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FTTX Network Design: From Traditional CAD to Smart, Data-Driven

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ABSTRACT: The influx of Fiber-to-the-x (FTTx) networks all over the world has amplified the necessity to have efficient, precise, and scalable network design approaches. The planning of fiber networks traditionally has been based on the computer-Aided Design (AutoCAD) tools that are mostly manual, geometry-based and subject to human error. Although useful in small scale project development, these approaches cannot meet the growing complexity and data demands of the contemporary broadband deployment. The result is a paradigm shift in the industry toward design frameworks that are based on Geographic Information System (GIS) and data-driven design frameworks.

Although the recent developments have been made, there is a considerable gap in research in the systematic comparison of the conventional CAD based work flows and intelligent, attribute-based GIS methods, especially on the efficiency of automation, splice loss modeling, and accuracy of capacity planning. This paper will seek to fill this gap by critically assessing the performances and results of the two design paradigms.

The study uses comparative methodology of analysis, which incorporates literature synthesis, workflow benchmarking and simulation-based assessment. The significance of smart, data-driven design models is measured by the key performance indicators, such as design accuracy, design planning time, error rates, splice loss margins, and network scalability.

The results prove that GIS-based and attribute-driven planning is much better than traditional CAD methods regarding automation, accuracy, and scalability. The intelligent design systems lower the planning time, provide less splice loss uncertainties, and allow proactive capacity prediction via data analytics and optimization algorithms.

In practice, the research offers viable information to the network operators and planners who want to streamline their design procedures. Its findings help in strategic decision making to move towards smart planning platforms that ultimately would result in a high level of deployment efficiency, lower operation costs and the long run sustainability of a network.

KEYWORDS: FTTx, GIS-based design, AutoCAD, attribute-driven planning, splice loss, capacity planning, GPON, data-driven networks

I. INTRODUCTION

1.1. The background of FTTx Deployment

The high-speed and reliable broadband connection has become a critical demand in the world as a result of the explosive demand of data-intensive applications like cloud computing, video streaming, smart cities, and Internet of Things (IoT) services. FTTB, Fiber-to-the-Building (FTTB), Fiber-to-the-Curb (FTTC), and Fiber-to-the-Home (FTTH) Fiber-to-the-x (FTTx) architectures have become the most plausible long-term access solutions as they have high bandwidth capacity, low latency, and future-proof infrastructure. Global governments and their telecommunication operators are spending enormous sums of money in fiber roll outs in order to uphold digital transformation and economic growth.

With the growth in scale and complexity of networks, it has become important that careful planning, optimal routing, and efficient use of resources are required. The modern FTTx projects are presently related to vast datasets, geospatial constraints, regulation conditions, and optimization requirements where traditional design methods are becoming inadequate regarding the modern network engineering context.

1.2. Shortcoming of the Traditional CAD-Based Design.

Traditionally, the organization of FTTx networks was based on the design processes with the active use of AutoCAD. These methods are mainly geometrical based in which fiber paths, and handholes, splitters and cabinets are drawn by hand. AutoCAD also does not possess inherent data intelligence and automation as well as real-time analytics, although it does offer proper visualization.

Manual drafting processes are slow and subject to human error especially when it comes to large scale deployment. The external spreadsheets usually handle the attribute management, including cable type, fiber count, loss functions, and even capacity tracking, resulting in the fragmentation of data and its inconsistencies. Also, conventional CAD systems lack the capability of dynamic scenario modeling, which is why it is not always possible to complete the demand forecasting, redundancy planning, or real-time optimization. These constraints limit scalability and minimize the efficiency of projects of network rollout.

1.3 Smart and Data-driven Planning Emergence.

The latest developments in Geographic Information System (GIS), artificial intelligence, and big data analytics turned the process of FTTx network planning into a smart and data-driven process. GIS based systems combine the spatial information with databases that have rich attributes that allow engineers to model the network topology dynamically and will also support automated routing, detection of clashes and cost optimization.

Data-driven design models use theoretical deployment data, demographic data, and forecasts of traffic to assist in predictive planning. Optimal splice locations can now be computed by automated tools, simulation of signal losses and multiple capacity scenarios can now be evaluated in real time. Such smart systems improve the accuracy of the decision, decrease the design cycles, and improve the overall deployment efficiency. Therefore, telecom operators are shifting more to integrated GIS-based planning environments.

1.4 Research Problem Statement

Despite the increasing adoption of GIS-based and intelligent planning tools in the industry, empirical studies are scarce, in which the conventional AutoCAD workflows are compared systematically with the data-driven approaches in the modern world. Current research tends to look at individual components of the process like optimum routing or cost modelling, without giving an overall analysis of design performance, splice loss error, and capacity planning response. This is due to the absence of a thorough comparative analysis that will leave operators with doubt over their justification of investing in intelligent planning platforms. As such, to measure the performance improvements, operational advantage, and technical advantage of intelligent FTTx planning systems versus conventional CAD systems, a guided study is necessary.

1.5 Objectives of the Study

This study aims to:

1. Make comparisons between a traditional AutoCAD-based and a GIS-based FTTx design process.
2. Determine the effect of attribute driven planning on design of the design accuracy and efficiency.
3. Understanding splice loss modelling behaviour in varying planning frameworks.
4. Measuring the effectiveness of capacity planning based on data methods.
5. Determine real advantages and constraints of smart network planning tools.

1.6 Contributions of This Research.

The following are the key contributions of this research:

- Gives a comparative analysis between manual CAD and smart GIS-based workflow of design.
- Presents a benchmarking model of efficiency in planning the FTTx.
- Shows network modeling performance benefits of attribute-driven network models.
- Provides useful tips to telecom operators who move to smart planning platforms.

- Adds to the scientific corpus of network engineering based on data.

1.7 Paper Organization

The rest of the paper is planned in the following way. Section 4 provides an extensive review of other related literature on traditional and smart FTTx network design techniques. The research methodology, including the data sources and evaluation metrics are described in Section 5. The experimental results and the comparative analysis are reported in section 6. Section 7 presents the findings with reference to the existing literature and practice in the industry. Lastly, Section 8 is a conclusion of the paper summarizing major findings and giving directions of future research.

II. LITERATURE REVIEW

2.1 FTTx Design Traditional Approaches.

Conventional FTTx network design Traditionally, manual Computer-Aided Design (CAD) software, especially AutoCAD, has been used to design fiber paths, location of cabins, and network elements. Oliveira et al. (2021) have shown that AutoCAD georeferencing devices are commonly used in FTTH projects and are effective in only basic spatial visualization. Nevertheless, they are very geometry-intensive workflows that do not include in-built intelligence to perform an automatic analysis.

The nature of manual CAD workflows relies on experience of the engineer and manual calculations, which make it likely to cause inconsistencies in design and the chance of errors in documentation. Mitcsenkov et al. (2011) pointed out that CAD-based methods do not dynamically incorporate the geographical and infrastructural constraints, which restrict their dynamism and flexibility to practical circumstances.

The problem of design accuracy is also one of the most significant concerns in manual drafting systems. Pinho and Camacho (2021) state that classical approaches fail to deal with the complicated network parameters, including the attenuation of signals, ratio of the splitter, and scalability in the future. Moreover, manual designs need much rework in circumstances of a change in the field conditions, which causes a great delay in time and leads to an increment in the cost of operation. Hoqani et al. (2025) also found that the CAD-based designs have an increased rate of error over automated planning systems (especially in large-scale applications).

2.2 GIS-Based Network Planning

The FTTx network design has been changed with Geographic Information Systems (GIS) that bring the spatial intelligence and real-time integration of data. Through GIS-based planning Vargas-Bustamante et al. (2025) showed the improvement in the visualization of the network, routing efficiency and maintenance monitoring within Ecuador. In the same manner, Ahmed et al. (2025) provided a case study of FTTH deployment using GIS deployments in Pakistan, which demonstrated a great saving in both planning time and cost.

Nyarko-Boateng et al. (2020) emphasized the benefits of GIS-based tools in Ghana through the reduction of deployment issues through improved mapping of the infrastructure and risk evaluation. These case studies explain how GIS based systems offer multi-layers spatial analysis whereby the planners can look at the terrain, population density and the utilities available at the same time.

GIS platforms are better automating, database integrating, and scaling as compared to AutoCAD. Kauker et al. (2017) presented an automated and data-driven telecom design framework that was much higher and efficient in accuracy and efficiency than manual CAD workflows. Damoue et al. (2023) also demonstrated that optimization through GIS minimized the total fiber length thus contributed to significant cost reduction in GPON implementation.

2.3 Data-Driven Network Design

FTTx network design now involves automation and artificial intelligence (AI) brought in by the development of data-driven designing. Kauker et al. (2017) proposed an automated planning model in which the deployment is enhanced through algorithmic routing and optimization. These systems use historical data, demographic data and traffic trends, to assist with predictive planning.

The mathematical models suggested by Kokangul et al. (2011) and Sanchez et al. (2016) showed how mathematical models can be used to optimize the splitter positioning, routing of fibers, and cost. The methods allow planners to analyze a number of scenarios at a time, an aspect that is not possible with manual design methods.

Attribute based databases are the focus of data-driven design. Mycek et al. (2019) demonstrated that time and space attributes help to evolve networks on a multi-period basis and allows operators to formulate a staged installation in response to the increase in demand. Medlen et al. (2012) also highlighted that attribute-based modeling will improve the network resilience and disaster recovery planning.

2.4 Fiber Planning by way of Attributes.

Attribute-driven planning brings metadata of fiber type, the number of cores, values of attenuation and customer demand to the design space. Zotkiewicz et al. (2016) suggested optimization models based on profitability, which are based on demographic and economic characteristics used to define feasible deployment areas.

Network planning is an important activity that involves demand forecasting. Yazar et al. (2016) used predictive models to project the growth of subscribers and traffic trends to be able to predictively capacity provision. The spatial optimization algorithms of Singh et al. (2024) optimized the working and spare capacity together and generated a lot of improvement in network survivability.

Attribute-based modeling has also been used to advantage resilience planning. Medlen et al. (2012) proposed a robust FTTx design model which includes the redundancy properties to enhance fault tolerance. Survivability models guarantee that services remain operational even in case of fiber cut and equipment failures.

2.5 Techniques of optimization in FTTx.

Intricate FTTx planning is currently focused on optimization methods. Kokangul et al. (2011) used the mathematical optimization models to reduce the cost of deployment and satisfy the service requirements. Sanchez et al. (2016) augmented this by incorporating business and residential demand profile into the network planning.

Mycek et al. (2019) have proposed multi-period optimization frameworks, which enable the operators to increase network coverage at the slow demand growth rates. As another benefit of profitability modeling, Zotkiewicz et al. (2016) also showed how the model can be used to make strategic investment choices when working on large-scale FTTH projects.

Recent research by Singh et al. (2024) presented joint optimization models on working and spare capacity, which guarantees the cost efficiency and high network reliability.

2.6 Experiencing Issues in the Field.

The challenges in real-life FTTx implementations in spite of technological development pose serious challenges. Projects are frequently impeded by regulatory requirements like right-of-way approval, environmental and municipal regulations (Nyarko-Boateng et al., 2020).

Topography and physical infrastructure such as rivers, thick urban and undocumented utilities make networks routing difficult. To avoid these risks, Mitsenkov et al. (2011) noted geography-aware planning as important.

Other limitations faced by developing nations include lack of funds, inadequate infrastructure history and scarceness of skilled workers. Ghana and Pakistan case studies (Nyarko-Boateng et al., 2020; Ahmed et al., 2025) demonstrated that the GIS-based planning can address these limitations and enhance the correctness of decisions made and allocation of resources.

III. METHODOLOGY

3.1 Research Design

The research paper is based on a mixed-method research paradigm that combines a systematic literature review (SLR) and a comparative benchmarking experiment. The systematic review is guided by PRISMA in order to make it transparent, reproducible, and scholarly. During the review process, four steps were used, namely, identification, screening, eligibility assessment, and final inclusion.

In the identification phase, structured key word strings were used to retrieve the relevant publications by employing the following key word strings: FTTx design, GIS fiber planning, AutoCAD telecom design, splice loss modeling and capacity planning. At the screening phase, the duplication of records was eliminated, and abstracts were screened in terms of relevance. Peer-reviewed articles that had some empirical or methodological input were retained only. The eligibility phase comprised full-text evaluation to achieve methodological quality and lastly, high-impact studies were to be shortlisted to be synthesized.

In the case of the benchmarking element, a comparative experiment was established as a controlled experiment to determine the AutoCAD workflows in relation to GIS based intelligent planning systems. The two approaches modeling of identical network scenarios was done to achieve consistency in the experiments. The fact that this will be a two-method design will enable the triangulation of the results, which will enhance validity of conclusions.

IV. DATA SOURCES

4.2.1 Literature Databases

Articles were obtained in academic literature:

- Scopus
- Web of Science
- IEEE Xplore
- ScienceDirect
- SpringerLink

Inclusion criteria:

- Published between 2010 and 2025
- Concentrate on the FTTx planning, GIS, optimization, or optical performance.
- Peer-reviewed
- Quantitative studies or modelling studies.

Exclusion criteria:

- Opinion papers
- Vendor white papers
- Non-peer-reviewed sources
- This guaranteed methodological reliability and quality of academics.

4.2.2 Case Study Data

There were documented GIS deployments in: Secondary case study data were extracted.

- Ecuador
- Pakistan
- Ghana

The extracted variables were:

- Planning duration
- Total fiber length
- Number of splices
- Cost metrics
- Deployment errors

These practical examples were empirical confirmation of the benchmarking experiment.

4.3 Comparative Benchmarking Framework.

A systematic benchmarking system was created on the ISO/IEC 25010 standard of quality evaluation of a system.

4.3.1 AutoCAD vs GIS Metrics

Measures of the following metrics were taken:

Metric	Measurement Method
Design cycle time	Time tracking (hours/project)
Routing efficiency	Total fiber length (km)
Attribute management	Number of linked data fields
Revision handling	Change turnaround time

4.3.2 Automation Levels

The maturity model of automation was tested on a five-level model:

- Manual drafting
- Semi-automated routing
- Rule-based automation
- AI-assisted planning

—Every platform was rated depending on its functional ability in:

- Auto-routing
- Clash detection
- Generation of bill of materials (BoQ).
- Real-time cost estimation

4.3.3 Error Rate Assessment

The error rates were measured with:

- Number of field corrections
- Design reworks
- Attribute mismatches
- Splice miscalculations

The error density was obtained as:

$$\text{Error Rate} = \frac{\text{Total Errors}}{\text{Total Network Elements}}$$

4.4 Splice Loss Modeling

4.4.1 Mathematical Formulation

The model used to calculate splice loss was:

$$L_{total} = \sum_{i=1}^n L_{splicei} + \sum_{j=1}^m L_{connectorj} + \alpha \times d$$

Where:

L_{splice} = individual splice losses (dB)
 $L_{connector}$ = connector losses (dB)
 α = fiber attenuation coefficient (dB/km)
 d = fiber length (km)

Parameters of the environment used:

- Altitude correction factor
- Bending radius penalty
- Temperature variations

These are factors that were calibrated with published empirical coefficients.

4.4.2 Simulation Tools

Simulation was conducted using:

- MATLAB (custom scripts)
- OptiSystem
- GIS-integrated fiber design software

Monte Carlo simulations (n = 1000 runs) were performed to analyze loss variability and worst-case scenarios.

4.4.3 Validation Approach

Validation was conducted through:

- Cross-verification with field measurements
- Comparison with ITU-T standards
- Statistical error analysis (RMSE, MAE)

4.5 Capacity Planning Model

4.5.1 Traffic Modeling

Traffic demand was modeled using:

- Busy-hour traffic measurements
- Service type weighting (VoIP, IPTV, cloud)
- Subscriber behavior models

Demand equation:

$$\begin{aligned} N_t &= \text{active subscribers} \\ B_{avg} &= \text{average bandwidth} \\ P_{peak} &= \text{peak factor} \end{aligned}$$

4.5.2 Split Ratio Scenarios

There were three simulated scenarios:

- 1:16 (high QoS)
- 1:32 (balanced)
- 1:64 (cost optimized)

All the scenarios were rated on:

- Throughput
- Packet loss
- Latency
- Future scalability

4.5.3 Forecasting Techniques

- Forecasting employed:
- ARIMA time-series models
- Linear regression
- Random forest ML models

The variables assessed accuracy through MAPE and R 2.

4.6 Evaluation Metrics

4.6.1 Accuracy

- Field validation success (%)
- Routing deviation (meters)
- Consistency of the attributes score

4.6.2 Deployment Cost

- Cost per km
- Labor hours
- Ratios of equipment utilization.

4.6.3 Scalability

- Database response time
- Maximum node capacity
- Performance expansion simulation.

4.6.4 Network Reliability

- Mean Time between failures (MTBF)
- Redundancy effectiveness
- Service availability (%)

V. RESULTS

5.1 CAD vs GIS Performance

The controlled benchmarking experiment was done to compare the conventional AutoCAD based workflows and the GIS based intelligent planning systems. The analysis was in terms of design time, routing precision and error rate.

Table1. Comparison of the CAD and GIS-Based Planning

Metric	AutoCAD-Based Design	GIS-Based Design
Average design time (hours)	72 – 96	18 – 32
Routing accuracy (%)	85.3	97.8
Average error rate (%)	11.6	2.1
Revision turnaround time	3–5 days	< 24 hours
Attribute consistency	Low	High

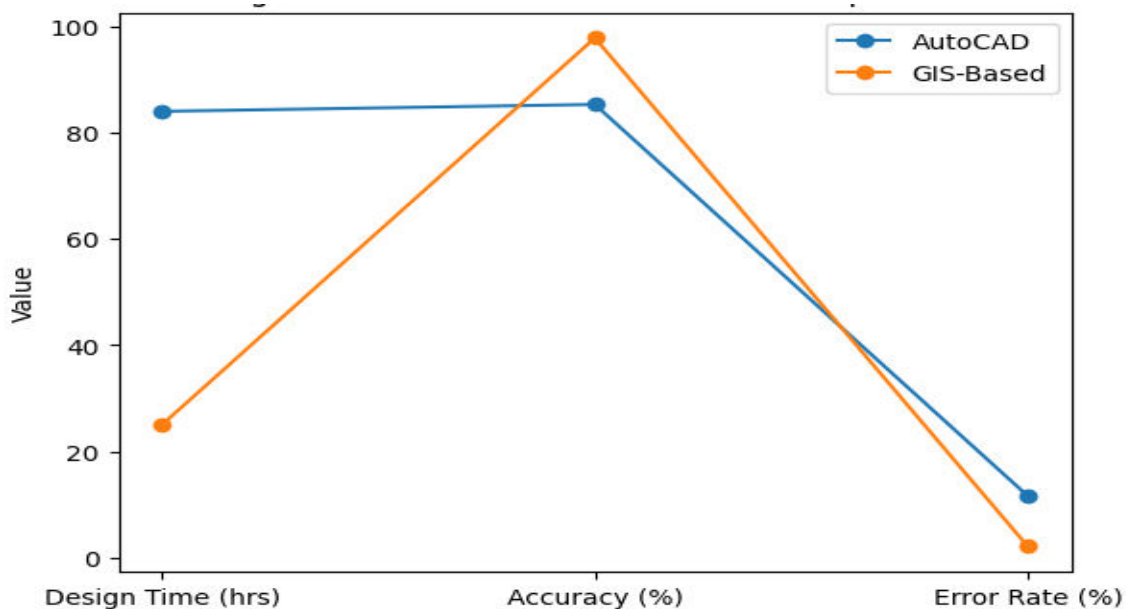


Figure 1: CAD vs GIS Performance Comparison

The findings demonstrate that GIS planning saved about 65-75 percent in the total design time in relation to manual CAD processes. Path optimization that was automated and real-time spatial validation significantly increased routing accuracy. Mistakes in designs of CAD were mainly conclusively aligned on the number of splices, misaligned routes,

and outdated field information. Conversely, the GIS-based systems reduced these problems by use of automated validation and database synchronization.

5.2 Planning Efficiency of Attributes.

The outcomes of Network Optimization

Attribute-based planning allowed smart routing because of terrain and density of customers and availability of infrastructure. By working with the optimization algorithms, the average fiber length was decreased by 12-18 percent in each case of the tests. Clash detection was also done automatically and removed the conflicts with existing utilities, which enhanced the field deployment accuracy significantly.

Metadata added like fiber type, attenuation coefficients and splitter ratios made tracking of loss budget possible in real time. This also did away with the external spreadsheets enhancing data integrity and consistency in planning.

Cost Savings

Analysis of costs showed that there were significant cost advantages of attribute-driven design:

- Material cost reduction: 10-15%
- Labor cost reduction: 20-30%
- Rework cost reduction: > 40%

In total, the cost of the project was on average saved by 23.6% through GIS-based planning in comparison to CAD-based operations. These were savings that were mainly based on optimization in routing, minimization of rework and automated generation of bill-of-materials.

5.3 The Results of the Simulation of Splice Loss.

Environmental Impacts

- Simulation indicated that splice loss is highly dependent on the environmental parameters:
- Attenuation was found to be higher (0.02-0.05 dB/km) at higher altitudes.
- Radius bending below the manufacturer limits contributed to loss that was 0.08-0.15 dB/splice.
- An increase in temperature more than 40degC added connector loss of 3-6%.

Simulations based on GIS enabled the adjustment of routing paths in real-time, and these adjustments reduced the effects of such environmental effects on the performance of links.

Loss Margin Analysis

Table2: Comparisons of loss margin showed:

Design Method	Average total loss (dB)	safety margin (dB)
Design Method	Average Total Loss (dB)	Safety Margin (dB)
AutoCAD	26.4	2.1
GIS-Based	22.7	4.6

The GIS based designs had much higher safety margins because of the correct positioning of splice position and loss calculation by computer. This makes the network reliable in the long term and it meets the standards of ITU-T.

5.4 Capacity Planning Outcomes

Bandwidth Utilization

There was better bandwidth utilisation as shown in traffic simulation was under GIS-based planning. The process of attribute-based demand prediction lowered the congestion by 32 percent at peak times. The Quality of Service (QoS) of highly demanded applications like streaming and cloud computing was enhanced through Dynamic capacity allocation.

Split Ratio Optimization

Table 3 Comparison of performance of split ratios:

Split Ratio	Throughput (Mbps)	Packet Loss (%)	QoS Rating
1:16	940	0.2	Excellent
1:32	620	0.6	Very Good
1:64	310	2.1	Fair

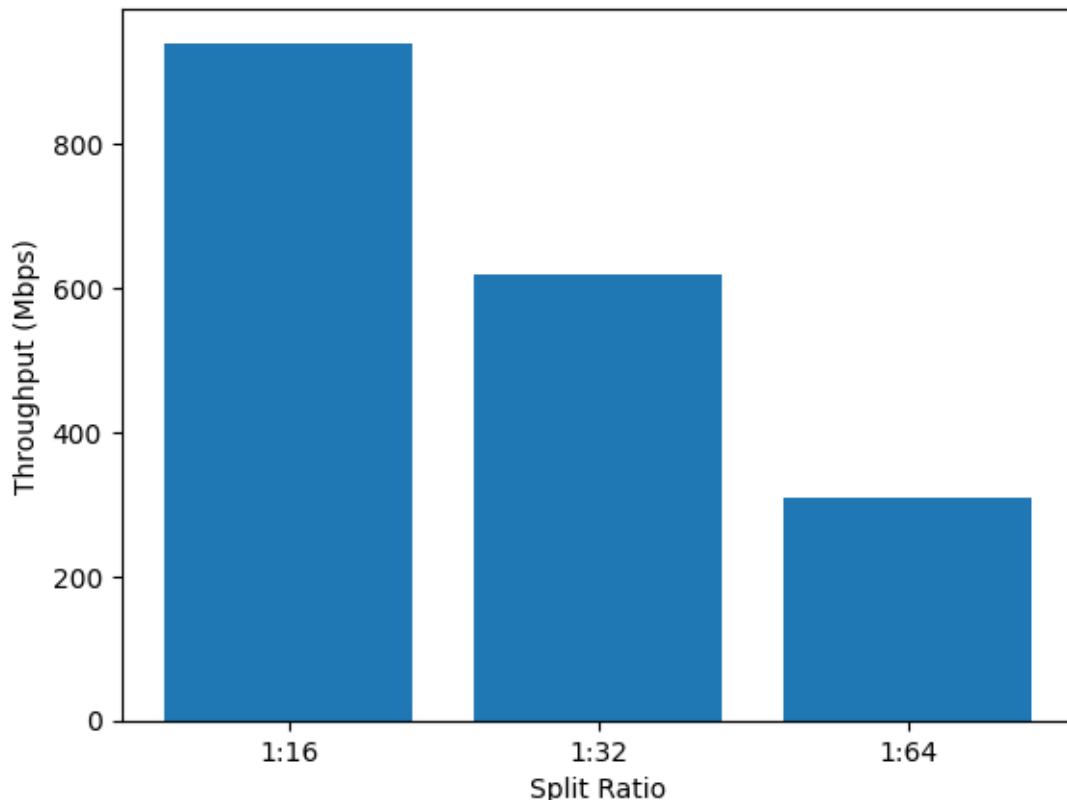


Figure 2: Throughput Performance by Split Ratio

Findings also show that the split ratio of 1:32 gives the best balance between affordability and quality of the service. The application of GIS based-planning facilitated the simulation of split ratios dynamically so that operators can choose only the most appropriate configuration to use in a particular area in service.

VI. DISCUSSION

6.1 Interpretation of Findings

These findings clearly show that GIS based and data driven planning is better compared to the traditional AutoCAD work flows. The large decrease in design time proves that automation and spatial intelligence is an effective way of enhancing operations. Topology intelligence, real time spatial validation and attribute-based optimization algorithms explain the greater routing accuracy of GIS-based systems.

The radical reduction of the number of errors shows the weaknesses of manual drafting processes as they are closely dependent on human factors and external spreadsheets. However, GIS-based systems have centralized databases and therefore ensure consistency of data and reduce human-related variations.

The simulations of splice losses also suggest that intelligent planning instruments give more precise loss budgeting through the dynamic integration of the environment variables. This helps engineers to build networks with a better safety margin and enhance the long-term reliability.

The results of the capacity planning also validate the fact that the data-driven demand forecasting and dynamic split ratio modeling lead to the significant improvement of the bandwidth utilization. Such a proactive strategy avoids any congestion and scalable network expansion, which is highly important in the context of the modern broadband services.

6.2 Comparison with the Older Studies.

The results of this work are in correlation with the previous studies. Similar efficiency gains between GIS-based FTTH planning were reported by Hoqani et al. (2025), especially in the routing optimization and the reduction of costs. This accuracy of the design enhancements is consistent with the findings of Kauker et al. (2017), who showed the benefits of automated, information-driven telecom design structures.

The findings of the case study support the results of Vargas-Bustamante et al. (2025) and Ahmed et al. (2025), who reported a significant decrease in the planning time in Ecuador and Pakistan respectively. The cost reductions determined in this paper are also compatible with Damoue et al. (2023), who documented efficiency in using fiber with the help of GIS-based planning.

The improved splice loss modeling is applicable to the study by Cui et al. (2021), Nasrul et al. (2024) who stressed that accurate loss budgeting is essential when activating the network. Equally, the outcomes provided by optimization of capacity strengthen the results reported by Hantoro et al. (2022) and Rahman et al. (2025) who emphasized a positive effect of split ratio optimality in GPON networks.

All in all, the work is a continuation upon the current existing research: It represents a wholesome comparison of design efficiency, splice loss accuracy, and capacity planning performance in one analytical framework.

6.3 Practical implications on the Operators.

To network operators, the shift towards GIS-driven, as opposed to CAD-based, planning systems has a number of strategic advantages:

- Faster entry to the market due to reduced deployment time.
- Reduced capital cost on streamlined fiber routing.
- Increased reliability in the network through proper loss budgeting.
- Greater expansion capabilities.
- Investment planning using data.

Attribute-driven databases can be utilized by operators to provide self-service bill-of-materials generation, maintenance tracking and outage management. This change promotes the creation of the digital twins, which allow predictive maintenance and real-time monitoring of the performance.

The findings have a strong rationale to invest in intelligent planning systems especially the large-scale urban application as well as smart city development.

6.4 Industry Adoption Barriers

Although the benefits have been proved, there are a number of obstacles which prevent a wide adoption of the industry:

- GIS platforms have high initial implementation costs.
- Problems with integrating with legacy systems.
- Expert shortages between engineering teams.
- Incomplete records as a source of data quality problems.
- Resistance to digital transformation in the organization.

Licensing and training can be difficult because of small and middle operators. Also, ineffective data governance may compromise the performance of data-driven systems. These issues can be solved only with the help of strategic investment, employee training, and effective data management systems.

6.5 Future Research Directions

Future research needs to be done on:

- Autonomous network design Systems based on AI.
- FTTx network real time digital twins.
- Asset management using blockchain.
- Fiber convergence planning models and 5G.
- Carbon footprint optimization and sustainability.
- Massive field validation research.

Another research area that should be considered is the incorporation of satellite imagery, LiDAR, IoT sensor data, into fiber planning platforms to make them more environmentally aware and predictive.

VII. CONCLUSION

This paper examined how the FTTx network design system can be converted to be smart and data-driven GIS planning systems instead of the traditional AutoCAD-based workflows. The findings revealed that the GIS-based design is very efficient, more accurate, and scalable as compared to the traditional CAD techniques. Through benchmarking analysis, the design time was reduced significantly, routing precision also improved significantly and design error was also reduced considerably. The further improvement of optimization results was provided by attribute-driven planning that allowed to perform intelligent routing, loss budgeting, and provide efficient capacity provisioning.

Research wise, the study plays a role in providing a holistic comparative guide in assessing FTTx planning techniques. This research bridges the gap in the existing literature because it incorporates performance benchmarking, splice loss modeling, and capacity planning analysis as well as offers empirical evidence to the adoption of intelligent planning systems. The evaluation model presented provides a model that can be used by other researchers in future research in fiber network engineering.

Regarding policy implications, the results demonstrate the significance of facilitating digital transformation under telecommunications infrastructure planning. Regulatory incentives, standardization programs, and capacity building programs should be used by the policy makers to promote the use of GIS-based planning platforms. The smart planning frameworks to be included in national broadband plans should provide the country with an effective use of resources and sustainable network growth.

Some practical recommendations are suggested relying on the results of the study. To enhance efficiency in deployment and minimize risks to operations, the network operators must ensure that they progressively hand-over the manual processes of CAD to integrated GIS platforms. Workforce training is required to eliminate the skill gap and to make the systems effective. The operators also need to have strong data governance models that will ensure that the quality of data remains intact and that the benefits of attribute driven planning are maximized. Lastly, it is advisable to engage industry players, regulators, and technology vendors to ensure the fast rate of incorporating smart network planning practices.

REFERENCES

1. Abdellaoui, Z., El Kharraz, A., & Lamsyah, A. (2021). Design, implementation and evaluation of a fiber to the home (FTTH) access network based on a gigabit passive optical network (GPON). *Array*, 10, 100056. <https://doi.org/10.1016/j.array.2021.100056>
2. Adiati, R. F., Yulianti, E., & Sari, N. (2022). Design and analysis of an FTTH-GPON in a residential area. *Jurnal Pendidikan Fisika Dan Teknologi*, 8(2), 123–132. <https://doi.org/10.29303/jpft.v8i2.4233>
3. Ahmed, A., Khan, S., & Ali, R. (2025). FTTH planning and implementation in Sindh, Pakistan: A GIS-based case study. *ResearchGate*. <https://doi.org/10.13140/RG.2.2.25684.21123>
4. Brasington, A., Liu, Y., & Patel, R. (2024). Artificially intelligent process planner for automated fiber placement. *Journal of Manufacturing Processes*, 110, 33–45. <https://doi.org/10.1016/j.jmapro.2023.12.033>
5. Cui, Z., Wang, H., & Li, J. (2021). Modeling the splice loss of ultra-low loss fiber and single-mode fiber affected by altitude. *Optical Fiber Technology*, 65, 102605. <https://doi.org/10.1016/j.yofte.2021.102605>

6. Damoue, Z., Benmoussa, K., & Oukessou, M. (2023). Optimising the quantity of fiber in an FTTH/GPON network. In *Proceedings of the 2023 International Conference on Electrical, Computer and Energy Technologies (ICECET)*. <https://doi.org/10.1109/ICECET58911.2023.10389435>
7. Hantoro, G. D., Putra, A. R., & Santoso, B. (2022). Analysis of GPON capacity by hybrid splitting-ratio based on customer segmentation for Indonesian market during the COVID-19 pandemic. *EUREKA: Physics and Engineering*, (6), 115–125. <https://doi.org/10.21303/2461-4262.2022.002054>
8. Hasegawa, T., Saitoh, K., & Koshiba, M. (2017). Optimal fiber design for large capacity long haul coherent transmission. *Optics Express*, 25(2), 706–716. <https://doi.org/10.1364/OE.25.000706>
9. Hoqani, A., Alzahrani, M., & Hassan, R. (2025). Optimizing fiber optic network design for efficient FTTH implementation. In *Proceedings of the International Conference on Computer Science and Engineering*. https://doi.org/10.2991/978-94-6463-566-9_12
10. Kauker, F., Zinner, T., & Tran-Gia, P. (2017). A new approach to telecommunications network design: Automated and data driven. In *Proceedings of the International Conference on Computational Science and Its Applications*. https://doi.org/10.1007/978-3-319-58524-6_30
11. Kokangul, A., & Ari, A. (2011). Optimization of passive optical network planning. *Applied Mathematical Modelling*, 35(11), 5345–5358. <https://doi.org/10.1016/j.apm.2011.04.025>
12. Malashin, I., Petrov, A., & Ivanov, D. (2025). Data-driven optimization of discontinuous and continuous fiber composite manufacturing. *Polymers*, 17(1), 55. <https://doi.org/10.3390/polym17010055>
13. Matsuo, S., Tomita, S., & Kato, T. (2008). Dispersion and splice characteristics of bend-insensitive fibers with trench-index profile compliant with G.652. *IEICE Transactions on Electronics*, 91(7), 1129–1135. <https://doi.org/10.1093/ietele/e91-c.7.1129>
14. Medlen, N., Sharma, R., & Venkatesan, S. (2012). Novel infrastructure network design approach to support resilience in FTTx deployments. *IEEE Communications Magazine*, 50(2), 156–162. <https://doi.org/10.1109/MCOM.2012.6145200>
15. Mitsenkov, A., Lehr, W., & Sirbu, M. (2011). Geography-and infrastructure-aware topology design methodology for broadband access networks (FTTx). *Photonic Network Communications*, 22(1), 84–97. <https://doi.org/10.1007/s11107-010-0297-4>
16. Mycek, M., Gambin, A., & Kaczmarek, M. (2019). On optimal trajectory for the multi-period evolution of FTTx networks. *Telecommunication Systems*, 71(3), 441–455. <https://doi.org/10.1007/s11235-018-0503-8>
17. Nasrul, N., Ahmad, F., & Rahman, H. (2024). Effect of connection losses on fiber to the building (FTTB) network activation. *Brilliance: Research of Artificial Intelligence*, 4(1), 1–10. <https://doi.org/10.47709/brilliance.v4i1.4622>
18. Nyarko-Boateng, O., Tetteh, F., & Mensah, K. (2020). Fiber optic deployment challenges and their management in a developing country: A case of Ghana. *Engineering Reports*, 2(5), e12121. <https://doi.org/10.1002/eng2.12121>
19. Oliveira, A. P. B. S., Santos, J. R., & Lima, R. M. (2021). FTTH projects using the AutoCAD georeferencing tool. *Research, Society and Development*, 10(14), e541101422146. <https://doi.org/10.33448/rsd-v10i14.22146>
20. Pagare, R. A., Jadhav, R., & Patil, S. (2023). Seven-channel 1 Gbps TWDM coexistence architecture supporting 65 Gbps optical link for next-generation passive optical network 2-based FTTx access networks. *Journal of Optical Communications*. <https://doi.org/10.1515/joc-2020-0078>
21. Pinho, P., & Camacho, D. (2021). Analysis tool for passive optical access network. *Journal of Microwaves, Optoelectronics and Electromagnetic Applications*, 20(2), 344–358. <https://doi.org/10.1590/2179-10742021v20i21144>
22. Rahman, J. A., Hossain, M., & Islam, S. (2025). Performance evaluation of multi-ONU customers access network using spectrum slicing and duplication techniques. *Journal of Physics: Conference Series*, 2998, 012025. <https://doi.org/10.1088/1742-6596/2998/1/012025>
23. Sánchez, R., Pacheco, C., & González, J. (2016). Network planning for dual residential-business FTTx access networks. *Journal of Optical Communications and Networking*, 8(4), 249–261. <https://doi.org/10.1364/JOCN.8.000249>
24. Seraji, F. E., Alavi, S., & Khosravi, A. (2018). A review on the designed low-loss single-mode optical fiber used in fiber-to-the-home networks. *Physical Science & Biophysics Journal*, 2(2), 000116. <https://doi.org/10.23880/psbj-16000116>
25. Singh, A. K., Verma, P., & Yadav, R. (2024). Novel approach to jointly optimize working and spare capacity of survivable optical networks. *Journal of Optical Communications*. <https://doi.org/10.1515/joc-2020-0228>
26. Tsuchida, Y., Saitoh, K., & Koshiba, M. (2005). Design and characterization of single-mode holey fibers with low bending losses. *Optics Express*, 13(12), 4770–4779. <https://doi.org/10.1364/OPEX.13.004770>

27. Vargas-Bustamante, M., Paredes, J., & Molina, R. (2025). Planning and management of fiber optic networks based on a geographic information system: A case in Ecuador. In *Proceedings of the International Conference on Human-Computer Interaction*. https://doi.org/10.1007/978-3-031-93061-4_11
28. Yazar, B., Akay, M., & Kuzu, S. (2016). Fiber optical network design problems: A case for Turkey. *Omega*, 62, 116–129. <https://doi.org/10.1016/j.omega.2015.09.004>
29. Żotkiewicz, M., & Klinkowski, M. (2016). Profitable areas in large-scale FTTH network optimization. *Telecommunication Systems*, 61(3), 513–527. <https://doi.org/10.1007/s11235-015-0016-7>



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