

Cost Optimization Strategies for Large-Scale FTTH Deployment In KSA

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Abstract- This review paper examines how large-scale fiber-to-the-home (FTTH) deployment in the Kingdom of Saudi Arabia (KSA) can be optimized for cost without weakening network quality, scalability, or long-term digital policy goals. The topic is strategically important because Saudi Arabia's digital transformation agenda depends on robust fixed infrastructure to support cloud services, smart homes, e-government, education, telemedicine, enterprise connectivity, and the backhaul requirements of wider 5G and smart-city ecosystems. Although the Kingdom has made notable progress in extending fiber access and stimulating infrastructure investment, the economics of mass FTTH rollout remain challenging because civil works, labor, permitting, route selection, demand uncertainty, low-density pockets, duplication of infrastructure, and technology migration all influence unit cost. Using a structured narrative review of recent literature and authoritative policy and industry sources published between 2020 and 2026, this paper synthesizes evidence across six cost domains: civil works and outside-plant design, architecture and splitter planning, infrastructure sharing and open access, demand-led rollout strategy, operational and energy efficiency, and governance and procurement. The review finds that the most effective cost optimization strategy is not a single technical choice but a portfolio logic. Costs fall materially when operators reduce unnecessary trenching, reuse ducts and poles, cluster demand through geospatial planning, align split ratios with realistic take-up, coordinate with utilities and municipalities, phase deployment according to adoption probability, and use open-access or wholesale mechanisms to avoid wasteful duplication. In the Saudi context, those levers are reinforced by national broadband targets, the open-access policy direction, operator scale, and strong urban demand, but they are constrained by heterogeneous urban form, patchy economics at the urban edge, and the need to future-proof networks for multi-gigabit demand. Based on the review, the paper proposes a KSA FTTH Cost Optimization Framework that links policy, planning, engineering, execution, and operations into one decision structure. The study contributes a set of unique review objectives, a Saudi-oriented analytical framework, and an implementation logic for reducing cost per home passed and cost per connected home while preserving long-run network value.

Index Terms- FTTH; Saudi Arabia; KSA; cost optimization; GPON; XGS-PON; broadband policy; open access; infrastructure sharing; fiber deployment

Table 1. Unique review objectives

No.	Objective
1	To identify the dominant cost drivers in large-scale FTTH deployment in KSA, with particular attention to civil works, labor, routing, permitting, and low-density service areas.
2	To evaluate how network architecture choices such as GPON, XGS-PON, split ratio design, cabinet location, feeder-distribution topology, and phased upgrade paths influence cost efficiency.
3	To synthesize evidence on how infrastructure sharing, open access, duct reuse, utility coordination, and municipal permitting reform can reduce duplication and improve capital efficiency.
4	To examine how geospatial demand modeling, market prioritization, and take-up-based phasing can lower the cost per connected home rather than focusing only on cost per home passed.
5	To review operational strategies, including energy efficiency, automation, standardized construction practices, and digital design tools, that reduce total cost of ownership after rollout.
6	To propose a Saudi-oriented FTTH cost optimization framework that integrates policy, planning, engineering, execution, and operations for large-scale deployment.

Source: Author synthesis based on the reviewed 2020-2026 literature.

I. INTRODUCTION

Saudi Arabia's digital transformation has elevated fixed broadband infrastructure from a telecommunications sub-sector issue to a national competitiveness issue. Vision 2030, the National Transformation Program, and related digital-economy initiatives all assume that high-capacity connectivity will be available at household, enterprise, and public-service level across the

Kingdom (Saudi Vision 2030, 2025; National Transformation Program, 2025). This strategic orientation matters because the performance of cloud services, remote work, streaming, digital education, e-health, gaming, and smart-home applications depends increasingly on reliable high-speed access, not only on mobile coverage. While mobile networks remain essential, the structural role of fixed fiber is different: it provides stable high-capacity access, supports multi-gigabit service tiers, improves backhaul and convergence options, and creates a durable platform for future digital applications (ITU, 2025; MCIT, 2024).

The Saudi broadband context is favorable in several respects. Internet usage is extremely high, the communications and technology sector is expanding, and the state has explicitly prioritized broadband and digital infrastructure as part of national modernization (CST, 2025a; GASTAT, 2026). The Kingdom also has a history of FTTH policy ambition. The national broadband plan sought to raise household fiber coverage substantially from its original baseline, and policy instruments such as open access were introduced to improve utilization of existing networks and strengthen competition (ITU, 2020; CST, 2021). Industry reporting further suggests that the Saudi market has become strongly fiber-led in fixed broadband, with substantial household coverage and growing subscriber migration toward fiber-based services (MCIT, 2024; OpenSignal, 2026; stc, 2025a).

Yet these strengths do not eliminate the core problem of rollout economics. FTTH is capital-intensive. Even where demand is robust, operators face large upfront expenditures for ducting, trenching, microtrenching or direct burial, handholes, cabinets, splitters, feeder and distribution fibers, splicing, labor, customer drops, customer-premises equipment, design, quality assurance, and reinstatement. Recent cost studies outside Saudi Arabia consistently show that civil works and labor dominate deployment costs, especially for underground networks, and that unit costs vary sharply with terrain, density, construction method, and infrastructure ownership (Fiber Broadband Association & Cartesian, 2025a, 2026; Lysenko et al., 2024). Consequently, the central managerial question is not whether FTTH is

strategically desirable, but how it can be deployed at scale with acceptable economics.

This question is especially important in the Saudi case because large-scale rollout combines dense metropolitan districts, fast-growing suburban zones, new real-estate developments, industrial areas, and lower-density peri-urban territories. A strategy that is economically sound in central Riyadh may not be efficient at the metropolitan edge or in smaller municipalities. Moreover, cost optimization in fiber is multidimensional. A network can appear cheap if it minimizes immediate capital expenditure but become expensive later through poor scalability, low take-up, excessive truck rolls, energy waste, or premature architectural obsolescence. Conversely, a network with higher initial cost may be economically superior if it reduces duplication, improves upgrade flexibility, and raises long-run asset utilization (Lee et al., 2021; Lorincz et al., 2025).

Recent literature has matured enough to support a more integrated answer. Research on passive optical network planning has become more explicit about splitter location, topology design, georeferenced optimization, genetic algorithms, and capacity planning (Dias et al., 2022; Pereira et al., 2024; Mrabet et al., 2024). Policy and techno-economic literature has also clarified the roles of infrastructure sharing, public tender design, and universal-service cost modeling (Araújo et al., 2022; Oughton, 2025). At the same time, Saudi policy and operator sources provide a contextual layer showing that fiber expansion is not an abstract possibility but an active national infrastructure agenda (CST, 2021; CST, 2025a; stc, 2025b; Mobily, 2025).

Against this background, the present paper reviews cost optimization strategies for large-scale FTTH deployment in KSA. It is not a field survey of one operator, nor a narrow algorithm paper. Instead, it synthesizes recent knowledge across engineering, techno-economics, policy, and operations in order to answer a practical question: which portfolio of strategies can reduce cost per home passed and cost per connected home in Saudi Arabia while preserving scalability, competition, and service quality? By answering that question, the paper contributes a Saudi-oriented framework for deployment decisions under Vision 2030 conditions.

II. AIM AND OBJECTIVES OF THE STUDY

This review aims to synthesize recent evidence on how KSA can lower the cost of large-scale FTTH deployment while preserving long-run network value, service quality, and upgrade flexibility. The study addresses the problem through six unique objectives shown in Table 1 and develops a Saudi-oriented implementation framework grounded in the reviewed literature.

III. METHODOLOGY

This study adopts a structured narrative review design informed by PRISMA-style review logic but adapted to a policy-engineering question. The user's sample paper emphasized a sequence of introduction, conceptual review, methodology, thematic synthesis, discussion, and framework development; the present paper follows that same procedural logic while producing fully original content. A narrowly quantitative meta-analysis would have been unsuitable because the FTTH cost optimization problem spans heterogeneous evidence types, including engineering articles, optimization studies, operator disclosures, regulatory documents, standards-oriented reports, and policy papers. The chosen method therefore prioritizes transparency in search logic, source selection, and thematic synthesis rather than statistical pooling.

The review window was limited to sources published between January 2020 and March 2026 so that the synthesis would reflect recent developments in Saudi broadband policy, post-pandemic demand shifts, current FTTH deployment economics, and new access technologies such as XGS-PON and 50G-PON transition planning. Sources were identified from peer-reviewed journal articles, open technical papers, institutional reports, operator annual or sustainability reports, and official Saudi digital-policy publications. The review emphasized high-relevance material dealing with one or more of the following domains: FTTH cost modeling, passive optical network planning, outside-plant design, broadband policy, infrastructure sharing, open access, energy efficiency in optical access networks, and the Saudi fixed broadband environment.

Search combinations included terms such as "FTTH Saudi Arabia", "KSA broadband fiber", "passive optical network cost optimization", "splitter planning", "fiber deployment cost", "open access fiber", "infrastructure sharing broadband", "GPON XGS-PON migration cost", "energy efficiency optical access networks", and "broadband universal service fiber cost". Backward review of cited references and forward searching of closely related papers were used to strengthen coverage. Sources were retained when they offered either direct evidence on fiber deployment economics or strong transferability to the Saudi context. Sources were excluded if they focused on unrelated optical theory, pre-2020 evidence without continuing relevance, or narrow technical performance questions with no deployment-cost implication.

The retained material was analyzed through six thematic lenses: (1) civil works and outside-plant costs, (2) architecture and capacity planning, (3) infrastructure sharing and open access, (4) market prioritization and take-up strategy, (5) operational and energy efficiency, and (6) governance, procurement, and implementation sequencing. To improve analytical rigor, each source was reviewed against four questions: what cost problem it addresses, what assumptions it makes about network architecture or market conditions, what optimization lever it identifies, and how transferable the insight is to the KSA environment.

The final synthesis is therefore best understood as a strategic review for applied decision-making. It does not claim to estimate the exact cost of a national Saudi FTTH program, because that would require operator-grade geospatial data, premises-level demand forecasts, asset inventories, and permit datasets. Instead, it identifies cost-optimization principles that repeatedly appear across the recent literature and interprets them for Saudi deployment strategy. This approach is appropriate because large-scale FTTH cost optimization is not only a mathematical exercise. It is a socio-technical problem linking policy, urban form, procurement, engineering design, and operational discipline.

IV. REVIEW FINDINGS AND THEMATIC SYNTHESIS

4.1 Civil works dominate cost, so trench minimization is the first lever

The strongest and most consistent finding in the reviewed material is that civil works dominate FTTH deployment economics. International cost studies repeatedly show that underground construction is substantially more expensive than aerial deployment and that labor is the single largest cost component in most fiber builds (Fiber Broadband Association & Cartesian, 2025a, 2026; Light Reading, 2026). Even though those reports are not Saudi-specific, their relevance is high because the underlying cost logic is structural: digging, reinstatement, right-of-way coordination, and skilled field labor usually account for most of the outside-plant bill. In Saudi cities, where road infrastructure, utilities, and urban growth patterns can create complex corridor conditions, the implication is immediate. Any strategy that reduces unnecessary digging produces disproportionate savings.

This makes duct reuse, corridor coordination, and selective construction methods foundational rather than secondary. Open-access and shared-infrastructure approaches are valuable partly because they reduce duplicate excavation. McKinsey's deployment analysis similarly argues that cost and speed improve when operators target lower-cost build zones first, automate resource-intensive functions, and build long-term coordination with suppliers and construction partners (Lysenko et al., 2024). For KSA, this suggests that municipal alignment, utility mapping, standardized microtrenching policies where technically appropriate, and systematic reuse of existing ducts or poles should be treated as core cost-optimization measures. The strategic objective is not simply cheaper construction in the abstract, but lower cost per productive meter of network deployed.

4.2 Geospatial planning matters because cost per premise is spatial, not average

A second major finding is that FTTH economics depend heavily on geography and density. The average cost figures often cited in broadband discussions can be misleading because the true

economics vary sharply by housing form, street pattern, duct availability, and the distance between feeder routes and premises. Lee et al. (2021) show, in the Korean universal service case, that bottom-up spatial analysis is essential for credible cost estimation. Their study is valuable for KSA because it demonstrates the importance of location-specific cost modeling rather than relying on generic national averages. Likewise, more recent GIS-based planning work and georeferenced optimization studies show that network design quality improves when demand clustering, route selection, and splitter allocation are optimized using actual maps rather than stylized layouts (Dias et al., 2022; Pereira et al., 2024; Babu, 2026).

In the Saudi context, this means rollout should be treated as a portfolio of urban morphologies. Dense apartment districts, villa compounds, suburban subdivisions, and mixed-use corridors do not yield the same economics. Cost optimization therefore requires granular classification of service areas before detailed design begins. In high-density zones, aggressive passing strategies may be justified because the incremental cost per premise is lower and take-up can build quickly. In lower-density or fragmented zones, the better strategy may be staged extension tied to pre-sales, wholesale anchor demand, or coordinated builds with utility or road projects. The policy implication is that KSA operators and regulators should favor planning systems that integrate GIS, premises databases, existing-asset maps, and demand forecasts, because these tools help convert a national coverage target into a set of cost-rational local decisions.

4.3 Architecture choices affect both immediate capex and future upgrade costs

The literature also makes clear that architecture design is a major cost lever. FTTH planners must choose among different logical and physical configurations, including feeder-distribution topology, single-stage versus multistage splitting, splitter location, cabinet density, and the balance between GPON and higher-capacity options such as XGS-PON. Abdellaoui et al. (2021) show why GPON remains attractive: it delivers high-capacity triple-play services at reasonable cost with passive outside-plant components. However, more recent

optimization work shows that “reasonable cost” depends on design discipline rather than the technology label alone. Dias et al. (2022) demonstrate that practical PON planning must optimize split ratios, splitter positions, and assignment of subscriber premises to splitters if deployment cost is to be minimized on real maps. Pereira et al. (2024) further show that specialized genetic operators can reduce unfeasible solutions and improve PON planning efficiency, while Mrabet et al. (2024) address capacity optimization in next-generation PONs.

For KSA, the central insight is that architecture should be future-aware but demand-disciplined. Overbuilding for peak theoretical capacity can waste capex if take-up is uncertain; underbuilding can create expensive retrofits later. The most economic strategy is typically a staged architecture with passive outside-plant designed for long asset life and upgrade flexibility, while active electronics are phased with demand. This favors robust feeder and distribution design, disciplined splitter placement, and migration pathways that allow operators to move from GPON to XGS-PON or coexistence models where demand justifies it. The Saudi rollout challenge is therefore not merely to choose today’s cheapest architecture, but to minimize total life-cycle cost under plausible traffic and service-growth scenarios.

4.4 Open access and infrastructure sharing reduce duplication and improve asset utilization

A fourth major finding concerns the economics of sharing. Infrastructure sharing is often discussed in mobile broadband, but the logic extends directly to fixed fiber, particularly where civil works are the dominant cost. Oughton (2025) quantifies the cost benefits of sharing in broadband infrastructure and finds that sharing can materially reduce necessary investments while also improving sustainability outcomes. In fixed networks, the mechanism is similar: the more operators can avoid duplicating ducts, trenches, cabinets, and feeder assets, the lower the aggregate cost of sector-wide rollout.

Saudi Arabia has already moved in this direction through open-access policy. CST’s Digital Insights report described the second phase of the open-access initiative as a mechanism through which providers of

FTTH and business fiber open their networks more broadly, with the aim of transforming the provision of fiber services in the Kingdom (CST, 2021). This matters because a national broadband strategy can fail economically if several operators duplicate the same infrastructure in profitable districts while underserved areas remain unattractive. Open access changes the calculus by encouraging fuller utilization of installed assets, expanding service competition over shared infrastructure, and reducing the amount of duplicated outside plant required to reach consumers.

From a cost perspective, open access is especially relevant in KSA’s dense urban markets. Where multiple retail providers compete for the same household base, wholesale access can preserve competition while improving capital productivity. The challenge is governance: pricing, service-level agreements, repair responsibilities, quality assurance, and information transparency must all be credible if open access is to lower costs without introducing operational friction. Still, the review suggests that sharing and open access are among the strongest non-technical levers available for reducing large-scale FTTH costs in Saudi Arabia.

4.5 Demand-led phasing matters because homes passed are not the same as paying homes connected. A recurring weakness in many large infrastructure programs is that they optimize for coverage outputs rather than commercial efficiency. FTTH economics are often reported in terms of homes passed, but operators recover value through homes connected and retained. This distinction is central. A build that looks efficient on a coverage map may underperform financially if adoption lags, churn rises, or neighborhoods were prioritized before demand matured. Recent Saudi and international market reporting indicates strong fixed-broadband demand, growing fiber adoption, and a fixed market increasingly led by FTTH (CST, 2025a; OpenSignal, 2026). Yet even in favorable markets, take-up rates differ by area, housing type, income level, and competitor presence.

The literature therefore supports demand-led phasing. McKinsey’s rollout framework stresses AI-enabled market targeting and operating models that direct

capital toward zones with both lower build cost and stronger penetration potential (Lysenko et al., 2024). Araújo et al. (2022) also highlight that broadband technology decisions in less dense areas should account not only for technical capability but for broader decision criteria, including credibility and practical fit. For KSA, the implication is that rollout sequencing should integrate expected adoption, not just engineering feasibility. In premium urban districts with high digital-service usage, early build may be justified because penetration can be rapid. In weaker-demand areas, pre-commitment models, wholesale anchor tenants, enterprise adjacency, or combined utility projects may be needed to make the business case stronger.

This is also why KSA operators should pay close attention to cost per connected home rather than treating cost per home passed as the single success metric. A low passing cost may still lead to weak returns if activation cost is high and take-up is thin. Conversely, a somewhat higher passing cost may be superior if adoption is strong and churn is low. The review suggests that demand-led phasing is one of the most underappreciated cost levers in large-scale FTTH strategy.

4.6 Standardization and industrialization of build practices reduce execution waste

Another important theme is execution discipline. Large FTTH programs can become expensive not only because of physical complexity but because of inconsistent engineering standards, repeated redesign, weak contractor management, poor quality control, and fragmented materials procurement. Standardization helps by reducing variability. When route-design conventions, cabinet specifications, splitter hierarchies, drop procedures, splicing standards, and quality-assurance protocols are standardized, field productivity increases and rework falls.

Industry evidence reinforces this point. Recent deployment-cost studies show that labor costs are not just high; they are sensitive to build method, contractor arrangement, and operational consistency (Fiber Broadband Association & Cartesian, 2025a, 2026). McKinsey likewise emphasizes the value of long-term supplier partnerships and operating models

that improve coordination and productivity (Lysenko et al., 2024). For KSA, this means that cost optimization should include program-management architecture, not just network design. Framework contracts, standardized bills of materials, disciplined acceptance testing, shared digital construction records, and contractor performance dashboards can lower total program cost by reducing delays, defects, and remedial works.

Saudi Arabia's scale gives this point extra weight. Once fiber deployment is treated as a multi-year national program rather than isolated city projects, standardization becomes a major source of savings. A repeated design language across metropolitan builds can also simplify training, spare-part stocking, maintenance, and future upgrades.

4.7 Energy efficiency and operations shape total cost of ownership

Large-scale FTTH cost optimization does not end when the network is built. Optical access networks are generally more energy-efficient than copper or many active access alternatives, but operational power consumption, field maintenance, truck rolls, and platform inefficiencies still affect total cost of ownership. Lorincz et al. (2025) provide a detailed review showing that FTTH PONs typically have lower energy consumption than active alternatives because passive splitters remove the need for powered intermediate equipment. Their analysis also stresses that OLT and ONU power-saving methods, architecture choices, and subscriber growth patterns influence long-run energy demand. Mlinar (2026) adds that comparing P2P and PON architectures from an energy-consumption perspective is increasingly relevant as sustainability and operating cost concerns intensify.

For KSA, this means that cost optimization should include operational design decisions such as energy-efficient access architecture, remote monitoring, predictive maintenance, standardized CPE management, and reduction of unnecessary site visits. In a hot-climate country where energy cost, cooling, and outdoor asset reliability are material concerns, operational efficiency is not a marginal issue. Lower truck rolls, better diagnostics, stronger asset registers, and reduced active-field equipment all help contain

opex after rollout. A build that minimizes upfront capex but locks the operator into higher maintenance and energy cost may not be economically optimal.
 4.8 Policy and governance are cost variables, not only compliance variables

A final core finding is that policy and governance shape FTTH economics directly. Permitting delays, unclear right-of-way rules, poor utility coordination, and weak information sharing all raise cost. Conversely, broadband strategies, permitting reform, digital asset registers, and coordinated infrastructure policies reduce transaction costs and shorten build time. Saudi policy documents already indicate a strong official commitment to broadband development, digital infrastructure, and improved household access (ITU, 2020; National Transformation Program, 2025; MCIT, 2024). The open-access initiative is especially significant because it recognizes that sector-wide efficiency depends on more than one operator’s internal optimization (CST, 2021).

The policy challenge now is implementation depth. Cost optimization in KSA would benefit from a more systematic corridor-management model, stronger one-stop permit processing, better as-built data exchange among utilities and municipalities, and planning rules that encourage fiber-ready new developments. Where developers and telecom operators coordinate early, retrofit costs fall sharply. Therefore, governance quality should be understood as a deployment cost variable. Good governance lowers search costs, reduces delays, minimizes redesign, and supports better asset utilization. Poor governance does the opposite.

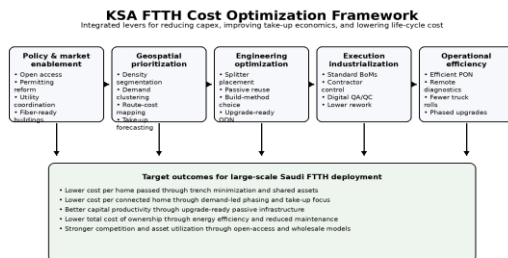


Figure 1. KSA FTTH Cost Optimization Framework. Source: Author synthesis from the reviewed 2020-2026 literature.

V. DISCUSSION

The evidence reviewed indicates that cost optimization for large-scale FTTH deployment in KSA should be approached as a layered strategy rather than a narrow engineering exercise. The most visible cost component is civil works, but the most durable savings come from linking civil-works discipline to sharing mechanisms, spatial planning, architecture choices, and demand-led rollout. This is why the Saudi case is especially interesting. The Kingdom combines strong digital-policy ambition with real deployment scale, urban growth, and operator capability. In such an environment, the cost problem is not whether fiber is too expensive in absolute terms, but whether each meter of network installed generates enough long-run value.

Three implications stand out. First, outside-plant reuse and coordinated construction are more important than marginal savings on electronics. Because passive outside plant has long life and civil works dominate cost, the highest-value strategy is to minimize duplicate excavation and make each trench, duct, or corridor serve as much future demand as possible. This supports continued emphasis on open access, coordinated utility works, and fiber-ready urban development. Second, demand quality matters as much as engineering density. Operators that optimize only for homes passed may misallocate capital toward visually impressive but commercially weaker footprints. In KSA’s strongest urban markets, a cost-per-connected-home lens is likely to produce better sequencing decisions than coverage metrics alone. Third, operational efficiency should be designed at the beginning. Energy-efficient architecture, digital records, and standardized field practices lower life-cycle cost and protect the business case after the initial build phase.

The review also suggests that Saudi Arabia is unusually well positioned to benefit from these strategies. National policy support, high internet use, and the scale of major operators create conditions in which shared and standardized approaches can work. stc’s reported household fiber reach and the broader fixed-market shift toward fiber indicate that the installed base is already significant (stc, 2025b; OpenSignal, 2026). This means the next phase of

optimization is less about proving that FTTH belongs in KSA and more about improving the economics of extending, densifying, and monetizing the network footprint.

Still, constraints remain. The economics of the urban edge, low-density pockets, and competing access technologies such as FWA can complicate the decision model. A rational strategy does not require fiber everywhere at once. Instead, it requires careful segmentation: pure FTTH where density and long-run usage justify it; phased extension where demand is emerging; and technology-neutral solutions in some marginal areas where fixed wireless or mixed models may temporarily be more efficient. This is consistent with broader broadband-cost literature, which treats technology choice as a context-specific decision rather than an ideological one (Lee et al., 2021; Araújo et al., 2022).

Overall, the literature supports a clear conclusion: the cost-optimal Saudi FTTH program is likely to be one that combines open-access logic, GIS-led planning, standardized design, demand-prioritized sequencing, and disciplined upgrade pathways from GPON toward higher-capacity PON generations. The challenge is execution coherence. The more fragmented the rollout, the higher the cost. The more integrated the rollout across policy, planning, engineering, and operations, the stronger the economics.

VI. KSA FTTH COST OPTIMIZATION FRAMEWORK

Based on the review, a practical KSA FTTH Cost Optimization Framework can be organized into five linked layers.

The first layer is policy and market enablement. This includes broadband targets, open-access rules, right-of-way simplification, utility coordination, and incentives for fiber-ready buildings. Its purpose is to reduce duplication, shorten approval cycles, and improve the institutional environment for large-scale buildout.

The second layer is geospatial planning and prioritization. Here operators classify territories by density, premises type, expected take-up, competition

intensity, and infrastructure availability. The key outputs are ranked rollout zones, route options, and the expected cost-to-revenue profile of each cluster.

The third layer is engineering optimization. This layer covers feeder-distribution topology, splitter placement, cabinet location, architecture selection, construction method, and passive infrastructure reuse. The objective is to minimize capex while preserving upgrade flexibility and service quality.

The fourth layer is execution industrialization. This includes standardized bills of materials, contractor governance, digital work orders, acceptance testing, materials planning, and quality dashboards. The aim is to reduce execution waste, rework, and schedule slippage.

The fifth layer is operational efficiency and monetization. This covers energy efficiency, remote diagnostics, reduced truck rolls, demand stimulation, service activation, churn control, and phased electronics upgrades. The goal is to lower opex and increase revenue realization from the passed footprint.

When these five layers are connected, KSA operators can move from project-by-project cost control toward a system for sustained capital efficiency. The framework therefore treats cost optimization not as one decision at design stage, but as a continuous governance process from policy through monetization.

VII. CONCLUSION

This review set out to examine cost optimization strategies for large-scale FTTH deployment in KSA and to translate recent evidence into a Saudi-oriented framework. The synthesis shows that the central cost challenge in fiber deployment remains civil works, especially underground construction and labor, but the strongest solutions are cross-functional. Costs can be lowered materially when operators reduce trenching through infrastructure reuse, coordinate with utilities and municipalities, deploy open-access models where appropriate, use GIS-based market segmentation, align architecture with realistic demand, standardize field execution, and design for low-cost operations after rollout.

For Saudi Arabia, these findings have practical importance because the Kingdom's digital ambitions require fixed infrastructure that is both scalable and economically sustainable. The evidence does not support a simplistic "build everything everywhere immediately" model. Instead, it supports a portfolio strategy: dense and high-demand zones should be accelerated; medium-potential areas should be phased with stronger demand evidence; and marginal areas should be assessed through technology-neutral economics. Open access and corridor coordination are especially important because they address the biggest cost driver: duplicated outside-plant investment.

The paper's main contribution is therefore conceptual and strategic. It brings together policy, engineering, planning, and operational insights into one KSA FTTH Cost Optimization Framework. Future research should extend this work with Saudi premises-level geospatial modeling, municipality-specific permitting analysis, and operator-side simulations comparing cost per home passed, cost per connected home, and long-run opex under different architecture and sharing scenarios. Even without those microdata, the direction of the evidence is clear. In KSA, the most cost-effective FTTH strategy is not the lowest upfront spend in isolation, but the design that maximizes asset reuse, prioritizes high-probability demand, preserves upgrade flexibility, and minimizes duplication across the sector.

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