Optimization of Road Construction Project Resource Allocations Using Artificial Neural Network

Feyisa Shante Defo

A Thesis Submitted to the department of Civil
Engineering collage of Civil Engineering and
Architecture
Presented in Partial Fulfillment of the Requirement for the Degree of Master's in
Civil Engineering (Specialization in Construction Engineering and
Management)

Office of Graduate Studies
Adama Science and Technology University

June ,2025

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DECLARATION

I hereby declare that this Master thesis entitled "Optimization of Road Construction Project Resource Allocations Using Artificial Neural Network" is my original work. That, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation. It is being submitted for the partial fulfillment for the award of the degree of Master of Science in Construction Engineering and Management at Adama Science and Technology University collage of Civil Engineering and Architecture

Name of student	Signature	Date

RECOMMENDATION

I hereby certify that I have read and evaluated this thesis entitled "Optimization of Road Construction Project Resource Allocations Using Artificial Neural Network" prepared under my guidance by Feyisa Shante Defo submitted in partial fulfillment of the requirements for the degree of Masters of Science in Construction Engineering and Management. Therefore, I recommend that the candidate has fulfilled the requirements and hence he can submit the thesis to the department.

Bahiru Bewket Mitikie (PhD)	______________	____________
Major Advisor	Signature	Date

APPROVAL SHEET

I hereby certify that all the correction and recommendation suggested by the board of examiners are incorporated into the final thesis entitled “Optimization of Road Construction Project Resource Allocations Using Artificial Neural Network” by Feyisa Shante Defo.

Bahiru Bewket Mitikie (PhD)	_______________	_______________
Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis open defense by Feyisa Shante Defo have read and evaluated his thesis entitled Optimization of Road Construction Project Resource Allocations Using Artificial Neural Network and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the degree of Master of Science in Construction Engineering and management.

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ACKNOWLEDGEMENT

First and foremost, I extend my gratitude to the Almighty Allah for his mercy and giving me the strength and knowledge to complete this thesis. I want to acknowledge all the people who have been integral parts of this study. Without them, this thesis would not have been possible. I sincerely thank my advisor, Bahiru Bewket(PhD) for his knowledgeable guidance, wisdom, patience, and encouragement throughout my thesis journey, even while he was busy. His persistent support inspired me with the confidence that this journey was possible to complete on time. I deeply appreciate my teachers for their invaluable help in developing ideas and maintaining the logical flow of my thesis, as well as for their attention to detail and willingness to share their expertise and knowledge with me whenever I needed help.

Lastly, I would like to thank my family and my best friends for their extraordinary support during my studies.

TABLE OF CONTENTS

Contents page

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

LIST OF ACRONYMS

ANN	Artificial Neural Network
AI	Artificial Intelligence
GDP	Growth Domestic Product
ML	Machine Learning
IRI	International Roughness Index
BIM	Building Information Modelling
CDE	Common Data Environment
TRP	Target Resource Plan
NCA	National Construction Authority
WBS	Work Breakdown Structure
CSF	Critical Success Factor
SCM	Supply Chain Management
RM	Relationship Marketing
CPM	Critical Path Method
BIM	Building Information Modeling
MSE	Mean squared Error

ABSTRACT

As a vital economic driver, the construction industry contributes an average of 8-10% to national GDP of developed countries, while stimulating growth, creating employment, and enabling cross-sector economic linkages. Despite its significance, the sector faces persistent challenges including low productivity, inefficient resource allocation, frequent project delays, and cost overruns. This research proposed an Artificial Neural Network (ANN) approach to optimize resource allocation in construction projects, addressing three key objectives: analyzing critical factors affecting resource allocation, identifying enabling factors for optimal resource distribution, and developing an ANN-based optimization model. The study employed mixed methods research, combining semi-structured interviews and questionnaire surveys to examine key determinants of resource allocation, including budget constraints, project scale, timelines, financial management, and resource availability. The research also identified crucial enabling factors such as detailed planning, effective project management, and robust monitoring systems. Quantitative data analysis utilized descriptive statistics, Relative Importance Index (RII), and correlation methods. The developed ANN model, implemented in MATLAB R2019a, features a three-layer architecture (input, hidden, and output layers) specifically designed to predict equipment utilization in asphalt construction projects. The model demonstrated remarkable predictive accuracy, achieving a near-perfect regression value ($R = 0.9999$) and an extremely low Mean Squared Error ($MSE = 9.26\times10^{-16}$), with minimal deviations between predicted and actual values. These results confirm the model's capability to transform historical project data into reliable decision-support tools, offering significant improvements in resource planning accuracy and cost estimation efficiency. The findings present a valuable framework for construction project managers seeking to enhance resource allocation through advanced predictive analytics, ultimately contributing to improved project outcomes and sector-wide productivity gains.

Key words: *construction, resource allocation, artificial neural network, optimization*

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

In the world, the construction industry contributes to the economies of individual countries with about 8-10%, accelerates growth, creates employment, and provides a link between different sectors and the economy. hence, it acts as a driver of growth, whereby goods and services are transferred from one sector to another. the output of the global construction industry in 2017 was over USD 10 trillion. for example, in 2017, the construction industry in Australia accounted for 8.1% of the national gross domestic product and 9% of the employment in the country. its contribution to the national gross domestic product in the UK was 6.5% and China at 5.7%. while the construction industry plays such a key role in most economies, its output is generally characterized by low productivity(Opoku et al., 2021).

Resource loading, which involves allocating the required resources including quantity and timing to each project activity, is categorized into four key areas known as the 4Ms: Manpower, Money, Materials, and Machinery. Resource leveling aims to smooth out peak resource requirements by distributing resources across different activities while taking into account the time available. this means reducing the inconsistency of resources used to conduct a project when resources are unlimited, leveling assists in reading fluctuations for sinkers; but when resources are scarce, they must be distributed optimally. leveling resources: prevents large variations in resource utilization and is an important factor in efficient project implementation. (Azim Eirgash, 2020) Resource allocation refers to the distribution of limited resources between work so that they can reach their aims with certain constraints. In construction projects, various uncertainties lead to implementation constraints that limit the ability of a project to meet planned resource demands and are an impediment to achieving project objectives and maximizing benefits. As a result, the optimization and resource allocation at various construction stages becomes highly critical(Huang et al., 2010a).

The last decade has revealed a significant contribution of AI toward business operation improvement, enhancement of service functions, and overall industrial efficiency. a greater competitive advantage exists, for example, in sectors of AI, like machine learning, natural language processing, computer vision robotics, optimization, and automated planning and scheduling-to tackle real-world problems and back decision-making in the industry. take, for instance, industry 4 the fourth industrial revolution centered explicitly on automation, data-driven technologies, and employing advanced AI applications within the manufacturing sector, yet another phase of this revolution to optimize working processes, therefore leading to reduced costs and production times, safety improvements, and achieving sustainability targets(Abioye et al., 2021).

Artificial Neural Network (ANN) is defined as a computing system which is an efficient imitation of biological networks. they are also known as artificial neural systems or parallel distributed processing systems or connectionist systems; these networks consist of interconnected units or nodes, also called neurons, which act in parallel. the neurons are connected by synapses, with each connection having a weight which conveys a measure of the importance of the connection toward the working of the system and subsequently this often causes the triggering of signal transmission. each neuron also has an inner state, called the activation signal. the combination of input signals and activation rules produces an output signal; then signals may be transmitted to other neurons or devices(zulunov et al., 2024). Artificial Neural Networks (ANNs) are highly advantageous for solving nonlinear relationships among different variables. over the past three to four decades, Machine Learning (ML) approaches have been widely applied in predicting the International Roughness Index (IRI). Techniques including grey forecasting, genetic programming, and multiple regression have been utilized to estimate IRI deterioration trends.ANNs, as computational tools, simulate human cognition to solve intricate problems through a network of interconnected neurons. these tools are known for their extreme flexibility, adaptability, versatility, and scalability. they effectively address many limitations associated with traditional methods, such as conventional statistical analysis and finite element methods. ANNs have also been used in construction sector to investigate the relationship between pavement distresses and the IRI, showcasing their potential in analyzing complex data and providing insightful predictions (Abdualaziz Ali et al., 2024).

1.2 Statement of the Problem

In practical applications, resources related to construction projects are usually limited. the construction industry has always been characterized by low productivity, and poor resource allocation makes the problems of project delays, cost overrun, and resource waste even worse. project managers in the construction industry have to tackle the important task of managing resources from multiple perspectives, as they need to optimize several conflicting objectives such as time, cost, and energy consumption. (Piryonesi et al., 2020).

Road construction projects frequently face delays and cost overruns due to inefficient equipment utilization, poor resource management, and inaccurate project forecasting. These issues lead to extended project durations, increased expenses, and disruptions in infrastructure development. A key challenge is the lack of reliable predictive models to optimize equipment usage and improve decision-making in asphalt pavement construction. Traditional methods often rely on manual estimations, which are prone to errors and fail to account for dynamic project variables.

Road construction projects in Ethiopia frequently suffer from significant delays and cost overruns, leading to substantial economic losses, reduced infrastructure quality, and delayed socio-economic benefits. Studies by the Ethiopian Construction Works Corporation (ECWC) reveal that over 70% of road projects experience delays, with average time extensions ranging from 30% to 50% beyond the original schedule (Gizaw, y,2021).on the other hand the Addis Ababa City Roads Authority reports that urban road projects typically face 6-12 months of delays due to inefficient resource allocation and bureaucratic bottlenecks(Tesfyae, s,2023). Concurrently, cost overruns plague these projects, with World Bank estimates indicating budget exceedances of 20–40% due to inflation, material price fluctuations, and poor contract management, and a 2022 study on Ethiopian highway projects showing average cost escalations of 35%, with some projects surpassing 60% due to delays and design changes. The primary contributing factors include poor planning and forecasting (40% of cases), equipment and labor inefficiencies (25%), and delays in fund disbursement and procurement (20%). The economic consequences are severe, with the Ethiopian Roads Authority (ERA) estimating annual losses exceeding $500 million due to lost productivity and increased maintenance expenses, while inefficient road construction drives up transport costs, inflating goods prices by 10–15% in remote regions. These persistent challenges underscore the urgent need for improved project management strategies, advanced predictive tools, and optimized resource allocation to enhance the efficiency and sustainability of Ethiopia's road infrastructure development.

In construction projects effective construction management, which involves the optimized allocation of resources by using Artificial Neural Network is essential for directly impacting project progress. that might reduce construction time, and prevent construction wastage

1.3 Objective of the Study

1.3.1. General objective

The primary aim of this thesis paper is to optimize the project resource allocation efficiency in construction by applying Artificial Neural Network (ANN).

1.3.2. Specific objectives

- To analysis the influencing factors that affect resource allocations in construction projects
- To analysis enabling factors for appropriate resource allocation in construction projects

- To develop model using Artificial Neural Network for optimization of resource allocation in road construction projects

1.4 Research Questions

1. What are the main factors influencing resource allocation in construction projects?
2. What are the enabling factors for appropriate resource allocation in construction projects?
3. How the Artificial Neural Network (ANN) model is developed, and applied to optimize resource allocation in road construction projects?

1.5 Significance of the Study

The ANN model which was developed in this study provides a more accurate and predictive method for resource management, enabling project managers to make data-informed decisions that minimize waste, prevent delays, and ensure better project outcomes. Furthermore, by focusing on Ethiopian Road Administration projects, the study not only offers actionable insights for policymakers and industry practitioners but also sets a foundation for future AI applications in other construction sectors. The integration of modern AI techniques contributes to the industry's technological transformation, promoting efficiency, cost-effectiveness, and sustainability. Ultimately, this research inspires broader adoption of AI in construction management, fostering innovation and improving overall project performance for contractors, clients, and the industry as a whole.

1.6 Scope of the Study

The scope of the research dwell on the construction phase and observe resource allocation practices and optimizations during the construction of road project owned by Ethiopian road administration (ERA), in Ethiopia and hence provide the local context of resource allocation challenges and optimization strategies, which are relevant to project and client. Emphasis is given to how ANNs can be applied in optimizing resource (construction equipment) allocation, at wearing coarse asphalt construction which also looks into the structure and functioning of ANN model.

1.7 Limitations of the Study

One of the primary limitations of this study is the lack of well-organized historical data on resource usage, allocation, and scheduling among many contractors. Proper documentation of such data is crucial for developing accurate optimization models, yet this remains a challenge in collecting data from the construction companies. The data used in this research were collected exclusively from road construction projects under the Ethiopian Road Administration, meaning the findings may not be generalizable to other sectors or clients. Additionally, the limited adoption of advanced technologies like Artificial Neural Networks (ANN) among professionals and companies in the industry poses a significant barrier. Many lack sufficient knowledge about ANN, making it difficult to gather the necessary historical data required to formulate and train effective optimization models. These constraints may affect the broader applicability and accuracy of the study's outcomes.

1.8 Organization of the Document

This thesis consists of five chapters. The first chapter provides an overview of the thesis. It begins with a background to the research and emphasizes the statement of the problem, research objective, and research questions. It additionally outlines the research scope, the significance of the study, the limitations, and the structure of thesis.

The second Chapter is review of the literature on resource allocation in construction projects, explaining the key factors that influence effective resource allocation. It explores enabling factors for appropriate resource allocation, including proper planning, skilled workforce availability, and advanced project management tools. The chapter also assesses optimization techniques for resource allocation, such as mathematical modeling simulation, and heuristic approaches. Additionally, it discusses the impact of AI in the construction industry, highlighting how machine learning and automation enhance decision-making and efficiency. The section further examines technological advancements in construction projects, focusing on Building Information Modeling (BIM), IoT, and cloud-based collaboration tools. Finally, the chapter presents an overview of Artificial Neural Network (ANN) applications in various sectors, demonstrating their potential in predictive analytics, risk assessment, and resource optimization within construction projects.

Chapter three addresses how the thesis was carried out. It describes the processes involved in achieving the aim of this study, including the research design, target population, sources of data, sampling techniques, data collection tools and methods, and data analysis techniques. This section also covers the validation and reliability. the fourth presents a summary of the results of the analysis based on the data gathered through the process of questionnaires, and interview, and development neural network model. This includes the comparison of findings with the existing body of knowledge. A detailed discussion of the findings is also included.

Chapter five is the conclusion and recommendation. It draws the final statement of the overall finding and suggests possible strategies for the problem of the study based on what has been discussed in the previous chapters.

CHAPTER TWO
LITERATURE REVIEW

2.1 Resource Allocation in Construction Projects.

Resource allocation in construction projects is influenced by a multitude of parameters that can significantly affect project outcomes. these parameters can be broadly categorized into human resources, material resources, technological integration and strategic management (Du et al., 2019).

Resource allocation in a multiple project environment is common practice in contemporary projects and operation management. More than 90% of manufacturing and service projects are managed and executed within such environments. Effective project delivery and enhanced return of investment often require the simultaneous optimization of several projects(Li et al., 2021).

Material costs can constitute up to 60% of a construction project's total cost, making material management crucial for schedule and cost control. centralized material management, where the owner handles planning, purchasing, transportation, storage, and allocation, ensures efficient monitoring, information exchange, quality control, and cost reduction. however, the variability of project environments and dynamic progress lead to unpredictable material demand and uncertain supply yield, often resulting in mismatches and material shortages. inventory buffers can help, but inventory management is complex, requiring decisions on levels and allocation during shortages. traditionally based on managers' experience, these decisions can lead to overstock or understock situations. integrating supply and site logistics for modelling inventory replenishment and allocation under variable demand and supply conditions is essential for enhancing project schedule and cost performance (Lu et al., 2018).

construction equipment allocation should be performed effectively to avoid wasting resources and to enhance the efficiency of a project. for large projects, resource sharing is necessary, and traditional methods, such as branch-and-cut algorithms and linear programming, are insufficient (Xu et al., 2013).

over the past two decades, numerous studies have emphasized the critical role of human resources in organizational and project success. strategic planning in Human Resource Management (HRM) is vital, as people are seen as a company's key competitive advantage. optimal human resource allocation involves considering skills, personal motivation, and career goals. different research has been done to explore methods, including algorithms for fast food stores and hierarchical team coordination, to enhance the process of decision-making and the outcomes of projects. successful human resource allocation hastens data processing and generates accurate results, thereby adding to overall success in diverse fields(J. H. Chen et al., 2008).

Scheduling financial resources is very important in mitigating the associated risk due to changes in project outcomes. it starts by developing a project budget, followed by the allocation of required funds, thereby creating a financial foundation on which project goals are achieved. financial resource scheduling, therefore, helps a project manager in estimating the required financial resources, controlling costs within the approved budget, and achieving the project objectives. the present study, therefore, recommends that project managers should make appropriate cost estimates, monitor expenditure over time, and take appropriate action where there is overspending, underspending, or the opportunity for budget saving. a project budget template must be managed under the supervision of a project manager, with both customer and sponsor involvement in the allocation and management of financial resources(Rwamba et al., 2024)

2.2 Factors Influencing Resource Allocation in Construction Projects

2.2.1. Project Size and Complexity

The more complex the construction projects are, the larger they are, the more prone or susceptible the accuracy of cost estimates. Typically, these projects have multiple stakeholders, intricate designs, and extensive interdependencies between multiple project components. Increased complexity is caused by the multiplying number of variables upon project size, leading to increased uncertainties in cost estimation for example, a broad composite project, for example a highway or bridge, may require organizing many subprojects owned by different contractors, subcontractors, and regulating bodies. All associated costs can't be accurately captured when estimating this multifaceted collaboration(Merrow, E. W,2024)

In general, the connection between the intricacy of a project and its achieved outcomes or success is perceived unfavorably. This idea has been empirically examined in many studies owing to its contribution toward cost and schedule overruns in large-scale projects. With its nature, project complexity adds considerable uncertainty and risk that increases costs while having a severe impact on project performance if the project team does not manage it proactively during the earlier phases of the project life cycle, for example, found that project complexity is one of the most important factors driving costs and time defining activities(Nguyen et al., 2019).

Construction resource management is closely related to cost performance and plays crucial role in success of projects in a long-term study under the scientific activity on Construction Project Risk and Resource Management reported that the projects were being overbudgeted in at least 81% of the projects surveyed. Past research indicates several construction resource variables that play a significant role in influencing project costs. delays in construction and supplying raw materials and machinery by contractors, changes in prices of building materials, and fiscal constraints in terms of allocation of resources and its attendant dependencies were among the foremost determinants of construction costs. Financial issues faced by the contractor and owner were highlighted as being of utmost significance in determining Vietnam's construction prices. Through the presence of a contractor resolving issues of misuse and insufficient construction equipment, and lacking materials of quality, it can be minimized in order to reduce construction's budget (Nguyen, H. D.,2017).

According to (Lu et al., 2015) the factors of project complexity are mission, organization, delivery, stakeholders, and team dynamics. project complexity is categorized into three forms: organizational, resource-based, and technical complexity. discovered four dimensions influencing project complexity: experience and capacity of the team members in managing different types and levels of complexity, organizational structure and its alignment between the project and other essential factors, project culture, and business processes involved in the project also separated complexity into five levels: task, societal, cultural, operational, and cognitive complexities.

2.2.2. Budget Constraints

Effective project management entails the integration of time and cost limitations into resource allocation decision-making to ensure projects are completed within given deadlines and budgets. Dynamic programming techniques can be utilized to integrate such limitations into project scheduling for increased efficiency, focusing on their time limitations refer to the time deadlines for completing the project tasks, and their completion is extremely crucial since any delays will lead to higher costs, missed opportunities, and unhappy stakeholders. Similarly, budget limitations refer to the financial limits that have been earmarked for the project, and adherence to these limits is crucial in terms of maintaining financials intact and organizational viability(Reddy Goda et al., 2023).

Naturally, the execution mode with the lowest cost was chosen for construction activities. As the project is ruled by reinforced concrete work, the "cast-in-situ" mode was chosen for all reinforced concrete works. To minimize the cost overrun as much as possible while keeping the overall duration to a minimum, the "Shove joint brickwork" mode was chosen for masonry walls, and the "Prefabricated" mode was chosen for foundation piles. In contrast, prioritized meeting the deadline by selecting the "Precast" mode of reinforced concrete members, which has a shorter activity duration. In the case of foundation piles and masonry walls, low-cost execution modes were chosen without prolonging the project duration significantly. This comparison shows that both budget and deadline constraints influence the selection of execution modes, and the proposed planning model effectively calculates feasible solutions within the constraints(Liu et al., 2019).

The empirical results imply that, as often underlined by facility managers, severe budget limitations are a very strong motivator in the FM (Facility Management) outsourcing process of services. the service provider side respondents identified three significant means by which tight budget constraints are actualized. firstly, clients like to have service providers who offer lower prices for highly demanded services. second, tight budgets create lengthy and complex negotiations throughout the outsourcing process because clients stringently examine and demand justification for proposed budgets for new projects. third, the client-side procurement process is typically experienced to be excessively bureaucratic from the perspective of strict budget control, and this has a tendency to cause project-delivery delays. these findings point out the severe challenges introduced by budget limitations in the FM outsourcing process(Hou et al., 2016).

2.2.3. Timeline and Deadlines

Timelines are effective visualization and control instruments for construction project schedules. they break down the work to be accomplished at various phases of the project life cycle, allowing instant evaluation of progress. it’s believed that timelines have significant elements such as tasks to be performed, task dates, task durations, and task dependencies. Gantt charts, one of the most popular construction schedules, present a detailed overview of what is in progress now and what can be anticipated by milestone or by stages of project evolution, as well as materials and resources needed. the construction managers ought to define tasks to be finished within specific periods so that not defining the timelines impacts project success negatively (Shehu,2021).

Timelines play a vital role in successful project execution by offering a structured approach to monitor progress and manage delays. This methodology enables project managers to assess the root causes of setbacks and implement weekly corrective measures. While traditional practices often emphasize tracking recurring delays, they frequently neglect to examine how these delays influence overall schedule performance. The proposed framework fills this gap by systematically analyzing delay frequency, severity, and their underlying cause-and-effect relationships. using a weighted average approach, it identifies delays with the most significant impact on timelines and distinguishes between those affecting all activities and those targeting critical tasks. this enables managers to prioritize resources and address critical delays effectively. by implementing this approach, project teams can identify productivity issues, reducing wasted time, resources, and costs(González et al., 2014).

Timelines play a vital role in ensuring the successful completion of construction projects, such as roads and infrastructure, yet delays persist as a significant challenge in both developing and developed nations. While investors demand guarantees on schedules and budgets to prevent setbacks and their consequences, numerous factors frequently disrupt project delivery. in the USA, project owners often cancel or reduce capital construction projects due to cost uncertainties, financing issues, and concerns over delays that could jeopardize project feasibility. similarly, it was found that conflicts often arise in the UK construction industry over balancing project objectives such as time, cost, and quality. Their research highlights the critical need for project managers to have excellent time management skills, enabling them to develop realistic schedules and ensure timely project completion. As a result, well-structured timelines are essential for preserving project viability, satisfying stakeholder demands, and securing successful outcomes(Mutugi et al., 2020).

2.2.4. Availability of Resources

The availability of resources is a key determinant of project success, including its related activities. For effective monitoring and evaluation. sufficient resources-such as personnel, funding, materials, and equipment-are critical to maintaining an efficient and unbiased process. Proper resource planning plays a vital role in the success of M&E initiatives, as it supports a results-driven approach and reduces potential limitations. This planning process entails outlining all necessary resources required to accomplish designated tasks. proper resource planning and allocation are therefore vital for achieving project objectives and ensuring efficient M&E processes(Rugiri & Njangiru,2018).

Resource allocation must account for the supply and demand conditions at the construction site. the Target Resource Plan (TRP) is defined as the daily resource allocation results that reflect actual site conditions. in essence, the TRP serves as a resource allocation graph, created as a goal during task execution by optimizing the resource allocation histogram based on practical field conditions, resource supply, and demand dynamics after the initial allocation plan is set. For example, tasks are scheduled by setting targeted resource allocation plans for specific timeframes, accounting for variables such as extreme weather (like heavy rain or snow), equipment accessibility, and workforce availability-particularly in remote locations. The Time-Based Resource Plan (TRP) serves as a dynamic allocation benchmark, customized to the project's schedule and site-specific conditions. This method offers a more realistic and adaptable approach compared to conventional techniques, which frequently depend on rigid, uniform resource distribution or idealized projections that overlook real-world challenges(Kang et al., 2015).

2.2.5. Project Location

The data highlights differences between the marginal value and wages of normal staff for the three various project locations. normal project administrators in remote projects enjoy greater wage negotiation power due to their larger accountability for successful or unsuccessful outcomes of the projects. Well educated administrators demonstrate themselves by minimizing manager errors and project losses to a minimum. on the other hand, normal site engineers, being more competent than local ones, are economically disadvantaged by their higher wages and powerless project performance influence. normal site engineers can either lower their compensation expectations or become significantly more competent in order to be economically competitive. otherwise, normal site engineers' participation in international construction projects may be restricted by global trends(Lin,2011).

2.2.6. Stakeholder Requirements

The stakeholders' task is to collaborate together to create a system that effectively meets their requirements. this involves working side by side with others, even from outside their own specialties, with free exchange of all information even unfinished work and actively constructing their knowledge and expertise. they are also bound to examine work products, provide early feedback, and inform about requirement changes in a timely manner. these roles establish a coordinative rapport between the stakeholders and the project team, which is essential to the success of any project(Ignatius Teye Buertey, 2016).

Stakeholder involvement in decision-making was ranked as the most significant factor influencing continuous support in the stakeholder management process. the other salient factors proposed by the respondents include effective and periodic communication with stakeholders, getting endorsement from higher authorities, maintaining and enhancing long term stakeholder relationships, offering access to knowledge and resources, reducing uncertainty, tracking stakeholder changes in involvement and relationship, building mutual respect and trust, and having alignment among stakeholders. all these factors cumulatively emphasize active stakeholder involvement and collaboration for successful project outcomes(Sunny ,2018). A critical task for project managers is to recognize stakeholders capable of impacting the project and to address their varying expectations through proactive and transparent communication, particularly during initial phases. In the analyzed projects, multiple stakeholder groups shaped decision-making, frequently in ways outside the project team's direct authority. This underscores the need to examine how stakeholder management intersects with other key processes—such as cost and risk management—to enhance overall project outcomes(Olander & Landin, 2005).

2.2.7. Regulatory and Environmental Factors

Environmental and regulatory factors have a significant impact on construction projects through their influence on sustainability efforts and compliance requirements. Environmental and social performance allow firms to avoid legal penalties, fines, and reputational loss, as clients who are environmentally aware avoid firms with poor compliance records. Government regulations, such as emissions standards and product prohibitions, demand specific environmental levels of performance or technology, forcing firms to adopt sustainable strategies. However, the development and enforcement of these regulations may be difficult, with uncertainty about their effectiveness. Most of the regulation reinforces and substantiates sustainability, and government regulation is among the strongest drivers of sustainable development in construction, with compliance with these regulations not only minimizing risks, but also resulting in better reputation and marketability of a company(Akadiri & Fadiya, 2013).

The regulatory structure of the project is an external project management element that influences, limits, or directs project processes, at times outside the project team, and can have beneficial or detrimental impacts on project results. Building regulations entail registration of contractors, projects, trained staff, site managers, and training organizations, as well as the facilitation of the collection and payment of construction levies. In most countries, permission for much construction work must comply with building regulations. Building regulations make a marked influence on execution and performance during projects. The governments appreciate the need for deciding what has an impact on future building regulations and related standards, particularly on aiding sustainable construction. Construction activities in Kenya are regulated by the National Construction Authority (NCA), which is a statutory body responsible for overseeing the construction industry and its growth. The function of the NCA is to encourage the standardization and improvement of the construction techniques and materials, and to provide, promote, inspect, and arrange courses of training(CharlesWanja,2024).

2.2.8. Technological Factors

Complexity of construction work is defined by a number of factors, including the need for taking requirements in order to induce industrialization. Planning generally involves the consideration of machinery and mechanisms specified in normative and technical documents; however, due to the higher rate of modernization of construction equipment, newer models with improved operating capabilities must be considered while designing. Insufficient examination of working conditions is also one reason for complexity, and it may be counteracted by redesign decisions, for example, designing components mounted higher so as to simplify processes. End product unit labor costs, governed by building codes with as much as 10% variations allowable, correspond proportionally to work complexity. To minimize such costs, optimizing design choices and reducing project lifespans are crucial for enhancing efficiency and decreasing overall costs(Lapidus et al., 2020).

The adoption of innovative construction materials, technologies, and methods is greatly driven by increased marketing efforts and simplified training requirements for understanding and implementing these advancements. Construction manufacturers and stakeholders who focus on entering new markets, improving the quality of construction work, and enhancing promotional strategies tend to achieve wider diffusion of their innovations. Moreover, the perception of risk associated with adopting new construction technologies plays a key role; as this perceived risk decreases, the integration and spread of innovative practices across the construction industry become more extensive(Gambatese & Hallowell, 2011).

(Hardie & Newell, 2011) Emphasizes the high technical ability in the client company as one of the greatest driving forces for innovation in the construction industry. maintaining the core capability of the client is key to building innovative strategies among construction contractors. the majority of clients embrace and are open to innovation in building works they commission. this openness enables technological advancement to drive innovation in a way unrelated to traditional "market push" factors. to elicit the best contractor contribution to innovation and value creation, the clients have to take a long-term view and actively encourage an ethos favorable to innovation. client active support is crucial for developing a "best for project attitude" among all stakeholders so that collective efforts are made towards innovation and perfection in construction.

2.2.9. project Management and Planning

Project scheduling and planning, project management, resource allocation, resource automation systems, and resource planning form the foundation for a conceptual framework to guide resource allocation procedures in construction. Results of a survey-based study conducted among contractor firms in Pakistan reveal current trends and practices within this context. The results based on data analysis show that only 17% of the firms realize the importance of project management, and 62% barely adhere to effective project scheduling. Additionally, only 8% of contractors plan their project resources, and 11% have resource allocation procedures. A worrying observation is that only 1.5% of companies have embraced computer-based resource allocation systems or automated processes. This suggests that resource allocation procedures are generally not given attention by contractor firms. Highlighting resource planning and scheduling above all other factors is important, as proper resource allocation can drastically improve organizational performance for construction projects(Khattak & Qureshi, 2015).

Most African countries are undergoing huge infrastructural transformation, particularly in the road sector, to keep pace with the demands of emerging economies. project management is crucial in infrastructural and road development. for instance, in Nigeria, road construction and maintenance are outsourced to construction companies that contribute meaningfully to the industrial and infrastructural development of the nation. similarly, Kenya has invested massively in infrastructural projects like the standard gauge railway and the thika superhighway, the developments being devolved to the county levels by devolved government institutions. the development of roads is a fundamental aspect of government operations in developing nations, and the government of Kenya prioritizes development by striving to provide citizens with well-networked, quality roads. while there has been development despite these initiatives, in some projects, there have been drawbacks due to factors such as corruption. effective project management is not always guaranteed. most project practices in Kenya put much emphasis on planning, such as budgeting, scheduling, and project quality assurance. road projects in particular need total and overall management skills in order to drive performance and achieve objectives(Chepng & Kimutai, 2021).

In construction, efficient management of multiple projects requires optimizing time management and resource allocation. Time management is a critical factor, as accelerating project completion reduces costs, addresses delays effectively, and enhances competitiveness by offering optimal delivery timelines. This makes timely project realization a key challenge in construction. Although limited research exists on this topic, few studies specifically focus on managing multiple construction projects. Resource allocation, alongside time management, is also a fundamental task for effectively steering construction projects toward successful outcomes(Kane et al., 2012).

2.2.10 External Factors (e.g., Weather, Market Fluctuations)

External environmental circumstances constitute a collection of circumstances beyond the control of construction project managers. These circumstances comprise inter-related influence drivers that are always in touch with construction projects, often bringing about threats that can hinder the success of a project. it is the responsibility of construction project managers to detect, analyze, and apply risk management practices in a bid to discourage these potential negative impacts. there is also a requirement of effective risk management to safeguard the project deliverables and overall success by addressing and minimizing adverse risks(Mols,2021). Natural disasters like hurricanes significantly affect the prices of construction materials, and it is therefore necessary to offer quantitative analyses of material price changes after disasters. This assists capital planners, construction managers, and engineers in making more informed decisions in planning and budgeting for reconstruction material procurement in case of future disasters. It helps project managers make realistic and knowledgeable choices, particularly at the project level in affected areas. While advances are being made in our understanding of natural hazards, successful translation of scientific studies into policy decision-making remains elusive, reducing their potential benefits(Khodahemmati & Shahandashti, 2020).

The COVID-19 pandemic significantly disrupted the global construction sector, impairing workers' physical and mental health while triggering project delays, budget overruns, and financial strain. While numerous studies have examined pandemic-related delays across industries, limited research has explored how these causes vary by project type and the scale of construction firms. To fill this void, a detailed study was undertaken, encompassing a review of literature, survey design, and analysis of 131 survey responses. Major drivers found were procurement difficulties, lack of heavy equipment, change orders associated with varying material specifications and prices, design and shop drawing approval delays, owner delays, and delays in getting governmental approvals. These issues significantly affected construction companies in all forms of projects, with the big-scale industries most affected, even though small- and medium-scale industries were susceptible as well(Adepu et al., 2023).

2.2.11. Supply Chain Management

Supply chain management is one of the drivers of construction projects, particularly in project-based industries, where inherent uncertainties regarding project timing and specifications present different challenges than process-based supply chains with repetitive demands. While most companies utilize generic project management templates, they do not have supply chain-specific templates for these industries, and therefore real-time supply chain visibility is typically absent. This can lead to delays in project execution and revenue realization, especially in today's technology-driven and high-speed economy. Further exploration is that industries based on projects maintain high inventories to meet demand, increasing the requirement for working capital, while traditional approaches that handle services and supply chains as separate entities exacerbate coordination issues, leading to delays and customer dissatisfaction(Behera et al., 2015).

Over the past decades, efforts have been made to apply Supply Chain Management (SCM) techniques and principles into construction management. The application has been limited and gradual compared to other industries. SCM in construction today focuses primarily on managing materials and resources, with emphasis on internal supply chain integration. One of the key issues is the lack of coordination among supply chain stakeholders, which stifles strategic decisions such as partnership formation, IT planning, and logistics planning during the design and planning phases. This widespread practice reduces the responsiveness and flexibility of the construction supply chain (CSC) to uncertainties that arise during construction(Le et al., 2020).

The construction supply chain highlights how stakeholders prioritize relationship marketing (RM) over traditional marketing, focusing on building long-term relationships to achieve strategic goals. RM is ideal for transformative supply chain initiatives, as success depends heavily on the quality of stakeholder relationships. In construction, RM is particularly effective due to high client involvement during project inception, deep integration with clients, and the need for close coordination and continuous communication to manage complexity. Applying RM to construction and similar industries offers a new direction for business-to-business activities, emphasizing customer focus-a key driver of success in industrial and service sectors. This RM approach fosters long-term relationships, enhancing business dealings and ensuring sustainable success for construction stakeholders(Davis, 2008).

2.2.12. Labor Skills and Availability

Labor is a fundamental pillar of construction projects, having a major impact on productivity, efficiency, and project success. Numerous studies emphasize the importance of labor skills, safety, and labor management in determining project results. A well-trained and skilled labor force guarantees quality work, completion of projects on schedule, and reduces errors or rework. Site safety is the most prominent among them, as a robust safety management system fosters good work culture and contributes positively to productivity. Effective management practices and project-specific features also better the labor performance. Although safety and skills training programs involve up-front costs, the resulting long-term benefits in terms of improved productivity, reduced risk, and fewer delays dwarf them. In summary, work cannot be substituted in construction, and there is a need to invest in skilled labor, safety measures, and proper management to achieve project goals and ensure industry growth(Chaturvedi et al., 2018).

The quantity of skilled labor also has a direct correlation with productivity and efficiency on the ground, pointing to the importance of training and workforce development. Where there is an abundance of labor and adequately skilled, projects can more readily stay on schedule, achieve quality standards, and keep within budget. Shortages of labor or skill mismatches, however, can disrupt workflows, increase reliance on overtime, and test project schedules. Having a dependable and skilled labor supply is therefore a major recipe for successful construction project management and overall success(Ardila et al., 2024).

Labor quality and availability are most relevant to construction productivity, as in a study putting labor productivity determinants in order of severity based on ratings by supervisors, project managers, and engineers. Workforce related factors are dependent on access to skilled, experienced labor, particularly in a nation like Ethiopia, where there is still lack of trained manpower. Productivity can be fostered by supporting the development of the workforce so that the economy is boosted. Sound management is also crucial, since inadequate planning and control may lead to delays and inefficiency. In addition, motivation of employees is another critical one for preventing issues like low quality output, turnover, absenteeism, and lateness. Motivation of workers by means of money, recognition, job security, and involving them in decision-making can significantly improve productivity. Mitigating these variables quality labor, competent management, and employee motivation is critical to productive construction projects and economic development, particularly in labor-surplus areas(Mengistu et al., 2016).

2.2.13. Material Quality and Availability

Successful material management is most crucial for the success of a construction project, but it faces numerous challenges in all its processes. At the material planning stage, vaguely established roles and responsibilities are the primary challenge, followed by material storage away from the site and poor store arrangement. At the vendor analysis stage, coordination and communication among contractors and material suppliers become essential problems. The material purchase stage is most commonly affected by site factors causing delays and unavailability of material. At the storage and inventory stage, lack of sophisticated equipment and handling processes is the predominant issue. Finally, at the supply and distribution stage, material damage on site and inadequate material control on site are the most predominant issues. The determination of such critical factors for every stage in material management provides a focused measure towards overcoming delay and construction project(Vipin & Rahima Shabeen, 2019).

The unavailability of materials at construction sites significantly impacts project performance, leading to time and cost overruns. This study identifies key contributors to delays in Saudi

Arabian capital projects: the project owner (e.g., scope changes), the consultant (e.g., design errors, poor tendering documents), and the contractor (e.g., inefficient procurement, inaccurate estimations). Economic factors like material cost inflation and price fluctuations further exacerbate delays. Addressing these issues is crucial for ensuring timely material availability and successful project completion within budget and schedule(Kar & Jha, 2020).

The unavailability of materials on construction sites is among the key reasons for poor project performance, including time and cost overruns. In this study, various factors with varying degrees of influence were found to hinder the timely availability of materials, leading to delays and increased costs in Saudi Arabian capital projects. The key reasons for the delays are the project owner, consultant, and contractor. The owner contributes through repeated but low-impact causes such as scope changes. The consultant contributes the most frequent and severe delays, such as design and contractual document faults, and poor tendering documents. Contractors contribute to delays through ineffective material purchasing systems, poor estimation practices, and unrealistic data used in estimations. Additionally, economic factors such as inflation of material costs and price fluctuation of raw materials result in material delivery to the site being significantly delayed. These need to be addressed to improve material availability and achieve timely and cost-effective project completion(Shash&AbuAlnaja,2023).

2.2.14. Equipment Availability and Condition

The application of higher levels of construction equipment management practice increases the possibility of achieving higher productivity, and lower levels of application reduce this possibility. The possibility may be represented by a logistic regression function. While previous studies developed tools for assessing construction equipment and tools management practices for industrial and infrastructure projects, the tools lack a probability function to analyze the productivity level as compared to the practice implementation level. Hence, the users of existing tools are unable to determine the probability of exceeding baseline factors of productivity. This probability allows project managers to plan and implement appropriate practices for future building projects. For example, when the probability of exceeding baseline productivity is low, managers can choose to enhance the implementation of such practices in order to improve the chances of greater levels of productivity(Gurmu & Aibinu, 2017).

The selection of sustainable construction equipment for on-site mechanization requires criteria that extend beyond traditional factors like cost, time, and quality, aligning with the global shift toward sustainability. This study proposes six key factors life cycle cost, performance, system capability, operational convenience, environmental impact, and social benefits-supported by 38 criteria items reflecting socio-economic, engineering, and environmental aspects. Statistical analysis ranked all criteria as "High" or "High Medium," with the top five being equipment productivity, safety features, ownership cost, operational cost, and efficiency. Environmental criteria, however, did not rank among the top five, indicating their lower priority in current selection practices(Waris et al., 2014).

2.2.15. Contractor and Subcontractor Performance

Subcontractors are of great significance to construction works and are tasked with the performance of most work transferred to main contractors. Project success in totality thus depends on the shoulders of subcontracting organizations that are more vulnerable to market volatility and fluctuations. However, performance measures and prime contractor or client initiatives are generally focused on producing end-project outcomes to the exclusion of subcontractor CSFs. To fill this gap, this paper presents results of research activity designed to establish the CSFs of equipment-intensive subcontractors a subsector best known for its high plant and equipment assets, in combination with other capabilities. Understanding these CSFs is fundamental to improving subcontractor performance and subsequently project success(Thomas Ng et al., 2009).

To enhance subcontractor behaviour and improve workflow in construction projects, it is essential to develop models that account for their inherent interests, encompassing social, organizational, and character aspects, alongside economic and financial factors. Such models must also consider the unique environments of different projects, including strategic, physical, and contractual conditions. A critical starting point is defining the appropriate goal function to optimize. Lean thinking advocates focusing on the value defined by the building's occupants (end-users), which contrasts with traditional goals such as individual project benefits for main contractors or aggregate benefits for general contractors and subcontractors across multiple projects. A broader perspective suggests optimizing global benefit achievable by all stakeholders-clients, contractors, and subcontractors-across multiple projects. While the presented economic model provides one potential approach, alternative methods such as game theory or discrete event simulation could also be valuable for testing predicted outcomes. However, the example underscores the limitations of models with overly narrow scopes, highlighting the necessity for comprehensive frameworks that address the multifaceted nature of construction projects. This approach aligns with the need for holistic strategies in the literature to improve subcontractor performance and project outcomes(Sacks,2004).

2.2.16. Risk Management

key construction project risks, including payment delays, funding issues, safety concerns, defective designs, inaccurate schedules, poor subcontractor performance, exchange rate fluctuations, improper scope definition, material quality issues, and supply delays. Risk responsibility is allocated as follows: six risks to contractors, eight to clients, and eight as shared responsibilities, with five risks unallocated. Contractors handle risks under their control, clients manage risks within their domain, and shared risks require collaboration.it was highlighted the effectiveness of preventive techniques, such as producing accurate schedules using updated information and referencing similar projects, and remedial techniques like close supervision and coordination with contracting parties(Iqbal et al., 2015).

Every project involves risk-taking by nature, and hence businesses must be prepared for potential risks. New businesses take high risks at the onset, and therefore the bankruptcy rate is high for them in the first two years. Banks and other financial institutions, since they are working with depositors' money, prefer stability and select projects with acceptable variance (uncertainty) levels. Projects must be screened for risk before implementing them, i.e., disclose potential risks, their nature, and assess their probability. It is a key activity in making decisions, particularly investors assessing project feasibility. The outcome of risk identification and analysis is an extensive listing of potential occurrences, their triggers, probabilities, and environmental impacts(Szymański, 2017).

2.2.17. Communication and Coordination

In research’s coordination theory examines the dynamics of coordination and social influence, particularly exploring how centrality relates to coordination processes. The study's hypotheses were formulated to establish this foundational relationship. Using social network analysis (SNA), the research tests these hypotheses, grounded in coordination theory's core principles: information production, distribution, and processing. This work integrates text mining, statistical analysis, and coordination theory to develop a process-action framework. To assess how centrality influences coordination, data was gathered on process participants, and their centrality metrics were analyzed to identify potential correlations. This methodology offers a comprehensive lens for analyzing centrality's role in organizational coordination(Hossain, 2009).

Improved interfaces and workflows enhance coordination and communication among project stakeholders significantly reducing project delays. Communication and coordination are critical in project management, as evidenced by the performance of two sulfur recovery plants. Effective use of process improvement methodologies can be able to improve the removal of non-value-added activities and provide improved overall project performance. For instance, the installation of a test package control unit during the construction phase of the second sulfur recovery unit eliminated delays and identified areas of concern for stakeholders. Maintaining improvement methodologies and quality culture can further enhance processes, serving as a strategic initiative for minimizing project delays(Bubshait et al., 2015).

2.2.18. Project Scope Changes

Magnitude of scope change was a key driver of project results, as it highlighted the necessity of prudent scope management to keep costs and timelines in check. Task interdependencies and productivity rates also played significant roles together with scope changes, highlighting the necessity of handling task interdependencies with care and optimizing workforce productivity. Estimate cost, actual cost, and project duration were determined to be the major predictors, which underscores the need for accurate cost estimation, vigilant cost control, and good schedule control. Moreover, it was discovered that some Work Breakdown Structure (WBS) elements significantly impact cost and schedule performance. Such observations are most beneficial to project managers who need to make cost-effect estimate based on available information, for instance, WBS, scope change size, dependency of tasks, and similar factors(Sadeghi,2024).

Scope changes are not confined to the planning phase; unplanned changes can also arise during the implementation or execution phase. Conducting annual quality audits helps identify, track, and address these changes, enabling corrective actions when necessary. The proposed method categorizes scope changes into five types: healthy changes (positively impacting the project), unhealthy changes (negatively affecting cost and schedule baselines), alternative changes (neutral impact, serving as backup solutions), critical changes (failing to meet project goals or organizational objectives), and unplanned changes (scope creep). While the first four types are planned, scope creep is a significant challenge in project management, often leading to project failure. Healthy changes, such as discovering alternative approaches or eliminating redundant functions, can reduce project time, effort, or cost, presenting valuable opportunities for improvement. This structured approach to managing scope changes ensures better control over project outcomes and minimizes risks associated with unplanned alterations(Althiyabi, T., & Qureshi, M.2021).

2.2.19. Quality Control and Assurance

Quality control and quality assurance are critical aspects of construction projects, and it was explored that the determinants of such in light of a comprehensive review of literature, observations, and interviews with expert artisans and construction professionals. the study determines and classifies important quality factors into five categories: manpower-related factors, equipment/machinery-related issues, management-related issues, funding-related issues, and duration-related issues. Study comes up with the determination of every factor group's importance. the most significant factors influencing construction quality are the findings, and such information is useful in improving quality assurance and control strategies in construction projects(Ribah & Singh, 2023).

Quality control is a vital component of project management, significantly impacting product engineering and delivery. planning decisions shape production conditions, including schedules, budgets, resource allocation, and quality standards. this study evaluates key activities in resource allocation and quality control, using a questionnaire-based approach to assess their impact on project outcomes. findings emphasize the need for effective planning and monitoring to ensure success. resource allocation across projects can create dependencies; while balancing quality is crucial-higher quality may raise costs, but lower quality risks rework and deviations from key performance indicators. addressing these challenges requires efficient planning, realistic resource management, and strong monitoring. by focusing on quality control, this study provides insights for optimizing project performance and achieving organizational success(Grigore & Ionescu, 2019).

2.2.20. Financial Management and Funding Availability

Study draws a conclusion that both contractors and consultants agree on the most frequent site management-related causes of rework in Nigerian oil and gas infrastructure projects. these include poor site leadership, breakdown in communication, ineffective planning and resource allocation, poor quality management practices, and constructability problems. these problems significantly influence the cost and time performance of projects, showing the need for actions to minimize rework and improve project performance. the findings show that the solution to these site management issues can enhance financial management and availability of funds by reducing unnecessary delays and expenses. interestingly, the study revealed that the frequency and impact of these rework causes are consistent across the south-south region of Nigeria, which implies that the location of projects does not influence(Geri, 2017).

Financial management and funding availability are critical to the success and efficiency of construction projects. effective budgeting and sufficient funding ensure projects are completed on time, while accurate activity duration estimation and diligent project scope management are vital for timely delivery and cost control. human resource planning and training programs enhance project outcomes by improving team efficiency and operational performance. Additionally, material resource planning, including timely availability of high-quality materials and appropriate resource selection, directly impacts project success. integrating robust financial management practices, securing adequate funding, and aligning human and material resource planning are essential for achieving successful construction project outcomes. these findings highlight the importance of a holistic approach to resource management in construction (Abdirahman,2024).

2.3. Enabling factors for appropriate resource allocation in construction projects.

The construction industry's persistent inefficiencies marked by wasteful practices and non-value-adding activities demand robust management solutions to curb rising costs and declining productivity. Research reveals alarming resource wastage, with studies suggesting up to 57% of productive time being squandered through obsolete management approaches and insufficient innovation adoption. Conventional project management techniques have consistently demonstrated their limitations in addressing these systemic issues, underscoring the urgent need for transformative practices lean construction principles offer a transformative approach by focusing on minimizing waste, improving workflow reliability, and enhancing value generation. this method shifts the focus from labor flow to efficient processes, providing a robust framework for tackling inefficiencies. by adopting lean principles, the industry can achieve better resource utilization, increased productivity, and improved project outcomes. effective management through lean construction not only addresses current inefficiencies but also ensures sustainable growth and long-term success. ultimately, embracing innovative management strategies is key to unlocking the construction sector's full potential and driving meaningful progress(Ansah et al., 2016).

Successful accomplishment of construction projects hinges significantly on good planning and scheduling, with Building Information Modeling (BIM) increasingly being used to help project managers with this formidable task. Planning is not merely building elements but also external factors like approvals, weather, and cost that influence time and risk management but are absent in standard IFC-based BIM models. Intermediate states model interdependencies between processes that occur at the same time, allowing one process to initiate based on another's condition, dividing processes by default where splits are needed. A hierarchical layout structures multiple levels of information into the schedule. With better BIM-based planning, this technique increases the precision of planning, risk estimation, and overall project effectiveness, providing a solid foundation for optimizing construction outcomes(*Hartmann2012b*).

Accurate budgeting is a major challenge in project management, as cost overruns remain a persistent issue in spite of efforts to attain budget, time, and performance objectives. the project budget, which is pre-planned, tries to forecast the total cost of project completion. this is difficult to estimate because there is a lack of information and risk-related uncertainties are a natural issue. the early-stage project management plans, such as budgeting, are prepared prior to actual construction; however, as the detailed information is not available, precise budgeting becomes a problem. sound budgeting is not only required to rationalize projects on economic grounds but also for efficient capital planning and financing. these problems have to be resolved using improved methods that take into account both recognized and unrecognized risks, yielding better budget estimates and reducing the threat of cost overruns(Kwon & Kang, 2019). The construction industry relies on a number of resource management applications such as Microsoft Project and online applications such as Asana and Trello to formulate project efficiency through improved time, cost, and resource allocation. However, these applications have some grave shortcomings such as their lack of ability to perform resource allocation and leveling for multiple projects where the resources are common, a functionality that is important to ascertain resource demand or waste. They also lack real-time information, relying on manual inputs that are time-consuming and error-prone, and fail to use historical data to optimize project delivery and anticipate issues. The common workaround is using Microsoft Excel to track resources, but it requires manual updating and is not integrated with project management software, leading to outdated information and excessive administrative costs. These constraints point to the need for more advanced management tools with real-time feedback, utilization of historical information, and cross-project resource leveling to achieve greater accuracy and effectiveness in construction project management(Kusimo et al., 2019).

Procurement is a critical factor in shaping the success of construction projects, as it determines responsibilities, authorities, and the level of collaboration among project participants. despite its importance, the construction industry has faced widespread criticism for inefficiencies such as time and cost overruns, low productivity, poor quality, and inadequate customer satisfaction.

traditional procurement methods often lead to adversarial relationships and challenges throughout the project lifecycle, highlighting the need for improved practices. clients, as key change agents, play a pivotal role in driving this transformation by adopting innovative procurement approaches tailored to specific project objectives. however, clients often rely on familiar methods, regardless of project differences, due to a lack of understanding or confidence in new procedures. for meaningful change, clients must gain a deeper understanding of how innovative procurement practices function and their potential to enhance project outcomes. by fostering awareness and confidence in these methods, the industry can address inefficiencies, improve collaboration, and deliver higher-quality projects, ultimately contributing to economic and social development(Eriksson & Westerberg, 2011).

2.4 Optimization Techniques for Resource Allocation

In a construction project group, the construction processes are so complex and the resources in need so different that the optimal resources' allocation is at risk of being imbalanced over time. in this regard, an optimal allocation model for resource equilibrium is established to achieve balanced resource allocation among multiple projects. this ensures that the logical sequence of construction process in every project is guaranteed and the supply quantities of every resource are within a given range of daily supply every day. this model can be solved by using a heuristic algorithm to balance the resources distribution. practical examples' analysis confirmed the validity of this approach, which can be a useful reference for solving the resource imbalance problem in an engineering project group(Chunguang et al., 2016).

An alternative model using genetic algorithms optimally allocates resources to repetitive construction projects. it calculates the optimal duration of such projects with a minimum number of days of crews' work interruption. the model can be easily implemented in spreadsheet software and for a variety of problems. furthermore, GA-based optimizations typically yield superior solutions compared to those by other models(Huang et al., 2010b).

Multi objective model, comprising a startup module, scheduling module, and multi-objective genetic algorithm module, uses new metrics to minimize resource release and idle days. integrated into commercial project management software, the model facilitates use by planners, offering significant improvements in productivity, duration, and cost(Heon Jun & El-Rayes, 2011).

2.5 Impact of AI on Construction Industry

Artificial Intelligence, AI, can be referred to as the ability of machines to emulate intelligent human behavior by applying human-inspired algorithms to traditionally difficult problems. application within construction projects takes different styles according to the needs that each firm may have.it has been deduced that AI will increase productivity, enhance the quality of the activities performed, and provide job opportunities. AI helps construction companies to satisfy the customer's objectives, such as delivering the project on time. however, the adoption of ai in the construction sector is still not complete when compared with other sectors. the sector has been characterized by poor productivity and performance, coupled with lower technological software utilization. besides, AI is viewed as a tool that can help to tackle major issues of the industry: safety, additional costs, and time delays(Phaladi et al., 2022).

AI will bring great advantages during the planning phase of construction projects by providing high accuracy in event, risk, and cost forecasting. one significant opportunity in the adoption of ai is the ability to save time in repetitive tasks through big data analytics and improved processes of work. however, the fragmented nature of the construction industry makes ai integration a huge challenge in data acquisition and retention. the international construction market may record an 85% increase to USD 15.5 trillion by 2030, boosted by ai through increased productivity of between 0.8% and 1.4% annually. however, the global construction industry has been growing at a mere 1% average annual rate over the recent decades, making it really important to develop technological changes throughout all stages of the construction life cycle-planning, design, and construction(Regona et al., 2022).

AI and robotics bring huge potential to address many construction challenges by automating unsafe or physically demanding tasks, while significantly improving productivity and the safety of workers. smart robots can take care of impracticable, repetitive, or dangerous tasks on job sites, while AI simulates human thought processes through algorithms to perceive, learn, reason, and behave rationally. these are programmable devices that contain sensors and controls; hence, it can lift, move, and assemble an object. by integrating data-driven approaches of AI with the capabilities of robotics, the technologies can collaborate with construction crews or operate in an autonomous way to enhance processes. key applications include the following: autonomous vehicles for material handling and earthworks, wearable exoskeletons enhancing human strength, risk-inspection and payload-delivery drones, machine learning-powered safety monitoring systems, and 3d printing of building components. collaborative robots assist in welding and painting, while digital tools using augmented reality, building information modeling, and IOT sensors enable real-time management of projects(Faheem et al., 2024).

2.6 Technological Advancements in Construction Project

Industry 4.0 developments have greatly benefited the construction industry, hence the development of the concept of construction 4.0. the construction concept digitizes on four themes: digital data, automation, connectivity, and digital access. according to (sawhney et al,2020), construction 4.0is a "transformative framework" that has three transformations: industrial production, cyber-physical systems, and digital technologies. examples of such technologies include building information modelling, common data environments, unmanned aerial systems, cloud-based project management, augmented reality/virtual reality, artificial intelligence, cybersecurity, big data and analytics, blockchain, and laser scanning. cyber-physical systems would involve technologies such as robotics and automation, sensors, the internet of things, wearable sensors, actuators, additive manufacturing, and sensor-equipped equipment. they enhance competitiveness, improve the quality of work, ensure timely completion of projects, and create new services for the customers(Forcael et al., 2020).

The whole process of sustainable development needs a balanced approach, considering not only technological advancement but social, economic, cultural, and environmental questions as well. where technological progress, therefore, tends to decrease the effective price of energy services by enhancing energy efficiency, the original expected energy conservation can be softened. evidence indicates that green construction involves the use of effective ways that aim to reduce consumption in non-renewable energy and have minimal environmental impacts without compromising quality and safety(Liu & Lin, 2016).

productivity gains are lagging in the construction industry compared to other industries. for productivity improvement, automation of at least part of the construction process is one of the promising avenues. that can be made possible through various means: the more frequent use of cross-functional groups dedicated to learning and to leading the implementation of new technologies or through the deployment of robots to replace on-site labor. Practitioners are presently working on construction automation, and a synthesis of present efforts and suggestions for future focus areas is of high interest to those striving to enhance construction productivity(Q. Chen et al., 2018).

prefabrication, has advanced the construction methodologies by the involvement of time control, cost savings, quality, productivity, and safety. its initial uses in low-cost mass housing projects lately have been sculpted towards economic affordability and ecological sustainability. prefab manufacturing of its components involves factories and transporting for on-site installation; a method to be well known during the second world war. in those countries which have smaller workforces, more manufacturing industries, and colder climates, the technology has already been put into place: Sweden, the USA, the Netherlands, Germany, the UK, Portugal, and Japan. Prefabrication reduces material waste, energy use, carbon footprint, operational impact, and environmental disturbance while it improves working conditions, efficiency, and cost-effectiveness(Chippagiri et al., 2022).

Adoption of technologies such as BIM has indicated certain changes within the construction industry. However, globally, the adoption of BIM has been slow because of perceived risks and challenges in its development. Besides, there is a misunderstanding among individuals and organizations of the actual potential that BIM has in mitigating the identified challenges of the industry, which has led to its abandonment and a decline in knowledge and understanding of the technology (Opoku et al., 2021).

2.7 Overview of Artificial Neural Network Application in Different Sectors.

Artificial Neural Networks are a major part of artificial intelligence, which started in the 1980s and draws inspiration from biological neural systems of the human brain for its information processing model. ANNs comprise several nodes connected with each other, commonly called neurons, where each neuron expresses an activation function. the weights associated with the node connections mimic memory and thereby determine the output from the network as a result of the structure of the weights. ANNs can approximate algorithms or functions and express logical strategies. they usually involve input units receiving external signals, hidden units processing these inputs, and output units delivering the results. weights in connections reflect strength between neurons, carrying information processing within the network. ANNs process information adaptively in parallel, distributed functions and mimic the processing of information by the human brain and nervous system to a degree. they are an important subpart of neuroscience, artificial intelligence, and computer science-they bridge interdisciplinary gaps (Wu & Feng, 2018).

Artificial Neural Networks (ANNs) are computational architectures modeled after the structure and function of biological neural networks in the brain, which may become predictive models if adequately trained. once an ANN is properly trained with experimental data and validated by independent data, it attains predictive power. they can re-learn with novel data sets to enhance their performance. typically, ANNs can predict multiple output variables using multiple input variables, differentiating them from conventional modeling methods by the ability to memorize the system. thus, for ANNs, modeling can be made without a prior knowledge of process relationships(Tuan Hoang et al., 2021).

The first application of ANNs to chest pain appeared in 1989. in this study, the authors trained a multilayer network on 174 patients with anterior chest pain, classifying them into high-risk cardiac, low-risk cardiac, and non-cardiac groups, although these classes were not based on any strict criteria. a further study retrospectively analyzed 356 patients who had been admitted to a cardiac intensive care unit; 120 of the patients had suffered from a myocardial infarction. the network was trained by backpropagation on half of the patients, both with and without myocardial infarction, and then tested on the remaining patients not used in the training phase (William G Baxt,1995).

Estimation of energy flow and system performance is typically conducted by using analytic computer codes with intricate algorithms to solve nonlinear differential equations. many programs require substantial computational resources and take quite a long period to deliver an accurate prediction. on the other hand, an ANN learns patterns of important information within multi-dimensional data without recourse to complicated rules or mathematical procedures. in addition, ANNs are fault-tolerant, robust, and noise-immune, hence well- suited for the intrinsically noisy data from energy systems(Kalogirou,1999).

The classification and identification of environmental micro-organisms are difficult because of the varied traits of more than 100 prokaryotic genera, especially between fresh and stored isolates. phenotypic methods, which include traditional approaches like chemotaxonomy and whole-cell protein analysis, usually are not satisfying and require complex genotypic methods. fatty acid methyl ester analysis and whole-cell protein analysis are reliable and cost-effective, with fame rapid and automated. however, further development requires application of new methods of data processing, such as fuzzy logic and artificial intelligence

ANNs were developed to classify bacteria and identify them at the genus and species levels using fatty acid and protein profiles. supervised ANNs process input and output data while unsupervised ANNs categorize input patterns into classes to assist in the identification of unclassified strains based on learned patterns(Giacomini et al., 2000).

Multiple ANN applications were developed in various fields. for example, "de telegraaf," one of the largest Dutch publishing companies, developed an ANN approach to predict newspaper sales at various sales points. this can help each sales point be properly supplied but the stochastic nature of the sales required calculating margins in addition. another application was the prediction of currents for shipping guidance in ijmuiden. here, the North Sea directorate used a current, wind, and water level input-trained ANN to make the forecasting of currents more accurately predictable to improve navigational safety for deep- draft ships. in chemical process technology, akzo cooperated with the university of nijmegen in developing an ANN to predict yarn properties related to different production technologies and molecular structures, thus saving much in experimental costs. lastly, shell research utilized ANNs to classify rock types based on wireline data, improving the identification of economically recoverable oil and gas wells, and outperforming traditional statistical techniques(Kappen, 1996).

2.8 Research Gaps

The literature highlights significant gaps in current approaches to construction resource allocation, particularly in addressing regional variations like those in Ethiopia. While various influencing factors, and enabling have been identified across different contexts, there remains a critical lack of understanding of how these factors interact in specific regional settings, and from project to project. Existing optimization methods such as heuristic algorithms, genetic algorithms (GA), fall short in adapting to location-specific challenges, including volatile climates, supply chain vulnerabilities, and economic constraints. Additionally, current methods rely on static inputs, failing to adapt to real-time changes a major limitation in environments with material shortages, inflationary pressures, and infrastructure challenges where resource availability fluctuates rapidly.

Another critical gap is the lack of robust predictive analytics models capable of incorporating historical data, multi-source inputs, and regional risk factors to forecast and prevent delays or cost overruns. Furthermore, existing optimization methods struggle to integrate complexity metrics, real-time data processing, and learning capabilities needed for effective resource allocation across diverse project types and locations. Their inability to handle nonlinear relationships and multi-source data integration limits their effectiveness in complex, real-world scenarios. Compounding this problem is the cross-project learning gap, where current systems cannot leverage past project data to improve future allocations a critical need in regions with recurring projects but variable conditions.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter clearly defines methods and procedures implemented to achieve the specific objectives of this research. These methods and procedures were chosen based on the type of study undertaken and the anticipated outcomes. The research primarily focused on analyzing the problems associated with the three core objectives outlined above. This section provides a detailed explanation of the methodology and design used to conduct the research. It includes an overview of the research approach, including information about the study area, research design, target population, sampling techniques, sources of data and its collection methods, tests employed to ensure questionnaire reliability and validity, and ethical considerations.

3.2 Study Area

The study was conducted in adama area road projects. adama is one of cities of Oromia region in central Ethiopia and is located at a distance of 100km away from the capital city Addis Ababa in southeast direction. It is bordered on the South by Arsi zone, on west adama woreda, on the north by lume woreda, and on east by boset woreda;Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), this city has a total population of 220,212, an increase of 72.25% over the population recorded in the 1994 census, of whom 108,872 are men and 111,340 women. With an area of 29.86 square kilometers, (Central Statistics Agency (CSA), 2007)

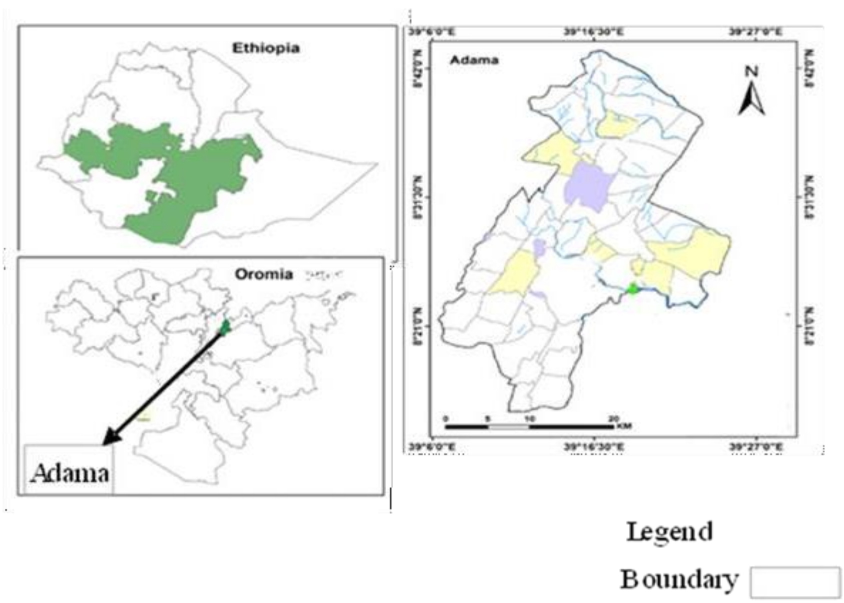

Figure 3.1:Location of the study area

3.3 Research Design

A research design refers to the systematic organization of conditions for gathering and analyzing data in a way that ensures alignment with the research objectives while maintaining efficiency in methodology (Kothari, 2004). This study adopted a descriptive survey design to facilitate comprehensive data collection, analysis, and presentation. According to (Aday, L. A., & Cornelius, L. J,2011), this design allows researchers to gather sufficient data, address detailed research questions, and derive reliable insights into the subject under investigation. Consequently, the descriptive survey approach was selected to examine and evaluate current practices in the field.

Quantitative research adopts an objective approach, typically involving respondents' input on their attitudes, opinions, or beliefs using structured numerical scales (Krosnick & Presser, 2010). In contrast, qualitative research is inherently subjective, emphasizing observation of individuals in their natural settings and engaging with them in their own language and context. Qualitative research methods focus on exploring non-numerical data such as opinions, attitudes, and satisfaction levels to develop behavioral insights or understand complex dynamics that cannot be easily quantified (Odiadi, J. 2024). By combining both methodologies, their combined disadvantages are reduced, while their combined advantages enhanced.

For this study, both quantitative, and qualitative approach were employed, utilizing both primary and secondary data sources. Primary data was collected through questionnaires with contractors, consultants, and client involved in road construction project in Ethiopia. Secondary data was gathered from existing thesis, journal articles, books, and other published documents. Questionnaire survey, and interview were used to obtain measurable data to subject matter. The adopted research design and methodology is shown in Figure 3.2 below

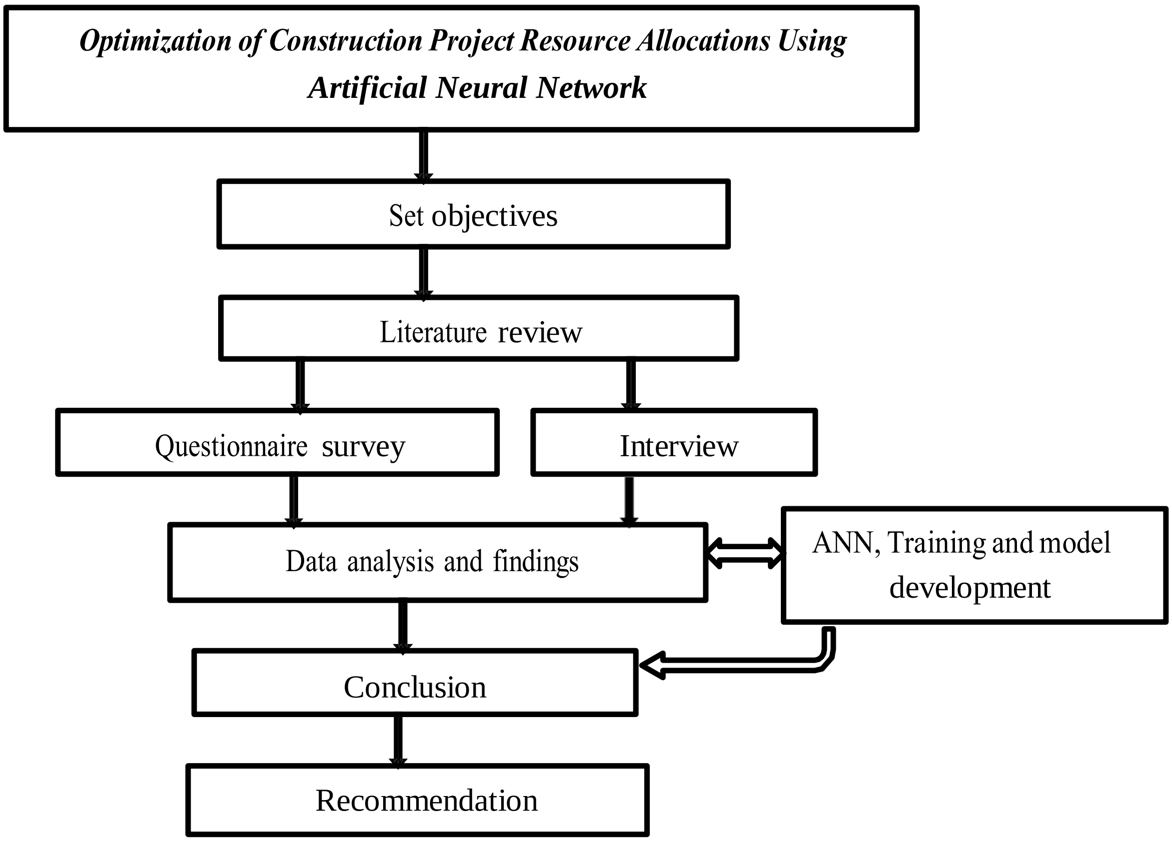

Figure 3.2: adopted research design

3.4 Target Population

According to Kumar (2010), the target population, or research population, refers to a group of individuals or objects that share common characteristics or traits.in the context of this study the target population is the specific group from which the research sample is selected. The target population of this study comprises client, contractors, and consultants actively engaged in asphalt road construction projects under the Ethiopian Road Administration (ERA) in Ethiopia. These professionals were selected based on their direct involvement and expertise in construction project resource allocation, ensuring the gather data is both relevant and reliable. Additionally, this study incorporates historical data from seven asphalt road construction projects to support Artificial Neural Network (ANN) model development and training. By focusing on these key stakeholders and past project records, the research ensures a comprehensive analysis of resource allocation practices in Ethiopia's road construction sector. The questionnaire forms were distributed and collected by the researcher in hard copies and google forms.

3.5 Sampling of the Target Population and Respondents

Sampling methods are broadly classified into two types: probability sampling and non-probability sampling. In probability sampling, every individual in the population has an equal opportunity to be included in the sample. On the other hand, non-probability sampling does not involve random selection, meaning there is no way to determine the likelihood of any particular individual or group being chosen (Stratton, S. J.2023). Unlike probability sampling, non-probability sampling does not require statistical representativeness, but it should still follow a logical basis for selecting specific participants or cases over others.

For this study, a purposive (non-probability) sampling technique was employed to select participants. This approach ensures that only individuals with sufficient expertise and experience in the research topic contribute to the study, enhancing the reliability and relevance of the collected data. Ethiopian Road Administration (ERA) is currently undertaking many road construction projects around Adama. some road projects were taken among them as a sample of the population for this study mainly on collection of historical construction data.

3.6 Sources of Data

This research employed a mixed-method data collection approach, incorporating both primary and secondary data sources. Primary data was gathered through direct engagement with seasoned industry professionals involved in road construction projects owned by Ethiopian Road Administration, including Project managers, Office engineers, Construction Engineers, Resident Engineer, and Site Engineer

For secondary data, the study relied on existing academic literature such as published research papers, journal articles, and proceedings from international conferences. These sources helped establish the research foundation by identifying key issues and informing the analytical framework for analysing the primary data.

3.7 Data Collection Tools and Methods

In this research both primary and secondary data sources were adopted for data collection. Primary data were gathered using questionnaires, and interview while the secondary sources include journals, thesis, books and different articles in published documents.

3.7.1 Questionnaire

Questionnaires serve as an effective data collection instrument, enabling respondents to provide input at their preferred time and location (Taherdoost, H. (2021). This study primarily employed questionnaire-based data collection due to its multiple advantages: the capacity to gather diverse perspectives from participants, the ability to reach a broad sample size for enhanced result generalizability, and its cost-effective nature.

This method was particularly suitable as it supports quantitative analysis, facilitating statistical examination of the data to derive meaningful and interpretable findings. The structured nature of questionnaires ensures clarity and consistency, making the survey results more reliable and easier to analyze.

To ensure validity and applicability, the questionnaire underwent rigorous refinement based on expert input before finalization. A pilot study was conducted to assess its reliability and internal consistency, verifying whether the identified factors, that influence resource allocation in construction projects, and enabling appropriate resource allocation in construction projects, which are identified from literatures.

This iterative development process helped tailor the survey instrument to accurately reflect sector-specific conditions while maintaining methodological robustness.

The questionnaire's design plays a pivotal role in gathering accurate and meaningful responses from participants (Aghayev et al., 2020). To maximize response rates and data quality, the survey instrument included a detailed cover letter outlining the research objectives, completion guidelines, study significance, and assurances of data confidentiality.

Structured in three distinct sections, the questionnaire first focused on collecting demographic and professional background information. This initial segment gathered key details about respondents, including their organizational role, educational qualifications, and years of industry experience. This foundational data helps establish the credibility and relevance of participant responses to the studies.

The second part of the questionnaire is about the factors that influence resource allocation in construction projects. The factors rated on a scale of 1 to 5, 1 being the factor with very low influence on resource allocation and 5, for factor with very high influence on resource allocation in construction projects. In the context of road construction projects.

The third part of the questionnaire is about Enabling factors for appropriate resource allocation in construction projects. The factors rated on a scale of 1 to 5, 1 being the factor with very low effect in enabling appropriate resource allocation and 5, for factor with very high effect in enabling appropriate resource allocation in construction projects. In the context of road construction projects

The fourth part of the questionnaire focuses on the collection of input and output variables required to develop an Artificial Neural Network (ANN) model for optimizing construction equipment allocation in asphalt road projects from sites. The input variables include the length and width of the road, which determine the project scale, while the equipment details (such as quantity, operating time, fuel consumption, and total equipment cost) for key machinery like pavers, rollers, asphalt mixing plants, dump trucks, and sprayers are essential for cost and duration calculations. The output variables are the overall cost for asphalt surfacing (in Birr) and the actual duration (in days), which the ANN model will predict based on the given inputs. This data helped to train the model to optimize resource allocation for similar future projects.

3.7.2 Interview

The interview was carried out in person, where selected individuals were asked questions to identify both exceptional practices and challenges related to the topic. Semi-structured interviews were conducted with a project engineer, two resident engineers, two project managers, and three office (planning) engineers. The goal was to collect insights on the factors affecting resource allocation in construction projects and to explore the enabling conditions for effective resource allocation.

3.7.3 Artificial Neural Network Model Development

An Artificial Neural Network (ANN) model was developed using MATLAB R2019a to predict construction equipment utilization in the wearing (surface) course of asphalt construction based on historical data. The ANN model consists of three interconnected layers: an input layer, a hidden layer, and an output layer, where each neuron processes and transmits information to the next layer to execute the desired function.

The input layer includes six neurons corresponding to the following variables collected from different asphalt construction sites: Length of road, total fuel consumption, number of pavers, number of rollers, number of dump trucks, number of sprayers. The hidden layer which serves as an intermediary was set between input and output, linking input data to the output through nonlinear transformations. The network was trained by optimizing its properties, including the number of neurons, activation functions, and learning algorithms, to enhance prediction accuracy. Finally, the output layer generates predictions for cost and duration once the ANN model is adequately trained. This trained model enables accurate forecasting of equipment utilization and project performance based on the given input parameters. The historical data was used to validate the model's reliability and predictive capability.

3.8 Data Analysis

In the analysis phase, data collected from various sources were examined and interpreted using appropriate techniques. The study's conclusions were drawn from findings obtained through literature reviews, questionnaires, and interviews. Both quantitative and qualitative data were analyzed. As Saunders et al. (2009) explain, quantitative data analysis involves systematically transforming data into numerical form and applying statistical methods for evaluation.

Descriptive statistics were employed to analyze the questionnaire data, including the biographical information of respondents. This analysis helped outline the participants' characteristics, such as their qualifications, years of experience, and organizational roles. Additionally, descriptive statistical methods were applied to the main research questions to identify trends and patterns in respondents' perceptions.

The study employed multiple analytical techniques to examine the collected data. For quantitative analysis, descriptive statistics were used to summarize the dataset, while the Relative Importance Index (RII) helped prioritize key factors. The strength and direction of linear relationships between variables were assessed using Pearson's correlation coefficient, which quantifies how two continuous variables co-vary. For non-parametric or ranked data, Spearman's rank correlation coefficient was applied. Data processing was performed using Microsoft Excel and SPSS (Statistical Package for the Social Sciences) version 25, selected based on the specific analytical requirements. The qualitative interview data were analyzed using thematic analysis, with the research questions serving as the foundational framework for identifying and organizing key themes.

For the first and second objectives, the collected data through questionnaire was analyzed using Relative Importance Index (RII) to determine ranking of factors that influence resource allocation in construction projects, and Enabling factors for appropriate resource allocation in construction projects. according to perceptions of client, consultants and contractors.

The relative importance index was computed as using equation 3.1

$\mathrm{RII} = \frac{\Sigma W}{AN} = \frac{(5n5)+(4n4)+(3n3)+(2n2)+(1n1)}{5N}$, Where W is the Weight given to each factor by respondents, A is the highest weight (i.e. 5) and N is the total number of samples of respondents. RII is relative important index, 0<RII<1. (0.8 – 1.0.) Very Significant, (0.60 – 0.79) significant, (0.40 – 0.59) moderately significant, (0.20 – 0.39) little Significant, (0.00 – 0.19) very little significant (Alshehri, K. A., & Youssef, N. H. (2022)

The Spearman's rank correlation coefficient (rho, ρ) is a statistical method used to compare the perceptions of different respondent groups by analyzing their rankings of various factors. (i.e. Clients versus consultants, clients versus contractors, and consultants versus contractors). In this research Spearman Rank's correlation coefficient method was used to know client's consultants and contractors' perceptions of factors influence resource allocation, and factors enables appropriate resource allocation in construction projects. The Spearman rank correlation coefficient is calculated using the following Equation: (Romero, A., & Esenarro, D. 2024).

$$\text{Rho } (\rho cal) = 1 - \frac{6\sum di^{2}}{N(N^{2}-1)}$$

Where Rho (ρcal) = Spearman rank correlation coefficient

d = difference in ranking between two parties

N = the number of variables

The value of Spearman Rank's correlation coefficient varies between -1 and +1.

- A correlation coefficient of +1 means perfect positive correlation.
- A correlation coefficient close to 0 means no correlation.
- A correlation coefficient of -1 means negative correlation

For the third objective historical data collected from different sites, were normalized and used for artificial neural network model development by prediction on MATLAB software.

3.9. Validity and Reliability of Study

3.9.1. Validation of data

Validity in questionnaires refers to the extent to which a questionnaire accurately measures what it is designed to measure. In other words, it ensures that the findings obtained from the questionnaire truly reflect the real-world aspects being studied (Saunders et al., 2009). One way to assess validity is through content validity, which evaluates whether the questionnaire's items appropriately represent the concept under investigation (DeVellis, R. F., & Thorpe, C. T,2021). To ensure content validity, a pilot study was conducted before the main data collection. The preliminary questionnaire was distributed to professionals, including one project manager, two construction engineers, two site engineers, four office engineers, and two resident engineers. Their feedback was used to refine and improve the questionnaire. Additionally, suggestions from the research advisor were incorporated to enhance the instrument's effectiveness. After these revisions, the questionnaire was deemed valid and suitable for measuring the intended constructs in the actual data collection phase

Alongside the pilot survey, the researcher employed both data triangulation and investigator triangulation to enhance the validity of the study. Data triangulation, which involves gathering evidence from multiple sources to strengthen the reliability of findings, was implemented by cross-referencing questionnaire responses with existing literature, allowing for robust comparisons with prior research. Additionally, investigator triangulation was utilized by comparing the study's results with findings from other researchers and studies, thereby confirming the consistency and generalizability of the outcomes across different contexts and research teams. Together, these methods provided a more comprehensive and credible validation of the research finding.

3.9.2. Reliability of Data

The collected data through questionnaires on listed items was checked by Cronbach's alpha (α) coefficient for reliability or consistency. Cronbach's alpha is a measure of reliability of the data on a questionnaire and ranges from 0 to 1.0. It indicates the extent to which the respondents rate the same question. For example, if all respondents give same answer to all questions, the alpha for these questions would be 1.0. The minimum level for reliability when using Cronbach's alpha coefficient is 0.7 and any value below this indicates that the variables are inconsistent and unreliable (Fellows & Liu, 2007). In this research Cronbach's alpha (α) coefficient was checked for reliability on listed items of factors that influence resource allocation in construction projects, and Enabling factors for appropriate resource allocation. Table 3.1 shows the result of Cronbach's alpha (α) for each field of the questionnaire. From the table it can be concluded that the questionnaire was reliable

Table 3.1: Result of Cronbach's alpha (α)

Field	Number of items	Chrombach's alpha
Factors that influence resource allocation in construction projects	20	0.928
Enabling factors for appropriate resource allocation in construction projects	14	0.913

3.9 Ethical Consideration

The study was conducted in full compliance with the ASTU post-graduate study guideline as of 2021, with both ethical and methodological principles fully adhered to at every stage of the research. Volunteers who took part in the questionnaire, and interview were duly informed of what the research seeks to find out and their voluntary response, which was requested prior to administering the questionnaire and interview. This assisted in informing the volunteers for what purpose they were taking part and doing so willingly. To assist in enhancing transparency and accuracy, the participants were also provided with the opportunity to read the final product before publication. This enabled them to check the information they had provided to ensure that it was truthful and accurate. These actions were all taken with an eye toward maintaining the highest degree of ethics, thus creating trust among the participants and researchers. By placing ethical issues first, the research aimed to develop sincere and credible results that would have the ability to be a worthwhile contribution to the field. Not only were the privacy and rights of the participants maintained, but also the quality and integrity of the research, in general, were enhanced. Such practices simply equate to responsible and ethical research practice, as demanded by academic and institutional expectation.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This chapter analyzes the data collected from interviews and questionnaires based on the research objective and present the findings. The results obtained from the respondents were presented, analyzed, and discussed in this chapter by dividing into the research specific objectives of the study: the factors that influence resource allocation in construction projects, and Enabling factors for appropriate resource allocation Each part answers the research questions and achieves the objectives of the research. A questionnaire survey and interview have been conducted to gather the required information from client, consultants, and contractors involved in asphalt road construction projects

4.2 Response Rate and Demographic Characteristics

4.2.1. Response rate of respondents

The questionnaire was prepared and distributed to the three contractual parties that play the main role in the day-to-day construction activities. These are client, consultants, and contractors working on road construction projects. A total of seventy-two (72) questionnaires were distributed to the respondents by google form and paper. The questionnaires were distributed for representatives of each party those believed to have sufficient knowledge of subject matter. From seventy-two (72) questionnaires distributed to respondents, six (6) questionnaires were distributed to the client (8.3%) of the total questionnaires. Forty-four (44) questionnaires were distributed to the contractors (61.1%) of the total questionnaires twenty-two (22) were distributed to the consultants (30.6%) of the total questionnaires. From six (6) questionnaires distributed to the client, all questionnaires were returned. From forty-four (44) questionnaires distributed to the contractors, forty-one (41) questionnaires were returned and two (2) of them was considered to be invalid. From twenty-two (22) questionnaires distributed to the consultants, twenty (20) questionnaires were returned and one (1) of them was considered to be invalid. The client (100% of response rate) has the highest percentage followed by the contractor (88.4%) and the consultant has the least response rate (86.4%) compared to client and contractor. A total of seventy -two (72) questionnaires were distributed to the respondents and sixty-seven (67) of them were returned out of which sixty-four (64) questionnaires with valid responses were collected which indicates an 88.9 % valid response rate. Reflecting strong engagement from participants. the response rate was computed and presented in Table 4.1 below

Table 4. 1: Response rate of respondents

	Frequency	Percentage	Respondents' organization	Frequency	Percent
Distributed	72	100%	client	6	9.4
Responded, valid	64	88.9%	consultant	19	29.7
Rejected +invalid	5+3=8	11.1%	contractor	39	60.9
			Total	64	100.0

4.2.2. profile of respondents

Among the six (6) responses collected from the client, in terms of positions within the projects four (4) of them were site engineers one (1) of them was construction engineer, and one (1) is project manager. Among nineteen (19) responses collected from the consultants, in terms of the position of consultants within the projects four (4) of them were resident engineers, three (3) are office engineers, one (1) site engineer and eleven (11) are others (work inspectors, material inspectors and structural inspectors). Among thirty-nine (39) responses collected from the contractors, in terms of the position of contractors within the projects twenty (20) of them were site engineers, four (4) of them were project managers, six (6) construction engineers, six (6) office engineers, and three (3) others (material engineers). From the result, 39.1% of the respondents were site engineers. It can be concluded that most of the respondents were site engineers

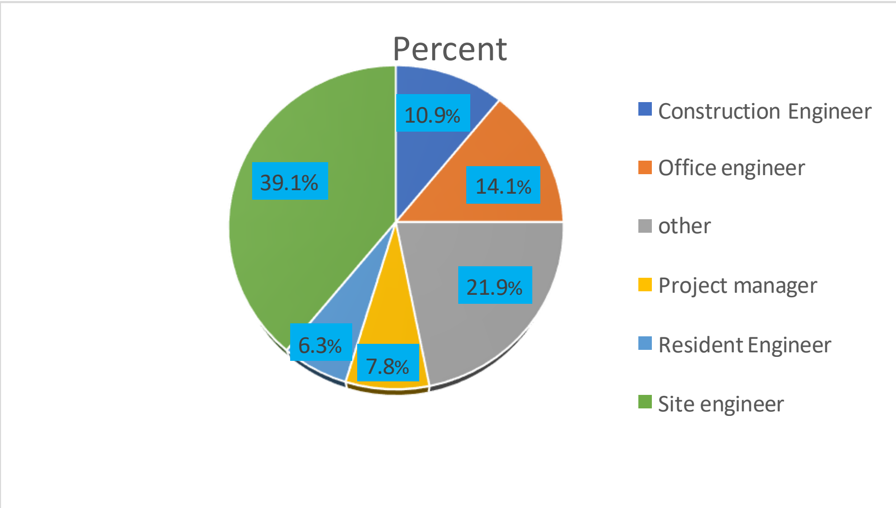

Figure 4.1: work Position of the respondents

The survey statistics shows that 28 (43,8%) of the respondents have experiences between five to ten years', 35.9% (23) of the respondents have experiences less than five years and 20.3% (13) of the respondents have above ten years' experiences as illustrated in Figure 4.3 below

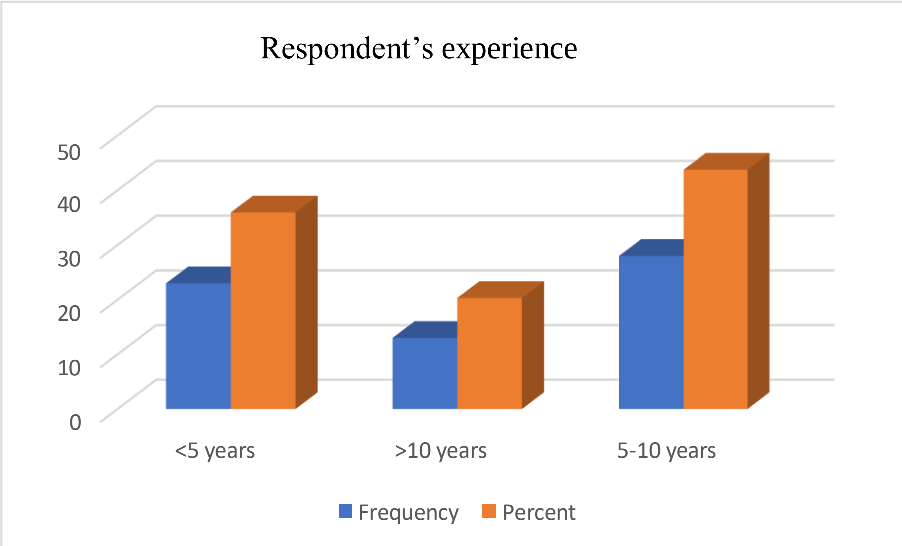

Figure 4.2: Respondent's experience

In terms of education levels of client respondents, four of them were BSc holders two were MSc holder. From consultant respondents, thirteen of them were BSc holders and six were MSc holder. In terms of education level of contractor respondents, thirty-one of them were BSc holders and eight of them were MSc holders. None of them were Diploma and PhD holders. It can be concluded that most of the respondents were BSc holders

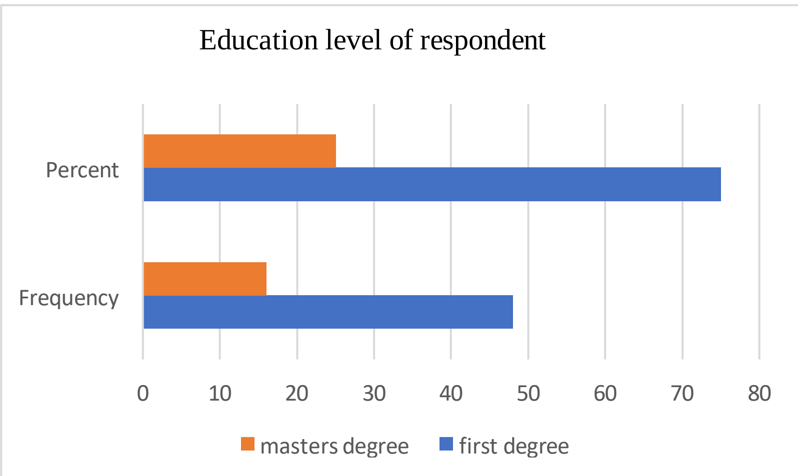

Figure 4.3: Education level of respondent

4.3 Factors that Influence Resource Allocation in Construction Projects

The factor's ranking system was ordered by comparing the relative important index and standard deviation of each section for those variables with equal relative importance index. The rankings as responded by the three groups of parties were compared to show the viewpoint of the three parties and a correlation test was done between the parties. Finally, the overall ranking was determined to identify the major factors that influence resource allocation in construction projects

Table 4.4: Responses on factors that influence resource allocation in construction projects

	Contractor		consultant		Client		overall	
Factors that influence resource allocation in construction Projects	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Project Size and Complexity	0.811	3	0.82	2	0.767	2	0.809	2
Budget Constraints	0.905	1	0.92	1	0.967	1	0.916	1
Timeline and Deadlines	0.832	2	0.76	7	0.700	7	0.797	3
Availability of Resources	0.747	5	0.78o	4	0.700	6	0.753	5
Project Location	0.626	17	0.66	17	0.533	19	0.634	15
Stakeholder Requirements	0.668	11	0.64	19	0.600	11	0.653	12
Regulatory and Environmental Factors	0.574	20	0.69	14	0.533	18	0.606	20
Project Management and Planning	0.679	10	0.81	3	0.600	15	0.713	8
Technological Factors	0.616	18	0.64	20	0.467	20	0.613	19
External Factors (e.g., Weather, Market Fluctuations)	0.589	19	0.67	16	0.600	15	0.616	18
Supply Chain Management	0.653	13	0.71	12	0.667	8	0.669	11
Labor Skills and Availability	0.700	7	0.71	13	0.633	9	0.691	9
Material Quality and Availability	0.737	6	0.77	6	0.733	4	0.744	6
Equipment Availability and Condition	0.695	8	0.72	11	0.733	4	0.703	7
Contractor and Subcontractor Performance	0.663	12	0.74	10	0.600	14	0.684	14
Risk Management	0.642	14	0.66	18	0.633	10	0.650	13
Communication and Coordination	0.637	15	0.76	8	0.567	17	0.669	17
Project Scope Changes	0.684	9	0.68	15	0.600	11	0.678	10
Quality Control and Assurance	0.632	16	0.75	9	0.600	13	0.669	16
Financial Management and Funding Availability	0.758	4	0.78	5	0.767	2	0.756	4

According to the responses of client, contractors and consultants; budget constraint was the major factor that influence resource allocation in construction projects. As it is ranked by overall respondents in Table 4.4 it was in first position with RII = 0. 916.It was ranked by client in first position with RII = 0.967, ranked by contractor in the first position with RII = 0.905, and ranked by consultant respondents in first position with RII = 0.92. Indeed, the critical role of budget constraints in influencing resource allocation decisions in construction projects is well- documented in prior research and industry findings. Studies consistently highlight how financial limitations shape procurement strategies, contractor selection, and project execution efficiency. For instance, facility managers emphasize that tight budgets compel clients to prioritize low- cost service providers, even for high-demand services, often at the expense of quality or long- term value (Hou et al., 2016).

Project size and complexity was the second major factor that influence resource allocation in construction projects which similarly confirms with the finding from the interview. As it is ranked by overall respondents in second position with RII = 0.809. It was ranked by client in second position with RII = 0.767, ranked by contractor in the third position with RII = 0. 811, and ranked by consultant respondents in second position with RII = 0.82. Poor resource management as reviewed from the literature was one of the major influence resource allocations in construction projects. The obtained result agrees with the previous study done by (Reddy Anireddy, 2020) who said that the Project size and complexity significantly impact resource allocation in construction, as larger, more intricate projects involve multiple stakeholders, interdependencies, and uncertainties, making accurate cost estimation and resource distribution challenging

The third major factor that influence resource allocation in construction projects was timeline and deadline of project. As it is ranked by overall respondents in third position with RII = 0.797. It was ranked by client in seventh position with RII = 0.700, ranked by contractor in the second position with RII = 0.832, and ranked by consultant respondents in seventh position with RII = 0.760. In fact, Timelines and deadlines are key factors in resource allocation, as they define task schedules, durations, and dependencies, ensuring efficient distribution of materials and labor (Gantt charts help visualize these needs). Clear deadlines enhance task efficiency, while poor timeline planning disrupts resource flow and project success(Shehu,2021).This result is supported by studies like, González et al., 2014) Timelines and deadlines directly influence resource allocation by helping managers prioritize critical delays, optimize productivity, and minimize wasted time and costs. A structured timeline framework ensures efficient resource distribution, enabling timely project completion.

The fourth major factor that influence resource allocation in construction projects was Financial Management and Funding Availability and it becomes in the fourth place from overall respondents with RII = 0.756. It was ranked by client in second position with RII = 0.767, ranked by contractor in the fourth position with RII = 0.758, and ranked by consultant respondents in fifth position with RII = 0.780. Proper budgeting and funding stability enable optimal distribution of human and material resources, preventing delays and cost overruns. A holistic approach to financial planning is thus essential for efficient project execution... In support of this result, (Abdirahman,2024)) Effective financial management and consistent funding availability directly influence resource allocation in construction by ensuring timely material procurement, skilled labor deployment, and adherence to project schedules

The fifth factor that influence resource allocation in construction projects availability of resource. As it is ranked by overall respondents in fifth position with RII = 0.753. It was ranked by client in sixth position with RII = 0.700, ranked by contractor in the fifth position with

RII= 0.747, and ranked by consultant respondents in fourth position with RII = 0.780. Inadequate resources disrupt execution, emphasizing their critical role in achieving objectives. This fact is supported by the interviewees and it is similar with the literature review. The study revealed similar result with other studies like (Kang et al., 2015) (Rugiri & Njangiru, 2018) who have identified that. Resource availability, human, financial, and material directly impacts construction project allocation, ensuring smooth execution. Inadequate resources disrupt progress, highlighting their critical role

4.3.1. Spearman (rho) rank correlation coefficient

The Spearman (rho) rank correlation coefficient was conducted to check the validity by measuring the differences in ranking between two groups (i.e. Clients versus consultants, clients versus contractors, and consultants versus contractors) of respondents scoring for factors that influence resource allocation

Spearman's rank correlation coefficient (ρ) can be classified into distinct strength categories based on its numerical value. A strong correlation encompasses values ranging from ±0.6 to ±0.9, indicating a substantial monotonic relationship where variables demonstrate a clear and consistent trend, with ±0.9 representing an almost perfect association. A moderate correlation covers the range of ±0.4 to ±0.6, suggesting a discernible but less pronounced relationship significant enough to indicate a pattern, yet not as robust as strong correlations. Finally, a weak correlation includes values between ±0.1 and ±0.3, reflecting only a slight monotonic tendency that may lack practical significance, with values approaching ±0.1 being nearly negligible Akoglu, H. (2018). Table 4.5 :Spearman's correlation coefficient

Respondent	Rho $=1-\frac{6\sum di^{2}}{N(N^{2}-1)}$	Relationship
Client vs contractors	0.805	Strong
Client vs consultants	0.817	Strong
Consultantvscontractors	0.707	Strong

As shown in the above Table 4.5 Spearman's correlation coefficient of 0.805, 0.817 and 0.707 were obtained for client vs contractor. client's vs consultants, and consultant vs. contractor respectively. These values are greater than critical correlation coefficient. This reveals that there is a strong correlation between the perspectives of the respondents in all three groups. It indicates that most of the respondents have the closer perspectives in ranking the factors that influence resource allocation.

4.3.2. Correlation analysis

To examine the presence of relationships among factors that influence resource allocation.

A Pearson correlation analysis was done in the first top-five factors. As exhibited in the Table 4.6 below, it is found that project Size and Complexity is positively correlated with Timeline and Deadlines of project and Financial Management and Funding (r = 0.438, p=0.000) and (r = 0.552, p=0.000) respectively and timeline and deadline of the project is also positively correlated with financial management and funding availability (r=0.405, p=0.001. According to the analysis result, there is a positive and strong correlation between factors. From the result, it can be concluded that the influences of one factor were explained by the other factors

Table 4.6: Pearson Correlation analysis of factors that influence resource allocation

Rank		1	2	3	4	5
Budget Constraints,1	Pearson Correlation (r)	1	0.244	0.238	0.102	0.175
	Sig. p		0.054	0.058	0.423	0.166
project Size and Complexity,2	Pearson Correlation	0.244	1	0.438	0.552	0.608
	Sig.	0.054		0.000	0.000	0.000
Timeline and Deadlines,3	Pearson Correlation	0.238	0.438	1	0.405	0.503
	Sig.p	0.058	0.000		0.001	0.000
Financial Management and Funding Availability,4	Pearson Correlation	0.102	0.552	0.405	1	0.535
	Sig.	0.423	0.000	0.001		0.000
Availability of Resources,5	Pearson Correlation	0.175	0.608	0.503	0.535	1
	Sig.	0.166	0.000	0.000	0.000	

4.3.3. Findings from interview

Concerning factors that influence resource allocation in construction projects, finding from interview agreed that factors listed as a major influencer for resource allocation were well analyzed, and indicates in road construction development, working within tight budgets and complex project require strategic resource allocation and risk management. When faced with a significant post-tender budget reduction on a road project, optimization is done by prioritizing high-traffic sections for cost savings, and reducing overtime extending the timeline slightly while maintaining quality through enhanced testing protocols. For complex urban road projects, unexpected challenges like utility delays were addressed through dynamic crew reassignments, advanced 3D modeling for adaptive planning, and decentralized material storage to prevent workflow disruptions. These approaches ensured efficient resource use while mitigating schedule risks.

Managing funding uncertainties and resource shortages requires proactive financial planning and workforce flexibility. On a road project delayed by inconsistent payments short-term financing is secured to keep operations running, prioritizing critical phases like drainage to avoid future rework, and negotiating flexible payment terms with suppliers of materials. To counter skilled labor shortages, investment is done in training local workers, ensuring continuity without compromising quality. These strategies highlight strategy to stabilize projects financial and logistical constraints while sustaining progress and minimizing disruptions

4.4 Enabling Factors for Appropriate Resource Allocation in Construction Projects.

The ranking system for the factors was determined by evaluating the relative importance index of each section. In cases where variables had equal relative importance indices, their standard deviations were compared. The rankings provided by the three groups of stakeholders were then analyzed to highlight their differing perspectives, and a correlation test was conducted to assess the alignment between the groups. Finally, the overall ranking was determined to identify the major Enabling factors for appropriate resource allocation in construction project

Table 4.7:Responses on Enabling factors for appropriate resource allocation in construction projects

	Contractor		consultant		client		overall	
Enabling factors for appropriate resource allocation in construction projects.	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Effective Project Management	0.889	1	0.86	1	0.733	4	0.809	2
Detailed Planning and Scheduling	0.879	2	0.81	4	0.800	1	0.916	1
Accurate Budgeting	0.847	3	0.81	3	0.767	3	0.797	3
Resource Management Tools	0.826	4	0.78	5	0.733	4	0.753	4
Clear Communication	0.763	5	0.75	9	0.767	2	0.634	8
Stakeholder Engagement	0.705	6	0.75	8	0.633	12	0.653	6
Training and Development	0.642	8	0.69	13	0.633	11	0.606	7
Regular Monitoring and Evaluation	0.695	7	0.82	2	0.667	9	0.713	5
Risk Management	0.621	9	0.68	14	0.667	10	0.613	10
Flexibility and Adaptability	0.584	11	0.71	12	0.600	14	0.616	11
Quality Control	0.600	10	0.78	6	0.667	6	0.669	13
Supplier Relationships	0.526	14	0.74	10	0.667	6	0.691	9
Efficient Procurement Processes	0.584	11	0.72	11	0.667	8	0.744	12
Team Collaboration	0.579	13	0.77	7	0.633	12	0.703	14

As ranked on the questionnaire's response on Table 4.7, Detailed Planning and Scheduling was the first enabling factor for appropriate resource allocation in construction projects. It becomes in the first place from overall respondents with RII = 0.916. It was ranked by client in first position with RII = 0.800, ranked by contractor in the second position with RII = 0.879, and ranked by consultant respondents in fourth position with RII = 0.810.(*Hartmann2012b*) emphasised that Detailed planning and scheduling, enhanced by BIM, enable precise resource allocation by integrating critical factors like approvals, weather, and costs

Effective Project Management was the second ranked enabling factor for appropriate resource allocation in construction projects. As it is ranked by overall respondents in second position with RII = 0.809. It was ranked by client in fourth position with RII = 0.733, ranked by contractor in the first position with RII = 0. 889, and ranked by consultant respondents in first position with RII = 0.860. By reducing non-value-added activities, effective project management enhances cost control and productivity. As reviewed in the literature part of the research (Ansah et al., 2016) revealed that Effective project management, particularly through lean construction principles, minimizes waste and optimizes resource allocation by improving workflow efficiency.

Accurate Budgeting was the third ranked enabling factor for appropriate resource allocation in construction projects and it becomes in the third place from overall respondents with RII = 0.797. It was ranked by client in third position with RII = 0.767, ranked by contractor in the third position with RII = 0.847, and ranked by consultant respondents in third position with

RII= 0.811. Sound budgeting prevents financial waste, optimizing resource distribution across project phases. This result is supported by (Kwon & Kang, 2019) who has described that Accurate budgeting is crucial for proper resource allocation, as cost overruns often stem from early-stage uncertainties and incomplete data. Reliable budget forecasts enable efficient capital planning and financing, ensuring funds are allocated where most needed. Improved risk- assessment methods help mitigate uncertainties, leading to more precise cost estimates Resource Management tools was the fourth ranked enabling factor for appropriate resource allocation in construction projects. as it is ranked by overall respondents in fourth position with RII = 0. 753.It was ranked by client in fourth position with RII = 0.733, ranked by contractor in the fourth with RII = 0. 826, and ranked by consultant respondents in fifth position with

RII= 0.78. reliance on manual inputs and Excel leads to delays, errors, and inefficiencies in tracking shared resources. Advanced tools with real-time feedback and historical data analysis could enhance demand forecasting and minimize waste. (Kusimo et al., 2019). described that Effective resource management tools are critical for optimal allocation in construction projects, yet current solutions like Microsoft Project and Asana lack multi-project resource leveling and real-time data.

Regular Monitoring and Evaluation was the fifth most suggested enabling factor for appropriate resource allocation in construction projects and it becomes in the fifth place from overall respondents with RII = 0.713. It was ranked by client in nineth position with RII = 0.667, ranked by contractor in the seventh position with RII = 0.695, and ranked by consultant respondents in the second position with RII = 0.820. projects with structured evaluation systems achieve better cost and schedule control (Liu et al., 2020). Proactive adjustments based on data-driven insights optimize workforce and material distribution. Thus, Regular Monitoring and Evaluation is vital for effective resource management in construction.

4.4.1. Spearman (rho) rank correlation coefficient

to evaluate validity, the Spearman's rho correlation coefficient was used to measure the consistency in rankings between different respondent groups clients vs. consultants, clients vs. contractors, and consultants vs. contractors regarding enabling factor for appropriate resource allocation Spearman's rank correlation coefficient (ρ) can be classified into distinct strength categories based on its numerical value. A strong correlation encompasses values ranging from ±0.6 to±0.9, indicating a substantial monotonic relationship where variables demonstrate a clear and consistent trend, with ±0.9 representing an almost perfect association. A moderate correlation covers the range of ±0.4 to ±0.6, suggesting a discernible but less pronounced relationship significant enough to indicate a pattern, yet not as robust as strong correlations. Finally, a weak correlation includes values between ±0.1 and ±0.3, reflecting only a slight monotonic.

Table 4.8: Correlation test on the ranking of enabling factors for appropriate resource allocation

Respondent	Rho $= 1 - \frac{6\sum di^{2}}{N(N^{2}-1)}$	Relationship
Client vs contractors	0.614	Strong
Client vs consultants	0.625	Strong
Consultantvscontractors	0.629	Strong

4.4.2. Correlation analysis

A Pearson correlation test was performed to assess the relationships between key enabling factors for proper resource allocation, focusing on the top five factors. The findings, presented in Table 4.9, demonstrate that Detailed Planning and Scheduling has a significant positive correlation with Effective Project Management (r = 0.8123, p =0.000), Accurate Budgeting (r=0.753, p=0.000 and Resource Management Tools (r = 0.700, p = 0.000). Furthermore, Effective Project Management was also positively correlated to Accurate Budgeting (r=0.736, p=0.000) and Resource Management Tools (r = 0.667, p = 0.000). These results confirm strong, statistically meaningful correlations, indicating that these enabling factors collectively play a crucial role in resource allocation it can be concluded that the influences of one factor were explained by the other factors

Table 4.9 Pearson Correlation analysis of enabling factors for appropriate resource allocation

Rank		1	2	3	4	5
1 Detailed Planning and Scheduling	Pearson Correlation	1	0.812	0.753	0.700	0.365

	Sig. (p		0.000	0.000	0.000	0.003
2 Effective Project Management	Pearson Correlation	0.812	1	0.736	0.667	0.387
	Sig.	0.000		0.000	0.000	0.002
3 Accurate Budgeting	Pearson Correlation	0.753	0.736	1	0.697	0.420
	Sig.	0.000	0.000		0.000	0.001
4 Resource Management Tools	Pearson Correlation	0.700	0.667	0.697	1	0.350
	Sig.	0.000	0.000	0.000		0.005
5 Regular Monitoring and Evaluation	Pearson Correlation	0.365	0.387	0.420	0.350	1
	Sig.	0.003	0.002	0.001	0.005	

4.4.3. Findings from interview

Regarding the result of factors enabling for appropriate resource allocation finding from interview revealed that the implementation of structured planning and scheduling methodologies significantly enhances resource allocation efficiency in construction projects. by employing Work Breakdown Structures (WBS) and Critical Path Method (CPM), project teams can systematically deconstruct tasks and identify critical dependencies, ensuring optimal workflow sequencing. Head-to-head meetings became a core project control mechanism, gathering stakeholders to align on progress, identify bottlenecks, and coordinate upcoming work. These collaborative sessions enabled proactive decision-making by incorporating all key perspectives, ensuring schedule integrity while managing complex construction interdependencies. The structured participation of both execution teams and oversight stakeholders created an effective forum for addressing challenges while maintaining project objectives.

Good scheduling and planning are key to road construction projects, where complex coordination amongst earthwork, paving, utilities, and traffic management is critical. Methodology includes combining strategic pre-construction planning, collaborative workface scheduling, and dynamic performance monitoring systematically enhances road construction

execution while mitigating delays. The method has proven effective in maintaining schedule adherence, minimizing disruptions, and optimizing resource allocation. three-stage methodology to attain effectiveness and minimize delay

Accurate budgeting serves as the foundation for strategic resource allocation in road construction by providing a clear financial framework that aligns physical resources with project requirements. When budgets precisely reflect scope and timelines, project teams can optimally mobilize labor crews, schedule equipment deployments, and procure materials without wasteful overages or dangerous shortages. This financial precision enables informed trade-off decisions, The budget also functions as a dynamic tool for risk management, allowing teams to strategically reallocate contingency funds when unforeseen issues like weather delays or utility conflicts inevitably arise

4.4 Development of Model Using Artificial Neural Network for Optimization of Resource Allocation in Construction Projects

Artificial Neural Networks are a major part of artificial intelligence, which started in the 1980s and draws inspiration from biological neural systems of the human brain for its information processing model. ANNs comprise several nodes connected with each other, commonly called neurons, where each neuron expresses an activation function. the weights associated with the node connections mimic memory and thereby determine the output from the network as a result of the structure of the weights. ANNs can approximate algorithms or functions and express logical strategies. they usually involve input units receiving external signals, hidden units processing these inputs, and output units delivering the results. weights in connections reflect strength between neurons, carrying information processing within the network. ANNs process information adaptively in parallel, distributed functions and mimic the processing of information by the human brain and nervous system to a degree. they are an important subpart of neuroscience, artificial intelligence, and computer science-they bridge interdisciplinary gaps. (Wu & Feng, 2018)

In this study An Artificial Neural Network (ANN) model was developed using MATLAB R2019a software to predict construction equipment utilization in the wearing (surface) course of asphalt construction based on historical data. The model consists of three interconnected layers: an input layer, a hidden layer, and an output layer, where each neuron in layers processes and transmits information to the next layer to execute the desired function.

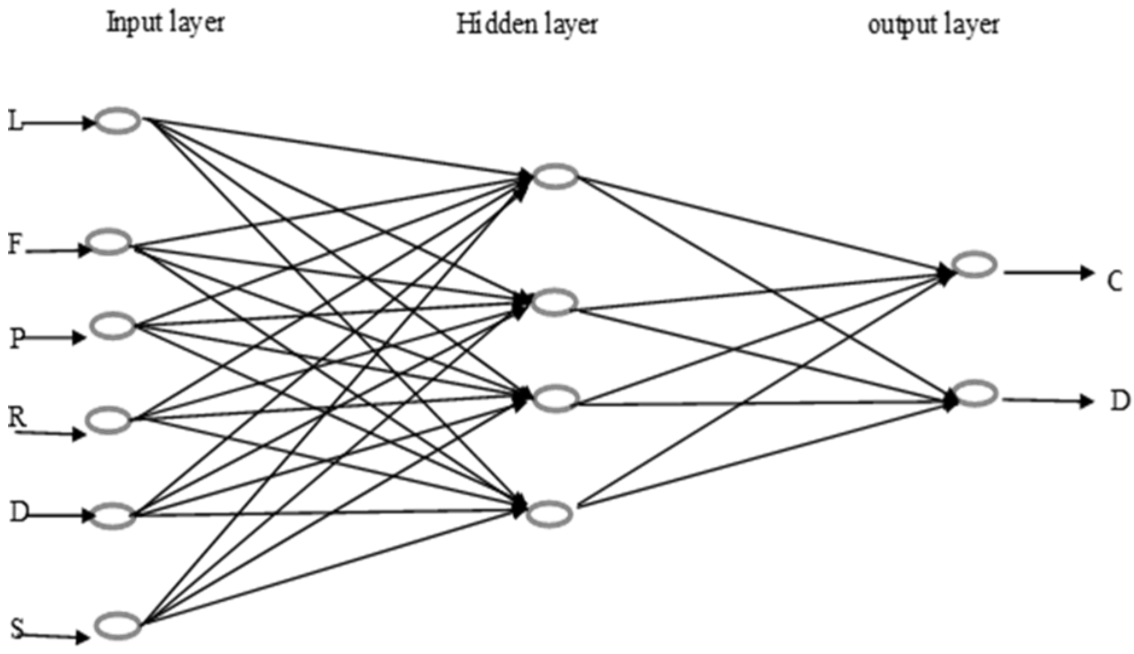

Figure 4:4 ANN design for resource allocation model

The input layer includes six neurons corresponding to the variables: length of road (L), totalfuel consumption (F), number of pavers (P), rollers (R), dump trucks (D), and sprayers (S), all collected from site data. The hidden layer serves as the intermediary, networking input data with output data, and is trained by selecting appropriate network properties.

Finally, the output layer generates predictions for cost (C) and duration (D) once the ANN model is adequately trained, enabling accurate forecasting based on the given inputs.

Table 4.10 Actual data collected from sites for ANN model development

no	Length(L) ,Km	Fuel (F),Lt	Paver (P)	Roller (R)	Dump track(D)	Sprayer(S)	Duration(T),Hr	total cost(C), birr
1	16.45	33508	2	4	16	2	80	11042600
2	11	17137	1	2	12	1	56	6321325
3	19	46789	3	6	20	3	88	14454845
4	22.6	67788	3	6	25	3	112	21338465
5	14	22958	2	4	13	1	64	7746461
6	9	13276	1	2	10	1	48	4908407
7	12.2	18361	1	2	12	1	60	6748537

The input and output datasets need to be normalized to a range between [0-1] to transform data into a consistent scale, improve model performance, ensure fair comparisons between features. This normalization should be implemented in Microsoft Excel, using the following equation,

$$\text{Normalized value} = \frac{Actual\ value - Minimum\ value}{Maximum\ \ value - Minimum\ \ value}$$

Table 4.11 normalized dataset for ANN model development

Input variables						Output variables	
L	F	P	R	D	S	T	C
0.55	0.37	0.50	0.5	0.40	0.50	0.50	0.37
0.15	0.07	0.00	0	0.13	0.00	0.13	0.09
0.74	0.61	1.00	1	0.67	1.00	0.63	0.58
1.00	1.00	1.00	1	1.00	1.00	1.00	1.00
0.37	0.18	0.50	0.5	0.20	0.00	0.25	0.17
0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
0.24	0.09	0.00	0	0.13	0.00	0.19	0.11

The following steps were implemented in ANN optimization model development

1. Installed MATLAB application, with neural network fitting, this neural fitting app is used to select data, create and train network, and evaluate performance using mean squared error, and regression analysis
2. The network has been created by opting appropriate network properties. During this research work, the following network properties were considered for creating the ANN model.
   i. Network name: ANN equipment optimization model
   ii. Network type: Feed-forward back propagation
   iii. input data, which is saved (consists six neurons) of seven samples
   iv. target data which is saved (consists two neurons) of seven samples
   v. The number of hidden layers is set to be 1 with 4 neurons
   vi. Training algorithm was set; Levenberg-marquardt back propagation
   vii. Performance function: MSE (mean square error)
3. After the above settings were being customized the model was trained, and the performance of the model was tested through mean squared error (MSE) and training regression, for neural network mean squared error (MSE) quantifies how far the neural network's predictions are from the true values by computing the average squared difference between predicted values after training and actual historical values fed to the

network. A low MSE (close to 0) means predictions are very close to true values or error is less.

In this model as shown in figure 4.5 below the MSE value obtained after training is 9.26*10^{-16} which is closer to zero. And training regression value, that indicate relationships between output and target data, is 0.9999, which means target and output data are directly proportional.

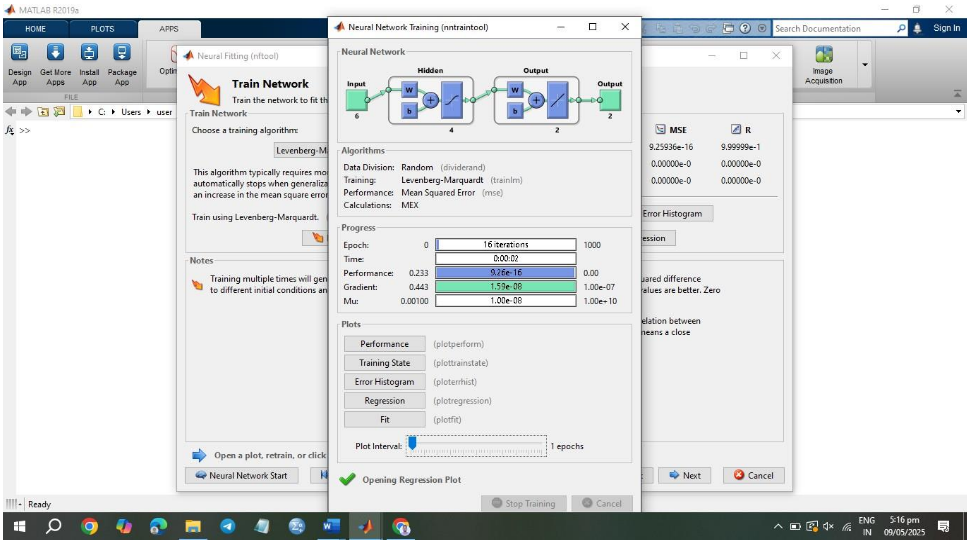

Figure 4.5 ANN training picture

4. neural network for deployment with MATLAB coder tools was prepared to reproduce results and solve similar problems

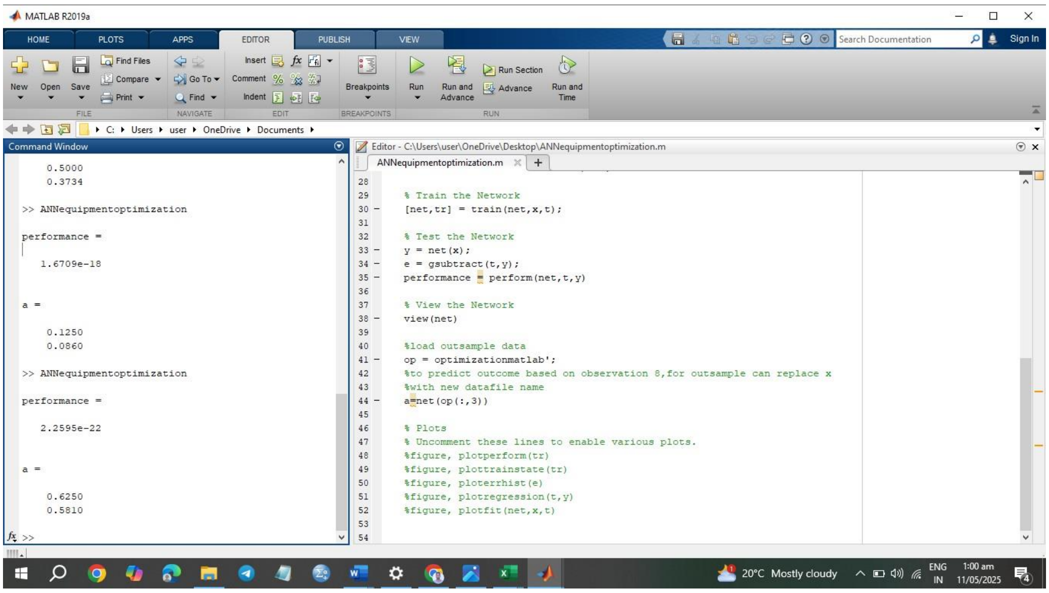

Figure 4.6 neural MATLAB coder tool, and predicted output val

5. The ANN output was extracted from MATLAB, and compared with the target data (data which was inserted to model before training).

Table 4.12 comparison between target and ANN output

Actual target data							
sites	1	2	3	4	5	6	7
T	0.500	0.125	0.625	1.000	0.250	0.000	0.188
C	0.373	0.086	0.581	1.000	0.173	0.000	0.112
ANN output							
T	0.500	0.125	0.625	1.000	0.250	0.000	0.188
C	0.373	0.086	0.581	1.000	0.173	0.140	0.112
MSE	2.24E-21	9.82E-21	4.04E-18	9.14E-17	1.89E-17	1.54E-20	5.37E-21

The Artificial Neural Network (ANN) model developed in this study demonstrates exceptional performance in predicting output values based on the given input data. The extremely low Mean Squared Error (MSE) of 9.26×10^{-16} obtained after training indicates that the model's predictions are nearly identical to the actual target values. This near-zero MSE suggests that the ANN has learned the underlying patterns in the data with remarkable precision, minimizing prediction errors to an almost negligible level. Additionally, the training regression value (R) of 0.9999 further confirms the model's accuracy, as it shows an almost perfect linear relationship between the predicted outputs and the true target data. This high correlation indicates that the ANN is capable of capturing the direct proportionality between inputs and outputs effectively.to ensure practical applicability, the trained ANN model was prepared for deployment using MATLAB Coder tools. This step is crucial for converting the neural network into a standalone application or integrating it into other software environments, allowing for real-time predictions without requiring MATLAB to be installed. The MATLAB Coder tool facilitates the generation of optimized C/C++ or other language code, making the model portable and efficient for industrial or research applications. Figure 4.6 illustrates the neural network deployment process and the predicted output values, demonstrating that the model can reliably reproduce results when applied to new, similar datasets.

The performance of the ANN model was rigorously validated by comparing its predictions with the actual target data. Table 4.12 presents a detailed comparison between the target values and the ANN-generated outputs across multiple sites. The results show that the model accurately predicts values for most sites, with only minor deviations observed in some cases (e.g., a slight discrepancy at site 6 for variable C). The MSE values for each individual site are exceptionally

low (ranging from 10^{-21} to 10^{-17}), reinforcing the model's reliability. These minimal errors confirm that the ANN's predictions are well within acceptable limits, making it a trustworthy tool for future applications.

Given the outstanding agreement between the ANN's outputs and the actual target data, the model is deemed highly accurate and robust for predictive tasks. The near-perfect regression value and the extremely low MSE values indicate that the ANN has been successfully trained to generalize well on unseen data. Consequently, this model can be confidently used in real-world scenarios to predict outputs for new input datasets, ensuring reliable and precise results. The successful deployment using MATLAB Coder further enhances its practical utility, making it a valuable tool for engineers, researchers, and industry professionals working on similar predictive modeling challenges.

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CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This chapter presents the conclusions and recommendations of the research which are based on the results of data analysis and discussion made in the previous chapter. The main findings from questionnaires distributed and interviews have been derived and summarized in accordance with the objectives of the research.

- **Factors that influence resource allocation in construction projects**

From the responses of client: Budget Constraints, Project Size and Complexity, Financial Management and Funding Availability, Material Quality and Availability, and Equipment Availability and Condition were the most factors that influence resource allocation in construction projects. From the responses of consultants: Budget Constraints, Project Size and Complexity ,Project Management and Planning, Availability of Resources , and Financial Management and Funding Availability were the most factors that influence resource allocation in construction projects From the responses of contractors': Budget Constraints, Timeline and Deadlines ,Project Size and Complexity , Financial Management and Funding Availability ,and Availability of Resources were the most factors that influence resource allocation in construction projects. From interview and overall responses received, it was therefore concluded that Budget Constraints, Project Size and Complexity, Timeline and Deadlines, Financial Management and Funding Availability, Availability of Resources were the most factors that influence resource allocation in construction projects.

- **Enabling factors for appropriate resource allocation in construction projects**.

From the responses of client: Detailed Planning and Scheduling, Clear Communication, Accurate Budgeting, Effective Project Management, and Resource Management Tool, were the most Enabling factors for appropriate resource allocation in construction projects. From the responses of consultants: Effective Project Management, Regular Monitoring and Evaluation, Accurate Budgeting ,Detailed Planning and Scheduling ,and Resource Management Tools were the most Enabling factors for appropriate resource allocation in construction projects from the responses of contractors' Effective Project Management ,Detailed Planning and Scheduling, Accurate Budgeting ,Resource Management Tools, and Clear Communication were the most Enabling factors for appropriate resource allocation in construction projects. From interview and overall responses received, it was therefore concluded that: Detailed Planning and Effective Project management, Accurate Budgeting, Resource Management Tools, and Regular

Monitoring and Evaluation, were the most Enabling factors for appropriate resource allocation in construction projects

- **Development of model using Artificial Neural Network for optimization of resource allocation in road construction projects**

The developed Artificial Neural Network (ANN) model demonstrated exceptional performance in optimizing resource allocation for asphalt pavement construction projects, achieving near-perfect prediction accuracy with an extremely low Mean Squared Error (MSE = $9.26*10^{-16}$) and a regression value of 0.9999. By leveraging a feed-forward backpropagation architecture with a single hidden layer, the model effectively processed six key input variables (road length, fuel consumption, number of pavers, rollers, dump trucks, and sprayers to forecast project duration and cost. The normalization of input and output data ensured consistent scaling, while the Levenberg-Marquardt training algorithm optimized weight adjustments, resulting in minimal deviations between predicted and actual values. These outcomes validate the ANN's capability to transform historical construction data into reliable decision-making tools for resource planning and cost estimation.

The success of the ANN model highlights its potential as a robust tool for construction project management, enabling more efficient resource allocation and reducing uncertainties in project scheduling and budgeting. The integration of MATLAB Coder tools further enhances the model's practicality, allowing for seamless deployment in real-world scenarios and adaptability to similar construction problems. The study also underscores the transformative role of artificial intelligence in civil engineering, bridging data-driven insights with operational efficiency to advance the construction industry's technological capabilities.

5.2 Recommendation

Based on the findings of the research the following recommendations are forwarded:

- Clients should ensure budgets account for contingencies while financial institutions offer flexible financing, and all stakeholders must collaborate from the start to align on scope, timelines, and resource needs, to reduce delays, and cost overruns
- All parties in construction should utilize BIM, and project management software for real-time tracking of labor, materials, and equipment to optimize efficiency.
- Contractors should maintain strong supplier relationships for timely material delivery, and workforce training to minimize wastage and boost productivity.
- Consultants and contractors should conduct regular progress evaluations and develop contingency plans for financial, material, and labor risks, while regulators must streamline bureaucratic permit processes and suppliers should guarantee reliable

material quality and delivery schedules to mitigate project disruptions.

- Construction firms and project managers should consider integrating the developed ANN model into their resource allocation and cost estimation processes to improve accuracy and efficiency
- Future iterations of ANN model should incorporate additional variables, and the model should be tested on larger dataset from diverse construction projects to enhance prediction robustness, and insure generalizability across different scale and type of construction operations.

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APPENDICES

Appendix I: Questionnaire

Title: -Optimization of Construction Project Resource Allocations Using Artificial Neural Network

Dear Sir /Madam,

I am Feyisa Shante Defo, a postgraduate Construction Engineering and Management (CEM) student presently pursuing M.sc thesis at Adama Science and Technology University, Adama, Ethiopia., I am undertaking research on the topic of "Optimization of Construction Project Resource Allocations Using Artificial Neural Network." The findings from this research can serve as valuable insights for decision makers, professionals, academics, and other interested groups in their respective roles to achieve project objectives. Your participation in this study is crucial for meeting the research goals. The quality of your responses to the questionnaire directly impacts the quality of the research results. Therefore, I kindly request you to answer the questions as thoroughly, objectively, and honestly as possible, following the instructions provided in the questionnaire. Rest assured that all information you provide in this survey will be kept strictly confidential and will only be used for the purposes of this research. Thank you in advance for your valuable time and cooperation.

Best regards!

Feyisa Shante
Adama, Ethiopia
Cell phone: 0930820493
Email: fayeshanted@gmail.com

Part 1: General questions (background information)

The questions below are related to your organization and yourself. Please indicate your response by ticking (X or √) the appropriate box (es), or by writing your answer in the space provided.

1. What is your position in the organization?

Project manager ☐ Office engineer ☐

Construction Engineer ☐ Resident Engineer ☐

Site engineer ☐

Other please specify ………………………………………

2. Type of organization you are working for?

Client ☐ Contractor ☐ Consultant ☐

3. What is your highest Educational Level?

Diploma ☐ First degree ☐

Master's degree ☐ PhD ☐

4. Your work experience in construction projects and construction project-related works:

<5 years ☐ 5-10 years ☐ >10 years ☐

Part 2: factors that influence resource allocation in construction projects

Below listed are factors influencing resource allocation in construction projects. Based on your experience you are kindly requested to rate the level of effects of these factors using scale 1- 5. (Please put a tick (√) mark in the appropriate column according to your preferences. 1 = Very low, 2 = Low, 3 = Medium, 4 = High, 5 = Very High

Factors that influence resource allocation in construction projects	Very Low	low	Medium	High	Very High
	1	2	3	4	5
Project Size and Complexity					
Budget Constraints					
Timeline and Deadlines					
Availability of Resources					
Project Location					
Stakeholder Requirements					
Regulatory and Environmental Factors					
Project Management and Planning					
Technological Factors					
External Factors (e.g., Weather, Market Fluctuations)					
Supply Chain Management					
Labor Skills and Availability					
Material Quality and Availability					
Equipment Availability and Condition					
Contractor and Subcontractor Performance					
Risk Management					
Communication and Coordination					
Project Scope Changes					
Quality Control and Assurance					
Financial Management and Funding Availability					
If there are any other factors, please specify					

Part 3: Enabling factors for appropriate resource allocation in construction projects.

Below listed are Enabling factors for appropriate resource allocation in construction projects. Based on your experience you are kindly requested to rate the level of effects of these factors using scale 1- 5. (Please put a tick (√) mark in the appropriate column according to your preferences. 1 = Very low, 2 = Low, 3 = Medium, 4 = High, 5 = Very High

Enabling factors for appropriate resource allocation in construction projects.	Very Low	low	Medium	High	Very High
	1	2	3	4	5
Effective Project Management					
Detailed Planning and Scheduling					
Accurate Budgeting					
Resource Management Tools					
Clear Communication					
Stakeholder Engagement					
Training and Development					
Regular Monitoring and Evaluation					
Risk Management					
Flexibility and Adaptability					
Quality Control					
Supplier Relationships					
Efficient Procurement Processes					
Team Collaboration					
If there are any other factors, please specify					

Part 4: - To develop a model using Artificial Neural Network (ANN) for optimization of resource (construction equipment) allocation in road construction projects (in this case, equipment in construction of surface (wearing course of asphalt construction is considered)

The following historical data(dataset) which will be used to train ANN model are needed Therefore, I kindly request you to answer the following questions.

Input variables

1 length of the road(km) ___________

2 Width of the road(m)______________

Equipment	Unit (pcs)	Operating time hr/day	Fuel consumption ltr/hr	Total equipment cost (Birr)
Paver				
Vibratory Roller				
Pneumatic roller				
Asphalt mixing Plant				
Dump truck				
Sprayer				
Total				

Output variable is

Overall cost for asphalt surfacing (birr) ______________

Actual duration for asphalt surfacing(day)_____________

Appendix II: Interview

Interview guidelines

- The researcher (interviewer) introduces himself for the interviewee and asks for voluntariness to respond for the interview
- The interviewee introduces himself for the researcher including his name, role in a company and experience

Questions: -

1. How do budget constraints influence your decisions on resource (Labor, materials, and equipment allocation?
2. How do the size and complexity of a project affect your resource allocation plans? What challenges arise in distributing manpower or materials, and what strategies do you use to prevent misallocation or delays?
3. How do inconsistent funding or resource shortages impact your projects? What financial or logistical practices do you rely on to ensure steady resource flow during critical phases
4. How do you integrate detailed planning and scheduling into your projects to optimize resource allocation?
5. What planning tools or methods (e.g., BIM, lean principles) do you use to improve resource allocation and what impact did they have on project efficiency?
6. How do you think accurate budgeting enables appropriate resource allocation?

Appendix III: contractors' response on factors that influence resource allocation in construction projects

factors that influence resource allocation in construction projects	1	2	3	4	5
Project Size and Complexity	0	1	7	19	11
Budget Constraints	0	0	0	18	20
Timeline and Deadlines	0	0	7	18	13
Availability of Resources	0	2	13	16	7
Project Location	0	7	24	2	5
Stakeholder Requirements	0	4	20	11	3
Regulatory and Environmental Factors	2	8	23	3	2
Project Management and Planning	0	6	19	5	8
Technological Factors	0	10	20	3	5
External Factors (e.g., Weather, Market Fluctuations)	1	9	22	3	3
Supply Chain Management	0	4	25	4	5
Labor Skills and Availability	0	4	13	19	2
Material Quality and Availability	0	2	11	22	3
Equipment Availability and Condition	0	2	20	12	4
Contractor and Subcontractor Performance	0	4	24	4	6
Risk Management	0	5	25	3	5
Communication and Coordination	0	9	19	4	6
Project Scope Changes	0	3	19	13	3
Quality Control and Assurance	0	8	20	6	4
Financial Management and Funding Availability	0	2	14	12	10

Appendix Iv: client's response on factors that influence resource allocation in construction projects

	1	2	3	4	5
Project Size and Complexity	0	0	3	1	2
Budget Constraints	0	0	0	1	5
Timeline and Deadlines	1	0	2	1	2
Availability of Resources	0	0	3	3	0
Project Location	1	2	1	2	0
Stakeholder Requirements	0	1	4	1	0
Regulatory and Environmental Factors	0	3	2	1	0
Project Management and Planning	0	3	1	1	1
Technological Factors	0	4	2	0	0
External Factors (e.g., Weather, Market Fluctuations)	0	3	1	1	1
Supply Chain Management	0	0	4	2	0
Labor Skills and Availability	0	1	3	2	0
Material Quality and Availability	0	0	3	2	1
Equipment Availability and Condition	0	0	3	2	1
Contractor and Subcontractor Performance	0	2	3	0	1
Risk Management	0	2	2	1	1
Communication and Coordination	0	3	2	0	1
Project Scope Changes	0	1	4	1	0
Quality Control and Assurance	0	2	2	2	0
Financial Management and Funding Availability	0	0	3	1	2

Appendix v: consultants' response factors that influence resource allocation in construction projects

	1	2	3	4	5
Project Size and Complexity	0	1	4	6	8
Budget Constraints	0	0	0	8	11
Timeline and Deadlines	0	2	4	9	4
Availability of Resources	0	1	7	4	7
Project Location	0	2	11	4	2
Stakeholder Requirements	2	1	7	9	0
Regulatory and Environmental Factors	1	2	6	7	3
Project Management and Planning	0	1	5	5	8
Technological Factors	0	5	8	3	3
External Factors (e.g., Weather, Market Fluctuations)	2	2	6	5	4
Supply Chain Management	0	3	6	7	3
Labor Skills and Availability	2	2	4	6	5
Material Quality and Availability	1	1	4	7	6
Equipment Availability and Condition	1	2	6	5	5
Contractor and Subcontractor Performance	1	2	4	7	5
Risk Management	1	3	6	7	2
Communication and Coordination	0	2	5	7	5
Project Scope Changes	1	2	5	10	1
Quality Control and Assurance	2	0	5	6	6
Financial Management and Funding Availability	1	1	4	6	7

Appendix vi: contractors' response on Enabling factors for appropriate resource allocation in construction projects.

Enabling factors for appropriate resource allocation in construction projects.	1	2	3	4	5
Effective Project Management	0	1	4	10	23
Detailed Planning and Scheduling	1	0	4	11	22
Accurate Budgeting	0	2	4	15	17
Resource Management Tools	0	1	7	16	14
Clear Communication	0	4	10	13	11
Stakeholder Engagement	0	1	22	9	6
Training and Development	1	4	23	6	4
Regular Monitoring and Evaluation	0	4	19	8	7
Risk Management	0	12	14	8	4
Flexibility and Adaptability	1	13	17	2	5
Quality Control	1	13	13	7	4
Supplier Relationships	1	20	11	4	2
Efficient Procurement Processes	1	19	6	6	6
Team Collaboration	5	12	10	4	7

Appendix vii: client's response on Enabling factors for appropriate resource allocation in construction projects.

	1	2	3	4	5
Effective Project Management	0	2	0	2	2
Detailed Planning and Scheduling	0	1	1	1	3
Accurate Budgeting	0	2	0	1	3
Resource Management Tools	1	0	0	4	1
Clear Communication	0	1	1	2	2
Stakeholder Engagement	1	0	3	1	1
Training and Development	0	1	3	2	0
Regular Monitoring and Evaluation	0	1	3	1	1
Risk Management	1	0	2	2	1
Flexibility and Adaptability	1	0	3	2	0
Quality Control	0	0	4	2	0
Supplier Relationships	0	0	4	2	0
Efficient Procurement Processes	0	1	2	3	0
Team Collaboration	1	0	3	1	1

Appendix viii: consultants' response on Enabling factors for appropriate resource allocation in construction projects.

Enabling factors for appropriate resource allocation in construction projects.	1	2	3	4	5
Effective Project Management	0	1	2	6	10
Detailed Planning and Scheduling	0	2	3	6	8
Accurate Budgeting	0	0	6	6	7
Resource Management Tools	0	0	6	9	4
Clear Communication	0	1	7	7	4
Stakeholder Engagement	0	1	5	11	2
Training and Development	0	1	9	8	1
Regular Monitoring and Evaluation	0	1	2	10	6
Risk Management	1	2	4	12	0
Flexibility and Adaptability	0	3	6	7	3
Quality Control	1	0	6	5	7
Supplier Relationships	0	3	5	6	5
Efficient Procurement Processes	0	3	3	12	1
Team Collaboration	0	2	3	10	4

Appendix viiii: neural network with matlab coder

```
% Solve an Input-Output Fitting problem with a Neural Network
% Script generated by Neural Fitting app
% Created 10-May-2025 23:36:41
%
% This script assumes these variables are defined:
%
% data - input data.
% data_1 - target data.

x  = data';
t = data_1';

% Choose a Training Function
% For a list of all training functions type: help nntrain
% 'trainlm' is usually fastest.
% 'trainbr' takes longer but may be better for challenging problems.
% 'trainscg' uses less memory. Suitable in low memory situations.
trainFcn = 'trainlm'; % Levenberg-Marquardt backpropagation.

% Create a Fitting Network
hiddenLayerSize = 4;
net = fitnet(hiddenLayerSize,trainFcn);

% Setup Division of Data for Training, Validation, Testing
net.divideParam.trainRatio = 90/100;
net.divideParam.valRatio = 5/100;
net.divideParam.testRatio = 5/100;

% Train the Network
[net,tr] = train(net,x,t);

% Test the Network
y = net(x);
e = gsubtract(t,y);
performance = perform(net,t,y)

% View the Network
view(net)

%load outsample data
op = optimizationmatlab';
%to predict outcome based on observation 8,for outsample can replace x
%with new datafile name
a=net(op(:,7))

% Plots
% Uncomment these lines to enable various plots.
%figure, plotperform(tr)
%figure, plottrainstate(tr)
%figure, ploterrhist(e)
%figure, plotregression(t,y)
%figure, plotfit(net,x,t
```