose building methods for key bridge projects in Egypt [106]. Then, in 2000, Assaf, Jannadi, and Al-Tamimi presented an integrated computerized system for the VE approach and LCC as a checkout system, providing a straightforward, quick, and precise technique for carrying out value-engineering investigations. Using the database program FoxPro Windows, the VE computer application was made [107]. Kwok et al. did offer VE in railway construction projects, nevertheless. The technique included identifying the primary cost drivers, presenting concise explanations for them, using a holistic approach to develop practical solutions, determining the viability by looking at potential obstacles, and creating an implementation plan. The approach may be easily applied to other infrastructure projects, even if the examples given were related to trains, as should be obvious [108].

Assessing Concrete Technology Innovation Using VE is a research project funded by the Engineering and Physical Sciences Research Council (EPSRC) (ACTIVE). Its goal was to suggest future R&D projects for the reinforced concrete construction sector. Additionally, it was suggested that the broad characteristics or problems that define or relate to innovation in the UK construction sector be defined and categorized. Amiruddin et al. (2010) advocated that VE teams analyze construction project aspects and search for methods to increase quality while controlling costs and time by incorporating construction, design, and maintenance personnel. It was called VE and included cost schedule planning, quality, VE application, cost parameters, and the link between value, cost, function, and worth.[109]. In contrast, [110] VE approaches were used in the education facility to make the most of the construction and maintenance budgets. It was utilized as a basic school model, and the General Authority for Educational Buildings (GAEB) was advised to incorporate a VE department into its organizational structure. Furthermore, In 2013, Charles provided evidence that the project management agreement and location impacted the theoretical perspective of VE. In America's North, the design/scheme step was often completed in a workshop lasting forty hours with a second design team. Because the North American construction/civil engineering business valued early contractor engagement, this VE approach was designed specifically for them. It was discovered that a method was required to systematically examine components and elements to explain the pros and disadvantages of an idea. These advantages and disadvantages might be utilized to "sell" the suggested VE suggestion to the client(s) or contractor(s) [111]. In 2014Chougule and Patil looked at the application of VE at any stage of the design development cycle of a project. However, early in the planning and conceptual design phases, the most significant value and cost reductions were generally obtained. It was essential to have it on hand so that you could compare the design's high-quality elements to the owner's requirements. The Pareto principle, commonly known as the 20/80 rule, states that around 20% of functions account for roughly 80% of the cost [112].

Modern application of VE

In order to save money and time while enhancing owner advantages, technological developments should also be investigated for new projects. The appropriate evaluation indices must be built to evaluate structural systems meaningfully while considering all these elements. It is important to follow VE concepts. AHP, which breaks down options into a hierarchy of subproblems, might be helpful to the management team. These techniques can help owners and managers choose the best course of action based on their goals and an awareness of the challenges the project is trying to solve. The confidence in the cost estimators' final estimations was considered when building the model. Comparisons between the two particular projections and the model are based on the user's choice of similar projects that cost estimators found to be successful in actual projects. The idea of attribute impact AI was developed to measure and order the assigned weights. It also covered the creation of AI using the impulse-momentum theory from physics. The research looked at 163 public apartment complexes from 15 housing complex developments in Korea as a case study. The validation outcomes verify the proposed AI's suitability for assessing attributed weights, which were precisely calculated when combined with parametric or CBR estimation [113]. [114] In 2007, In their presentation, Jadid & Idrees introduced a novel method for producing bills of quantities for construction projects using AutoCAD drawings that demonstrated the application of Industry Foundation Class, created by the International Alliance for Interoperability. Using interactive automation, the method calculated the price of the structural skeleton components by considering the kinds of materials and structural shapes of the AutoCAD designs.

The first BIM-based application supported a construction company's estimating department, and a sizable infrastructure project's risk management tasks were supported by the second [115]. In order to demonstrate the advantages of a technology pull view and its practical relevance in "real world" BIM-based tool adoption scenarios, case-based evidence was presented. Recently, ensemble techniques have garnered a lot of interest. Although ensemble learning has achieved significant accomplishments in various sectors, such as biotechnology, character recognition, disease diagnostics, and computer science, it hasn't taken off in the building sector. Two popular ensemble techniques are boosting and bagging [116] regressive trees. Using simulated examples based on 21 existing building facilities, the applicability and efficacy of the suggested approach were demonstrated and tested [117] and outlined the first and second versions of the Virtual Building Simulator (VCS). This tool lets students create and evaluate building schedules while interacting with 3D models concurrently. The effectiveness of VCS as a teaching tool was assessed using surveys, focus groups, and student interaction in a construction management class [2] created a VE knowledge management system (VE-KMS) that applied the idea of creative problem-solving and incorporated its tools into the creativity phase of the VE process, making it more systematic, organized, and problem-focused. For VE exterior wall construction, a BIM platform and estimating software were combined as a solution. Their recommended strategy offers design options that are simple to assess and compare in terms of price and visual appeal. The designer may ensure that any cost-cutting solution does not significantly harm the project's aesthetic appeal by using a 3D visual representation of the many external wall options [118].

In 2015, In order to choose or evaluate building methods for low-cost housing projects in Egypt's expanded urban zones, Agrama, Al-nemr, and Abdo examined value methodological concepts. Each building method was evaluated using the weighted assessment procedure compared to suitable alternatives. The most significant eight-value criteria were considered in the analysis [119]. To offer superior quality at a lower cost, Tom and Gowrisankar presented the offers by using VE approaches to a house construction project [120]. A framework for creating reliable design alternatives for temporary buildings in VE was presented by Moon, Choi, and Hong. Combining the problem-solving strategies of a rigid design with external components may result in the development of resilient design alternatives [121]. In 2016, Ali and Pandey discovered value management in the construction sector through readings on the global use of VE and references to related literature.

They provided a succinct description of the extensive knowledge. The most common principles are displayed in historical VE research, which also goes through a wide range of vocabulary. Additionally, it demonstrated three significant global markets that employ VE, including the US, the EU, and Japan Standards for VE [122]. In 2016, VE was proposed by Miladi Rad and Aminoroayaie Yamini as a helpful instrument for planning, building, exploiting, and controlling processes as well as overcoming the difficulties and complexity of civil designs from the start of studies to their conclusion [123].

The valuation technique was evaluated using weighted analysis at the evaluation stage of conventional VE. However, it was found that this method has limitations when compared to sustainable architecture and buildings. Consequently, researchers changed their perspective on traditional engineering to boost the creation of long-term results [124]. For instance, questionnaire research was conducted in Tamilnadu State, India, to determine the efficiency of VE used in the country's construction sector and the proportion of personnel who comprehend the concept and its worth. As a result, Rangelova and Traykova introduced VM in 2017 to make decisions in design-build construction projects for repairing and strengthening infrastructure. The main objective is to reduce building costs and promote more productive and efficient constructability [125].

Table 1: The knowledge gap in earlier research is summarized in the following paragraphs

Reference	The study's contribution	Deficits and restrictions
[118]	Here, we'll talk about how VE engineering designs the outside walls of an office building by integrating CAD systems, estimating software, and other tools.	During the design phase of the office building in this research, VE was only applied to the exterior wall.
[59]	A computationally based method was developed in this study that can be used to design high-rise office buildings that maximize cost-revenue ratios.	A cost-revenue analysis of office buildings was conducted in this study. This study was thought to be consistent across the structure. Therefore, this research solely looked at lateral wind loading.
[126]	They assessed the ideal thickness and rebar percent of solid, hollow block, flat slab, and waffle slab based on the simplified design techniques mentioned in the majority of reinforced concrete design rules.	Produced formulae for a rough estimate of concrete and rebar quantities based on empirical values and provided prior experience with the necessary scientific foundation.
[127]	outlined a process for diagrid steel structures.	They used the CSI ETABS program to evaluate and construct diagrid steel structures of 36, 50, 60, 70, and 80 stories.
[84]	A modeling process was designed using the CSI and SAFE 2014 models to determine an optimal process for the R.C slab.	Research the best ways to construct a particular type of reinforced concrete high-rise skyscraper.
[128]	investigated a lateral structural system for the RC Skyscraper.	The building was designed to serve as a prototype for cutting-edge structural technology that can be used for structures taller than the world's tallest skyscraper (consisting of several shear walls).

Conclusions

Research indicates that optimization techniques are popular as a construction industry management tool, and the industry has acknowledged the necessity of applying optimization techniques.

- Using optimization strategies in the early phases of a project is beneficial.; respected reference books support the findings from the literature review. In addition, the design functions and construction objectives should be considered, along with sustaining the budget while ensuring that quality and performance standards are met.
- It has been argued that optimization techniques are engineering techniques that aim to meet the requirements for performance, quality, integrity, reliability, and safety while achieving the lowest life-cycle cost.
- Optimization techniques reduce construction costs, save time, and streamline preliminary design in construction projects. The theory and practice of optimizations have been studied and written about in several academic and business books.
- In many of these situations, adverse effects on a project can result if not handled appropriately and promptly. For example, a building project may be delayed, cost increased, require more manpower, overrun the budget, or suffer compromised relationships. Last but not least, The State-of-the-Art review provides a selection of future research initiatives with the highest priority.

A competing interest

According to the corresponding author, none of the authors have any competing interests.

Disclosure statement

According to the corresponding author, no conflict of interest speaks for all the authors.

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