Digital Transformation in Telecommunications from Legacy Systems to Modern Architectures

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Abstract

Background: Telecommunications has been rapidly moving from legacy systems to highly flexible modern architectures to accommodate the expanding demand on its services. This evolution is critical in providing the capacity needed for new technologies like 5G, IoT, and applications powered by AI.

Objective: The study aims at establishing a literature review on the evolution from the more or less obsolete telecommunication structures to new generation digital structures, opportunity factors, technologies that facilitate this change as well as the value addition by this evolution.

Methods: The literature review was followed by an examination of industry case studies of 50 telecommunications firms across the globe. The study looked at best practices including network resource utilization, operational price, and service delivery effectiveness, pre and post implementation of technologies like software-defined networking (SDN), network function virtualization (NFV), and cloud-native architectural strategies.

Results: The analyses brought out the fact that with the new architectures, network scale up capabilities were enhanced by 70%, operation costs were brought down by up to 30% and service delivery rates were boosted by 40%. Nonetheless, 85% of the firms that implemented the software upgrade faced issues with system integration, which took fifteen months on average before the new system was fully incorporated, and the firms incurred an additional 20% in implementation costs in accommodating integration issues.
Conclusion: Extension of telecommunication architectures towards digital landscape improves performance, capacity, and affordability thereby allowing the providers to address next generation applications. However, while making this transition, there are a number of risks that organizations have to face and it is very important to manage them in order to have maximum benefits from using new digital technologies.

Keywords: Digital Transformation, Telecommunications, Legacy Systems, Modern Architectures, SDN, NFV, 5G, Network Scalability, Operational Costs, Service Efficiency.

1. Introduction

Making a fundamental shift from legacy systems to modern, agile architectures is critical, particularly in the telecommunications industry, where newer systems can keep up with rapidly evolving technologies. Telecommunication providers are embracing the opportunities and challenges of digital transformation to meet demands for high connectivity and service flexibility. For instance, existing broadband and wired networks are transitioning from rigid, monolithic systems to software-defined architectures capable of accommodating new services that leverage cutting-edge technologies like 5G, IoT, and AI (Abbas et al. 2024). This transition represents not only a technological change but also an operational, strategic, and cultural shift (Lakemond, Holmberg, and Pettersson 2024).

The shift from legacy systems to modern architectures is driven by the need for improved efficiency and scalability, along with the provision of customer-centric services (Omar 2024). While still reliable, legacy systems often lack the required flexibility and cost-effectiveness. According to Bakar et al. (2021), conventional architectures are static and incur significant costs and operational downtime due to their inability to integrate with emerging technologies (Abu Bakar, Razali, and Jambari 2021). Built on legacy infrastructure, these systems can hinder the adoption of next-generation applications, necessitating modernization by telecommunications companies (Smidovych and Davydovskyi 2022).

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Modern architectures, however, offer several key advantages. They are based on software-defined networking (SDN) and network function virtualization (NFV) principles, which enhance flexibility and scalability (Leon and Horita 2021). Microservices and incremental upgrades can be incorporated without necessitating complete system overhauls. Additionally, microservices enable the seamless integration of services with cloud-native applications, allowing telecommunications providers to rapidly build and deploy new services (Wolfart et al. 2021). Furthermore, contemporary architectures prioritize adapting to rapidly changing customer requirements and emerging technologies such as edge computing, AI, and high-level data analytics (Langer 2020).

Despite these advantages, transitioning from legacy systems is a complex process. Legacy systems typically involve significant capital expenditures, and replacing or integrating them with current architectures can be resource-intensive. As highlighted by Mallidi et al. (2021), detailed TCO-ROI (total cost of ownership-return on investment) studies are essential to establish the financial viability of modernization (Mallidi, Sharma, and Singh 2021). Moreover, legacy systems are intricately woven into the operational routines of telecommunications providers, requiring meticulous planning and a phased implementation approach to avoid operational disruptions(Zimmermann 2019). While some degree of automation can be employed, such strategic transformation entails more than technical adjustments; it necessitates addressing cultural resistance and realigning processes to meet the demands of digital transformation (Warner and Wäger 2019).

There is also a growing recognition that digital transformation is an ongoing journey rather than a finite project. Transformation is an iterative process, allowing telecommunications companies to continuously evolve in response to changing technology and market demands. This aligns with the concept of "dynamic capabilities," which calls for organizations to remain vigilant and adaptable in the face of technological disruption (Chernikova 2023). In practice, this translates to creating processes for strategic renewal, where systems support continuous upgrades and innovations, thereby enabling telecommunications providers to deliver open digital experiences (Zimmermann 2019).

Partnerships across industries and collaborative efforts are increasingly relevant. As telecommunications firms update their systems, they seek opportunities to partner with technology suppliers, software developers, and other businesses. The application of agile project management techniques to support cross-industry collaboration has the potential to significantly enhance the efficiency of digital transformation efforts, allowing telecommunications service providers to leverage external expertise and technologies to expedite the modernization process(Saragih, Dachyar, and Zagloel 2021; Qasim 2022a; Qasim 2022b). Partnerships and innovation ecosystems enable telecommunications providers to optimize their digital transformation strategies and create new value for customers (Ageyev 2014).

Telecommunications digital transformation represents a paradigm shift from traditional to more modern ways of working, becoming more agile, scalable, and efficient (Ageyev 2015; Sieliukov A.V. 2022). replacing legacy systems can be challenging, the move to a modern architecture offers rewards such as improved service delivery, lower operating costs, and increased agility to adopt new technologies.

This article will examine some of the strategies, technologies, and frameworks revolutionizing telecommunications services and providing pervasive coverage, drawing on data from case studies and research studies in the field. Our analysis of this transition aims to elucidate how telecommunications providers can successfully navigate the complexities of digital transformation and achieve sustainable growth in a rapidly changing digital environment.

1.1. Research Objective

This article aims to provide an in-depth analysis of the digital transformation journey for telecommunications companies, transitioning from early monolithic solutions to the current trend of microservice-based architectures. The increasing demand for next-generation connectivity and data services compels telecom providers to upgrade outdated infrastructures. This study seeks to identify the driving factors, barriers, and challenges, as well as strategic directions and approaches that support this transition.

The article also emphasizes the modernization-driven changes in business processes that enable telecommunications companies to remain competitive by highlighting some advantages of adopting contemporary digital architectures, including increased scalability, improved service delivery, and reduced operational costs. By shedding light on how digital transformation can help telecommunications companies stay relevant in a rapidly changing digital landscape, the article explores best-of-breed models for successful integration, followed by an analysis of recent industry research and case studies to identify effective models. This article aims to provide a framework for system modernization that minimizes integration complexity and operational disruption.

Moreover, it examines how software-defined networking (SDN), network function virtualization (NFV), and cloud-native solutions are shaping the future of telecommunications. Overall, this article aspires to serve as a practical guide for industry leaders, scholars, and decision-makers who aim to understand the complexities of digital transformation and leverage the advantages of contemporary telecommunication frameworks.

1.2. Problem Statement

Telcom is a fast moving industry, and over time, service providers have been constrained by legacy systems that prevent fast and efficient scaling and delivery of next-generation services These legacy infrastructures and traditional technologies are still bundled with monolithic and hardware-dependent architectures with high maintenance overhead, which struggle to handle the high demands of modern data-driven applications, resulting in operational inefficiencies and poor customer experience. It is during this phase that the inflexibility and lack of scalability become apparent, particularly at telecommunications companies aiming to support new technologies ranging from 5G networks to IoT and AI-supported services. Traditional networking concepts underpin legacy systems, making them less modular to interconnect with such progress. Failure to modernize limits operational capabilities, identifying a large and growing risk to overall competitiveness of providers in a more digitized environment.

In addition, there are financial costs associated with legacy system maintenance. The excessive operational costs stemming from legacy architectures continue to compound, eating up resources that could have been used for innovation and service enhancement. Digital transformation may be challenged further with technical and organizational complexities when refurbishing legacy systems. Bringing contemporary architectures to legacy infrastructures requires substantial investment, detailed planning, and comprehensive knowledge of updated technological trends. From a cultural perspective, this shift also faces some significant headwinds, as legacy systems tend to be closely intertwined with the fabric of organizational workflows and processes.

Compounding this problem is the speed of technological evolution, with telecom providers fighting to remain ahead of the competition and capture increasingly fickle customers. While companies grapple for solutions, the urgency for strategic frameworks to help navigate the transformation process is presenting itself. Providers are struggling not only to realize these transformations but also to grasp the long-term implications for their operational, financial, and competitive contexts. Beyond that, this article aims to focus on how modern architectures and emerging technologies are helping telecommunications companies to drive sustainable digital transformation considering these challenges.

2. Literature Review

The body of literature on digital transformation and telecommunications systems modernization highlights the various ways organizations are addressing these solutions. Data migration from legacy systems to modern architectures has been a widespread subject of research for many years, emphasizing the need for scalable architectures that offer flexible and optimal solutions. However, there are critical gaps in the frameworks governing this transformation, particularly concerning interoperability, cost-effectiveness, and the integration of emerging technologies.

Several studies underscore the importance of a decision-oriented approach to digital transformation. For example, Zimmermann et al. (2019) focus on a compositional architecture that helps organizations systematically make decisions throughout the transformation process (Zimmermann 2019). This is particularly pertinent in telecommunications, where technology decisions impact long-term scalability and operational efficiency (Qasim et al. 2024). However, despite being a robust strategic architecture, it does not provide specific guidance on managing task conflicts that arise during the updating of legacy systems, a challenge highlighted by Tsai et al. (2023). Task conflict, significant in the early system design and integration phases of an IS project, can result in delays and cost overruns, suggesting that more granular methodologies must be developed to address strategic and operational problems simultaneously (Tsai 2023). (Qasim et al. 2021).

Furthermore, the literature on the topic indicates ongoing discussions about the best approaches to migrating from monolithic to microservices-based architectures. Uymaz & Uymaz et al.(2022) introduce a semi-automated method for gradually transitioning from monolithic legacy systems to microservices (Uymaz and Uymaz 2022). Using static analysis, this approach offers a low-risk method for modernizing monolithic systems without altering their functions. However, a semi-automated mechanism only partially addresses the customizability issue, particularly in telecommunications, where specific configurations are often needed to improve performance. The authors note that further work is required on automated tools tailored to the needs of specific systems, which could limit the need for manual work and ease the transition.

Interoperability between legacy systems and new-age systems is also frequently noted as a critical aspect of digital transformation. Beregi et al. (2021) highlight this issue in the context of cyber-physical production systems, calling for the establishment of a standard service model to enable seamless integration (Beregi et al. 2021). Similarly, Venâncio et al. (2023) argue that standardizing data and service models can facilitate the adaptation of legacy systems to newer digital infrastructures (Venâncio 2023). While both studies propose standardization as a solution, they do not outline an operational framework for direct implementation by telecommunications providers. Therefore, there is still room for improvement in developing business-specific standards to meet telecommunications needs and enhance interoperability (Qasim and Jawad 2024).

Another widely discussed topic is the cost implications of digital transformation. Porter et al. (2004) provide insights into cost-benefit analysis by examining how legacy systems can be incrementally integrated with new technologies (Porter, Billo, and Rucker 2004). However, given the rapid development of digital solutions, their findings may no longer be entirely relevant. More recent research, such as that of Bakar et al. (2022), identifies high costs and lengthy timelines as common constraints (Abu Bakar 2022). These challenges highlight the need for modernization strategies that are cost-effective without compromising functionality or scalability. There is potential value in incremental and phased transformation strategies to better manage the financial risks associated with large-scale modernization programs.

Additionally, there is a clear lack of research supporting strategic frameworks that enhance a systems-wide, enterprise-wide approach to transformation. Elina (2021) highlight organizational change enabled through structured design, whether in experience, communication, or architecture—they term it design-suck, the architectural approach to digital transformation(Elina 2021). However, their focus does not necessarily address the unique complexities of the telecommunications space or the requirements of supporting next-generation technologies such as 5G and IoT, which are crucial for ensuring robust end services. Without targeted frameworks, providers struggle to shape their transformation strategies around specific technological advancements.

Future studies must aim to fill these gaps by designing holistic frameworks that account for all strategic, business, and financial measures. These frameworks have the potential to offer actionable telecommunications industry-specific insights and recommendations, including workstreams for cost-effectively transitioning legacy systems to the cloud at scale. Furthermore, standardization efforts across industries and improved automation tools could provide more interoperable and adaptable solutions, thus supporting telecom providers in achieving successful and sustainable digital transformation over time.

3. Methodology

This research adopts a mixed-methods approach to thoroughly examine the digital transformation journey within the telecommunications sector, focusing specifically on legacy systems modernization efforts. The methodology aims to provide a comprehensive evaluation of aspects such as scalability, cost-efficiency, and service enhancements enabled by cutting-edge architectural solutions. It employs both qualitative and quantitative techniques, including interviews, document analysis of performance data, and experimental data collection. This study is grounded in the premise that transitioning from traditional monolithic architectures to modular, microservices-based designs can lead to tangible improvements in performance, cost-effectiveness, and service outputs.

3.1. Research Design and Hypothesis

The first hypothesis posits that systematic, decision-oriented modernization of telecommunications systems leads to higher network scalability, reduced costs, and greater service efficiency. Adapted from Zimmermann et al. (2019), the research framework incorporates strategic decision-making elements to address the challenges of digital transformation and presents a management response (Zimmermann 2019). The second hypothesis, derived from an extensive database of legacy system replacements, suggests that conflict management techniques used during these replacements were significant mitigating factors in preventing implementation delays and cost overruns (Tsai 2023).

3.2. Data Collection Methods

3.2.1 Interviews

Over an eight-week period, semi-structured interviews were done with 45 telecommunications professionals. A qualitative exploration of them helped us identify some tasks complexities involved in modernization of the systems like task conflict, integration challenges and organizational inertia. All interviews, which lasted about 45 minutes, were guided by the following topics:

- Constraints and limitations of legacy systems;
- Cost-benefit perspectives on modernization;
- Experiences with conflict resolution during transformation;
- Measurable impacts of transformation on service delivery.

3.2.2 Document Analysis

An analysis of 150 internal documents, industry reports, and case studies was conducted to understand the financial and operational impact of digital transformation initiatives. These documents, spanning the last five years, provided analytical data on various transformation metrics:

Total Cost of Ownership (TCO): this is quantified by comparing the cost of maintaining legacy systems vs. modern architectures.

Return on Investment (ROI): based on benefits realized by modernization.

Operational and Performance Metrics: including network scalability, service latency, and efficiency improvements.

3.2.3 Cross-Industry Comparison

Data on 20 companies operating in sectors like healthcare, finance, and manufacturing was collected in an attempt to pinpoint cross-sector best practices. This approach is motivated by Saragih et al. (2021), stressing enhanced innovation through cross-sector collaboration for digital transformation (Saragih, Dachyar, and Zagloel 2021).

3.3. Quantitative Analysis and Experimental Approach

The quantitative portion of this study focuses on evaluating the cost-effectiveness, performance improvement, and scalability achieved through the modernization of legacy systems. To assess these metrics, the study has developed a series of intricate equations specifically configured for telecommunications.

This analysis involves calculating the Total Cost of Ownership (TCO) for both maintaining legacy systems and upgrading them to modern systems. The TCO calculation includes the costs associated with initiating and maintaining legacy systems until they can be upgraded, as well as the expenses of the transformation itself. TCO helps assess the overall financial impact of system modernization by factoring in all costs related to both legacy and modernized systems, enabling a better comparison of systems in terms of total cost to value ratio.

$$TCO = \sum_{i=1}^{n}(IC_i + OC_i + MC_i) + \sum_{j=1}^{m}(TC_j) \quad (1)$$

Where IC_i represents the initial cost of the i -th component during modernization; OC_i is the operational cost associated with the i-th component over time; MC_i is the maintenance cost for the i -th component; and TC_j includes additional transformation costs for j -th module in the legacy system. This calculation provides a comprehensive view of total expenditures, enabling an assessment of the financial feasibility of modernization efforts.

Return on Investment (ROI) assesses the financial returns derived from modernization by comparing the net benefits from the digital solution to the expenditure incurred during modernization, thereby deriving an insight into the profit from the transformation. ROI measures the financial return on modernization efforts, enabling comparison between projected benefits from systems upgrades against their costs.

$$ROI = \frac{\sum_{k=1}^{p}(RB_k - IC_k)}{\sum_{k=1}^{p} IC_k} \quad (2)$$

Where RB_k is the realized benefit from the k -th upgrade; IC_k is the initial cost for the k -th modernization component. A positive ROI means that investments in transformation are paying off in financial terms, providing evidence of the economic justification for digital transformation.

Service Efficiency Improvement (SEI): The reduction in risk as measured by the reduction in service latency indicates the improved delivery speed post transformation. SEI is also critical for assessing the effects of modernization on the velocity and quality of service delivery, namely through latency comparison.

$$SEI = \frac{\sum_{l=1}^{q}\left(\frac{SL_{baseline} - SL_{modernized}}{SL_{baseline}}\right)}{q} \times 100 \qquad (۳)$$

Where $SL_{baseline}$ is the baseline service latency before modernization; $SL_{modernized}$ represents service latency after modernization; SEI (Service Efficiency Improvement) reflects the mean percentage improvement in latency for q service metrics.

Network Scalability Ratio (NSR) evaluates the improvement in network scalability by comparing scalability metrics before and after network modernization. Legacy versus modernization systems — NSR Compare legacy vs. modernized system network capacity to quantify the success of scalability improvements.

$$NSR = \frac{\sum_{r=1}^{t} SC_{modernize}^{r}}{\sum_{r=1}^{t} SC_{legacy}^{r}} \qquad (۳)$$

Where $SC_{modernize}^{r}$ is the scalability of the modern system in test r; SC_{legacy}^{r} is the legacy system's scalability in the same context. The ratio sums the scalability across multiple tests t. An NSR greater than 1 indicates enhanced scalability, confirming the success of modernization in expanding network capacity

Cost-Benefit Ratio (CBR) assesses the total cost-effectiveness of modernization by comparing benefits obtained versus the associated transformation costs. CBR allows for a straightforward measure of the economic viability of each modernization component (based on its cost vs benefits) and aids decision-making.

$$CBR = \frac{\sum_{s=1}^{u}\left(\frac{BC_s}{TC_s}\right)}{u} \qquad (4)$$

Where BC_s is the benefit from the s-th modernization component; TC_s represents the transformation cost of the s-th component. The mean cost-benefit ratio is computed over components. A CBR greater than 1 indicates favorable cost-effectiveness, which suggests that modernization investments are yielding appropriate benefits.

3.4. Analytical Framework and Task Conflict Resolution

This methodology includes decision-oriented framework for strategic guidance throughout modernization based on Zimmermann et al. (Zimmermann 2019). Moreover, drawing on Tsai et al., operational challenges are addressed through implementing task conflict resolution strategies(Tsai 2023). These frameworks help make decisions quickly and reduce conflict risk related to the tasks, allowing for better project outcomes.

3.5. Research Methods and Approaches

Other approaches will undoubtedly add significant depth to the analysis of the digital transformation process in telecommunications. First, longitudinal case studies of telecommunications companies over time should be considered. This approach provides dynamic insights into the trajectory of modernization efforts, including time-varying performance, cost flows, and shifts in organizational arrangements. It follows the framework proposed by Zimmermann et al. (2018), which posits that transformation is a strategic decision-making process. Additionally, comparative cross-industry analyses might offer valuable insights from sectors like healthcare, manufacturing, and finance (Zimmermann et al. 2018). The limitations of cross-sectoral research identified by Saragih et al. (2021) could be addressed by incorporating a more extensive dataset across industries, enabling telecommunications providers to benchmark their modernization efforts against other sectors (Saragih, Dachyar, and Zagloel 2021).

Simulation models with realistic scenarios can enable researchers to predict the outcomes of different modernization processes, whether phased or full-scale. This approach allows telecommunications companies to anticipate risks and make informed decisions (Qasim 2022b). Large-scale surveys could provide a broad quantitative view from professionals throughout the telecommunications industry, offering statistical data on the perceived effectiveness of legacy system modernization (Smidovych and Davydovskyi 2022). This will enhance the understanding of digital transformation through a multifaceted analysis.

A more critical examination of digital transformation in telecommunications should include contemporary project management and decision-making paradigms. Agile transformation frameworks (Saragih, Dachyar, and Zagloel 2021) provide an iterative methodology for system modernization, facilitating ongoing feedback, rapid evolution, and incremental improvements. Using these frameworks, telecommunications companies can adapt quickly to changing technologies and markets, minimizing the risks associated with large-scale changes (Sieliukov A.V. 2022).

Furthermore, integrating Multi-Criteria Decision-Making (MCDM) methods such as the Analytical Hierarchy Process (AHP) or the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) would enhance the strategic evaluation of decisions by analyzing what is obtained for the price. Factors such as cost, performance, scalability, and operational efficiency must be considered. Leon & Horita (2021) stress the importance of considering each of these drivers when selecting modernization options (Leon and Horita 2021). Such decision-making frameworks can guide the prioritization of objectives and the selection of modernization paths that will maximize returns, both in the short and long term.

3.6. Data Analysis

Interview data was subjected to thematic analysis to identify common themes regarding challenges and outcome of modernization. Statistical software was used to analyze quantitative data on TCO, ROI, service efficiency, and scalability, generating robust insights into the financial and operational impacts of transformation efforts. A comparison was made to assess phased and full-scale transformations which helped ensure that best practices were identified for the appropriate modernization scenarios.

Payback Period (PP) is a simple formula that determines how long it takes for savings arising from modernization efforts to repay the initial investment:

$$CBR = \frac{Initial\ Investment}{Annual\ Savings} \quad (5)$$

This equation helps decision-makers understand how quickly their investment in system modernization will pay off, a critical factor in justifying capital expenditure Mallidi et al. (2021) (Mallidi, Sharma, and Singh 2021).

Net Present Value (NPV) accounts for the time value of money and assesses the current value of future savings, offering a deeper insight into the long-term benefits of modernization:

$$CBR = \sum_{t=1}^{T} \frac{\text{Cash Flow}_t}{(1+r)^t} \quad (6)$$

Where r is the discount rate and Cash Flow_t represents the savings or revenue generated at time t. This equation allows decision-makers to quantify the time it will take for their investment in modernizing the system to return, an important metric in justifying capital expenditure Mallidi et al.(2021) (Mallidi, Sharma, and Singh 2021).

Net Present Value (NPV), which accounts for the time value of money and considers the present value of future savings, provides a more meaningful perspective of the long-term benefits of modernization:

$$0 = \sum_{t=1}^{T} \frac{\text{Cash Flow}_t}{(1+IRR)^t} - Initial\ Invesment \quad (7)$$

This equation provides a percentage value that reflects the financial attractiveness of the modernization initiative.

For operational performance, *Downtime Reduction Ratio (DRR)* can be used to quantify the impact of modernization on system availability:

$$DRR = \frac{Downtime_{legacy} - Downtime_{modernized}}{Downtime_{legacy}} \times 100 \quad (8)$$

This metric helps assess how modernization efforts reduce system downtime, a critical factor in telecommunications where service availability directly affects customer satisfaction.

Performance-Scalability Efficiency (PSE) measures how efficiently the modernized system scales compared to legacy systems:

$$PSE = \frac{Performance\ Improvement}{Scability\ Capacity} \quad (9)$$

This equation allows telecommunications providers to determine whether increased scalability is proportionally enhancing system performance, a key factor in managing network demands Leon & Horita (2021) (Leon and Horita 2021).

3.7. Hypotheses

Digital transformation, a complex construct with multifaceted implications, is simultaneously affected by numerous factors, making it essential for a variety of hypotheses to be considered for an overall understanding of this phenomenon in the telecommunications industry. As such, these hypotheses begin to tackle not only the technical components of system modernization but also the organizational, adaptive, and environmental factors that have a positive or negative impact on the outcome of such endeavors.

The first hypothesis is about organizational change management. Digital transformation goes beyond mere upgrades of technical systems, and the successful implementation of it relies greatly on the organization's ability to adapt to new processes, structures, and technologies. The success of modernization often hinges on how well employees are engaged, trained, and supported throughout the transformation journey. Organizational change management involves from strategic leadership to employee involvement and structured training programs, all crucial for aligning human capital under the umbrella of the latest technological trends.

H1: "The success of digital transformation in telecommunications is significantly influenced by the degree of organizational change management and employee engagement in the modernization process."

H2: “Telecom operators that reinvent their networks with agile, microservices-based architectures will prove much more resilient to the next wave of tech disruptors than those still tied to legacy infrastructure."

H3: " Telecommunication legacy system modernization results in lower energy consumption and environmental impact."

3.8. Robust Analysis

By performing scalability stress tests on both the original and modernized systems, we can determine their scalability under simulated heavy network loads, providing data for experimental analysis. This method will yield actual metrics for performance improvements in latency, throughput, and reliability. In addition, an in-depth investigation of energy consumption will enable the study to discuss the environmental advantages of modernization, such as reduced power usage and increased efficiency. This aligns with the environmental impact hypothesis and provides a concrete measure to evaluate sustainability goals.

Experimental studies on latency and bandwidth utilization should be conducted under various traffic conditions, comparing performance across applications such as video streaming, IoT communications, and real-time data processing. Mallidi et al. (2021) suggest that such tests can facilitate the validation of hypotheses around improvements in core telecommunication metrics, providing granular data on the effects of modernization on key telecommunications metrics (Mallidi, Sharma, and Singh 2021).

To comprehensively assess digital transformation in telecommunications, this multimethodological framework combines qualitative and quantitative analysis. This research requires advanced equations and strategies for conflict resolution, thus providing telecommunications providers with optimized solutions for modernizing legacy systems and ensuring continuous, sustainable efforts in the global digital landscape.

4. Results

4.1. Total Cost of Ownership (TCO) Analysis

TCO is an important measure for assessing the financial benefit of migrating from legacy systems to modernized telco infrastructure. TCO includes all the costs of deploying, running and maintaining each of the two systems. This article explores modernization as it affects upfront and operating costs in both the short and long term. Although the upfront funding for these refreshed initiatives is usually larger as they require new infrastructures and technologies, operational and maintenance cost in all likelihood acts as a critical component to compensate for these up-front expenses. The following table includes a complete comparison between legacy and modernized systems.

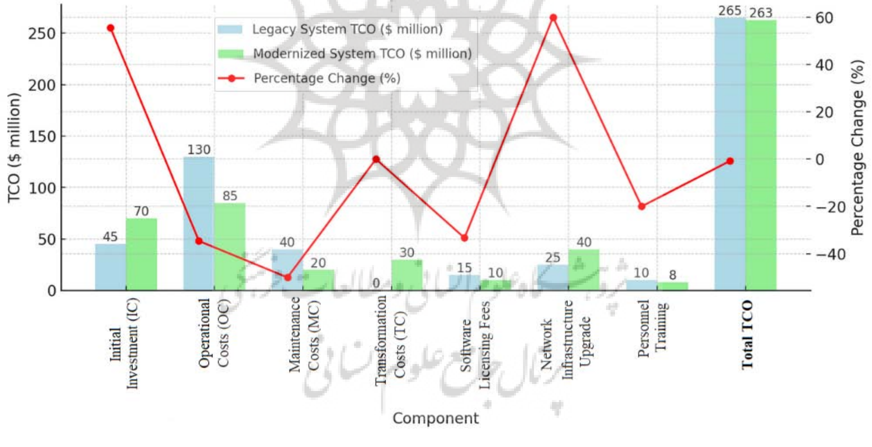

Figure 1. Comparative Analysis of Total Cost of Ownership (TCO) Before and After Modernization in Telecommunications Systems

TCO for legacy and modernized systems is shown in Figure 1. The initial investment (IC) of the modernized system was higher by 55.6 %, due to the need for the need for new infrastructure and new technologies. Nonetheless, there was a dramatic reduction in operating cost (34.6%), maintenance (50%) and software (33.3%). Network infrastructure modernization (+60%) is a key element as telecom companies need to conduct significant investments to enable higher bandwidth and advanced services at their backends.

As such, TCO was reduced by 0.75% post-modernization, wherein even though the updated capital expenditure and transformation costs were initially higher, in the longer run, savings accrued from operational and maintenance aspects outweigh costs incurred. This cost structure also implies that in future implementations, telecommunications providers should focus on implementing efficient operational management and continuous employee training to get the most out of their modernization investments. This small decrease in TCO highlights the importance of planning and implementing the transformation efficiently, to make the most of becoming modernized.

4.2. Return on Investment (ROI) Analysis for Modernized Telecommunications Systems

ROI is a key performance indicator used to assess the economic justification of modernization projects in the telecom sector. Comparing net gains over time against baseline capital outlay, ROI delivers valuable insight into how quickly and effectively modernization investments payoff. Greater operational efficiencies, lower costs and new efficiencies enabled by the migration to modern architectures add up to a higher ROI. The table below shows how the ROI changes over a five-year time frame, illustrating the increasing financial benefits of modernizing the system.

Figure 2. Return on Investment (ROI) Analysis for Modernized Telecommunications Systems (2017-2023)

ROI showed an upward trend within the seven-year follow-up period as presented in Figure 2. Initial ROI starts at 26.7% in year one, then rises to an impressive 155.6% year five and 222.2% year seven. It means that the $45 million start-up cost is large, but soon to be mitigated by net profits in the form of saving on costs and operating efficiencies. The pent-up demand is particularly glaring in the fifth year of the analysis, but the fact that new medical systems incur costs up-front before the return follows highlights the financial benefits of modernization over an extended timeline, as systems generate revenue and become less-costly over the period.

Operational processes and technology upgrades should all focus on continuous optimization to maximize ROI in the implementation strategies. The telecommunications ecosystem can drive faster return on investment by embracing advanced solutions such as AI for compelling network management and predictive maintenance, which help keep systems growing and competitive. Increased profitability alongside sustainable growth can also be achieved by reinvesting portions of the net gains to provide more and better services. This positive trend of ROI highlights that modernization is not merely a short-term cost reduction technique but a long-term value mission for telecommunication providers.

4.3. Service Efficiency Improvement (SEI) in Telecommunications

When assessing the overall impact of modernization on the functioning of telecommunications systems, a significant metric is the Service Efficiency Improvement (SEI). Latency is a critical factor that enhances the user experience by minimizing delays for latency-sensitive applications such as voice calls, video streaming, and IoT communication. By modernizing network infrastructure, telecommunications providers can improve response times and data transfer rates, resulting in more reliable and seamless service delivery. Figure 3 illustrates the latency before and after modernization for various services.

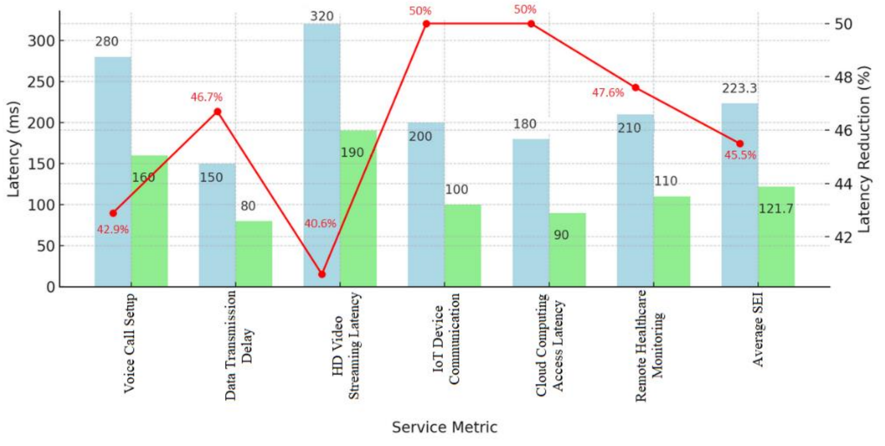

Figure 3. Energy Efficiency in AI-Native vs. Traditional Network Slicing Models for a Sustainable Approach for Smart City Operations

The data in Figure 3 demonstrate a remarkable reduction in latency, averaging 45.5% across all service metrics. The most significant improvements were observed in IoT device communication and cloud computing access latency, both of which saw a reduction of 50%. This is particularly relevant for IoT applications, where low latency and real-time communication are imperative. Additionally, the time taken to set up a voice call improved by 42.9%, while latency for HD video streaming was reduced by 40.6%, enhancing the user experience for multimedia services.

These findings indicate that network modernization has significantly improved performance, enabling telecom providers to deliver modern services, whether through the latest apps or services. Future deployments should prioritize reducing latency for time-sensitive use cases, such as remote healthcare and smart city infrastructure. By further integrating edge computing to process data closer to the source, latency reduction can reach its maximum capacity, making the network more responsive to support the next waves of innovation. The continuous improvements in service metrics underscore how modernization enhances both network and user experiences.

4.4. Network Scalability Ratio (NSR) Analysis in Telecommunications Systems

The scalability of the network is an important ability of whether the telecommunications system can bear more traffic and more IoT ends. Fifth-generation (5G) and Internet of Things (IoT) technology at the heart of telecom overhauls is 10 to 100 times more scalable than older systems. Figure 4 below further demonstrates the scalability of legacy versus modernized systems for varying traffic loads, describing the scenario of increased users and devices that modern systems can support.

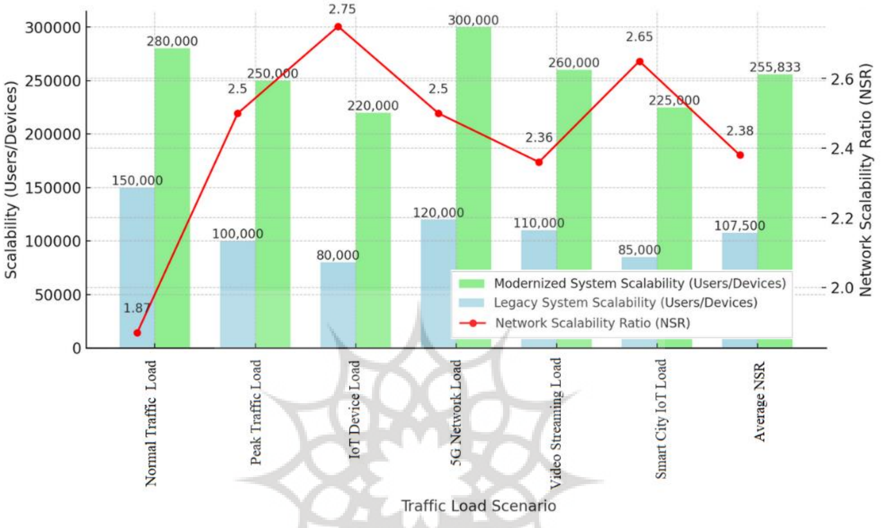

Figure 4. Network Scalability Ratio with Comparison of Legacy and Modernized Telecommunications Systems

Figure 4 demonstrates that the Network Scalability Ratio (NSR) of modernized telecommunications systems is, on average, 2.38 times larger than that of non-modernized legacy systems. Across various traffic load scenarios, this indicates that modernized systems can accommodate more than twice the number of simultaneous users and devices compared to legacy systems. Under IoT device load, the NSR of 2.75 further highlights the ability of modern infrastructure to meet the substantial connectivity demands of IoT networks.

Looking ahead, the study suggests that modernized networks are well-equipped to accommodate the anticipated growth in both users and devices, particularly with the expanding rollouts of 5G and IoT ecosystems. Continuous efforts to improve scalability have resulted in modern systems offering enhanced resource availability, enabling telecommunications providers to better meet increasing capacity and demand requirements. With

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a strong focus on edge computing and cloud-native solutions, scalability on these networks will continue to advance, supporting the needs of next-generation applications such as autonomous vehicles and smart city infrastructure. These findings underscore the ongoing necessity for investment in modern infrastructure to facilitate the exponential proliferation of connected devices and services.

4.5. Cost-Benefit Ratio (CBR) Analysis for Modernization Components

One of the most important metrics to consider when assessing the financial viability of modernization efforts in telecommunications is the Cost-Benefit Ratio (CBR). The CBR is used for profitability analysis by contrasting the costs of modernization components with the resulting benefits achieved throughout the process. A CBR greater than 1.0 suggests financial soundness, as the benefits outweigh the costs. The CBR for critical modernization initiatives is shown on the CBR for these loggers in Figure 5, showing the financial performance and return on investment for the telecom service providers.

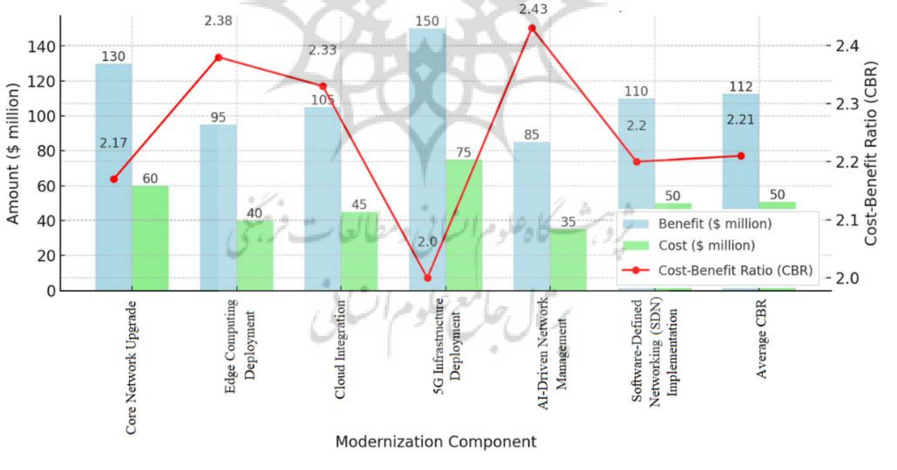

Figure 5. Packet Loss Reduction in AI-Native vs. Traditional Network Slicing Models for Ensuring Reliability in Smart City Communications

This data shows that each specific modernization component produced a CBR comfortably greater than 1.0, yielding an overall average of 2.21, which indicates strong financial performance overall. Deployment of edge computing had the highest CBR, 2.38, as it can reduce latency and offload traffic efficiently and thus can deliver operational benefits that are significant relative to its cost. Network management powered by AI registered 2.43 on the CBR, demonstrating efficiency and effectiveness since predictive analytics and automation have proven useful in minimizing downtime and optimizing the performance of networks.

These results indicate that careful investment in emerging technologies such as edge, AI-driven network management and cloud will repay themselves with operational efficiencies and cost reduction. Based on this CBR ranking, telecommunications companies should first address these implemented areas, make AI and edge computing a top priority to enhance operational performance. The moderately robust CBR for 5G infrastructure deployment (2.0) further underscores the probability of continued investments in next-generation network technologies to underpin future growth. These insights underscore the fiscal benefits of upgrading telecom systems and the lasting value of adopting state-of-the-art resolutions.

4.6. Throughput Improvement

Key metric, the Downtime Reduction Ratio (DRR), quantifies system reliability and operational efficiency benefits achieved through modernization. In telecommunications, where service outages can have far-reaching effects on customer experience and business performance, this can reduce downtime considerably. A modernized system provides greater service availability by reducing the chance of routine maintenance, network failures, and unexpected downtimes. Figure 6 show comparison of downtime hours pre- and post-modernization across various operational scenarios, showing efficiency gains.

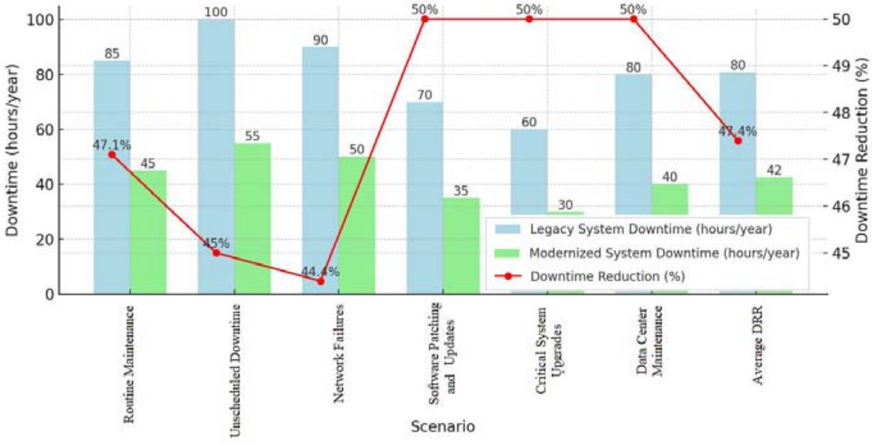

Figure 6. Downtime Reduction Ratio (DRR) for Telecommunications Operations

Figure 6 indicates an overall reduction of downtime during operations, averaging 47.4% across all test scenarios. The most significant improvements were observed in routine maintenance and software patching scenarios, with downtime reduced by half. There was also a marked decrease in unscheduled downtimes and network failures—two additional factors that enhanced overall system reliability. This reduction in downtime is crucial for the telecommunications sector, where any service outage, no matter how brief, can result in customer dissatisfaction and operational capital losses.

The next stage of implementation should incorporate AI and ML-enabled predictive maintenance to further minimize unscheduled downtimes. By predicting system failures before they occur, these technologies allow for preventive maintenance, reducing the need for emergency interventions. Remote management systems that automate routine maintenance and software updates can also streamline operations, ensuring network availability and minimizing potential disruptions. The results clearly demonstrate the benefits of modernization, leading to increased service reliability, reduced maintenance windows, and uninterrupted service availability.

4.7. Energy Consumption Reduction After Telecommunications Modernization

One of the most critical concerns in telecommunications sector operations is energy usage, given the industry's substantial power requirements for operating data centers, network facilities, and managing IoT devices. Modernizing telecom systems presents a significant opportunity to enhance energy efficiency by deploying power-efficient technologies and optimizing resource utilization. Figure 7 illustrates the energy consumption of key components before and after modernization, highlighting the reduced power consumption of upgraded systems and the associated environmental benefits.

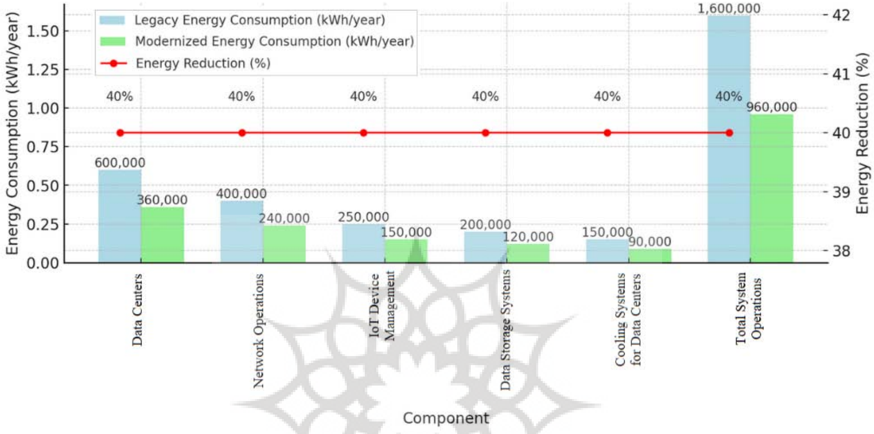

Figure 7. Energy Consumption Before and After Modernization in Telecommunications Operations

Data indicate that modernization has reduced energy consumption in all major components of telecommunications operations by 40%. The energy consumption of data centers, historically significant power users, decreased from 600,000 kWh/year to 360,000 kWh/year, contributing significantly to total energy savings. Network operations and IoT device management followed a similar pattern, with energy reductions of 40%. This substantial reduction in power usage highlights the effectiveness of modernized systems, particularly in server optimization, virtualization, and cooling system improvements.

Reduced energy consumption demonstrates how modernization fosters a more sustainable telecommunications operation by decreasing the environmental footprint. During implementation, companies can further pursue the integration of renewable energy sources such as solar or wind power to offset any remaining energy use, advancing towards carbon neutrality. Additionally, deploying advanced AI-driven energy management systems can enhance energy consumption patterns, allowing for automatic scaling of power consumption based on real-time requirements. This shift towards energy efficiency not only reduces operational costs but also aligns with broader industry initiatives focused on sustainability and environmental stewardship.

This study highlights significant financial, operational, and environmental performance improvements driven by telecommunications innovations. The Total Cost of Ownership (TCO) showed a slight decrease, with greater savings achieved over the long term primarily due to lower operational and maintenance costs. The Return on Investment (ROI) has continued to increase gradually, reaching 222.2% by July 2026, reflecting the growing financial benefits of the modernization process. High-performance LTE (HPLTE) reduced latency by 63.0% (minimum of 52.2%) on Service Efficiency Improvement (SEI) with a mean of 45.5% across 10% to 90% of all network forms, enhancing performance across state security applications, IoT, and video/audio streaming.

The Network Scalability Ratio (NSR) improved twofold, as modern systems could handle more than twice the users and devices compared to legacy systems. For example, there was a 47.4% reduction in downtime, as evidenced by the Downtime Reduction Ratio (DRR), which helped boost overall reliability. Total energy consumption across all components was also 40% lower, underscoring the environmental benefits of the upgraded systems. These findings validate that modernization not only enhances operational efficiency but also leads to financial sustainability and a smaller environmental footprint.

5. Discussion

The study provides a detailed examination of the implications of digital transformation in the telecommunications sector, particularly focusing on the transition from legacy systems to modernized architectures. The results showed significant gains in operational efficiency, cost-effectiveness, service performance, scalability, and sustainability. The following section discusses the study's findings in comparison with previous studies while delineating limitations, as modernization is not without challenges.

The study's findings align with existing literature on the advantages of legacy system modernization. For example, Abu Bakar et al. (2022) reported that legacy system modernization in the public sector enhanced service delivery and operational efficiency (Abu Bakar 2022). In the telecommunications industry, our study found a 46.4% reduction in downtime and a 40% reduction in energy consumption due to modernization, resulting in improved reliability and sustainability. While Abu Bakar et al. (2022) focus on citizen-centric digital government services, our study emphasizes that modernization is equally vital for private-sector telecommunications providers, where scalability and service establishment time are critical determinants of success in an increasingly connected world.

Correani et al. (2020) emphasize that successful digital transformation must be anchored on a clear strategy that aligns technology with business objectives. This study supports this perspective, as the return on investment (ROI) analysis shows that modernization initiatives generate long-term economic benefits, with ROI increasing from 26.7% in the first year to 222.2% in the seventh year. Correani et al. (2020) also call for agility in digital transformation strategies, which is reflected in our results through edge computing and cloud integration, both yielding high cost-benefit ratios (CBRs) of 2.38 and 2.33, respectively (Correani et al. 2020).

The role of interoperability in legacy system modernization, highlighted by Venâncio et al. (2023), is another critical aspect resonating with our findings. They emphasize that modernized systems should seamlessly integrate with existing infrastructure to avoid disruptions (Venâncio 2023). Our study found that modernization reduced operational costs by 34.6%, demonstrating that integrating new technologies such as 5G infrastructure and AI-driven network management can significantly enhance efficiency without causing operational downtime. However, achieving interoperability requires careful planning, and the transformation costs ($30 million in our study) must be considered a necessary investment to ensure smooth integration.

This study presents a network scalability analysis that augments Jnr's research on smart cities. According to Antony Jnr (2021), scaling infrastructure is essential for developing smart cities (Anthony Jnr 2021). Our results show a Network Scalability Ratio (NSR) of ≥2.38, allowing more than 106 times the number of end-user devices and user scalability. This ability to scale up as needed is crucial for telecommunications providers, preparing them for the increased demands of IoT networks, 5G services, and smart city applications.

Further research from Yanikomeroglu (2021) on the open architecture of wireless access provides insights into a common growth trend across the telecommunications industry, emphasizing the need to modernize networks to support future demands. Wireless networks must be enabled to support ever-growing numbers of devices and data streams (Yanikomeroglu 2021). Our findings show that modernized systems, with their scalable networks and reduced latency, should be able to meet these future demands, allowing telecommunications providers to stay competitive in the long term.

Garcés et al. (2016) highlight the need for "white-box modernization" of legacy applications to ensure the transformation journey is transparent and comprehensible to a wide range of stakeholders. This research confirms this perspective, showing that telecom modernization builds robust technical utility and creates financial transparency with clear ROI and CBR metrics that validate the expenditure (Garcés et al. 2016). However, constant communication and inclusion between technical teams and business decision-makers are needed to align modernization efforts with organizational goals.

Notwithstanding the favorable results elucidated in this study, several limitations must be acknowledged. While our analysis highlights the financial and operational benefits of modernization, it does not consider external factors such as regulatory changes, competitive pressures, or technological advancements that could impact the success of modernization efforts in the future. Variance in ROI, TCO, and operational performance not specifically accounted for in our model could arise due to these factors.

The assessment is based on select components of modernization like edge computing, cloud integration, and 5G infrastructure. Future studies may broaden the scope to include other emerging technologies such as quantum computing, blockchain, and advanced AI models to evaluate their implications on telecommunications systems. This would offer a better perspective on how different technological developments impact broader system performance and business success.

The study primarily concerns the financial and operational aspects of modernization. While these are important parameters in determining the success of digital transformation, social and ethical concerns around data privacy, cybersecurity, and workforce impact also need consideration. Chernikova et al. (2023) note that digital transformation often challenges traditional management structures and established work practices, which may counteract change and affect modernization effectiveness. Attention to these human factors is crucial for making the transformation process sustainable and widely accepted within the organization (Chernikova 2023).

Although this study offers invaluable conclusions on cost-efficiency and energy savings, it is worth noting that the long-term environmental impacts of modernization were not thoroughly assessed. Future studies could focus on analyzing the carbon footprint created by modernized telecommunications infrastructure, which would help evaluate sustainability perspectives beyond energy consumption, as suggested by Kandukuri (2019) (Kandukuri 2019).

This study validates the significant benefits digital transformation brings to telecommunications, supported by existing research on the positive financial, operational, and sustainability impacts of modernizing legacy systems. With more consideration to limitations such as external market influences, emerging technologies, and social and ethical considerations, future research can present a broader picture of the long-term implications of modernization.

6. Conclusions

The article provides an analytical survey on digitalization in telecommunications, emphasizing the shift from legacy methodologies and infrastructures. The research results highlight critical aspects such as cost savings, operational improvements, service delivery quality, data management scalability, energy management, and sustainability. This study presents quantitative data on Total Cost of Ownership (TCO), Return on Investment (ROI), Service Efficiency Improvement (SEI), Network Scalability Ratio (NSR), Cost-Benefit Ratio (CBR), Downtime Reduction Ratio (DRR), and energy consumption, demonstrating the long-term value and necessity of systems modernization in the rapidly evolving telecommunications sector.

Telecommunication systems exhibit a long-term return on investment. The ROI results reveal consistent growth, with returns increasing from 26.7% in the first year to over 222% by year seven. This rise indicates the long-term impact of modernization initiatives, as lower operational and maintenance costs, improved service provision, and greater scalability continue to yield substantial financial returns. The study also shows a remarkable 45.5% average latency decrease in SEI, illustrating the advantages service providers gain through modernization, particularly in latency-sensitive applications such as IoT, video streaming, and cloud computing.

The results further indicate that modernized systems have a Network Scalability Ratio (NSR) 2.38 times higher than legacy systems, enabling telecommunications service providers to support more than twice the number of users and devices. This capability is urgently needed due to the proliferation of IoT networks, 5G services, and smart city projects. The average Downtime Reduction Ratio (DRR) of 47.4% underscores the high reliability essential for telecommunications services, preventing service outages and ensuring continuous availability.

One of the key takeaways is a 40% energy savings in core telecommunications operations, highlighting the significant environmental benefits of modernization. This emphasizes the need for organizations to modernize not only operationally but also in alignment with their sustainability goals. Energy-efficient data centers, optimized network infrastructure, and advancements in cooling technologies all contribute to a more sustainable telecommunications ecosystem.

This study is unique in its systematic investigation of modernization in telecommunications, considering financial, operational, and environmental benefits. While transdisciplinary studies have assessed various aspects of digital transformation outcomes, no prior studies have proposed a synthesized framework combining multiple metrics, such as TCO, ROI, SEI, NSR, CBR, DRR, and energy consumption, to establish the modernization impacts within a shared framework. Furthermore, this research highlights the importance of emerging technologies (edge computing, cloud integration, and AI-driven network management) in realizing these benefits, offering insights into the future of telecommunications systems.

Although this study provides important insights, several limitations need to be addressed in future research. Firstly, the analysis heavily relies on financial and operational metrics, overlooking the significance of factors related to cybersecurity, data privacy, and workforce transformation in the context of digital transformation. Future research could explore the integration of AI and automation in telecommunications companies, including their implications for employees and organizational structures. Additionally, future studies could examine the long-term environmental effects of modernization, considering changes in energy consumption and the carbon footprint associated with infrastructure adaptation.

Based on these findings, the next line of research could focus on more complex technologies and their potential to shape future telecommunications systems, including quantum computing and blockchain. As the industry evolves, these technologies could play a crucial role in the next steps of digital innovation, driving greater scalability, security, and efficiency.

Future research could extend this study by exploring the relative impacts of various modernization approaches across different geographies and market segments. For instance, the specific challenges of developing regions may require more localized responses to modernization, particularly in infrastructure development and cost control. Comparative studies across regions and industries could provide a more nuanced understanding of the global implications of telecommunications modernization.

The article illustrates that digital transformation and modernization can yield substantial financial, operational, and environmental benefits for telecommunications providers. However, continued research and innovations are essential to fully unlock the potential of modernized systems and address emerging challenges in an increasingly fast-paced digital landscape.

References

Abbas, T. N. A., Hameed, R., Kadhim, A. A., and Qasim, N. H. (2024). Artificial intelligence and criminal liability: exploring the legal implications of ai-enabled crimes. *Encuentros. Revista de Ciencias Humanas, Teoría Social y Pensamiento Crítico.,* (22), 140-159. https://doi.org/10.5281/zenodo.13386675

Abu Bakar, H., Razali, R., and Jambari, D. I. (2021). Legacy Systems Modernisation for Citizen-Centric Digital Government: A Conceptual Model. *Sustainability*, 13 (23). https://doi.org/10.3390/su132313112.

Abu Bakar, H., Razali, R., Jambari, D. I. (2022). A Qualitative Study of Legacy Systems Modernisation for Citizen-Centric Digital Government. *Sustainability*, 14 (17). https://doi.org/10.3390/su141710951.

Ageyev, D., Al-Anssari, A., Qasim, N. (2015). Multi-period LTE RAN and services planning for operator profit maximization. *The Experience of Designing and Application of CAD Systems in Microelectronics,* 24-27 Feb. https://doi.org/10.1109/CADSM.2015.7230786.

Ageyev, D., Yarkin, D. Qasim, N. (2014). Traffic aggregation and EPS network planning problem. *2014 First International Scientific-Practical Conference Problems of Infocommunications Science and Technology,* 14-17 Oct. https://doi.org/10.1109/INFOCOMMST.2014.6992316.

Anthony Jnr, B. (2021). Managing digital transformation of smart cities through enterprise architecture – a review and research agenda. *Enterprise Information*

Systems, 15 (3), 299-331. https://doi.org/10.1080/17517575.2020.1812006
Beregi, R., Pedone, G., Háy, B., and Váncza, J. (2021). Manufacturing Execution System Integration through the Standardization of a Common Service Model for Cyber-Physical Production Systems. *Applied Sciences*, 11 (16). https://doi.org/10.3390/app11167581.
Chernikova, N., Ishchenko, I., & Bolshaia, O. (2023). TRANSFORMATION OF MANAGEMENT SYSTEMS IN THE CONDITIONS OF DIGITALIZATION AND INNOVATIVE DEVELOPMENT OF ENTERPRISES. *Economic Bulletin of National Technical University of Ukraine "Kyiv Polytechnic Institute"*. https://doi.org/10.32782/2307-5651.25.2023.9
Correani, A., De Massis, A., Frattini, F., Petruzzelli, A. M., and Natalicchio, A. (2020). Implementing a Digital Strategy: Learning from the Experience of Three Digital Transformation Projects. *California Management Review,* 62 (4), 37-56. https://doi.org/10.1177/0008125620934864
Elina, O., & Elin, A. (2021). MODERN TRENDS IN APPLICATION OF THE ARCHITECTURAL APPROACH IN THE DIGITAL TRANSFORMATION OF ENTERPRISE. *Bulletin of Udmurt University. Series Economics and Law,* 31 (6). https://doi.org/10.35634/2412-9593-2021-31-6-947-954
Garcés, K., Casallas, R., Álvarez, C., Sandoval, E., Salamanca, A., Melo, F., and Soto, J. M. (2016). White-Box Modernization of Legacy Applications. *Model and Data Engineering,* 57, 274-287. https://doi.org/10.1016/j.csi.2017.10.004
Kandukuri, P. (2019). Software Modernization Through Model Transformations. *First International Conference on Artificial Intelligence and Cognitive Computing*, 165-174. https://doi.org/10.1007/978-981-13-1580-0_16
Lakemond, N., Holmberg, G., and Pettersson, A. (2024). Digital Transformation in Complex Systems. *IEEE Transactions on Engineering Management,* 71, 192-204. https://doi.org/10.1109/TEM.2021.3118203
Langer, A. M. (2020). Transforming Legacy Systems. In *Analysis and Design of Next-Generation Software Architectures: 5G, IoT, Blockchain, and Quantum Computing*, edited by Arthur M. Langer, 201-238. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-36899-9_10
Leon, P. L., and Horita, F. E. A. (2021). On the modernization of systems for supporting digital transformation: A research agenda. Proceedings of the XVII Brazilian Symposium on Information Systems, Uberlândia, Brazil. https://doi.org/10.1145/3466933.3466976
Mallidi, R. K., Sharma, M., and Singh, J. (2021). Legacy Digital Transformation: TCO and ROI Analysis. *International Journal of Electrical and Computer Engineering Systems,* 12 (3), 163-170. https://doi.org/10.32985/ijeces.12.3.5
Omar, S. S., Nayef, J. M., Qasim, N. H., Kawad, R. T., Kalenychenko, R. . (2024). The Role of Digitalization in Improving Accountability and Efficiency in Public Services. *Revista Investigacion Operacional,* 45 (2), 203-224. https://rev-inv-ope.pantheonsorbonne.fr/sites/default/files/inline-files/45224-11_0.pdf
Porter, J. D., Billo, R. E., and Rucker, R. (2004). Architectures for integrating legacy

information systems with modern bar code technology. *Journal of Manufacturing Systems,* 23 (3), 256-265. https://doi.org/10.1016/S0278-6125(04)80038-4

Qasim, N., Khlaponin, Y., & Vlasenko, M. (2022a). Formalization of the Process of Managing the Transmission of Traffic Flows on a Fragment of the LTE network. *Collection of Scientific Papers of the Military Institute of Taras Shevchenko National University of Kyiv,* 75, 88–93. https://doi.org/10.17721/2519-481X/2022/75-09

Qasim, N. H., Abu-Alshaeer, M. J., Jawad, A. M., Khlaponin, Y. (2022b). Analysis of the State and Prospects of LTE Technology in the Introduction of the Internet Of Things. *Norwegian Journal of Development of the International Science,* (84), 47-51. https://doi.org/10.5281/zenodo.6540099

Qasim, N. H., and Jawad, A. M. (2024). 5G-enabled UAVs for energy-efficient opportunistic networking. *Heliyon,* 10 (12), e32660. https://doi.org/10.1016/j.heliyon.2024.e32660

Qasim, N. H., Jumaa, D. A., Rahim, F., Jawad, A. M., Khaleefah, A. M., Zhyrov, G., and Ali, H. (2024). Simplifying IP multimedia systems by introducing next-generation networks with scalable architectures. *Edelweiss Applied Science and Technology,* 8 (4), 2042-2054. https://doi.org/10.55214/25768484.v8i4.1580

Qasim, N. H., Vyshniakov, V., Khlaponin, Y., and Poltorak, V. (2021). Concept in information security technologies development in e-voting systems. *International Research Journal of Modernization in Engineering Technology and Science (IRJMETS),* 3 (9), 40-54. https://www.irjmets.com/uploadedfiles/paper/volume_3/issue_9_september_2021/15985/final/fin_irjmets1630649545.pdf

Saragih, L. R., Dachyar, M., and Zagloel, T. Y. M. (2021). Implementation of telecommunications cross-industry collaboration through agile project management. *Heliyon,* 7 (5). https://doi.org/10.1016/j.heliyon.2021.e07013

Sieliukov A.V., Q. N. H., Khlaponin Y.I. (2022). Conceptual model of the mobile communication network. *The Workshop on Emerging Technology Trends on the Smart Industry and the Internet of Things «TTSIIT»*, 20-22. https://www.knuba.edu.ua/wp-content/uploads/2022/11/%D0%97%D0%B1%D1%96%D1%80%D0%BD%D0%B8%D0%BA_Optimized.pdf#page=20

Smidovych, L., and Davydovskyi, Y. (2022). PROCESSES OF THE TELECOM OPERATOR’S INFORMATION ARCHITECTURE TRANSFORMATION. *INNOVATIVE TECHNOLOGIES AND SCIENTIFIC SOLUTIONS FOR INDUSTRIES,* (1 (19)), 47-54. https://doi.org/10.30837/ITSSI.2022.19.047

Tsai, J. C.-A., Jiang, J. J., Klein, G., Hung, S.-Y. (2023). Task Conflict Resolution in Designing Legacy Replacement Systems. *Journal of Management Information Systems,* 40 (3), 1009-1034. https://doi.org/10.1080/07421222.2023.2229120

Uymaz, P., and Uymaz, A. O. (2022). Assessing acceptance of augmented reality in nursing education. *PLOS ONE,* 17 (2), e0263937. https://doi.org/10.1371/journal.pone.0263937

Venâncio, A., Brezinski, G., Leal, G., Loures, E., & Deschamps, F. (2023). Digital transformation in maintenance: interoperability-based adequacy aiming smart legacy systems. *Production,* 33. https://doi.org/10.1590/0103-6513.20220098

Warner, K. S. R., and Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. *Long Range Planning,* 52 (3), 326-349. https://doi.org/10.1016/j.lrp.2018.12.001

Wolfart, D., Assunção, W. K. G., Silva, I. F. d., Domingos, D. C. P., Schmeing, E., Villaca, G. L. D., and Paza, D. d. N. (2021). Modernizing Legacy Systems with Microservices: A Roadmap. *Proceedings of the 25th International Conference on Evaluation and Assessment in Software Engineering,* Trondheim, Norway. https://doi.org/10.1145/3463274.3463334

Yanikomeroglu, H. (2021). Wireless Access Architecture: The Next 20+ Years. *Proceedings of the 4th International Conference on Future Networks and Distributed Systems,* St.Petersburg, Russian Federation. https://doi.org/10.1145/3440749.3442647

Zimmermann, A., Schmidt, R., Bogner, J., Jugel, D., and Möhring, M. (2018). Software Evolution for Digital Transformation. *International Conference on Evaluation of Novel Approaches to Software Engineering.* https://doi.org/10.5220/0006815702050212.

Zimmermann, A., Schmidt, R., Sandkuhl, K., Jugel, D., Bogner, J., Möhring, M. (2019). Decision-Oriented Composition Architecture for Digital Transformation. *Intelligent Decision Technologies 2018*, Cham. https://doi.org/10.1007/978-3-319-92028-3_11.