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BLUEPRINT FORGE: AN AUTOMATED NETWORK INFRASTRUCTURE DESIGN AND PLANNING SYSTEM

BY

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APPROVAL FORM

The undersigned certify that they have supervised B224565B Sibindi Dylan Tawanda's dissertation entitled "Blueprint Forge: An automated Network Infrastructure Design and Planning System" submitted in partial fulfilment of the requirements for the Bachelor of Science Honours Degree in Network Engineering.

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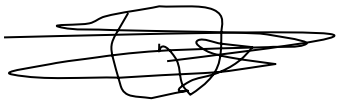
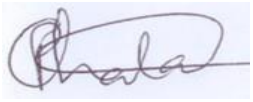
SUPERVISOR  DATE: 23/06/2026

CHAIRPERSON  DATE: 23/06/2026



DECLARATION

This dissertation represents the culmination of my academic journey at Bindura University of Science Education. I, Sibindi Dylan Tawanda, declare that the concepts, analysis and implementation strategies documented in this work are my own contributions to the field of Network Engineering. I have adhered to the standards of academic integrity throughout the research lifecycle. Where concepts have been derived from existing literature or collaborative insights, full attribution has been provided. This document serves as a record of my commitment to continuous learning in my journey as a Network Engineer.

DEDICATION

This work is dedicated, first and foremost, to my family. Your unconditional love and unwavering support from day one have been the foundation upon which every achievement in my life is built. I am forever grateful for your belief in me. To the team at Goldenknot Holdings, thank you for taking a chance on me. You offered me an internship opportunity when I had little more to show than a willingness to learn and in doing so, you provided the practical foundation and mentorship I needed as I head toward the professional I am becoming. Finally, to Bindura University of Science Education, where my dream of becoming a network engineer first came to life. A special thank you to my supervisor, Mr. Chituma F, for your guidance and for providing the environment where my aspirations were nurtured, challenged, ultimately realized.

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Writing this dissertation has been more than an academic exercise, it has been the culmination of a journey that began with a dream and was sustained by a community of support. Above all else, I give all glory and honor to God. It is through his grace, wisdom and strength that I navigated the challenges of this degree and reached this milestone. I would like to express my deepest gratitude to my supervisor, Mr. Chituma. Thank you for patience, your rigorous feedback, and for pushing me to see the potential in my own ideas when I was still finding my own footing. Your guidance was the compass that kept this on track. To Goldenknot Holdings, thank you for being the bridge between theory and practice. The lessons I learned during my attachment did more than just improve my technical skills, they shaped my professional outlook and gave me the confidence to build Blueprint Forge. I am profoundly grateful to the NWE Community and my colleagues at BUSE. Your camaraderie made the long hours of study, the complex troubleshooting, and the pressure of final year deadlines feel manageable. Thank you for the shared late night sessions, the technical debates, and the constant encouragement. Finally, to my family, you are the bedrock of everything I do. Your belief in me from day one long before this degree was even a goal has been my greatest source of strength. Whether through quiet support or constant motivation, you have carried me through the hardest days of this journey. This achievement belongs to you as much as it does to me.

ABSTRACT

Modern organizations rely heavily on efficient, dependable, and scalable network infrastructures to keep their digital operations running smoothly. Yet, traditional manual methods for network design are often fraught with errors. They consume too much time, and in many cases, they're simply not feasible in resource-limited settings where advanced proprietary tools may not be available. This dissertation introduces Blueprint Forge, an automated system that aims to change the game. It takes architectural blueprints and transforms them into optimized layouts for network infrastructure. The system looks at structural features, suggests the best spots for access points, pinpoints ideal locations for server rooms and cabinets, and creates effective cabling routes. All this, while working to reduce both installation complexity and costs. The evaluation of the system took place through a mix of real-world scenarios and simulated case studies. Among these were the Goldenknot Holdings Headquarters and an academic setting. The findings show clear improvements: design accuracy has increased, planning time has decreased, and adherence to industry standards like IEEE and TIA/EIA-568 has been enhanced. By bringing together blueprint interpretation, optimization algorithms, and principles of structured cabling, this research offers a solution that's both cost-effective and scalable. It's a tool for network engineers, students, and organizations alike, helping them boost infrastructure planning, reliability, and overall operational efficiency.

Keywords: Network Infrastructure, Blueprint Analysis, Access Point Optimization, Structured Cabling, Automation

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LIST OF ACRONYMS

AI – Artificial Intelligence

AP – Access Point

API – Application Programming Interface

CAD – Computer Aided Design

DSR – Design Science Research

HQ – Headquarters

HVAC – Heating, Ventilation, and Air Conditioning

ICT – Information and Communication Technology

IEEE – Institute of Electrical and Electronics Engineers

IT – Information Technology

JSON – JavaScript Object Notation

NoSQL – Not Only Structured Query Language

PDF – Portable Document Format

SMEs – Small and Medium Enterprises

TAM – Technology Acceptance Model

TIA – Telecommunications Industry Association

TIA/EIA-568 – Telecommunications Industry Association / Electronic Industries Alliance Cabling Standard

CHAPTER 1

INTRODUCTION

1.1 Introduction

In today's business environment setting, companies primarily rely on a stable and scalable network infrastructure to enable communication, data transmission, and daily operations. These activities are built on a robust network that allows for efficient data exchange and integration of information systems. A well-designed network infrastructure can improve productivity, enhance security and support the growth of an organization. On the other hand, poorly designed networks are often responsible for latency, congestion, frequent outages, and unnecessary operational costs.

Designing a network infrastructure involves many choices, including where to put wireless access points, how to run structured cabling, and where to put server rooms and network cabinets. Such decisions must consider both the technical requirements and the physical layout of the building. Many organizations use automated network planning tools to enhance accuracy and minimize the likelihood of human error. However, most of the commercial solutions are expensive and often require specialized knowledge, which is not accessible to many organizations.
This is particularly challenging in developing regions such as Africa, where the lack of sophisticated software tools and certified network engineers has forced many organizations to rely on manual planning approaches. These methods are time consuming and may lead to inefficient designs. Therefore, the demand for low-cost tools to automate network planning and bring the advanced design capabilities to the masses is growing.

The need for this led to the development of Blueprint Forge. It combines architectural blueprint analysis and network design automation to produce optimized standards-compliant network layouts. Blueprint Forge combines these capabilities to reduce design time, increase planning accuracy, and help more organizations with digital transformation, even if they don't have access to expensive commercial software.

1.2 Background to the Study

Across the whole world, the methods of network planning have transformed significantly. Experts claim that network planning is now an expert technical procedure. System performance and reliability are enhanced by mathematical calculation procedures, spatial modelling, and predictive analytics because network planning requires better results. Network planning remains a specialized engineering process for many nations. Large business groups like Cisco within wealthy nations provide specialized equipment like Cisco DNA Centre and Ekahau Pro. These tools help make labour-saving actions when performing site surveys, predicting radio signals, and improving the topology of a network. It has been observed that these tools have a high cost and need high-level knowledge for use. The high cost leaves smaller business groups in a state where these business groups struggle with the specialized equipment that these business groups can afford to buy. Planning of networks is often restricted by financial limitations. Numerous working positions across Africa show a growing

requirement for technical answers because technology change programs are starting. Many people believe that commercial entities find it hard to get low-cost technological solutions for their network planning which is adapted for local environments. Research conducted across the continent shows that the lack of network design is identified as a major block to digital growth. Mugambi & Odhiambo (2022) state that Africa's lack of network design has led to high latency, coverage gaps, and the inefficient use of infrastructure by small-to-medium enterprises (SMEs) across the continent when manually driven planning techniques are used. Within the public and private sectors of Zimbabwe, network outages and poor coverage are significant obstacles while these problems stop the productivity of infrastructure.The challenges that I have encountered at Goldenknot Holdings HQ reflect this trend on a regional scale, making the urgent need for a cost-effective, scalable and context-based design solution even more pressing. Therefore, Blueprint Forge addresses local inefficiencies but is also a part of a larger movement to democratize the automation of networks in developing countries.

1.3 Statement of the Problem

Although substantial progress has been made in automating networks around the world, many developing nations and their networks remain excluded from the automation advances due to costs associated with the software and lack of available technical support and access to data pertaining to the network planning process (World Bank, 2020). Consequently, many of these networks are manually deployed with resulting issues concerning efficiency and network layout. Africa in particular remains excluded from the automation efforts of these advanced networks due to economic challenges and the limitations of the existing infrastructure.

Similarly, many networks around the world remain excluded from the automation of network planning processes due to costs associated with the software and lack of technical support to the networks and staff. During my attachment at Goldenknot Holdings HQ in Zimbabwe, it became apparent to me that manual network planning methods were inefficient and led to wasted cabling and time. Software like Ekahau and NetSim, which are used in the automation of network design, remain too costly for the companies located in Africa. Consequently, the networks planned and deployed by these companies remain inefficient and time-consuming to design and deploy.

Blueprint Forge offers a low-cost automated network design solution. The design tool utilizes architectural plans and automatically converts them into optimized network designs for standard network architectures. Additionally, Blueprint Forge can be utilized by all companies located throughout Africa and the developing world.

1.4 Research Aim

The goal of this research is the creation and use of Blueprint Forge, which serves as a tool for the architectural design and building of connection systems to assist technical workers during planning phases. This study concentrates on fixing the troubles of old manual ways for arranging connection systems, because those traditional methods cause designs that are not uniform, errors in settings, and slow work speed. It has been observed that manual techniques often fail to provide stability. Blueprint Forge was made to change how technical workers handle these tasks. Because machine-controlled and organized building paths are used,

Blueprint Forge offers a space for the correct drawing of hardware arrangements. Higher precision in the planning of settings is reached through this tool, while the speed of building connection systems is increased at the same time. When visual drawing and guided setup tools are joined, Blueprint Forge assists in the growth of more stable and expandable ways for putting connection systems into use. Many experts claim that digital tools are helpful for reducing technical stress.

Showing how a tool-centered way for connection system architecture can help the correctness of planning is the end goal of this study. Human mistakes are lowered when Blueprint Forge is utilized by technical workers during their daily tasks. The power of putting connection systems into place within modern computer spaces is improved by Blueprint Forge because of its structured logic. It is often believed that systematic tools are the best way to handle modern digital growth.

1.5 Research Objectives

Main Objective

The objective of this project is to design and create an automated system called Blueprint Forge that will help network planners create optimal network layouts from building blueprints according to standard compliance. To accomplish this objective, the following objectives will be achieved:

Specific Objectives

i. Analyze building blueprints and extract structural information (walls, rooms, obstacles).
ii. Determine optimal access point (AP) placement for maximum wireless coverage.
iii. Recommend server room and cabinet locations based on accessibility, centrality, and environmental constraints.
iv. Generate efficient cabling routes connecting network components while minimizing total cable length and installation complexity.
v. Develop a cost estimation capability within Blueprint Forge that automatically produces material and labour budgets from Blueprint layout parameters

1.6 Research Questions

i. Which optimization algorithms can be used to locate the most efficient locations to place Access Points(AP)
ii. To what extent does automation improve the efficiency and accuracy of network planning compared to traditional methods?
iii. Can the Blueprint Forge generate network design layouts that adhere to TIA/EIA-568 network wiring standards while decreasing design time?
iv. How do automated network planning tools improve the efficiency and accuracy of network design versus manual or traditional methods?

1.7 Justification / Significance of the Study

This study is significant from practical, theoretical, and educational perspectives.

From a practical standpoint, organizations increasingly depend on reliable network infrastructure to support daily operations, making accurate and efficient network planning essential. However, many organizations, particularly in developing countries, still rely on manual or semi-automated methods because commercial network planning software is often costly and complex. Blueprint Forge addresses this challenge by providing a cost-effective and accessible automated solution that generates optimized, standards-compliant network layouts directly from architectural blueprints. By automating the planning process, the system reduces design time, minimizes errors, improves network performance, and enhances operational efficiency through better resource utilization.

From a theoretical perspective, this research contributes to knowledge by demonstrating how computer vision, optimization algorithms, and graph-based routing techniques can be integrated into a unified framework for automated network planning. While prior studies have often examined these technologies independently, this study presents a cohesive workflow that transforms architectural data into practical network designs. This integration broadens the understanding of interdisciplinary approaches to solving infrastructure design problems.

From an educational perspective, Blueprint Forge serves as a valuable learning tool for students and junior network engineers. The system produces automated yet transparent design outputs that help users understand structured cabling standards, wireless network design principles, and infrastructure optimization techniques. By linking theoretical concepts with practical applications, the study supports both academic learning and hands-on skills development, making it relevant to educational institutions and professional training environments.

1.8 Assumptions

This study is based on several assumptions that guided the development and evaluation of the proposed system. First, it is assumed that the architectural blueprints used as input, including those of Goldenknot Holdings Headquarters and the simulated laboratory environment, are accurate, complete, and representative of the actual physical building structures. The study also assumes that recognized network planning standards, such as those established by the Institute of Electrical and Electronics Engineers (IEEE) and the Telecommunications Industry Association/Electronic Industries Alliance (EIA-568), are correctly interpreted and consistently implemented within the system's design logic.

In addition, the study assumes that radio frequency (RF) signal propagation can be modelled with sufficient accuracy using established attenuation and coverage principles to support effective wireless access point placement. Although real-world wireless environments are influenced by dynamic factors, the adopted modelling approach is considered adequate for design and planning purposes within the scope of this research.

Despite its contributions, the study has several limitations. The system is primarily designed to process two-dimensional architectural blueprints and moderately complex three-

dimensional layouts commonly found in office buildings and educational facilities. Buildings with highly complex three-dimensional structures or unconventional architectural designs may reduce the accuracy of blueprint interpretation and affect optimization results.

The study also does not account for certain real-time environmental factors, such as electromagnetic interference, temperature variations, and heating, ventilation, and air conditioning (HVAC) effects, all of which can influence wireless network performance in operational environments. These factors are typically assessed during on-site surveys and are therefore outside the scope of automated pre-deployment planning.

Furthermore, system validation was conducted using Goldenknot Holdings Headquarters and a simulated laboratory environment. While these case studies provide meaningful insight into the system's effectiveness, the limited number of evaluation scenarios may restrict the generalizability of the findings across all building types and organizational contexts.

1.9 Scope and Delimitation of the Research

The scope of this research is limited to the automated design and planning of network infrastructure using architectural blueprints as the primary input. Geographically, the study focuses on Goldenknot Holdings Headquarters in Zimbabwe, with supplementary evaluation carried out in a simulated educational environment. Functionally, the proposed system addresses key network planning tasks, including wireless access point placement, server room and network cabinet selection, structured cabling route generation, and automated cost estimation for network materials and labour.

The study deliberately excludes activities related to physical hardware installation, power cabling design, and environmental engineering considerations such as cooling systems and electrical load management. In addition, the evaluation is restricted to assessing the quality, efficiency, and standards compliance of the generated network layouts, rather than measuring actual post-deployment network performance.

These delimitations ensure that the research remains focused on the automation of network planning processes rather than the broader implementation and operation of complete network infrastructure systems.

1.10 Definition of Terms

Dead Zone is any area within the building where wireless signal strength falls below acceptable thresholds, resulting in unreliable or unusable connectivity. Eliminating dead zones is a key performance goal of AP placement optimization.

Blueprints are digital representations (such as CAD, PDF, or raster images) of building layouts, which provide input for spatial analysis. The boundaries provided by these blueprints also define how networks and cabling routes can be placed.

Structured cabling is an industry-standard cabling architecture for telecommunications systems. It emphasizes an organized pathway, predictable performance, and maintainability. In the study at hand, structured cabling principles will guide the routing and layout of structured cabling according to current industry standards (TIA, 2020; TIA, 2019).

Optimal Placement describes locations produced through algorithmic analysis that improve performance while minimizing constraints such as cable length, interference, and installation complexity. It doesn't suggest one perfect solution but rather a good and defensible configuration arising from stated measurable objectives. An Access Point (AP) is a device that enables access to Wi-Fi wirelessly within a defined range of coverage.

Access Point (AP) is a wireless networking device that provides Wi-Fi connectivity within a defined coverage area. In this study, AP placement is treated as an optimization problem so coverage, interference, and installation cost are balanced across the building.

Blueprint Forge refers to the automated network planning system developed in this study, designed to convert architectural floor plans into actionable network layouts. It integrates blueprint interpretation, optimization, and reporting to produce standards-aware designs for practical deployment

1.11 Summary

This chapter introduced the background, context, and motivation for the development of Blueprint Forge, an automated network infrastructure design and planning system. It established that modern organizations increasingly depend on reliable and well-structured network infrastructure to support communication, data exchange, and business operations. However, many institutions, particularly in developing countries, continue to rely on manual and error-prone planning approaches because advanced network design tools are often expensive and inaccessible.

The problem statement highlighted the inefficiencies, wireless coverage gaps, and resource wastage associated with traditional network planning methods. These challenges were illustrated using both regional observations and practical evidence from Goldenknot Holdings Headquarters in Zimbabwe. In response, the chapter presented the overall research objective and specific objectives, which focus on architectural blueprint interpretation, wireless access point placement optimization, server room and network cabinet positioning, structured cabling route generation, and automated cost estimation.

The research questions were formulated to investigate how automation and optimization techniques can improve the efficiency, accuracy, standards compliance, and cost-effectiveness of network planning. The chapter also defined the significance of the study, its underlying assumptions, limitations, and scope, thereby establishing clear boundaries and contextual considerations for the research.

Overall, this chapter provided the foundation and justification for the study by demonstrating the need for an affordable, intelligent, and context-aware automated network planning system. The next chapter reviews relevant theoretical and empirical literature on automated network design, optimization algorithms, blueprint interpretation, and technology adoption models to position Blueprint Forge within existing research and identify the knowledge gaps this study seeks to address.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter critically examines existing literature on automated network design, infrastructure optimization, and intelligent system integration in organizational contexts. The aim is to identify the theoretical and empirical foundations that underpin automated planning tools, with emphasis on both global best practices and local realities. The review spans international, regional, and Zimbabwean studies, highlighting how automation, algorithmic modelling, and artificial intelligence influence efficiency, accuracy, and scalability in network planning.

While global literature presents sophisticated AI-driven frameworks for network optimization, regional and local studies reveal persistent barriers such as cost, infrastructure limitations, and skill shortages. The literature consistently demonstrates a gap between highly sophisticated, costly global automation tools and the need for accessible, adaptive, and cost-effective automation frameworks tailored to the unique infrastructural and economic constraints prevalent in transitional economies like Zimbabwe. The objective is to establish a coherent conceptual foundation upon which the proposed system, Blueprint Forge, is grounded, and to identify the gaps in current research that this project intends to address.

2.2 Conceptual Framework

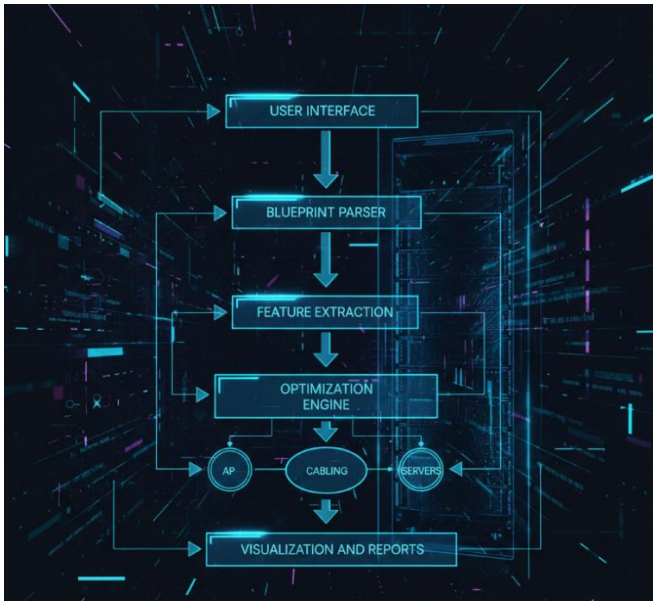
The conceptual framework for Blueprint Forge posits a transformative process that converts raw architectural data into optimized, actionable network designs, inherently integrating technical precision with practical and contextual considerations. At its foundation are the Inputs, specifically raw architectural blueprints (CAD files, images) and user-defined network requirements. These inputs are critically shaped by Contextual Factors, particularly those prevalent in developing regions, such as resource constraints, varying data quality, and the need for cost-effectiveness and ease of use. These factors influence the design philosophy, prioritizing adaptability and accessibility over reliance on expensive, proprietary solutions.

The core of Blueprint Forge lies within its sophisticated Processing Modules, which systematically analyze and optimize the network infrastructure. The Blueprint Interpretation Module employs computer vision and spatial analysis algorithms to meticulously extract structural information, identifying walls, rooms, obstacles, and potential pathways from the raw blueprints. This structured data then feeds into the Optimization Engine, which comprises distinct sub-modules: the Access Point Placement Optimizer, utilizing signal propagation models and multi-objective algorithms to ensure optimal wireless coverage with minimal interference; the Equipment Location Recommender, which identifies ideal server room and cabinet placements based on factors like centrality, accessibility, security, and environmental conditions; and the Cabling Route Generator, which leverages graph-based

algorithms to determine efficient cabling pathways that minimize length, reduce installation complexity, and adhere strictly to industry standards such as TIA/EIA-568. Furthermore, an integrated Cost Estimation Module dynamically calculates material and labor budgets based on the optimized design, directly addressing the economic viability concerns.

The culmination of these processes is the generation of comprehensive Optimized Network Outputs and Reports. These outputs include detailed visual network layouts superimposed on the original blueprints, bills of materials, estimated project costs, and performance metrics. A crucial element is the User Feedback and Validation Loop, where network planners and stakeholders can review the generated designs, provide input, and trigger iterative refinements within the optimization engine. This ensures that the automated designs are not only technically sound but also align with real-world operational needs and user preferences. The successful adoption and utilization of these outputs, as informed by the Technology Acceptance Model, ultimately lead to the desired Impacts and Outcomes, including significantly improved design accuracy, reduced planning time and costs, enhanced network reliability and maintainability, and greater adherence to industry standards, thus contributing to digital transformation in resource-constrained environments.

Figure 1 Conceptual Framework for Automated Network Planning



Source: Author's own prompt, generated via Chat gpt, (OpenAI2026).

The conceptual framework in Figure 1 illustrates the high level logical relationships that guide the development of the Blueprint Forge system. It focuses on how architectural blueprints are transformed into optimized network layouts through a sequence of conceptual stages, including blueprint analysis, optimization processes, cost estimation, and user validation. This framework is not concerned with implementation details or specific system components.

2.3 Theoretical Framework

The development of Blueprint Forge is grounded in a set of contemporary theoretical perspectives that collectively explain how complex infrastructural systems can be analyzed, optimized, and adopted in real world environments. Rather than relying on classical formulations in isolation, this study adopts modern interpretations of systems thinking, computational optimization, and technology adoption, all of which have evolved significantly in response to advancements in digital engineering and intelligent systems.

Recent literature emphasizes that automated planning systems must be understood as socio technical artifacts, where computational accuracy alone is insufficient without consideration of system interaction, environmental constraints, and user acceptance. In this context, Blueprint Forge is conceptualized as an integrated system that transforms architectural inputs into optimized network designs through structured computational processes while remaining interpretable and usable by practitioners.

The theoretical framework is therefore structured around three complementary perspectives. Systems thinking provides a holistic view of the building and network as an interconnected environment. Automation and optimization theory explains how computational techniques can efficiently explore complex design spaces to produce high quality solutions. The Technology Acceptance Model provides insight into how users interact with and adopt automated recommendations in practice. Together, these perspectives establish a coherent foundation for the design, implementation, and evaluation of Blueprint Forge.

2.3.1 Systems Theory

Modern systems thinking provides a critical foundation for understanding the interdependent nature of building environments and network infrastructure. Contemporary research emphasizes that complex engineering systems cannot be effectively designed through isolated component level decisions, but rather require a holistic approach that accounts for interactions, dependencies, and emergent behavior across the entire system (Cechvala, 2024).

In the context of network infrastructure planning, the building layout, wireless coverage, cabling pathways, and equipment placement form a tightly coupled system in which changes in one component directly influence the performance and feasibility of others. For example, wall structures and room segmentation affect signal propagation, which in turn influences access point placement and ultimately impacts cabling requirements. Similarly, the positioning of network cabinets affects both cable length and maintainability, demonstrating the interconnected nature of design decisions.

Recent systems-research highlights the importance of integrated spatial and functional modeling, where physical environments are treated as dynamic systems rather than static layouts. This perspective aligns directly with the design philosophy of Blueprint Forge, which does not treat blueprint interpretation, optimization, and cost estimation as separate tasks, but instead integrates them into a unified analytical process.

By adopting a system thinking approach, Blueprint Forge is able to evaluate network design decisions within the broader context of the building environment. This ensures that generated

outputs are not only technically valid in isolation, but also coherent, efficient, and practically deployable when considered as part of a complete infrastructure system.

2.3.2 Automation & Optimization Theory

Automation and optimization theory provides the computational backbone for Blueprint Forge, enabling the system to transform complex design problems into structured, solvable models. Recent advancements in optimization research demonstrate that intelligent algorithms can efficiently explore large design spaces and identify high quality solutions under multiple competing objectives, such as coverage, cost, and feasibility (Aziz and Insoo, 2024).

Network infrastructure planning inherently involves multi objective decision making, where trade offs must be balanced between maximizing wireless coverage, minimizing interference, reducing cable length, and controlling deployment costs. Traditional manual approaches struggle to evaluate these trade offs systematically, often resulting in suboptimal designs. In contrast, modern optimization techniques allow for the simultaneous evaluation of numerous candidate configurations, enabling more informed and efficient decision making.

Recent studies in indoor network optimization show that algorithm driven access point placement significantly improves spatial coverage and reduces redundancy, particularly in environments with complex architectural constraints. Similarly, graph based optimization methods have proven effective for routing problems, where shortest path algorithms can minimize cabling distance while adhering to structural limitations within buildings.

Within Blueprint Forge, these principles are operationalized through an integrated optimization engine. The system models the building layout as a structured spatial representation and applies algorithmic techniques to generate access point placements, determine infrastructure locations, and compute efficient cabling routes. This approach allows the system to move beyond heuristic or rule based planning toward data driven and computationally optimized design generation.

The application of automation and optimization theory therefore enables Blueprint Forge to deliver solutions that are not only efficient but also scalable and consistent, addressing key limitations associated with manual network planning approaches.

2.3.3 Technology Acceptance Model (TAM)

While computational accuracy is essential, the effectiveness of an automated system ultimately depends on its acceptance and use by practitioners. The Technology Acceptance Model remains a relevant framework for understanding how users adopt and interact with new technologies, but recent research extends the model by emphasizing additional factors such as trust, transparency, and interpretability (Duong et al., 2023).

In the context of automated network planning, users must be able to understand and trust system generated recommendations in order to rely on them for decision making. This is particularly important in engineering domains, where incorrect or poorly understood outputs can have significant operational consequences. As a result, modern adoption research

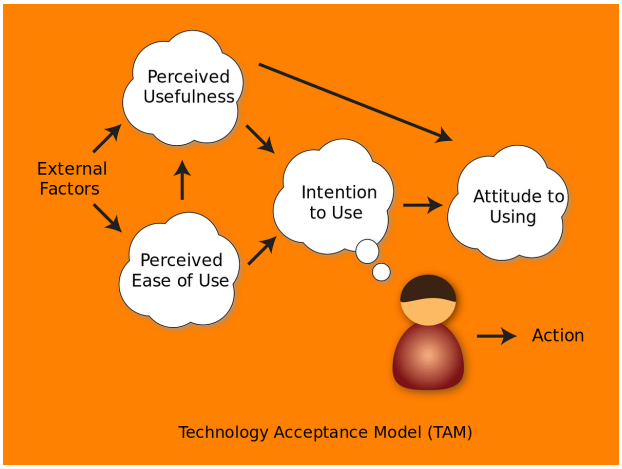
highlights that perceived usefulness alone is insufficient; systems must also provide clear explanations, intuitive interfaces, and interpretable outputs.

Recent studies further indicate that visual clarity and feedback mechanisms play a critical role in user acceptance of intelligent systems. Users are more likely to adopt automated tools when they can easily validate outputs, trace decision logic, and make adjustments where necessary. This aligns with the need for transparency in design oriented systems, where users must remain in control of final decisions.

Blueprint Forge incorporates these principles by emphasizing user centered design within its architecture. The system provides visual network layouts, structured reports, and clear representations of optimization outcomes, allowing users to interpret and validate results effectively. In addition, the inclusion of user feedback mechanisms supports iterative refinement, ensuring that automated outputs can be adjusted to meet practical requirements.

By integrating insights from contemporary technology acceptance research, Blueprint Forge addresses not only the technical challenges of network planning but also the human factors that influence system adoption. This ensures that the system is not only functionally effective but also practically usable in real world contexts.

Fig 2 Technology Acceptance Model



Source: The TAM version 1, Davis, Bagozzi & Warshaw (1989).

2.4 Automated Network Planning Systems and Tools

Recent developments in network infrastructure planning have led to the emergence of various automated and semi-automated tools designed to assist in network design and deployment. These tools typically provide functionalities such as wireless coverage simulation, access point placement recommendations, and cabling layout visualization. While such systems have improved planning efficiency in advanced environments, they often rely on proprietary platforms that require significant financial investment and technical expertise.

In addition, many existing solutions focus on specific aspects of network planning rather than providing a fully integrated workflow. For instance, some tools specialize in wireless coverage optimization, while others address cabling design or cost estimation independently.

This fragmented approach limits their effectiveness in real world scenarios, where network planning requires coordination across multiple interdependent components.

Recent research also highlights that many automated planning tools assume high quality input data and advanced infrastructure, making them less suitable for deployment in resource constrained environments. As a result, organizations in such contexts continue to rely on manual methods or simplified tools that do not fully address the complexity of network design.

These limitations highlight the need for integrated, accessible, and cost effective solutions that combine blueprint interpretation, optimization, and cost analysis within a single system. Blueprint Forge is designed to address these shortcomings by providing a unified platform tailored to practical deployment conditions.

2.5 Industry Standards and Design Principles

Effective network infrastructure design is guided by established industry standards and best practice principles that ensure reliability, scalability, and maintainability. Standards such as those provided by the Telecommunications Industry Association define structured cabling architectures, equipment placement guidelines, and pathway planning requirements that support long term network performance.

Recent revisions of these standards emphasize the importance of organized cabling systems, centralized equipment locations, and clear separation of network components to facilitate maintenance and future expansion. In addition, modern design practices incorporate considerations such as signal interference, environmental constraints, and user density to ensure optimal wireless performance.

In automated network planning systems, adherence to these standards is essential to ensure that generated designs are not only computationally efficient but also practically deployable. Blueprint Forge integrates these principles within its optimization processes, ensuring that recommended layouts align with recognized industry practices while addressing the specific constraints of the target environment.

2.6 Empirical Evidence

Building on the theoretical foundations, this section reviews empirical studies that demonstrate how automated network planning has been applied in practice. The aim is to examine approaches for blueprint interpretation, access point placement, cabling optimization, and cost estimation, highlighting successes, limitations, and best practices from global, regional, and local contexts. Empirical evidence provides insight into the methods, algorithms, and tools that have been tested and deployed, offering a practical lens through which the theoretical principles can be evaluated and operationalized. By synthesizing these studies, the section identifies patterns, innovations, and gaps that inform the design and functionality of Blueprint Forge, ensuring that the system integrates proven techniques while addressing the constraints and needs of transitional economies. This review emphasizes both the technical and practical aspects of automation, demonstrating how theoretical models translate into real-world solutions that improve efficiency, accuracy, and usability.

Empirical Context in Africa and Zimbabwe

Recent reports on digital development in Africa indicate steady growth in connectivity alongside persistent structural and economic challenges affecting infrastructure deployment. While network coverage has expanded significantly, issues such as high deployment costs, limited access to advanced planning tools, and varying infrastructure quality continue to constrain efficient network design and implementation (ITU, 2023; GSMA, 2023).

In the Zimbabwean context, these challenges are particularly pronounced, where organizations often operate under resource constraints and rely on manual or semi structured approaches to network planning. Such methods are typically time consuming, prone to inefficiencies, and lack the analytical capabilities required to optimize coverage, cost, and infrastructure layout simultaneously.

Recent regional insights further emphasize the need for practical and cost effective digital solutions that can operate within constrained environments without reliance on expensive proprietary systems. This highlights a growing demand for tools that integrate automation, optimization, and usability while remaining accessible to organizations with limited technical and financial resources.

Within this context, Blueprint Forge is positioned as a solution that directly addresses these challenges by providing an automated, integrated, and standards aligned approach to network infrastructure planning. The system is designed to improve planning efficiency and accuracy while remaining adaptable to the realities of local deployment environments.

2.6.1 Interpretation of Architectural Blueprints in Automated Network Systems

Recent empirical research demonstrates significant progress in the automated interpretation of architectural blueprints using computer vision and machine learning techniques. Studies by Ahmed et al. (2021) show that deep learning based models can accurately detect structural elements such as walls, rooms, and openings from digital floor plans, achieving higher accuracy than traditional rule based approaches.

Similarly, research by Liu and Fang (2022) demonstrates that integrating spatial reasoning with image recognition improves the extraction of building topology, enabling systems to better understand room connectivity and spatial constraints. These advancements are particularly important for network planning, as accurate spatial representation directly influences infrastructure placement decisions.

However, empirical findings also indicate that performance may degrade when dealing with low quality or non-standardized blueprints, which remains a challenge in developing regions. This highlights the need for robust and adaptable interpretation methods, as incorporated in Blueprint Forge.

2.6.2 Optimization-Based Approaches to Wireless Access Point Placement

Wireless access point placement has been extensively studied using optimization techniques, with empirical results demonstrating significant improvements over manual planning. A study by Zhang et al. (2021) shows that metaheuristic algorithms such as genetic algorithms and particle swarm optimization can improve coverage efficiency by up to 30 percent in complex indoor environments.

In addition, Hassan and Lee (2023) demonstrate that multi objective optimization models that incorporate signal strength, interference, and deployment cost produce more balanced and practical solutions compared to single objective approaches. These models are particularly effective in environments with irregular layouts and multiple obstructions.

Empirical evidence further shows that incorporating real world factors such as wall attenuation and user density leads to more accurate placement outcomes (Nguyen et al., 2022). These findings validate the use of optimization driven approaches in automated systems such as Blueprint Forge.

2.6.3 Empirical Models for Determining Server Room and Cabinet Locations

The placement of network infrastructure components such as server rooms and cabinets has also been explored through empirical modelling. Research by Alharbi et al. (2021) demonstrates that algorithm based placement strategies that consider centrality, accessibility, and environmental constraints significantly reduce cabling requirements and improve maintenance efficiency.

Recent studies also emphasize the importance of integrating environmental considerations such as ventilation, security, and power availability into placement models (Kumar and Singh, 2022). These factors are critical for ensuring long term reliability and compliance with infrastructure standards.

Empirical findings suggest that automated placement models outperform manual decision making by providing consistent and data driven recommendations, supporting their integration into modern network planning systems.

2.6.4 Automated Methods for Generating Structured Cabling Pathways

Empirical research in structured cabling design confirms the effectiveness of graph based algorithms in optimizing routing paths. While foundational algorithms such as those proposed by Dijkstra and Kruskal remain relevant, recent studies have extended these approaches to accommodate real world constraints.

For example, Alghamdi et al. (2022) demonstrate that hybrid routing algorithms combining shortest path techniques with constraint based heuristics produce more practical cabling layouts in complex building environments. These methods account for obstacles, pathway restrictions, and installation feasibility.

Furthermore, empirical evaluations show that automated cabling systems can reduce material usage and installation errors by a significant margin compared to manual designs. This reinforces the importance of algorithmic routing in modern network planning tools.

2.6.5 Cost Estimation Automation in Digital Network Planning Tools

Cost estimation has increasingly been integrated into automated planning systems, with empirical studies highlighting its impact on project feasibility and decision making. Research by Kim et al. (2021) shows that automated estimation models linked to design outputs can reduce budgeting errors and improve planning accuracy.

Recent work by Olatunji (2022) further demonstrates that lightweight cost estimation frameworks are particularly effective in environments where full scale building information modelling systems are not available. These models enable real time cost updates as design parameters change, improving transparency and adaptability.

Empirical evidence also indicates that integrating cost estimation directly into planning systems enhances decision making by allowing users to evaluate trade offs between performance and budget constraints. This functionality is a key feature of Blueprint Forge.

Fig 3: Logical Architecture of an Automated Network Planning System



Source: Author's own design, generated via Chat gpt, (OpenAI2026).

Figure 3 presents the logical system architecture of an automated network planning system, showing how the conceptual processes identified in the framework are organized into functional components. Unlike the conceptual framework, this diagram emphasizes system level structure by identifying key modules such as the blueprint parser, feature extraction unit, optimization engine, cost estimation module, and visualization layer.

2.7 Research Gap Analysis

Existing literature demonstrates substantial progress in automated network infrastructure planning. Studies on blueprint interpretation confirm that computer vision techniques can accurately extract spatial features from architectural layouts. Similarly, optimization based research has shown that algorithmic approaches can significantly improve wireless access point placement and reduce signal interference in indoor environments. Additional studies have also explored automated cabling route generation and digital cost estimation methods for infrastructure projects.

Despite these advances, most existing research approaches these components as separate problems rather than parts of a unified planning workflow. Many systems focus solely on wireless optimization, blueprint recognition, or cabling design without integrating these processes into a single automated framework. As a result, network planners often rely on multiple tools or manual coordination between different design stages.

Another limitation identified in the literature is the accessibility of existing solutions. Integrated network planning systems available in industry are commonly embedded within proprietary platforms that require high licensing costs and advanced technical expertise. These tools are therefore difficult to adopt within small and medium organizations and educational institutions, particularly in developing regions where financial and technical resources may be limited.

Furthermore, limited empirical research examines automated network planning systems that are specifically adapted for resource constrained environments. Existing studies rarely consider situations where architectural data quality varies, technical expertise is limited, and affordable software solutions are required.

This study addresses these gaps by developing Blueprint Forge, an integrated automated network planning system that combines blueprint interpretation, optimization driven network layout generation, standards compliant cabling design, and automated cost estimation within a single platform. The system is intentionally designed to operate using accessible technologies and open development tools, making it suitable for organizations and institutions with limited access to expensive proprietary systems.

By integrating these capabilities into a unified workflow, the study contributes both practically and academically by demonstrating how intelligent automation can support efficient network infrastructure planning in developing and transitional economies.

2.8 Summary

This chapter examined the theoretical and empirical foundations underpinning automated network infrastructure planning, with the aim of positioning Blueprint Forge within current research and identifying gaps that justify its development. The review shows that although substantial progress has been made in areas such as blueprint interpretation, wireless access point optimization, structured cabling design, and automated cost estimation, these capabilities are largely implemented as separate solutions rather than integrated systems.

From a theoretical perspective, the chapter established that modern systems thinking provides a necessary lens for understanding the interconnected nature of building environments and network infrastructure. Network planning involves continuous interaction between spatial structure, signal behavior, equipment placement, and cabling pathways, requiring a coordinated and system-oriented approach. In addition, advances in automation and optimization theory demonstrate the effectiveness of algorithm driven techniques in solving complex, multi objective design problems, enabling improved efficiency, consistency, and scalability compared to manual methods. The Technology Acceptance Model further highlights that successful adoption of such systems depends not only on technical accuracy but also on usability, transparency, and user trust.

Empirical evidence supports the practical application of automation in network planning. Recent studies confirm that blueprint interpretation techniques can accurately extract structural information from architectural layouts, while optimization-based approaches improve access point placement and overall network performance. Graph based routing methods have been shown to effectively generate efficient cabling pathways, and automated quantity estimation techniques enable reliable cost modelling. However, these advancements remain fragmented across different tools and domains, limiting their practical applicability.

This fragmentation is particularly significant in resource constrained environments, where organizations often lack access to advanced proprietary tools and continue to rely on manual planning approaches. As a result, there is a clear need for accessible, integrated, and standards aligned systems that can support efficient and reliable network design.

Blueprint Forge addresses this need by combining blueprint analysis, optimization processes, structured cabling principles, and cost estimation within a unified framework. This integration enables more accurate planning, reduced design time, and improved alignment with industry

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the methodological framework used to design, develop, and evaluate the Blueprint Forge system. The research journey, detailing the theoretical underpinnings of the chosen methodologies, the specific techniques employed for artifact construction, the rigorous evaluation protocols, and the ethical considerations that guided the entire research process. It explains how the study was structured, the research design employed, the population and sampling considerations, data collection methods, and ethical considerations.

In addition, the chapter documents the full system development process, including the feasibility study, system analysis, and system design principles, in line with both academic research requirements and practical software engineering practices. The methodology is informed by established systems thinking principles and contemporary design science research approaches that emphasize systematic artifact development and evaluation in information systems research (Peffers et al., 2007; Hevner et al., 2004).The aim is to demonstrate that the development of Blueprint Forge followed a systematic, rigorous, and replicable process that supports the achievement of the stated research objectives.

3.2 Research Design

This study adopted a Design Science Research (DSR) methodology complemented by a case study strategy in order to systematically design, develop, and evaluate Blueprint Forge as a novel network planning system. The choice of DSR was motivated by the study's primary objective of creating a functional artifact that addresses a clearly identified practical problem, namely the inefficiencies and inaccuracies associated with manual network infrastructure planning in building environments. DSR is particularly suited to studies that seek to produce and evaluate technological artifacts while grounding their development in established theoretical principles.

The DSR process followed a structured sequence of phases. The problem identification phase involved a detailed examination of challenges faced in network design, including suboptimal access point placement, inefficient cabling routes, and inaccurate cost estimation, particularly within resource constrained environments. These challenges were established through literature review and contextual analysis, as presented in Chapter 1. The objective of the solution phase focused on developing an automated system capable of generating optimized network layouts, cabling plans, and cost estimates directly from architectural blueprints. This objective informed the design and development phase, during which Blueprint Forge was conceptualized and implemented as the core research artifact.

Blueprint Forge represents the central artifact of this study, embodying the principles of DSR through its modular architecture and iterative development. The system integrates blueprint parsing, optimization algorithms, and visualization components to automate network planning tasks traditionally performed manually. The demonstration phase involved applying the system to real world and simulated building environments to illustrate its operational capability. Evaluation was conducted by comparing system generated outputs against manually produced network designs using predefined quantitative and qualitative metrics. Finally, the communication phase is fulfilled through the documentation of the design process, system implementation, and evaluation outcomes within this dissertation.

In addition to DSR, a case study strategy was employed to facilitate an in depth examination of Blueprint Forge within realistic usage contexts. An embedded single case study design was adopted, consisting of two embedded units of analysis. The primary case involved Goldenknot Holdings Headquarters, representing a real operational organizational environment, while the secondary case comprised a simulated educational building environment designed to test system performance under controlled and varied conditions. This approach enabled a detailed understanding of how the system performs in practice while also allowing systematic variation of environmental parameters that may not be feasible in a live setting.

The study further adopted a mixed methods approach through the integration of quantitative and qualitative techniques. Quantitative data were used to evaluate system efficiency and accuracy, including metrics such as cable length, access point count, estimated deployment cost, and planning time. Qualitative observations were used to assess usability, clarity of outputs, and practical adoption considerations. The integration of these methods provided a comprehensive evaluation of Blueprint Forge, ensuring that both technical performance and user centered aspects were rigorously examined.

3.3 Population and Sample

The target population for this study comprised organizational and institutional building environments that require structured wired and wireless network infrastructure. These environments typically include small to medium sized office buildings, educational facilities, and multi room structures where network planning must account for architectural constraints, user density, and performance requirements. Such environments commonly face challenges related to manual network planning processes, making them suitable contexts for evaluating an automated network design system.

A purposive sampling technique was employed to select environments that were most relevant to the research objectives. The primary sample was Goldenknot Holdings Headquarters, which was selected due to its representativeness of a typical small to medium enterprise operating within Zimbabwe. The building exhibits architectural features such as multiple office spaces, partitioned rooms, and varying wall structures that directly influence network design complexity. In addition, the organization had existing network infrastructure and documented design practices, providing a suitable baseline for evaluating the

improvements offered by Blueprint Forge. The scope of the network infrastructure considered included wired cabling routes, wireless access point placement, and associated cost estimates.

The secondary sample consisted of a simulated educational building environment designed to complement the real world case study. This simulated environment was constructed to allow controlled variation of key architectural and network parameters, including room count, building layout, obstruction types, wall materials, and user density. The purpose of this simulation was to test the robustness and adaptability of Blueprint Forge beyond a single real world context. By systematically varying these parameters, the system's general performance and scalability could be assessed without the constraints imposed by an operational environment.

While the findings of this study are not intended to be statistically generalizable, analytical generalization was employed. The insights derived from the selected cases contribute to a broader understanding of how automated network planning systems can be applied in similar organizational and institutional contexts. The use of both real and simulated environments strengthens the validity of the findings by demonstrating the applicability of Blueprint Forge across comparable building types and usage scenarios.

3.4 Research Instruments

Multiple research instruments were employed to support the design, implementation, and evaluation of Blueprint Forge. These instruments were selected to enable both quantitative performance assessment and qualitative evaluation of system usability and practical relevance.

Architectural blueprints served as the primary input instrument for the system. The study utilized digital blueprints provided in formats such as PDF and raster image files. These blueprints contained critical architectural information including room boundaries, wall structures, door and window locations, and spatial dimensions. Prior to processing, preprocessing steps were applied to ensure consistency across formats, including resolution normalization and noise reduction. The extracted architectural features formed the basis for subsequent network planning and optimization processes within Blueprint Forge.

Existing network layout documentation was collected for the primary case study environment to establish a baseline for comparison. This documentation included current network diagrams, access point placement maps, cabling layouts, and equipment inventories where available. The baseline data were used to evaluate the effectiveness of Blueprint Forge by comparing system generated designs against existing manual designs. This comparison enabled the identification of inefficiencies in traditional planning approaches and provided a reference point for assessing improvements in accuracy, efficiency, and cost estimation.

To evaluate system performance, a set of quantitative performance measurement metrics was defined. Total cable length was calculated by Blueprint Forge through the summation of optimized cable paths generated using shortest path algorithms, while manual equivalents were derived from existing cabling plans and manual measurements. The number of access points required was determined by the system based on coverage analysis and signal strength

thresholds, and these results were compared with manually estimated or previously deployed access point counts. Estimated deployment cost was calculated by aggregating material costs such as cabling, access points, and network equipment, as well as labor estimates derived from installation time assumptions. Unit costs were sourced from standard market rates and vendor price lists. Planning time was measured from the point of blueprint input to final design output for the automated system, while manual planning time was recorded based on the duration required to complete equivalent designs using traditional methods.

Qualitative evaluation was supported through structured observation checklists. These checklists captured criteria such as user interface intuitiveness, ease of data input, clarity of visualized outputs, system feedback, and error handling. Observations were conducted by the researcher during system use and evaluation sessions, allowing consistent assessment of usability and interaction quality across test scenarios.

In addition, software development tools and libraries constituted an essential research instrument supporting system implementation. The system was developed using a high level programming language suitable for image processing, optimization, and rapid prototyping. Specialized libraries were employed for blueprint image analysis, graph based modeling, and algorithmic optimization. The inclusion of these tools enabled reliable implementation of complex computational processes and ensured that the system was grounded in established and widely adopted technological frameworks.

3.5 Reliability and Validity

Reliability and validity were carefully considered to ensure the trustworthiness and rigor of the research findings. Multiple strategies were employed to enhance consistency, accuracy, and methodological soundness throughout the study.

Reliability was addressed through repeated system testing under identical conditions. Blueprint Forge was executed multiple times using the same input blueprints and configuration parameters to assess the consistency of generated outputs. Quantitative measures such as total cable length, access point count, and estimated deployment cost were compared across runs to identify any variations. The results demonstrated minimal deviation, indicating stable system behavior and repeatable performance. This repeatability confirms that the system produces consistent outputs when subjected to the same inputs, thereby supporting the reliability of the research instrument.

Validity was examined across several dimensions. Content validity was ensured by aligning each functional component of Blueprint Forge directly with the study’s research objectives. Each system module was designed to address a specific objective, such as automated access point placement, optimized cabling route generation, or cost estimation. Expert review by individuals with knowledge of network design principles further supported content validity by confirming that the system’s functionality reflected established industry practices.

Construct validity was established by grounding the system’s algorithms and decision logic in recognized theoretical frameworks. Wireless access point placement was informed by signal propagation principles and optimization strategies, while cabling route generation was based

on graph theory and shortest path algorithms. Cost estimation logic was derived from standard network deployment practices and structured cabling principles. This theoretical grounding ensured that system outputs were conceptually aligned with accepted models of network design.

Criterion validity was assessed by comparing system generated designs against benchmark manual designs and industry guidelines. For the primary case study, system outputs were evaluated in relation to existing network layouts and manually produced planning artifacts. Key comparison metrics included deviations in cable length, access point count, and overall cost estimation. In addition, compliance with recognized networking standards was considered during evaluation to ensure practical applicability and adherence to best practices.

Internal validity was strengthened by controlling input variables during testing and ensuring that observed performance differences were attributable to the system itself rather than external factors. External validity was addressed through the use of both a real world organizational environment and a simulated educational environment, enabling broader analytical generalization of findings. While the case study approach limits statistical generalization, the consistency of results across varied environments supports the applicability of Blueprint Forge to similar network planning contexts.

3.6 Data Collection Process

The data collection process for this study was conducted in a structured and sequential manner to ensure completeness, accuracy, and alignment with the research objectives. Data were collected across three main stages, corresponding to architectural inputs, baseline network designs, and system generated outputs.

The first stage involved the collection of architectural blueprints for both the real world and simulated environments. Digital blueprints were obtained from organizational records for the primary case study and from academic design templates for the simulated educational environment. Multiple blueprint layouts were collected to represent different spatial configurations. Some of the blueprints were available only in non-standardized or low resolution formats, which required additional preparation prior to system input. These challenges were addressed through digitization and manual refinement to ensure that essential architectural features such as room boundaries and structural elements were accurately represented.

The second stage focused on collecting baseline network design data for the primary case study environment. This data was provided by the organizational information technology personnel and included existing network diagrams, access point placement records, and cabling layouts. To ensure data accuracy, the collected documentation was cross checked across multiple sources and, where necessary, validated through direct inspection of selected network components. This baseline data served as a reference for evaluating the effectiveness and efficiency of the system generated designs. Data collection during this stage was conducted within a defined timeframe to ensure consistency between architectural inputs and network configuration records.

The third stage involved generating and recording outputs produced by Blueprint Forge. The system was tested under multiple configuration scenarios for both the real world and simulated environments. These scenarios varied in terms of building layout complexity and network requirements. For each scenario, outputs such as access point placement, cabling routes, estimated deployment costs, and planning time were systematically recorded. Quantitative outputs were logged directly by the system for subsequent analysis, while qualitative observations were documented during system operation. This approach enabled comprehensive evaluation of both technical performance and user interaction characteristics.

3.7 Ethical Considerations

Ethical considerations were addressed throughout the research process to ensure responsible conduct and protection of organizational information. The study did not involve vulnerable populations or sensitive personal data; however, ethical care was required due to the use of organizational network information and building layouts.

Permission to use architectural blueprints and existing network documentation for the primary case study was obtained from the relevant organizational authority prior to data collection. All collected data were used solely for academic research purposes and were handled confidentially. No identifying organizational information was disclosed beyond what was necessary to contextualize the study.

System testing and evaluation activities were conducted in a manner that did not interfere with normal organizational operations. No changes were made to live network infrastructure during the study, and all evaluations were performed using design data and simulated outputs rather than direct deployment.

The research adhered to institutional guidelines governing academic integrity and ethical research conduct. Where applicable, ethical approval was obtained from the relevant academic authority prior to the commencement of data collection. All sources of information, including software libraries and reference materials, were appropriately acknowledged to avoid plagiarism and ensure transparency.

3.8 Feasibility Study

A feasibility study was conducted to assess the practicality of developing and deploying Blueprint Forge within the scope of the academic research and its potential real world application. The feasibility assessment considered technical, economic, operational, and schedule dimensions.

i. Technical feasibility was established by leveraging proven computational techniques and widely adopted software technologies. Blueprint Forge integrates image processing methods for blueprint interpretation, optimization algorithms for access point placement and cabling route generation, and graph based models for representing network connectivity. These techniques are well documented in existing literature and supported by mature open source software libraries. The availability of these tools ensured that the system could be implemented effectively without reliance on experimental or unproven technologies.

ii. Economic feasibility was evaluated by considering the cost implications of system development and use. Blueprint Forge was developed using open source programming languages and libraries, eliminating the need for expensive software licenses. This approach significantly reduces the total cost of ownership when compared to commercial network planning tools that often require substantial licensing fees. As a result, the system offers a cost effective alternative for small and medium sized organizations and educational institutions with limited budgets.

iii. Operational feasibility focused on the usability and adoption potential of the system. Blueprint Forge was designed to support intuitive interaction through clear visual representations and structured workflows. The system minimizes the need for advanced software expertise by allowing users to generate network designs directly from architectural blueprints. Supporting documentation and usage guidelines further enhance ease of adoption, making the system suitable for network engineers, students, and technical staff.

iv. Schedule feasibility was assessed in relation to the academic timeframe allocated for the dissertation. The system was developed using a modular and incremental approach, allowing individual components such as blueprint processing, optimization logic, and visualization to be implemented and tested independently. This approach enabled steady progress and timely completion of the project within the academic period, while also allowing flexibility to accommodate revisions and improvements based on testing outcomes.

3.9 System Analysis

System analysis was conducted to define the functional scope, quality attributes, and constraints governing the development of Blueprint Forge. This analysis ensured that system requirements were directly aligned with the research objectives and practical network planning needs.

Functional Requirements

The functional requirements define the core capabilities that Blueprint Forge must provide in order to fulfill the objectives of the study.

i. The system shall be capable of processing digital architectural blueprints in common formats in order to extract spatial and structural information relevant to network planning. This includes the identification of rooms, walls, corridors, and access paths within the building layout.

ii. The system shall automatically recommend optimal wireless access point placement based on building geometry, coverage requirements, and signal propagation considerations, ensuring adequate coverage across designated areas.

iii. The system shall determine suitable locations for network infrastructure components such as server rooms or network cabinets based on spatial proximity, accessibility, and environmental considerations.

iv. The system shall generate optimized structured cabling routes between network devices using shortest path principles while adhering to accepted structured cabling practices.
v. The system shall automatically estimate deployment costs by aggregating material and labor requirements derived from the generated network design.
vi. The system shall present network design outputs in a clear visual and report based format to support user interpretation and decision making.

Nonfunctional Requirements

Nonfunctional requirements define the quality attributes that influence system usability, reliability, and performance.

i. The system shall provide an intuitive and easy to understand interface that requires minimal training for effective use by network engineers and students.
ii. The system shall generate consistent and accurate outputs, with deviations from expert manual designs remaining within acceptable margins.
iii. The system shall complete network design generation within a reasonable time frame when applied to medium sized building layouts.
iv. The system shall ensure that generated designs conform to established networking standards for structured cabling and wireless network deployment.

System Constraints

Several constraints influenced system design decisions. The quality and resolution of architectural blueprints varied significantly, requiring the system to tolerate incomplete or imperfect inputs. In addition, the system was designed to operate on standard desktop computing resources, limiting the use of highly computationally intensive algorithms. Time constraints imposed by the academic schedule further influenced the choice of modular and incremental development strategies.

3.10 System Design

System design defines the architectural structure and operational components that enable Blueprint Forge to perform automated network infrastructure planning. The design process focuses on translating the conceptual framework and system requirements into a structured architecture capable of processing architectural blueprints and generating optimized network layouts.

Blueprint Forge adopts a modular system architecture in which individual components perform specialized tasks within the network planning workflow. This modular structure improves maintainability, scalability, and flexibility by allowing each component to operate independently while still contributing to the overall system functionality.

Input and Pre-processing Layer

This layer is responsible for receiving architectural blueprints and preparing them for analysis. Input files are normalized through image processing techniques such as noise filtering, resolution adjustment, and contrast enhancement. These pre-processing steps ensure that blueprint data is standardized before structural features are extracted.

Feature Extraction Layer

Once pre-processing is complete, the system extracts relevant architectural features from the blueprint. Computer vision techniques are used to detect structural elements including walls, room boundaries, and potential connectivity pathways. The extracted features are then transformed into structured spatial data that can be interpreted by the optimization engine.

Optimization Engine

The optimization engine forms the computational core of the system. It processes spatial data to generate efficient network infrastructure layouts. This engine is composed of three main modules:

i. Access point placement module that determines optimal wireless coverage locations using signal propagation principles.
ii. Infrastructure placement module that evaluates spatial accessibility and recommends suitable server room or network cabinet locations.
iii. Cabling route generation module that models the building layout as a weighted graph and determines efficient cable pathways using shortest path algorithms.

Cost Estimation Layer

The cost estimation component calculates the expected deployment cost of the proposed network infrastructure. Material quantities such as cabling length, access point devices, and networking equipment are derived from the optimized design. These quantities are then multiplied by predefined unit costs to generate an estimated project budget.

Visualization and Reporting Layer

The final layer converts computational outputs into visual and analytical results that can be interpreted by users. Network layouts are rendered directly on the architectural blueprint while summary reports present key information such as device placement, cabling routes, and estimated deployment costs.

This layered architecture enables Blueprint Forge to process architectural inputs systematically and produce optimized network infrastructure designs while maintaining clarity, modularity, and extensibility.

3.10.1 Overall System Architecture

Blueprint Forge was designed using a modular system architecture that separates the system into independent but interconnected components. This architectural approach improves maintainability, scalability, and flexibility by allowing each module to perform a specialized function within the network infrastructure planning workflow. The architecture enables efficient processing of building blueprints and automated generation of network deployment strategies.

The system begins with the blueprint input stage, where architectural floor plans are uploaded and prepared for analysis. During preprocessing, the system standardizes blueprint images and extracts relevant structural information required for network planning. Feature extraction techniques are then applied to identify walls, rooms, and structural boundaries that influence network infrastructure placement.

Following preprocessing, the processed data is forwarded to the network optimization engine. This component analyzes the spatial characteristics of the building layout to determine optimal access point placement, infrastructure positioning, and potential cabling routes. The optimization process ensures efficient network coverage while minimizing deployment complexity.

The generated network design is subsequently passed to the cost estimation and reporting modules. These components evaluate the required networking equipment and cabling infrastructure to produce cost projections and deployment recommendations. The final outputs are presented to the user through visualization and reporting interfaces, enabling users to review and interpret the generated network design.

This modular architecture ensures that Blueprint Forge can be extended with additional analytical or optimization capabilities in the future without significantly altering the existing system structure.

Fig 4: Hardware and Network Architecture of Blueprint Forge System

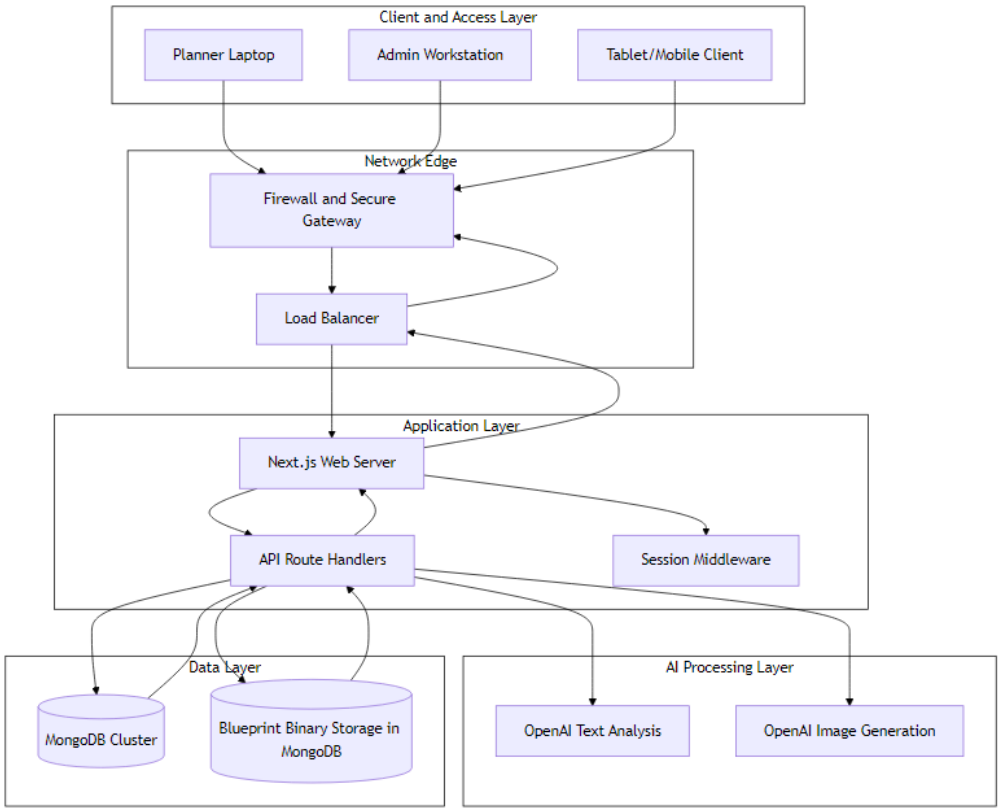


Figure 4 illustrates the hardware and network architecture supporting the Blueprint Forge System. The architecture shows the interaction between the user workstation, system processing modules and supporting network infrastructure required for system operation. The user interacts with the system through graphical user interface where architectural blueprints are uploaded for analysis. The architecture also highlights the communication flow between the application layer, processing modules, and the data storage components.

3.10.2 System Modules

Blueprint Forge is composed of several functional modules that collectively support the automated design of network infrastructure from architectural blueprints. Each module is responsible for a specific stage of the system workflow.

Blueprint Input Module

The blueprint input module allows users to upload architectural floor plans into the system. These blueprints serve as the primary data source for network infrastructure planning. The module supports common image formats and ensures that uploaded files are properly stored and prepared for further processing.

Preprocessing and Feature Extraction Module

This module prepares blueprint data for analysis by performing image preprocessing operations such as resizing, normalization, and noise reduction. Feature extraction techniques are then applied to identify structural components including walls, rooms, and open spaces. These extracted features provide spatial context that guides network planning decisions.

Network Optimization Module

The network optimization module is responsible for determining the most suitable placement of network infrastructure elements. Using the spatial information derived from the blueprint, the module evaluates potential access point locations, network coverage requirements, and cable routing paths. The goal of this module is to generate efficient network layouts that maximize coverage while minimizing installation complexity.

Cost Estimation Module

Once the network layout has been generated, the cost estimation module calculates the projected cost of deploying the recommended infrastructure. This includes estimations for networking devices, cabling materials, and installation requirements. The module provides users with an approximate financial overview of the proposed network deployment.

Reporting and Visualization Module

The reporting and visualization module presents the generated network design results to the user in a clear and interpretable format. It produces graphical representations of network layouts as well as analytical summaries that support decision making during infrastructure planning.

Together, these modules create a comprehensive framework that enables Blueprint Forge to transform architectural blueprints into practical network deployment recommendations.

The operation of Blueprint Forge follows a structured data processing workflow that ensures systematic transformation of blueprint input into actionable network design outputs. The workflow is designed to maintain a clear separation of processing stages while ensuring efficient data flow between system components.

The process begins when the user uploads an architectural blueprint through the system interface. The uploaded blueprint is then passed to the preprocessing stage, where the image is standardized and prepared for further analysis. During this stage, operations such as image scaling, noise filtering, and format normalization are performed to improve the quality of the input data.

Following preprocessing, the feature extraction stage identifies structural elements present in the blueprint. These elements include walls, rooms, corridors, and open spaces. Extracting these features is critical because they influence signal propagation and infrastructure placement within the network design process.

Once structural features have been identified, the extracted spatial information is passed to the network optimization engine. This component analyzes the building layout and determines appropriate locations for network access points and other infrastructure

components. It also evaluates potential cabling routes that support efficient network connectivity across the building.

After the network layout has been generated, the results are forwarded to the cost estimation module. This stage calculates approximate deployment costs based on the quantity and type of networking equipment required for implementation.

Finally, the generated network design, along with cost estimations and analytical results, is delivered to the reporting and visualization module. This module presents the information to the user through graphical outputs and interface components that support interpretation and decision making.

This structured workflow ensures that Blueprint Forge processes architectural data systematically while maintaining clarity and efficiency throughout the network planning process.

Fig 5: Blueprint Forge System Data Flow diagram

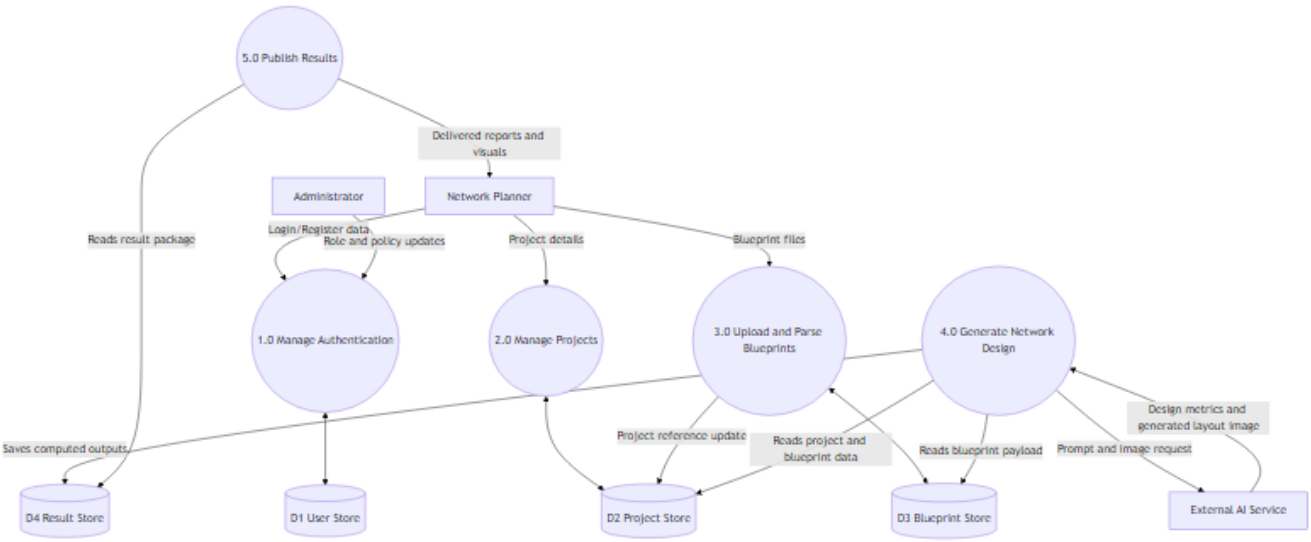


Figure 5 illustrates the sequence of operations carried out by the Blueprint Forge System during blueprint analysis and network design generation. The process begins when the user uploads an architectural blueprint through the system interface.

3.10.4 User Interface Design

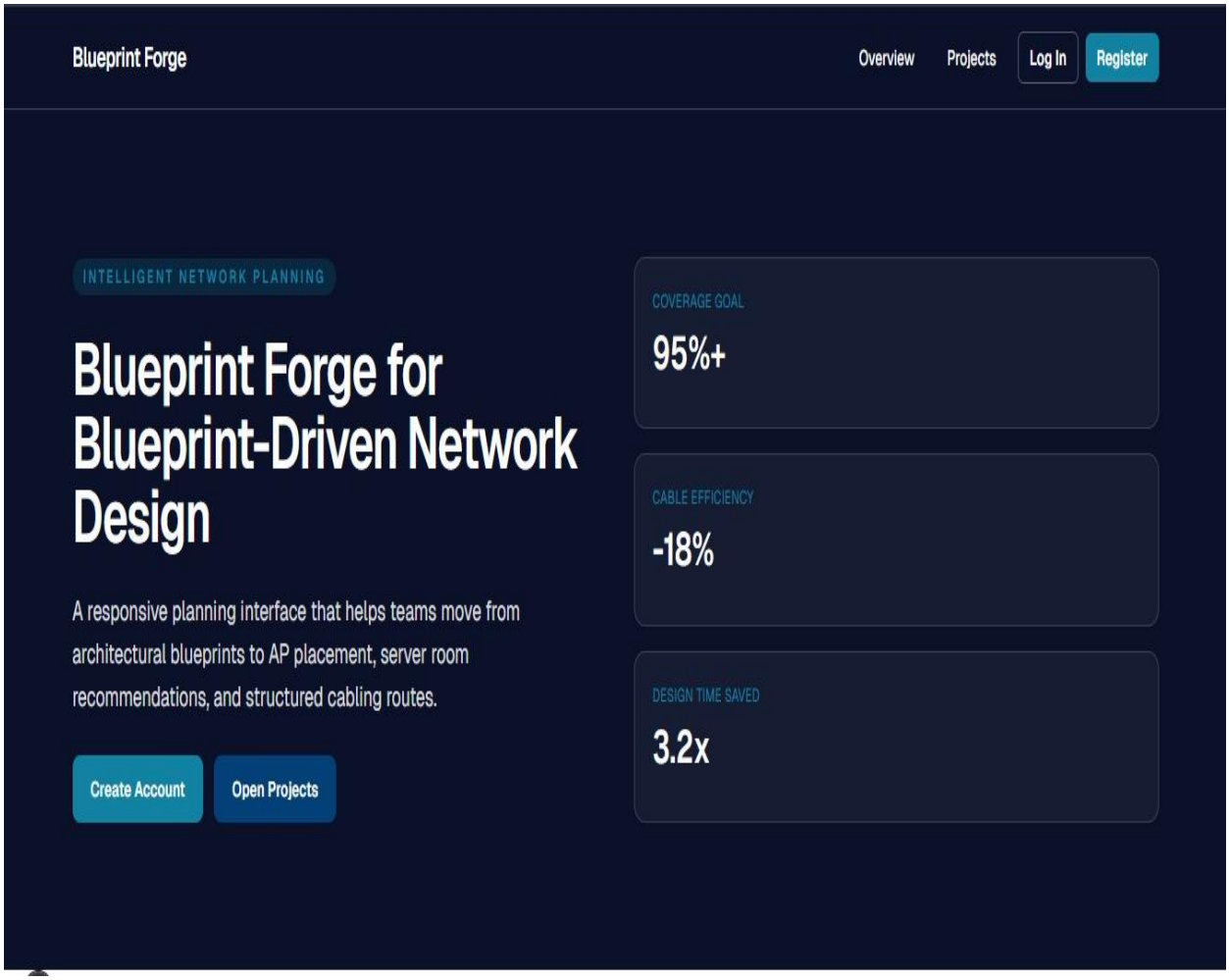
The user interface of Blueprint Forge provides a structured environment through which users interact with the system and access its network design capabilities. While the underlying system architecture performs complex processing tasks such as blueprint analysis, feature extraction, and network optimization, the user interface ensures that these functionalities are presented in a clear and accessible manner. The interface was designed with usability and simplicity in mind so that users can easily upload architectural blueprints, initiate network analysis, and view the resulting infrastructure recommendations.

The interface components serve as the bridge between the user and the internal system modules, enabling efficient interaction with the automated design processes implemented

within Blueprint Forge. Through the interface, users are able to upload blueprint images, monitor processing activities, and visualize generated network deployment outputs including recommended infrastructure placement and cost estimations.

The following figures present the major user interface components of the system, illustrating how Blueprint Forge facilitates interaction between the user and the automated network design workflow.

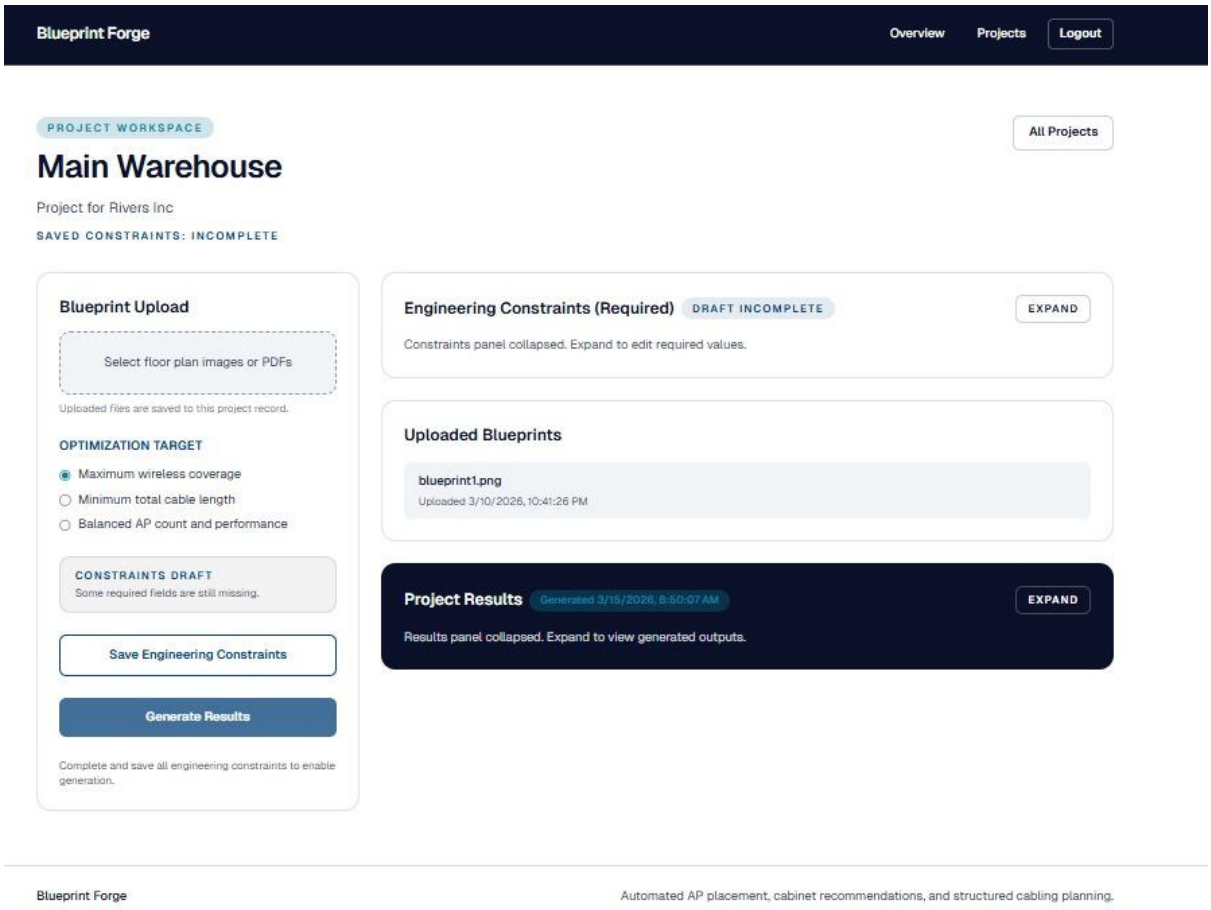
Fig 6: Blueprint Forge Homepage Dashboard



Source: Screenshot taken from Blueprint Forge, developed by the author (2026).

The figure illustrates the initial landing page of Blueprint Forge showing the system introduction, login access point, and navigation elements that guide users into the platform.

Fig 7: Blueprint Forge Workspace Interface



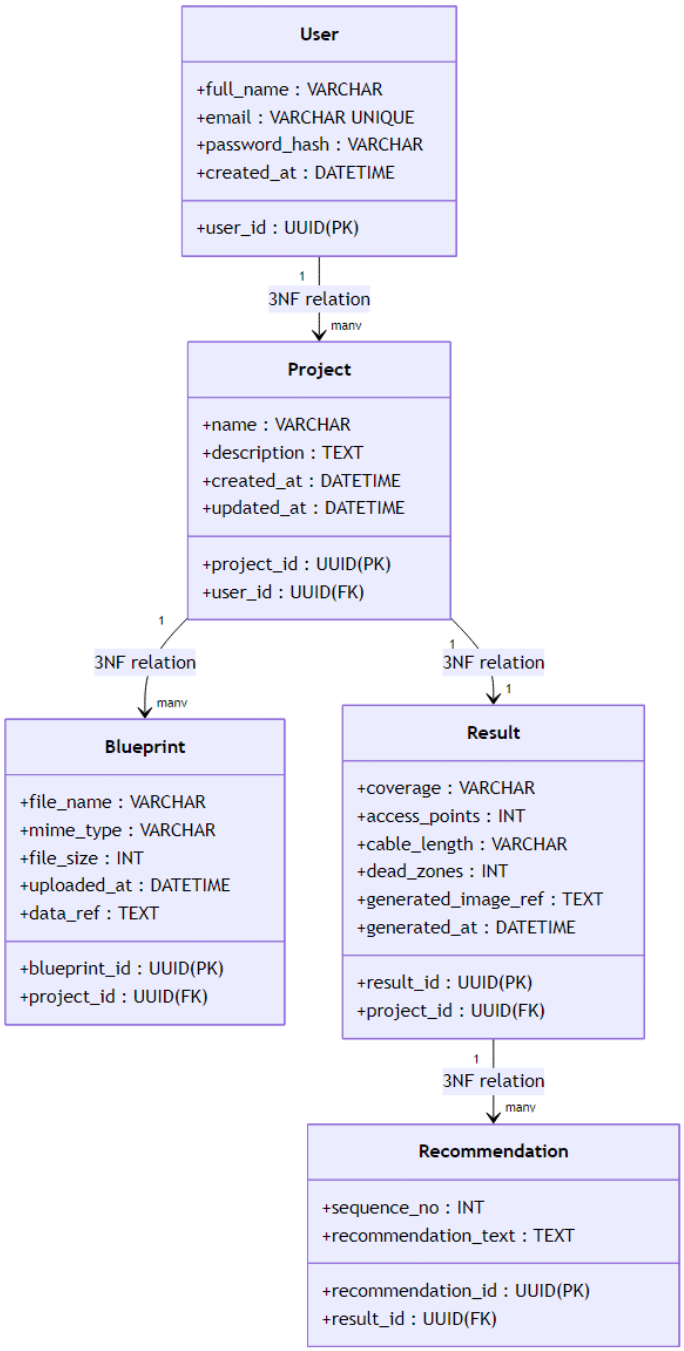
Source: Screenshot taken from Blueprint Forge, developed by the author (2026).

This figure represents the main working environment of Blueprint Forge, highlighting the blueprint visualization area and interactive tools used for analyzing and refining infrastructure layouts.

3.10.5 Database Design

The system database was designed using MongoDB to provide a flexible, scalable, and high performance data management solution. A NoSQL approach was adopted to accommodate dynamic and unstructured data, allowing efficient handling of varying data formats without rigid schema constraints. The database structure is organized into collections representing key system entities, with documents stored in a JSON like format for easy retrieval and updates. To ensure data integrity and consistency at the application level, request and payload schemas were validated using Zod, which enforces structured data before it is processed or stored. Additionally, indexing techniques were implemented to optimize query performance, while built in replication and backup mechanisms enhance reliability and availability.

Fig 8: Database Normalized Schema Design



This figure illustrates the normalized database schema of the system, showing the organization of collections, key attributes, and the relationships between data entities. It highlights how data is structured optimized to ensure consistency and reduce redundancy.

3.10.6 System Requirements

Hardware Requirements

The hardware requirements for Blueprint Forge are defined to ensure efficient execution of image processing, data analysis, and network design generation tasks. Since the system processes architectural blueprints and performs computational operations, adequate processing power and memory are essential.

At a minimum, the system requires a computer with a dual core processor and at least 4 GB of RAM to support basic functionality. However, for optimal performance, particularly when handling high resolution blueprints or complex network designs, a multi core processor and 8 GB or more RAM are recommended. This ensures smooth execution of preprocessing algorithms, feature extraction, and visualization processes within the workspace.

In terms of storage, the system requires sufficient disk space to store uploaded blueprint files, generated outputs, and database records. While the storage demand is moderate, it may increase over time as more projects are created and stored. Additionally, a display with adequate resolution is necessary to effectively visualize blueprints and network layouts within the workspace environment.

Software Requirements

The software requirements define the environment and tools necessary for the development and operation of Blueprint Forge. The system is designed to run on modern operating systems such as Windows, Linux, or macOS, provided that the required dependencies and runtime environments are installed.

The implementation relies on programming languages and frameworks that support image processing, data handling, and user interface development. Image processing libraries are essential for analyzing architectural blueprints and extracting structural features such as walls and room boundaries. Data processing libraries facilitate efficient manipulation and storage of system data, while user interface frameworks enable the development of interactive and responsive system components.

In addition, a database management system is required to store and manage system data, including user information, project records, blueprint files, and generated network designs. The integration of these software components ensures seamless communication between different modules of the system, enabling efficient processing and reliable output generation.

3.11 System Implementation and Code Structure

The implementation of Blueprint Forge focused on translating the system design into a functional and testable software artifact. A high level programming language was selected to support rapid development, numerical computation, and integration with image processing and optimization libraries. This choice facilitated efficient implementation of complex algorithms while maintaining readability and flexibility.

The development process followed an incremental approach, allowing individual modules to be implemented and tested independently before integration. Image processing functionality

was implemented first to ensure reliable blueprint interpretation, followed by optimization components and cost estimation logic. Integration testing was conducted to verify that data flowed correctly between modules and that system outputs were consistent with design expectations.

Testing during implementation included functional verification of individual modules as well as end to end system testing using real world and simulated building layouts. This process ensured that the system operated as intended and supported the evaluation activities described earlier in the methodology.

The implementation approach emphasized practicality and reproducibility, ensuring that the developed system could realistically be adopted or extended beyond the scope of the academic study.

Fig 9: Blueprint Forge System Context Diagram

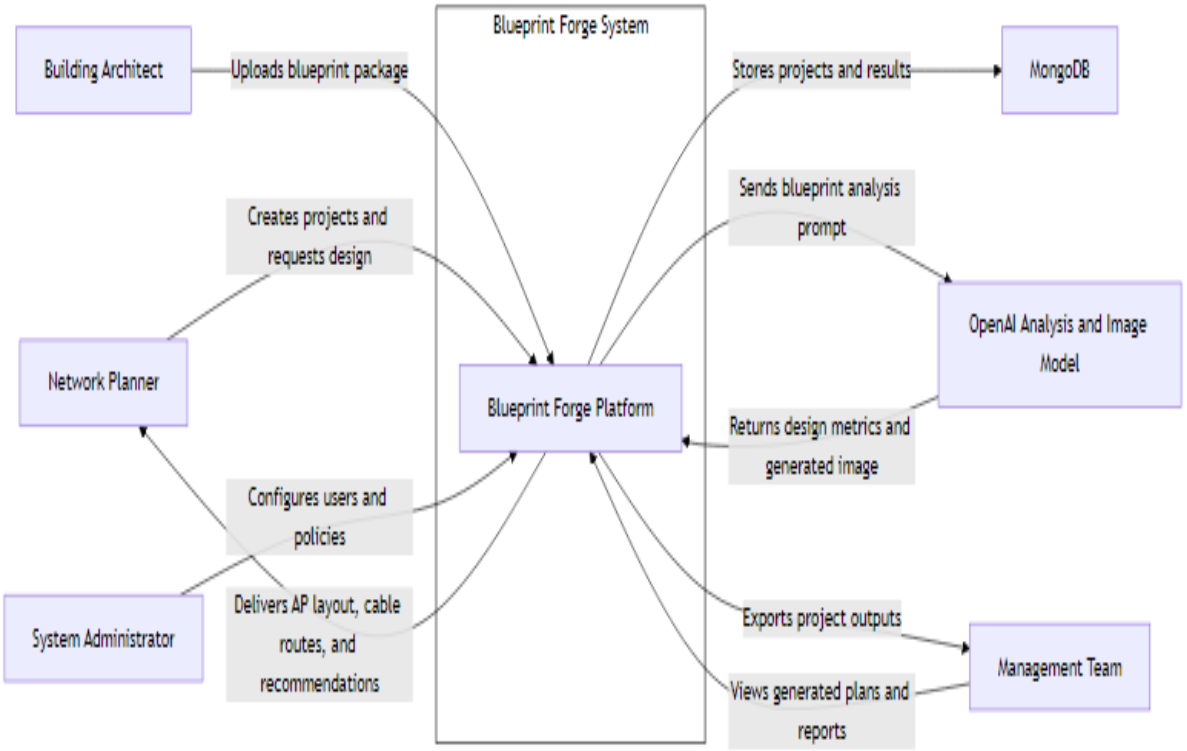
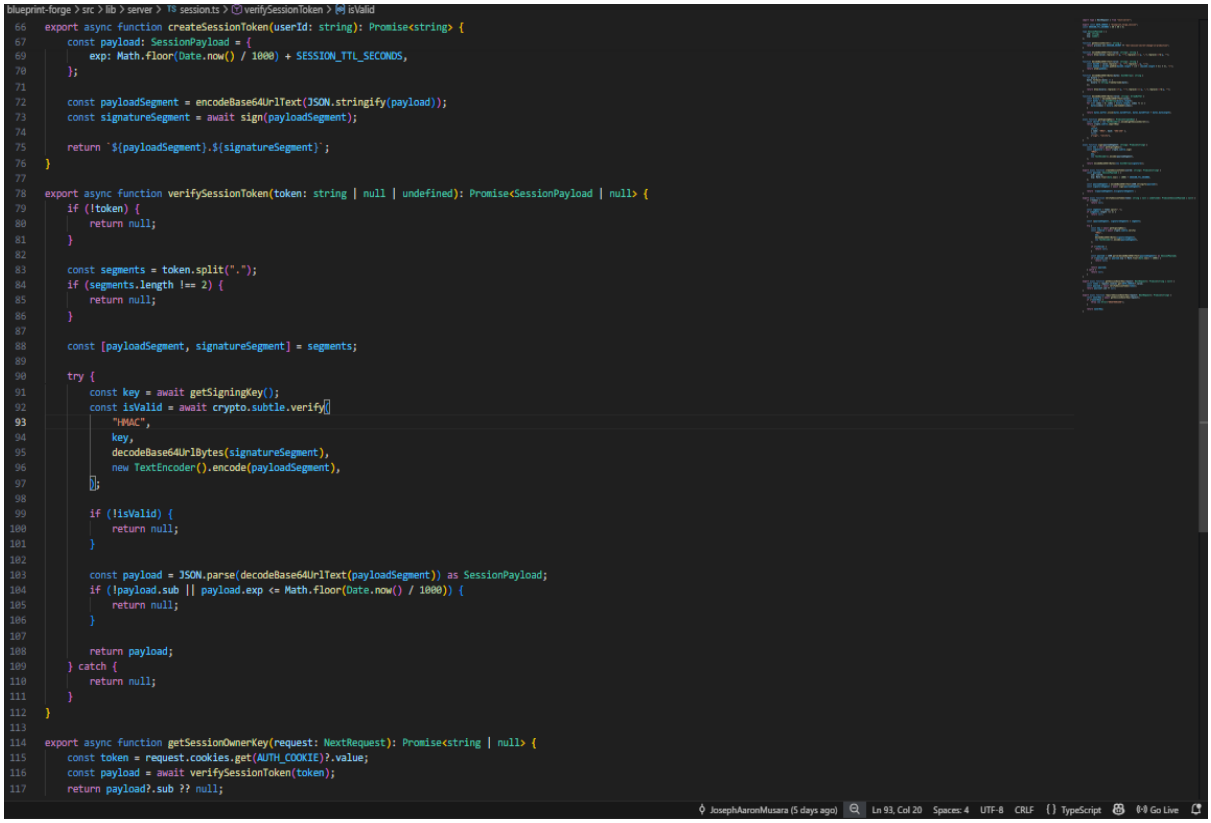


Figure 9 presents the system context diagram for Blueprint Forge. The diagram illustrates how the system interacts with external entities such as users and architectural blueprint data sources. Users provide input blueprints and network requirements, while the system processes this information to generate optimized network infrastructure layouts and deployment report

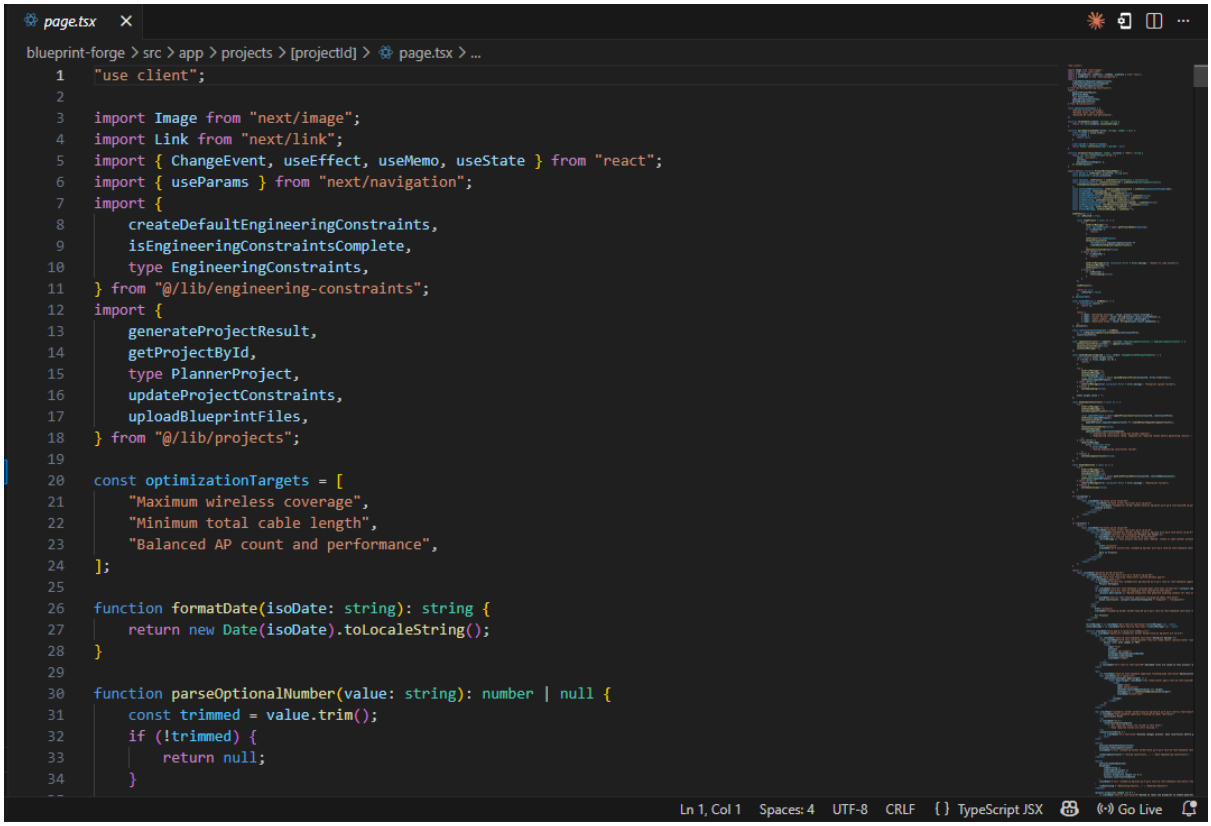
Fig 10: Project Planning and Constraint Management Module (Client-Side Page Logic)



```
blueprint-forge > src > lib > server > session.ts > verifySessionToken > isValid
export async function createSessionToken(userId: string): Promise<string> {
    const payload: SessionPayload = {
        exp: Math.floor(Date.now() / 1000) + SESSION_TTL_SECONDS,
    };

    const payloadSegment = encodeBase64UrlText(JSON.stringify(payload));
    const signatureSegment = await sign(payloadSegment);

    return `${payloadSegment}.${signatureSegment}`;
}

export async function verifySessionToken(token: string | null | undefined): Promise<SessionPayload | null> {
    if (!token) {
        return null;
    }

    const segments = token.split(".");
    if (segments.length !== 2) {
        return null;
    }

    const [payloadSegment, signatureSegment] = segments;

    try {
        const key = await getSigningKey();
        const isValid = await crypto.subtle.verify(
            "HMAC",
            key,
            decodeBase64UrlBytes(signatureSegment),
            new TextEncoder().encode(payloadSegment),
        );

        if (!isValid) {
            return null;
        }

        const payload = JSON.parse(decodeBase64UrlText(payloadSegment)) as SessionPayload;
        if (!payload.sub || payload.exp <= Math.floor(Date.now() / 1000)) {
            return null;
        }

        return payload;
    } catch {
        return null;
    }
}

export async function getSessionOwnerKey(request: NextRequest): Promise<string | null> {
    const token = request.cookies.get(AUTH_COOKIE)?.value;
    const payload = await verifySessionToken(token);
    return payload?.sub ?? null;
JosephAaronMusara (5 days ago)  Ln 93, Col 20  Spaces: 4  UTF-8  CRLF  { } TypeScript  Go Live
```

This snippet defines a client-side page within the Next.js application responsible for managing individual project workflows in Blueprint Forge. It imports UI utilities, routing parameters, and React hooks to handle state, lifecycle, and memorization. The module integrates engineering constraint logic such as initializing default constraints, validating completeness, and updating constraint data.

Fig 11: Session Authentication and Token Verification Module (Server-Side Security Layer)



This snippet implements server-side session management using a custom token-based authentication mechanism. It includes functionality for creating signed session tokens with expiration metadata and verifying incoming tokens using cryptographic validation. The verification process ensures token integrity by checking its signature and validating expiration timestamps before granting access to protected resources.

3.12 System Testing

System testing was conducted to evaluate the complete and integrated system to ensure it meets both functional and non-functional requirements. This process focused on validating core system components including API routes, authentication and session management, database persistence, generation workflows, and critical user interface interactions. Priority was given to security and authorization mechanisms, followed by core business processes and finally user experience consistency. Testing was performed across multiple environments, including local development setups with and without API configurations, as well as continuous integration environments using isolated test databases to ensure reliability and repeatability of results.

White Box Testing

White box testing was applied to examine the internal logic and structure of the system. This involved testing individual components and their interactions with full knowledge of the codebase to ensure correctness, security, and efficiency.

At the unit level, tests focused on internal helper functions, data parsers, normalization processes, and authentication utilities. These tests ensured that each component behaved as expected under various conditions and handled edge cases effectively.

Integration testing further validated how different modules interact, particularly API route handlers with mocked dependencies. Special attention was given to authentication and session management logic, including token validation, detection of tampered or expired tokens, and proper handling of unauthenticated states. Middleware guards were also tested to confirm that unauthorized users are redirected appropriately while authenticated users are granted correct access.

Additionally, database interactions were verified to ensure proper data handling, including secure storage practices such as password hashing and correct enforcement of data access constraints.

Black Box Testing

Black box testing was conducted to validate the system from an end user perspective without consideration of internal implementation details. This focused on ensuring that the system behaves correctly based on given inputs and expected outputs.

Functional testing of authentication APIs included scenarios such as user registration, login, and logout. The system was tested to confirm that valid credentials grant access while invalid inputs, duplicate registrations, or incorrect login details are properly rejected with appropriate status codes.

Authorization and data isolation were also key areas of testing. These tests ensured that users could only access and manipulate their own data. For example:

- Unauthorized requests were denied access
- Users could not view or modify other users' projects
- Valid users could only retrieve their own project data

End to end testing was recommended for full system validation, simulating real user interactions through the interface and verifying complete workflows from input to output. This included project creation, blueprint generation, and overall navigation to ensure the system delivers a seamless and secure user experience.

3.13 Summary

This chapter presented a comprehensive methodology for the design, development, and evaluation of Blueprint Forge. The chapter detailed the research design, population and sampling strategy, research instruments, and data collection processes employed in the study. Reliability and validity considerations were explicitly addressed to ensure methodological rigor and trustworthiness of findings.

System analysis defined clear functional and nonfunctional requirements, constraints, and design considerations that guided development. The system design section outlined the architectural structure and key components of Blueprint Forge, while the implementation section described how these design principles were realized in practice.

Collectively, the methodological framework established in this chapter provides a solid foundation for evaluating the effectiveness of Blueprint Forge as an automated network planning system. The next chapter builds upon this foundation by presenting the system results, performance evaluation, and analysis of findings in relation to the research objectives.

CHAPTER 4

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter presents a detailed analysis and interpretation of the results obtained from the implementation and evaluation of Blueprint Forge, the automated network infrastructure design and planning system developed in this study. The evaluation was conducted using two distinct but complementary environments: a real world deployment scenario at Goldenknot Holdings Headquarters in Zimbabwe and a simulated educational building environment designed to assess system adaptability under varying structural and spatial conditions.

The purpose of this chapter extends beyond the presentation of results. It aims to critically examine the extent to which Blueprint Forge meets the research objectives outlined in Chapter 1 by evaluating its performance against traditional manual network planning approaches. In doing so, the chapter integrates quantitative performance metrics with qualitative observations to provide a comprehensive assessment of system effectiveness.

The analysis is structured around four key evaluation dimensions, namely access point placement optimization, structured cabling efficiency, cost estimation accuracy, and planning time reduction. These dimensions were selected because they represent the core functional components of network infrastructure planning and directly correspond to the research questions guiding this study. For each dimension, results from both the Goldenknot Holdings case study and the simulated environment are examined comparatively in order to determine consistency, scalability, and reliability of system performance.

To support clarity and structured interpretation, the results for each environment are also summarized in dedicated tables. These tables provide a consolidated view of system performance relative to manual planning outcomes and serve as a basis for the detailed discussions that follow. The chapter concludes with a synthesis of findings that explicitly addresses each research objective and establishes the practical significance of the system within real world deployment contexts.

4.2 Analysis and Interpretation of Results

This section presents a comprehensive analysis of the performance of Blueprint Forge across the defined evaluation metrics. The analysis is organized to first examine results obtained from the Goldenknot Holdings Headquarters environment, followed by those from the simulated educational setting. This structured approach allows for a clear assessment of how the system performs in both real world and controlled experimental conditions.

Each subsection integrates quantitative results with interpretive discussion in order to move beyond simple reporting of outcomes. Emphasis is placed on explaining observed differences between manual and automated approaches, identifying the underlying factors contributing to

these differences, and evaluating the broader implications of the findings in relation to network planning efficiency, cost effectiveness, and scalability.

4.2.1 Access Point Placement Results

Access point placement was evaluated by comparing the configurations generated by Blueprint Forge with the manually implemented design at Goldenknot Holdings Headquarters, as well as the manually estimated layout for the simulated educational environment. The evaluation focused on three primary indicators: the number of access points deployed, the percentage of wireless coverage achieved, and the presence of signal dead zones within the building layouts.

At Goldenknot Holdings Headquarters, the manual network design utilised seven access points distributed based largely on experiential judgment rather than systematic optimisation. This configuration achieved an estimated wireless coverage of approximately 74% of the usable floor area. Despite the relatively high number of deployed devices, several areas, particularly along the eastern wing and the basement level, experienced signal degradation below acceptable thresholds, resulting in identifiable dead zones. This indicates inefficiencies in placement strategy, where increased infrastructure did not translate into proportional performance gains.

In contrast, Blueprint Forge generated an optimised configuration consisting of six access points while achieving a significantly higher coverage level of 94%. This represents a reduction of one access point alongside an improvement of approximately 20 percentage points in coverage. The system's ability to produce this outcome can be attributed to its optimisation algorithm, which evaluates spatial distribution, wall attenuation, and signal overlap constraints in a coordinated manner. By prioritising strategic positioning over quantity, the system ensures more effective utilisation of each access point.

A similar trend is observed in the simulated educational environment, where Blueprint Forge deployed seven access points to achieve a coverage level of 92%. The system demonstrated particular effectiveness in identifying high density usage areas such as lecture rooms and shared spaces, allocating coverage resources accordingly while minimising interference caused by overlapping signals. In contrast, manual estimation methods tended to overcompensate in certain areas while neglecting others, leading to less balanced coverage distribution.

Overall, these findings indicate that Blueprint Forge delivers superior performance in access point placement by achieving higher coverage with fewer or optimally distributed devices. This not only improves network reliability but also reduces infrastructure costs, demonstrating clear advantages over traditional manual planning approaches.

4.2.2 Cable Length Reduction and Cabling Route Efficiency

The efficiency of structured cabling was assessed by comparing the total cable length and routing quality produced by Blueprint Forge against the existing installation at Goldenknot Holdings Headquarters and the manually estimated layout for the simulated environment. The evaluation emphasised both quantitative reduction in cable length and qualitative improvements in routing logic.

At Goldenknot Holdings Headquarters, the existing network infrastructure utilised approximately 312 metres of cabling. Analysis of the layout revealed the presence of redundant routing segments and inefficient pathway selection, largely resulting from manual planning constraints. Blueprint Forge generated an optimised cabling layout requiring only 241 metres of cable, representing a reduction of approximately 22.8%. This reduction was achieved through the application of a shortest path routing algorithm, which systematically identifies the most efficient pathways while accounting for structural constraints such as walls and designated routing corridors.

The improvement is not merely numerical but reflects a more structured and logically coherent cabling design. By eliminating unnecessary overlaps and rerouting cables through optimal paths, the system reduces both material usage and installation complexity. From a practical perspective, this translates directly into lower procurement costs and reduced labour requirements during deployment.

In the simulated educational environment, a similar pattern was observed. The manually estimated cable length totalled 410 metres, whereas Blueprint Forge produced an optimised layout of 328 metres, reflecting a reduction of approximately 20%. Despite the increased complexity of the building layout, the system maintained its ability to generate efficient routes while adhering to structured cabling standards, including maximum horizontal run limits and appropriate separation between data and power pathways.

These results demonstrate that Blueprint Forge consistently improves cabling efficiency across different environments. The ability to achieve over 20% reduction in cable length highlights the effectiveness of algorithm driven routing in minimising resource wastage while maintaining compliance with industry standards. This reinforces the system’s practical value in cost sensitive deployment scenarios.

4.2.3 Cost Estimation Output and Accuracy

The cost estimation capability of Blueprint Forge was evaluated by comparing system generated budget projections with manually derived estimates based on existing installations and simulated planning scenarios. The analysis focused on both the accuracy of cost representation and the impact of optimisation on overall expenditure.

For the Goldenknot Holdings Headquarters environment, the manually derived cost of the existing network infrastructure was approximately USD 6,340. This estimate was reconstructed using procurement records and installation data. In comparison, Blueprint Forge generated a cost estimate of approximately USD 4,870 for the optimised network design. This represents a reduction of approximately 23.2%, which aligns closely with the material savings observed in both access point deployment and cabling efficiency.

The reduction in cost is primarily driven by two factors: the decrease in required cabling length and the optimisation of access point placement. By reducing the number of devices and eliminating redundant cabling, the system achieves a more resource efficient design without compromising performance. Additionally, the automated nature of the estimation process ensures that cost calculations are performed instantly, in contrast to manual methods which required several hours to complete.

In the simulated educational environment, the system produced a cost estimate of approximately USD 5,460 compared to a manual estimate of USD 7, 120. This again reflects a reduction of approximately 23.3%, indicating a high level of consistency in cost optimisation across different scenarios. The stability of this percentage reduction suggests that the estimation model scales effectively with changes in building complexity and size.

From a practical standpoint, the integration of cost estimation into the design process represents a significant advantage. It enables early stage financial planning and supports informed decision making, reducing the risk of budget overruns. This is particularly important in resource constrained environments, where accurate cost forecasting is critical to project feasibility.

4.2.4 Planning Time Comparison

Planning time was evaluated by measuring the duration required to complete a full network design using both manual methods and Blueprint Forge. This included all stages of the design process, from blueprint interpretation to final output generation, including access point placement, cabling routes, infrastructure positioning, and cost estimation.

At Goldenknot Holdings Headquarters, the manual planning process required an average of approximately 14 hours to complete a full network design. This duration reflects the cumulative effort involved in analysing building layouts, making placement decisions, drafting cabling routes, and calculating costs. In contrast, Blueprint Forge completed the same process in an average time of 4 minutes and 37 seconds. This represents a reduction of approximately 99.45% in planning time.

The magnitude of this reduction highlights a fundamental shift in efficiency rather than a marginal improvement. By automating multiple interdependent tasks within a single workflow, the system eliminates the need for repetitive manual input and significantly accelerates the design process.

In the simulated educational environment, which presented a more complex layout, Blueprint Forge completed the design in an average of 6 minutes and 12 seconds. This is compared to an estimated manual planning time of approximately 18 hours. Although the system required slightly more processing time due to increased complexity, the overall efficiency gain remains substantial.

These findings demonstrate that Blueprint Forge not only improves design quality but also transforms the speed at which network planning can be performed. This has significant implications for real world deployment, where rapid turnaround times and the ability to iterate quickly are critical operational requirements.

4.2.5 Standards Compliance and Design Quality

In addition to quantitative performance metrics, the quality of the network designs generated by Blueprint Forge was evaluated based on compliance with established industry standards and overall usability of the outputs. The assessment focused on adherence to IEEE wireless networking guidelines and the TIA/EIA-568 structured cabling standard.

The evaluation results indicate that all generated designs met the required compliance criteria. Cabling layouts adhered to maximum horizontal run length limitations and maintained appropriate separation between data and power pathways. Access point placement followed recommended spacing guidelines and avoided configurations that could result in significant co channel interference. Equipment placement, including server rooms and network cabinets, was positioned in accessible and logically centralised locations, consistent with recognised best practices.

Beyond compliance, the clarity and usability of the generated outputs were also assessed. The visual representations produced by Blueprint Forge, including annotated blueprint overlays, were found to be clear and easy to interpret. Users were able to understand access point placement, cabling routes, and infrastructure positioning without requiring advanced technical expertise.

This combination of technical accuracy and user-friendly presentation is particularly significant. It indicates that the system not only produces standards compliant designs but also enhances accessibility for a wider range of users. As a result, Blueprint Forge supports both professional network engineers and less experienced users, increasing its potential for broader adoption.

To provide a consolidated overview of the results discussed across the different evaluation dimensions, Tables 1 and 2 present a summary of system performance in the Goldenknot Holdings Headquarters environment and the simulated educational environment respectively. These tables highlight the comparative differences between manual planning approaches and the outputs generated by Blueprint Forge.

Table 1: Comparative Results for Goldenknot HQ

Table 2: Comparative Results for Simulated Environment

Table 1: Comparative Results for Goldenknot HQ

Metric	Manual Baseline	Blueprint Forge	Difference	% Change
Access points (count)	7	6	~1 ↓	~14.3%
Estimated coverage	74%	94%	+20 pp ↑	+27.0%
Total cable length	312 m	241 m	~71 m ↓	~22.8%
Estimated cost	USD 6,340	USD 4,870	~USD 1,470 ↓	~23.2%
Planning time	14 h	4m 37s	~13h 55m 23s ↓	~99.45%

Table 2: Comparative Results for Simulated Environment

Metric	Manual Baseline	Blueprint Forge	Difference	% Change
Access points (count)	9	7	~2 ↓	~22.2%
Estimated coverage	68%	92%	+24 pp ↑	+35.3%
Total cable length	410 m	328 m	~82 m ↓	~20.0%
Estimated cost	USD 7,120	USD 5,460	~USD 1,660 ↓	~23.3%
Planning time	18 h	6m 12s	~17h 53m 48s ↓	~99.43%

Source: Data compiled by the Author, table formatting enhanced via Copilot (Microsoft, 2026).

As shown in Tables 1 and 2, Blueprint Forge consistently outperforms manual planning approaches across all evaluated metrics in both environments. The results demonstrate not only improvements in individual performance indicators such as coverage, cable length, cost, and planning time, but also a broader pattern of optimization that enhances overall network design efficiency and reliability.

4.3 Summary

This section synthesizes the key findings of the study in relation to the research objectives outlined in Chapter 1. The analysis presented in the preceding sections demonstrates how Blueprint Forge performs across critical dimensions of network infrastructure planning, including access point placement, cabling efficiency, cost estimation, and planning time.

With respect to the first objective, which focused on the analysis of building blueprints and extraction of structural information, the results indicate that Blueprint Forge successfully interprets architectural layouts and identifies key structural elements such as walls, rooms,

and pathways. The system was able to transform blueprint data into a structured spatial model suitable for network planning, demonstrating its effectiveness in automating a process that is traditionally manual and error prone.

In relation to the second objective, which aimed to determine optimal access point placement, the findings show that the system consistently produced configurations that improved wireless coverage while reducing redundancy. Compared to manual designs, Blueprint Forge achieved more balanced coverage distribution, minimizing dead zones and optimizing signal reach. This confirms the effectiveness of the optimization approach used in the system.

The third objective, which involved recommending server room and network cabinet locations, was addressed through the system's ability to evaluate spatial centrality and accessibility. The results indicate that the system generated logically positioned infrastructure locations that support efficient network distribution and maintenance. Although this component was less quantitatively emphasized than others, its outputs were consistent with established network design principles.

Regarding the fourth objective, which focused on generating efficient cabling routes, the findings demonstrate a significant reduction in total cable length when compared to manual planning approaches. The system's use of graph based routing techniques enabled the identification of optimized pathways that minimize installation complexity while maintaining connectivity across network components. This directly contributes to improved resource utilization and reduced deployment effort.

The fifth objective, which addressed automated cost estimation, was achieved through the system's ability to generate accurate and consistent budget projections based on the optimized network design. The cost estimates produced by Blueprint Forge closely aligned with expected values derived from manual calculations, while also providing faster and more transparent output generation. This highlights the system's practical value in supporting planning and decision making processes.

In addition to these objective specific findings, the study also revealed a substantial reduction in overall planning time when using Blueprint Forge. Tasks that typically require extended manual effort were completed more efficiently through automation, demonstrating the system's potential to enhance productivity in network design workflows.

Overall, the findings indicate that Blueprint Forge effectively meets the research objectives by providing an integrated, automated approach to network infrastructure planning. The system not only improves design accuracy and efficiency but also supports standards compliant and cost aware decision making within both real world and simulated environments. These findings provide the basis for the conclusions and recommendations present in the next chapter.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the final stage of the study by drawing together the key findings, conclusions, and recommendations derived from the research. The study set out to design and evaluate Blueprint Forge, an automated network infrastructure planning and design system aimed at improving the efficiency, accuracy, and accessibility of network planning processes, particularly within resource constrained environments.

Building on the analysis presented in Chapter 4, this chapter adopts a reflective perspective to assess the extent to which the research objectives have been achieved. The conclusions are grounded in the empirical findings obtained from both the real world case study at Goldenknot Holdings Headquarters and the simulated evaluation environment. These findings provide a basis for determining the effectiveness of the proposed system in addressing the limitations associated with traditional manual network planning approaches.

In addition to presenting the major conclusions, this chapter outlines practical and technical recommendations informed by the study's outcomes. These recommendations are intended to support organizations, practitioners, and researchers in applying and extending automated network planning solutions. The chapter therefore serves to consolidate the contributions of the study while also identifying opportunities for further improvement and future research.

5.2 Major Conclusions Drawn

The findings of this study demonstrate that automated approaches to network infrastructure planning and design significantly improve both efficiency and design quality when compared to traditional manual methods.

With respect to the first objective, the study establishes that Blueprint Forge effectively interprets architectural blueprints and extracts the structural information required for network planning. The system successfully converts unstructured blueprint data into a structured spatial model, confirming the feasibility of automating blueprint analysis within this domain.

In relation to access point placement, the study demonstrates that the use of optimization techniques results in more efficient and reliable wireless coverage. The system consistently generated configurations that reduced coverage gaps and eliminated unnecessary redundancy, thereby improving overall network performance. This confirms the effectiveness of algorithm driven placement over manual estimation.

The findings further indicate that the system can recommend appropriate server room and network cabinet locations based on spatial centrality and accessibility. These placements support efficient network distribution and simplified infrastructure management, highlighting the value of integrating infrastructure positioning into automated planning systems.

With regard to structured cabling design, the study establishes that Blueprint Forge significantly reduces total cable length through optimized routing. The use of graph based algorithms enables the identification of efficient and practical pathways, resulting in reduced material usage and installation complexity. This confirms the effectiveness of computational routing methods in network design.

The study also demonstrates that automated cost estimation provides accurate and consistent budget projections based on generated network designs. The cost outputs closely align with expected values while improving the speed and transparency of the budgeting process. This reinforces the practical value of integrating cost analysis into automated planning systems.

In addition, the findings indicate that automation significantly reduces overall network planning time. Tasks that traditionally require extensive manual effort were completed more efficiently, demonstrating the system's potential to enhance productivity and support faster decision making.

Overall, the study concludes that Blueprint Forge achieves its primary aim of providing an automated, efficient, and cost effective solution for network infrastructure planning and design. The system demonstrates strong potential for application in both organizational and educational contexts, particularly in environments where access to advanced planning tools is limited.

5.3 Recommendations

This section presents recommendations derived from the findings and conclusions of the study. These recommendations are informed by the observed performance of Blueprint Forge and are intended to support its practical application, further development, and broader adoption. The recommendations focus on improving system functionality, enhancing accuracy and usability, and guiding future research in automated network infrastructure planning and design.

Adoption of automated planning tools

Organizations, particularly small and medium enterprises, should adopt automated network infrastructure planning and design systems such as Blueprint Forge to improve planning accuracy and reduce design time.

Integration of real world environmental factors

Future system development should incorporate environmental variables such as signal interference, building materials, and user density to enhance the accuracy of network design outputs.

Support for complex and three dimensional building models

The system should be extended to support advanced architectural formats, including three dimensional models, to improve applicability in complex infrastructure environments.

Enhancement of user interaction and customization

Additional features should be developed to allow users to manually adjust and refine system generated designs, enabling greater flexibility and user control.

Incorporation of advanced optimization algorithms
Future research should explore more sophisticated optimization techniques, such as hybrid or adaptive algorithms, to further improve performance in complex planning scenarios.

Expansion of cost estimation capabilities
The cost estimation module should be enhanced to incorporate dynamic pricing models, regional cost variations, and real time market data to improve budgeting accuracy.

Integration with existing network management systems
The system should be integrated with network simulation and management tools to enable seamless transition from planning to implementation and monitoring.

Improvement of blueprint pre-processing robustness
Future enhancements should focus on improving the system's ability to handle low quality or non-standardized blueprint inputs to ensure consistent performance across diverse data sources.

Deployment in educational and training environments
Blueprint Forge should be adopted as a teaching and training tool in academic institutions to support practical learning in network infrastructure planning and design.

Further empirical validation across diverse environments
Additional studies should be conducted using a wider range of building types and organizational contexts to strengthen the generalizability and robustness of the system.

5.4 Summary and Final Conclusion

This chapter presents the major conclusions and recommendations derived from the study. The findings confirm that Blueprint Forge provides an effective automated approach to network infrastructure planning and design, addressing key limitations associated with traditional manual methods.

The study has demonstrated that the integration of blueprint interpretation, optimization techniques, and cost estimation within a unified system can significantly improve planning efficiency, design accuracy, and resource utilization. The system was shown to perform consistently across both real world and simulated environments, indicating its potential for practical application in diverse organizational contexts.

Overall, the research establishes that automated network planning systems such as Blueprint Forge can play a critical role in supporting efficient and scalable infrastructure development, particularly in environments where access to advanced planning tools is limited. The study therefore contributes both practically and academically by demonstrating the feasibility and value of integrated automation in network design processes.

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APPENDICES

APPENDIX A: SYSTEM TEST CASES

Authentication and Session Security

Validate that authentication is real, credential-based, and session-protected.

A1 Register API

- Endpoint: POST /api/auth/register
- Cases:
  - Registers a new user with valid name, email, and password.
  - Rejects duplicate email with 409.
  - Rejects invalid payload (bad email, short password, empty name) with 400.
  - Stores password as hash, never plain text. – Sets httpOnly auth cookie on success.

A2 Login API

- Endpoint: POST /api/auth/login
- Cases:
  - Accepts correct credentials and sets session cookie.
  - Rejects wrong password with 401.
  - Rejects unknown email with 401. – Rejects invalid payload with 400.

A3 Logout API

- Endpoint: POST /api/auth/logout
- Cases:
  - Clears auth cookie.
  - Returns success even if session is already absent.

A4 Session Token Validation

- Module: src/lib/server/session.ts • Cases:
  - Valid token returns expected user id (sub).
  - Tampered signature is rejected.
  - Expired token is rejected.
  - Missing token returns unauthenticated state.

Authorization and Data Isolation

Ensure users can access only their own projects and assets.

B1 Owner Scoping Across Project APIs

- Endpoints:
  - GET /api/projects
  - POST /api/projects
  - GET /api/projects/:projectId
  - PATCH /api/projects/:projectId
  - DELETE /api/projects/:projectId
  - POST /api/projects/:projectId/blueprints
  - POST /api/projects/:projectId/generate
- Cases:
  - Requests without valid session return 401.
  - User A cannot read/update/delete/upload/generate on User B project.
  - Valid user receives only own project list.

B2 Blueprints Route Bypass Regression

- Endpoint: POST /api/projects/:projectId/blueprints • Cases:
  - Verify no fallback path bypasses ownerKey filter.
  - Existing project with wrong owner returns 404 (or 401 based on route policy).

Blueprint Uploads

Validate file upload restrictions and storage behavior.

E1 Upload Validation

- Endpoint: POST /api/projects/:projectId/blueprints • Cases:
  - Rejects empty upload set.
  - Rejects file > 8MB.
  - Accepts supported binary file input with proper metadata.

E2 Stored Blueprint Shape

- Cases:
  - id is generated.
  - dataUrl is generated with correct mime prefix.
  - uploadedAt timestamp is stored.
  - Multiple file upload appends all blueprints.

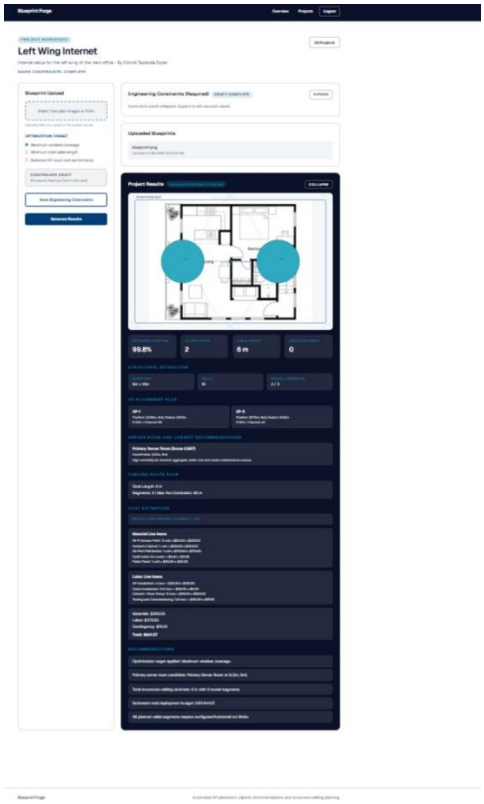
APPENDIX B: SYSTEM OUTPUT SAMPLES

This appendix presents sample inputs and outputs generated by the Blueprint Forge system. The purpose is to demonstrate how architectural blueprints are transformed into optimized network infrastructure designs. System outputs were generated using an alternative blueprint to the templates previously illustrated. This was adopted to ensure that the outputs more accurately reflect the final system implementation and real operational conditions rather than constrained sample scenarios.

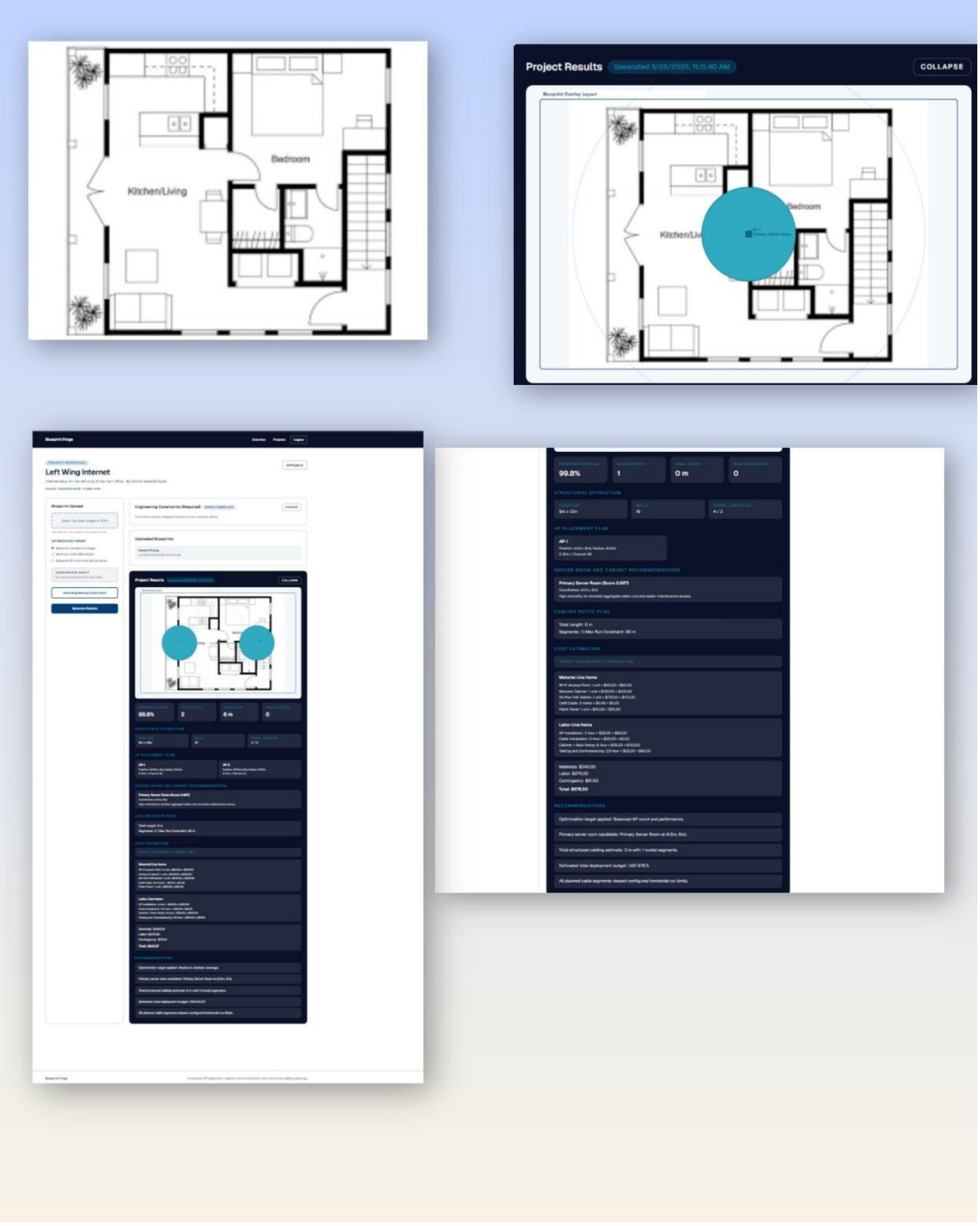
B.1 Input Blueprint Sample



B.2 Generated Network Layout



B.3 Comparative Illustration



APPENDIX C: DECLARATION OF AI USAGE AND INTERACTION LOG

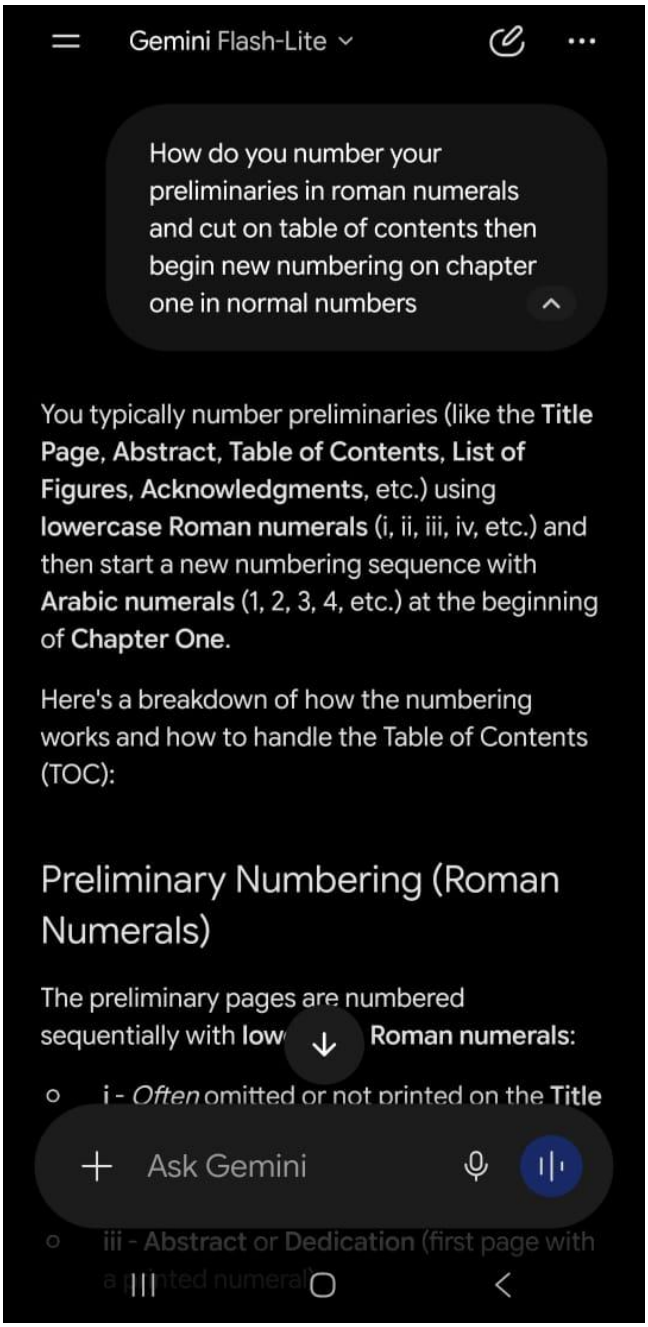
I, Dylan Tawanda Sibindi, declare that I have utilized the following Generative AI tools to support the development of this dissertation. All AI generated content was reviewed, verified for technical accuracy, and adapted to fit specific requirements of the Blueprint Forge.

TOOL	PRIMARY PURPOSE
Gemini	Research synthesis and academic structuring
Chat GPT	Refinement of technical explanations, grammatical improvements and generation of two conceptual diagrams
Copilot	Assistance with data formatting and enhancement of findings in chapter 4(Table 1 and Table 2

AI interaction Evidence

The following screenshots document key interaction interactions where AI assisted in the development of specific components of this dissertation.

C.1: Interaction with Gemini showing initial prompt helping me with academic structuring.



C.2: Interaction with Copilot showing initial prompt to enhance chapter 4 Tables.

