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Bridging Urban Gaps Through Strategic Digital Infrastructure in Sulaymaniyah City

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Abstract. The study examines how digital infrastructure affects urban life in Sulaymaniyah through its evaluation of the relationships between urban development and public services and digital economic progress. The evaluation of digital infrastructure distribution requires analysts to merge quantitative and qualitative methods along with GIS technology data processing for assessing urban quality of life. The research investigates Sulaymaniyah to reveal the operational mechanism of smart city policies through an assessment of their roles in developing sustainable urban growth with digital infrastructure. The fundamental outcomes from digital infrastructure expenditures enhance quick service delivery speed and enable partnerships that help sustain urban development zones. Public authorities should create supportive policies for digital transformation and form partnerships between public and private organizations to develop urban digital infrastructure according to the document.

Keywords: Digital Infrastructure, Digital Transformation, Smart Cities, Urban Development, Geographic Information Systems (GIS).

I. INTRODUCTION A. Background

The advancements in digital technology during the recent years have made digital infrastructure an essential factor to develop sustainable urban development because it helps enhance public service delivery and boosts essential sector efficiency while improving city management practices. Digital transformation represents a necessity rather than an option because economic and social changes demand it thus causing multiple cities to implement advanced technologies that enhance their administrative and service systems [1]. The improvement of digital infrastructure plays an essential role in enhancing city competitiveness through its development of intelligent urban systems that uphold current technical norms to deliver peak operational efficiency across transportation and energy fields and government services and digital marketplace sectors [2]. Sulaymaniyah city functions as the primary regional authority that executes digital solutions for contemporary urban systems development. A thorough assessment must be conducted to measure digital infrastructure integration with actual urban requirements since it encounters multiple challenges in this area.

The research investigates digital infrastructure impacts on urban life in Sulaymaniyah city through assessments of digital system integration across urban zones and identification of success and failure factors in digital solution adoption and recommendations for sustainable digital development strategies.

B. Research Problem

Although initiatives to develop digital infrastructure and accomplish effective digital transformation progress continues many hurdles limit the maximal use of these developments in urban life improvement. Digital transformation success requires harmonized strategic planning which extends past technology adoption to link information systems with Urban

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Planning as well as Economic Development and public utility management [3].Sulaymaniyah faces multiple challenges in developing its digital infrastructure, as Iraq suffers from a lack of digital infrastructure in general, with an internet access rate of 75%, which is lower than the global average.In urban areas such as downtown Sulaymaniyah, internet access reaches 84%, while in the surrounding rural areas it drops to 58%, creating a clear digital divide and the city suffers from multiple technical and economic challenges, including the increasing complexity of digital infrastructure and the high costs of equipment and software. Sulaymaniyah faces integration obstacles between its quick urban expansion and digital infrastructure advancement because digital inequality exists between social groups throughout the city [4].The city faces two main obstacles regarding supportive government policies in transformation alongside necessary strategic partnerships between public and private sectors for maintaining sustainable projects [5].The leading research inquiry of this study asks "How much can digital infrastructure improve Sulaymaniyah's urban life while overcoming obstacles to achieve sustainable development"

C. Research Objectives

This research identifies strategic objectives which explain how digital infrastructure relates to Urban Development through Sulaymaniyah as its applied research site. The investigation performs a comprehensive investigation of digital technology in urban planning while introducing methods to enhance their connection for sustainable development. A total of three essential research objectives underpin this project.

1. The study examines the effects that digital infrastructure has on urban living quality standards.
   a. Researchers explore how digital transformation support fundamental service development that consists of healthcare systems alongside educational facilities and power generation and transport services.
   b. Assessment of the impact of digital infrastructure on the speed and efficiency of the provision of public services to the population.
   c. Through its digital process establishments develop critical interconnecting capabilities that link multiple urban sectors by creating interactive systems to satisfy population needs.
   d. The analytical essay investigates how smart technology handles procedures to boost daily quality by using advanced urban facility management methods that integrate automated lighting systems together with digital waste disposal and smart environmental surveillance techniques.
2. Examine the extent of digital infrastructure which connects urban functions across the entire city territory
   a. The evaluation process aims to identify digital network coverage depth across Sulaimaniyah along with assessing modern telecommunication systems and broadband connectivity.
   b. The research monitors the preparedness levels among different city zones to execute digital changes via e-commerce and digital banking and smart transportation systems.
   c. GIS technology serves to evaluate how digital services disperse throughout various urban territories across the city boundaries.

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d. The evaluation of digital service equity requires research to assess the geographical separation between inner-city regions and outer urban districts.

3. Review of government policies and strategies in the development of digital infrastructure
   a. This assessment requires evaluation of digital transformation regulations from local government to check their consistency with modern standards of urban development.
   b. Performance assessment functions as the assessment technique adopted by researchers to evaluate digital infrastructure development initiatives run by the Sulaimaniyah government.
   c. Researchers evaluate area development criteria against digital city standards that stem from progressive global sustainable building frameworks.
   d. Top public officers need to examine how well government initiatives synchronize with market-driven approaches that facilitate digital transformation via technological advancement.
   e. Development-related knowledge enables digital transformation by conducting result transfer work at educational research centers and academic centers that perform research activities.

4. The assessment follows a structured process to find out what exactly prevents digital infrastructure expansion
   a. The price of development combined with funding constraints reduces digital infrastructure development in the city area.
   b. Digital transformation needs us to focus on legislative barriers that consist of weak data protection legislation and poor cybersecurity elements with inadequate protocols for implementing digital government services.
   c. The analysis of digital infrastructure starts by assessing inadequate telecommunication network infrastructure before moving onto the analysis of shortfalls in digital system management personnel and concludes by investigating differences between system interoperability.
   d. Technical perception among residents and resistance toward change among specific groups together with insufficient digital skills of population members become obstacles for implementing digital solutions.
   e. The environmental monitoring process for digital transformation measures power consumption increases in data centers as well as the electronic waste caused by rapid technology advancement.

5. The project needs to provide specific solutions which will create a unified digital transformation model for Sulaimaniyah.
   a. The author recommends applying particular implementations to merge urban infrastructure and digital tools so the public services function better with sustainable development processes.
   b. Executive templates from this project will exist for the city to use according to identified funding needs and required partnership partnerships.

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c. The strategy needs to provide digital transformation education to local people while also promoting technological adoption within residential activities.
d. A combination of legislative and regulatory elements must exist within the initiative to achieve data security increases with person-focused digital governance protection methods.
e. Aresearch analyzes international smart city successful models to generate recommendations about their implementation in Sulaimaniyah with emphasis on cultural, social and economic local conditions.

D. The Importance of Research

The research holds importance because it analyzes a fundamental modern challenge regarding digital solutions for sustainable urban development in present-day cities. For complete assessment of digital infrastructure researchers need to examine all key technical economic and social aspects which help boost urban quality of life [5].Three main research achievements mark the conclusion of this investigation.

1. The investigation of digital transformation effects on urban development needs to fill gaps which currently exist in research areas. The research conducted by local studies generally fails to analyze deep relationships between digital tools and urban master planning methods [6].
2. Urban management systems receive a boost from digital solutions during sustainable development goal advancement processes. The technology works as an enhancer for public service delivery and economically strengthens operational effectiveness [1].Analysis combining GIS and statistical data through urban policy assessments determines how digital services spread in Sulaymaniyah according to [1].
3. The city should support public-private partnerships for infrastructure development by forming collaborations to implement digital systems founded on worldwide leading practices [2].
4. Additional studies of digital transformation require scholarly support to evaluate its effects on multiple urban elements including sustainable housing and environmental maintainability and urban planning. The research work lays groundwork for creating contemporary analysis methods that determine digital technology effects on urban growth and transformations.

E. Expected Results of the Research

1. The existing previous objectives will lead to positive outcomes for this current study.
2. The research brings about precise outcomes regarding digital infrastructure effects on urban growth thus helping Sulaimaniyah develop better strategies.
3. This research needs to develop a standard digital readiness evaluation method to provide specific instructions about essential sustainability actions for the city.
4. Sustainable solutions are presented within this research to address digital transformation hurdles through economic administration technology and technological perspective implementation.

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5. This initiative helps public institutions establish new channels together with business entities and academic establishments for constructing smart cities in Iraq especially in Sulaymaniyah.
6. The development of technology implementation strategies depends on research insights which drives the creation of digitalization policies for urban management of the city.
7. The research undertakes a unified analytical approach for digital infrastructure investigation of urban growth while focusing the analysis on Sulaymaniyah. This study incorporates established work objectives to function as both(ErrorMessage: Context not provided. Context must be included to understand the response). Additional information about the subject is essential to understand the response it produces. This research establishes methods to integrate digital advancement within urban planning operations for developing cities which achieve smart operational capabilities combined with skilled future challenge management.

F. Research Hypotheses

1. The hypotheses will receive validation through existing research which supports this analysis.
2. Smart technology investments into digital infrastructure result in enhanced public service delivery which combines decreased operational costs with accelerated process and delivery services and improved organizational quality.
3. The support of microwave technology leads to positive economic expansion through its capability to help develop infrastructure and promote new business creation along with market system development.
4. The implementation of digital transformation projects encounters financial risks in addition to managerial challenges which demand legal involvement during every phase to reach digital success through stakeholder teamwork.
5. The efficiency of urban planners can be enhanced when they use GIS to monitor land patterns then predict future urban challenges for developing necessary digital services.
6. The combination of traditional methods with digital technologies in strategic plans generates optimal city performance outcomes and results in well-balanced development results when planning occurs.

II. METHOD A. Theoretical and Methodological Framework

This section deals with the theoretical and methodological framework on which the research is based in analyzing the role of digital infrastructure in enhancing urban life in the city of Sulaymaniyah. This part is divided into four main axes that include previous studies, the theoretical framework of digital infrastructure, research methodology and tools, and finally the study area with the analysis of detailed maps of the city of Sulaymaniyah.

B. Previous Studies

1. The Role of Digital Infrastructure in Supporting Inter-Institutional Cooperation

Digital transformation enables organisations to build better collaboration systems which enhance both administrative speed and reduce complex conventional operational

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processes [6].The research relied on data collection from different administrative institutions operating in Northern Technical University. The author explained that digital infrastructure delivers both improved information movement and expedited together with enhanced accurate decision processes. The research validation backs digital transformation initiatives in Sulaymaniyah by enhancing local administrative decisions and integrating body interactions and citywide services.

2. Digital Engineering and its Role in The Development of Urban Projects

The research in [7] demonstrates how digital engineering methodologies help lower operation expenses and boost efficiency in urban project infrastructure management systems. Cities implementing revolutionary digital solutions accomplish rapid growth because they deliver better services to their citizens. Land resource management along with service efficiency in Sulaimaniyah City needs artificial intelligence coupled with Internet of Things (IoT) integration into geographic information systems (GIS) for the realization of digital implementation of the urban framework.

3. Digital Transformation and Smart Societies in the Arab world

This academic work [8]. investigates digital transformation trends in Arab communities together with their effect on urban development. Digital transformation emerges as a unique chance to enhance city management because technology applies to government services along with education healthcare and urban planning. Future investigations of smart communities projects in Sulaymaniyah city and other Arab nation strategies need to evaluate their fit with local urban requirements.

4. The Development of Digital Infrastructure and its Impact on Economic Growth

The study by Bengali [9] shows a direct connection between digital infrastructure spending and economic progress. Research findings indicate that digital transformation generates both fresh employment possibilities and efficient capital flow that drives productivity growth for city economic power development. Enhanced digital infrastructure systems in Sulaymaniyah will elevate the private sector performance while elevating sustainable economic growth through foreign investments.

5. Digital Infrastructure and Attracting Foreign Investments

Digital infrastructure development maintains a connection with patterns of foreign direct investment as demonstrated by [10]. When cities unite their digital service networks under one unified system their investor appeal increases because this approach produces business conditions which combine stability with flexibility. The study presents advantages to Sulaimaniyah city through its findings about implementing better digital infrastructure to enhance foreign business attraction.

6.The Impact of Digital Infrastructure Development on Economic Growth

The research of [11] investigated the connection between digital infrastructure development and economic growth levels in developing nations. According to the research the funding of technology creation leads to better productivity rates together with increased economic competitiveness. The research examines local economic effects which digital

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transformation has on Sulaymaniyah's local economy and its potential as a factor for sustainable growth through this main research axis.

7. The Impact of Digital Technology on Productive Sectors

Studies have demonstrated that the integration of digital technology in agricultural farming produces higher production volumes and diminished waste levels according to [12]. Brought together AI systems and IoT enable better management of agricultural resources and supply chain operations according to research. Digital advancement throughout Sulaymaniyah needs to grow industrial operations and trade activities to build different economic revenue streams with long-term sustainability.

8. The Role of Infrastructure Networks in Improving Community Relations

The researchers in [13] investigated how digital infrastructure networks affect city community cohesion. Public relations enhanced through digital interactions between citizens and government agencies create better openness in governance operations and public engagement. The study must investigate digital infrastructure connections to population needs throughout Sulaymaniyah city and monitor their effect on service consumption rates among city residents.

9. The Economic Impact of Digital Infrastructure Investments

Through their analysis the author establishes that official investments in digital infrastructure support lasting economic expansion as they improve both manufacturing output and upcoming funding. [14]Research findings support the essential statement that digital infrastructure upgrades in Sulaymaniyah will stimulate economic growth and support balanced territorial development.

10. The Relationship Between Public Policies and Digital Economic Growth

Digital infrastructure development receives additional acceleration through governmental backing and financial expansion which drives economic growth when development strategies overlap with digital transformation initiatives [15]. Sulaimaniyah needs to assess digital transformation policies based on their financial alignment with development infrastructure demands.

11. The Impact of Technology on Economic Productivity

The [16] dealt with the role of technology in improving economic productivity, as it emphasized that digital innovation contributes to making qualitative leaps in operational efficiency, which leads to an increase in the growth rate. This axis represents one of the most important elements of the current research, where the extent of the impact of digital technology on improving the performance of economic sectors in the city of Sulaimaniyah will be assessed.

Table 1. Previous Studies in the Context of Digital Transformation: An Analytical Review:

Reference	Main Topic	Key Findings
Abdul Jabouri (2021)	Role of Digital Infrastructure in Management	Improved information flow and increased institutional efficiency

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Al-Bustanji (2024)	Digital Engineering in Municipal Projects	Improved resource management and reduced waste
ESCWA (2020)	Digital Transformation and Urban Development	Supported transparency and enhanced community participation
Shafaq News (2024)	Digital Investment and Economic Growth	Created job opportunities and stimulated investments
Rasheed & Kareema (2018)	Digital Infrastructure and Investment Attraction	Enhanced business environment and attracted global companies
Smithson (2023)	Digital Technology and Agricultural Production	Improved productivity and reduced waste
Solow (1956)	Technology and Economic Growth	Increased operational efficiency and achieved sustainable growth

C. Theoretical Framework of Digital Infrastructure

Bounded within the Kurdistan region of Iraq Sulaymaniyah stands as an important settlement due to its essential geopolitical position near the northeastern border of the country. Residents consider this city to be one of the priority settlements in its geographic territory. Sulaymaniyah governorate accommodates 2.3 million inhabitants with an urban population total of 1.9 million residents while its rural regions count 347 thousand people. Information transmission and processing activities rely on digital infrastructure which represents interconnected systems with technologies that create a digital base for their operations. Data centers along with Communication networks and Geographic Information Systems and Technologies that employ artificial intelligence and IoT represent examples of such systems.

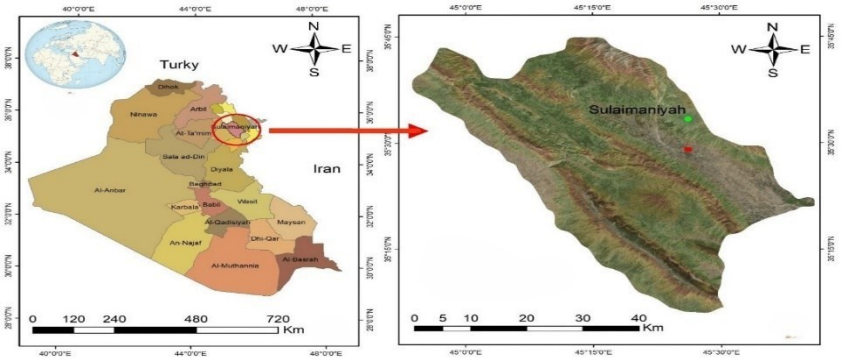

Figure 1. Map of the Geographical Location of Sulaymaniyah source "Kurdistan region Statistics Office"

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Modern technology adoption at high levels in Sulaymaniyah city generates fast development of digital network infrastructure alongside technological innovation. According to statistics smartphone adoption is very strong since users exceed 85% of the total population. Citizens from Sulaymaniyah heavily depend on digital services for daily operations since they utilize digital resources for 4.7 hours per day. It establishes firm support for this changing trend because the ICT industry experiences annual growth of 13%. The digital infrastructure of Sulaymaniyah needs better development because the urban districts get superior service quality than rural areas. Universal internet access in the city area stands at 84% but only 58% of people in rural areas have internet connectivity. Telecom providers in the area use their finances to create new infrastructure networks alongside expanding their service domains for better overall performance. Multiple technological elements used to improve urban service delivery merge into digital infrastructure which delivers smart city capabilities for operation. The smooth data transmission and unified system operation base depends on several fundamental structural elements. The regular digital infrastructure contains six basic elements presented in the picture below that include hardware, software, data management, cybersecurity, networking and systems administration and maintenance.

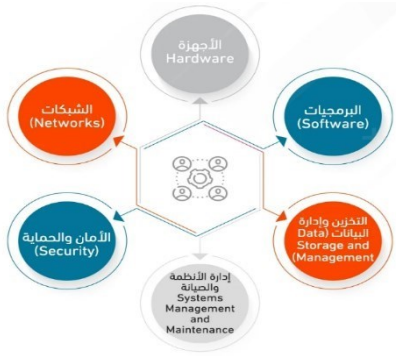

Figure 2. Basic Components of Digital Infrastructure

All essential parts which enable digital infrastructure systems for successful smart city development are shown in the exhibition model. Better public performance and urban economic success developed from digital systems because they used networked digital infrastructure components. Enterprise servers along with computers and IoT devices operate data procedures to enhance digital system performance at infrastructure bases. The system software provides users access to analytical tools along with operational management instruments which link smart city programs with advanced big data analytics solutions supported by cloud computing for exact data-based decision-making.On the other hand, storage and data management (Data Storage and Management) is one of the crucial factors that ensure the continuity of digital systems, as data centers and cloud storage bases allow storing and processing huge amounts of data quickly and efficiently, which contributes to improving decision-making mechanisms at the governmental and planning level. However, the development of these systems requires effective measures to protect and secure data, and here comes the role of security and protection (Security), as cybersecurity includes measures and technologies aimed at protecting information from cyber attacks and ensuring data integrity, which is extremely important in smart cities that rely on the flow of sensitive information through advanced digital networks [17] .Networks

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play a pivotal role in the integration of these elements, as they represent the backbone of the digital infrastructure, allowing various devices and systems in the city to be connected via the internet, which contributes to speeding up the transfer of information and improving the efficiency of providing digital services. Finally, systems management and Maintenance ensures the continuity of the efficient operation of these systems, as digital transformation requires periodic maintenance operations, intelligent management of digital facilities, which contributes to enhancing digital performance and reducing unplanned downtime[18].

Sustainable service delivery coupled with better living quality emerges from actual technological implementations which create the foundation for smart city development. The research analyzes sustainability in urban development by evaluating networking and digital changes then studies Sulaymaniyah's initiatives toward achieving Sustainable Development Goals. The construction of smart cities proceeds through physical elements up to programming levels until network completeness and data security measures are achieved. Sulaymaniyah city needs strategic planning based on modern technological solutions which will establish superior digital infrastructure. Public services within the city will experience improvements and economic digital expansion will increase hand in hand with extended sustainability. Successful digital transformation of smart cities depends on complete unified execution of their digital infrastructure according to this approach. Sulaymaniyah will acquire sophisticated digital infrastructure through government-sanctioned sustainable funding in addition to technological integration in local enterprise arenas.

D. The Role of Digital Infrastructure in Smart Cities

Perfect urban management relies on smart city technologies to maximize the sustainability of public resource and service operations. The primary success factor in smart city development relies on digital infrastructure because it provides the essential framework to unite all smart system networks including Transport and energy and security and health and education.

1. Improving the delivery of public services

   Better public service facilities arise from modern technology deployments in infrastructure to achieve successful smart city development. The executive leadership of hospitals directs administrative departments to monitor distant healthcare services through modern systems which provides advanced medical care quality and enhanced disaster readiness.

2. Enhance resource consumption efficiency

   Private network systems power the upcoming smart cities to improve energy usage and water management while achieving lower operational costs for environmental sustainability purposes. The collection of operational energy data by smart meters helps authorities create accurate energy usage patterns that show actual consumption rates.

3. Supporting innovation and entrepreneurship

   Startups can access AI and big data solutions with help from digital infrastructure because it enables digital enterprise growth and breakthrough business ideas. Digital infrastructure enables both the digital economy to run e-commerce operations and technological changes in diverse business sectors.

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4. Enhancing e-governance and community participation

   Digital infrastructure helps e-governance through its capability to enable the delivery of government services on digital platforms that both simplify administrative functions and make everything more transparent. The infrastructure makes it possible for citizens to take part in decision-making through digital questionnaire systems and social interaction platforms.

5. Achieving integration between different sectors

   The implementation of digital infrastructure enhances data exchange between different sectors which leads to enhanced cooperation between sectors. Smart cities operate electric vehicle charging station electricity consumption oversight by connecting their energy and transportation systems.

6. Improving security and Crisis Response

   The implementation of intelligent security systems which include AI-based video surveillance and security data analysis helps Crisis Response and decreases crime activities. Cities acquire real-time data abilities to make crucial emergency and disaster decisions by establishing rapid response systems through these technologies.

E. Research Methodology and Tools

An integrated analysis structure serves as the base for this research to examine digital infrastructure effect on Sulaimaniyah city urban development. The study employs geographical data evaluation together with statistical data analysis to establish digital service usage patterns while collecting field survey data about population digital service usage. This research uses field data evaluation to analyze digital transformation processes and metropolitan changes based on existing studies about digital infrastructure and economic growth analysis [19].

1. Analytical Approach

The analysis gathers numerical data concerning digital infrastructure coverage in Sulaymaniyah and its relationship to public services and economic growth. The analysis uses statistical tools to examine digital investment-performance relationships for life quality enhancement through predictive and statistical correlation methods supported by time trend evaluations. Research depends on internet distribution information together with network operation efficiency measurements and digital infrastructure budget figures to help researchers determine digital framework weaknesses and digital transformation approach in the city. The notion of sustainable development demands infrastructure investments as the economic growth theory states that this investment leads to elevated productivity and stimulates innovative measures. The development of environmentally sustainable business settings through economic and technological policies drives urban growth [20].

2. Study Tools

a. Analysis of Statistical Data

The research about Sulaymaniyah city contains statistical investigations of digital infrastructure spending and internet dissemination along with communication network efficiency. The statistical assessment demonstrates that enhancing telecommunications networks drives internet expansion together with superior urban

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life quality standards and it quantifies digital transformation results in education and healthcare sectors and e-commerce practices. The introduction of digital infrastructure investments into developing countries leads to enhanced economic competition and establishes innovation-driven economies to promote entrepreneurial activities according to research [21].

b. Using Geographic Information Systems (GIS) for digital mapping

Geographic Information Systems (GIS) technologies are employed to produce detailed maps showing the prevalence of digital services in various areas of Sulaymaniyah city. This helps to identify digital gaps, analyze the extent to which digital infrastructure is integrated with urban planning, which allows developing practical recommendations for improving digital services in underserved or less developed areas.

The geographical analyzes that will be carried out include:

1) The research analyzes how telecommunications networks along with the internet extend their reach through areas and which neighborhoods experience higher or lower internet service coverage.
2) The assessment of underdeveloped digital infrastructure areas will guide solutions to develop these areas based on economy and population group distribution.
3) The interactive mapping tool enables assessing digital service benefits for residents so that the city can create better policies to enhance digital inclusivity throughout the urban area.
4) Academia supports digital infrastructure investments because they help build connected urban space while enabling superior networked connections to services while promoting resource equality [22].

c. Distribution of Questionnaires to the Population to Measure the Extent of Utilization of Digital Services

1) The data collection research method includes distributing questionnaires to financial groups with different age backgrounds found throughout Sulaymaniyah city. Furthermore the questionnaire gathers information about these various areas:
2) The total adoption of digital services among society includes e-payments along with digital government platforms and online learning possibilities.
3) Digital technology determination factors together with population satisfaction toward internet and communication network quality function as points of analysis.
4) The research must evaluate digital service accessibility through population-based inequality assessments while examining both metropolitan and outlying zones and their associated service delivery levels.
5) The research team collects resident feedback about digital infrastructure improvement through their suggested solutions for city digital service creation by performing the survey.
6) Scientific studies reveal that enhanced economic development happens through innovation because accessible internet makes workplaces better and more productive [23].

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3. The Importance of Research Methodology in the Analysis of Digital Transformation in Sulaymaniyah

a. The consolidated method serves as an integrated system for evaluating digital infrastructure capabilities which lead to successful urban development in Sulaymaniyah. This study combines statistical digital data assessments with service territory evaluations alongside user questionnaire results to build an improved analytical model for finding gaps accompanied by their problems and solution methods.
b. Statistical data analysis will deliver quantitative findings about Internet and communication network growth relative to service quality throughout the city.
c. Research using geographic information systems (GIS) technology produces detailed spatial assessments about digital gap-affected areas to help experts develop project recommendations for these areas.
d. The insights gathered from the population through questionnaire surveys about digital benefits will result in tangible suggestions for elevating the success of complete digital services.
e. Studies validate digital infrastructure represents a vital factor towards developing sustainable development while boosting inter-city competitiveness through the distribution of improved economic gains from utilizing modern technology.
f. The analysis of digital infrastructure effects on Sulaymaniyah urban development utilized three research methods including quantitative data review and geographical visualization and onsite survey practices. The statistical information analysis leads to visible patterns of internet and communication network spread through GIS methods that show digital service delivery territorial challenges. The research used field questionnaire assessments to discover digital inclusion advantages before developing strategies for sustainability in urban development.

F. Study Area (With Detailed Maps of Sulaymaniyah City) 1. Administrative Divisions

Sulaymaniyah stands out as a significant cultural economic hub which makes it one of the key settlements in the Iraqi Kurdistan region. The established digital infrastructure of the city supports multiple industries through its well-developed nature such as telecommunications and digital government services as well as technological investments. The analytical high-level understanding of the region relies on mapping digital infrastructure distribution with simultaneous presentation of internet adoption levels and telecommunications network coverage along with recent investment projects. The Sulaymaniyah governorate contains multiple administrative districts including Sulaymaniyah, Jamjmal, Dukan, Kalar, Rania, Bashdar together with other districts. This division serves to examine how digital infrastructure distributes throughout different administrative areas to locate regions that require Internet and communication service development.

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Figure 3. Administrative Division of Sulaymaniyah Governorate Source "Practical Basic Data (COD)," Administrative Sub-Borders of Iraq

a. The map shows the geographical distribution of the main districts within the Sulaymaniyah governorate.
b. This division makes it possible to study the digital infrastructure based on the needs of each jurisdiction.
c. This map helps to identify the digital gaps between urban and rural areas within the governorate.

2. Main Roads and Digital Coverage

This map shows the main road network within Sulaymaniyah city, which includes the main roads connecting various areas, such as:

a. 60-meter street: one of the most important main streets, as it connects commercial and residential areas.
b. Salem Street: one of the important axes in the city, serving many neighborhoods.
c. Birmam Street: a main road connecting the city center and the northern areas.
d. King Mahmoud Street: a vital road serving the southern regions.

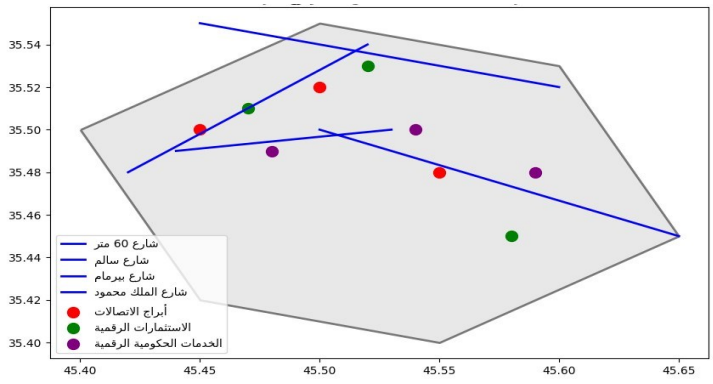

Figure 4. Map of Sulaymaniyah City With Main Streets.

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3. Telecommunications Network Coverage

The Map Shows How Digital Infrastructure Affects The Accessibility Of Digital Services.

a. This information contributes to understanding the relationship between the distribution of digital towers and centers and the transport network within the city.
b. This map helps in urban planning to expand the range of digital services based on the population density in different neighborhoods.
c. This map shows the distribution of coverage of various telecommunications networks 2G (G3, G4, G5) within the city of Sulaymaniyah. This information is necessary to assess the availability of digital communication services, identify areas that need to be developed in the communications infrastructure.

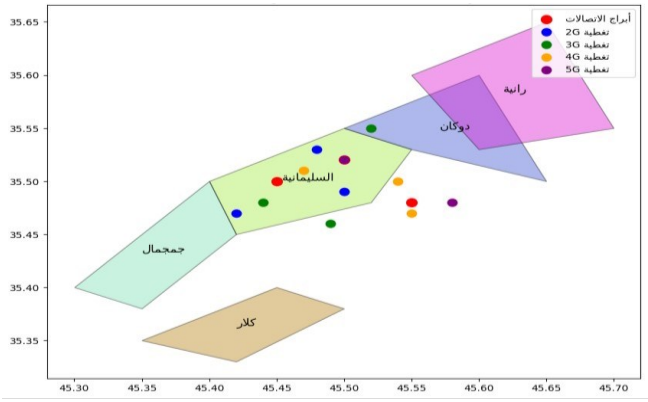

Figure 5. Map of Telecommunications Network Coverage in Sulaymaniyah

d. The map shows the areas of deployment of various communication networks, marking them with different colors.
e. The data shows areas of strong coverage versus areas with poor connectivity.
f. The map provides valuable information on how ready the city is for digital transformation, whether there are areas that need improvement in Internet speed and connection quality.

G. The Importance of Geographic Maps in Studying Digital Infrastructure in Sulaymaniyah

Geographic maps represent a powerful analytical tool for understanding the spatial distribution of digital infrastructure and its impact on urban development in Sulaymaniyah. Geographic analysis using maps helps identify digital gaps, monitor the spread of telecommunications and internet services, and evaluate digital investments in the city. This approach helps provide a more accurate picture of the challenges and opportunities associated with developing digital infrastructure, supporting data-driven decision-making in the digital transformation process [24].

1. Analyzing the Geographic Distribution of Digital Infrastructure

Geographic maps contribute to analyzing the relationship between administrative distribution and digital coverage, which helps formulate more efficient infrastructure

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development policies. The first map, which displays the administrative divisions of Sulaymaniyah Governorate, is a key reference for understanding the different needs of each region, enabling more accurate targeting of technological investments. According to [25]developing infrastructure in urban areas requires a careful analysis of the geographical distribution of digital services, as it is a crucial factor in achieving economic and social development. Second: Analyzing the extent of internet penetration and communication networks

2. The Second Map Shows The Availability of Internet Services and Communication Networks

In various neighborhoods, enabling us to identify digital gaps that need further improvement. This data reflects the city's readiness for digital transformation and its ability to embrace new technologies such as 5G, a key pillar in the development of smart cities. Investments in the internet and communications sector also play a significant role in improving digital services. [26]study indicates that internet service providers, such as Earthlink, are working to enhance digital infrastructure through fiber optic projects, which contributes to improving connectivity quality and internet speed.

3. The Role of Maps in Supporting Digital Urban Planning

Interactive maps help analyze how digital transformation will impact the future of urban planning in Sulaymaniyah. The map, which depicts the city's main road network, is a vital tool for identifying optimal locations for deploying digital infrastructure, such as communication towers and data centers, ensuring integrated access to digital services across various neighborhoods. [27] the equitable distribution of investments between urban and rural areas helps achieve balanced economic development. This means that understanding the geographical distribution of digital infrastructure can help reduce digital gaps between different areas within a city.

4. The Possibility of Planning for Digital Infrastructure Development

Maps provide valuable information that supports government agencies and the private sector in making informed investment decisions regarding digital transformation projects. For example, the third map shows the coverage of various telecommunications networks in the city, helping identify areas that need additional investment to enhance connectivity. Geographic data analysis is an essential tool for supporting the development of telecommunications services and expanding internet coverage to meet the growing needs of the population.

H. Summary of the Geographic Analysis of Digital Infrastructure

1. The maps provide a comprehensive analysis of the strengths and weaknesses of digital infrastructure within Sulaymaniyah, enabling improved efficiency of digital transformation strategies.
2. The digital gaps between different neighborhoods require targeted investments in telecommunications and internet networks to ensure digital equity.
3. Digital urban planning requires basing its decisions on accurate geographic data to ensure the provision of resilient and sustainable infrastructure that supports smart cities.

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4. Geographic data analysis supports directing investments to areas of greatest need, contributing to sustainable development at the economic and social levels.
5. Through this integrated geographic analysis, decision-makers in Sulaymaniyah can achieve a sustainable digital transformation, ensuring the city's evolution towards a smarter, more efficient model utilizing modern technology.

III. ANALYSIS AND RESULTS

This section aims to analyze the reality of the digital infrastructure in Sulaymaniyah by examining the development of telecommunications networks, internet penetration, and digital investments in the city. The analysis relies on official data issued by relevant authorities, along with a study of statistical indicators that reflect the extent to which the population and economic sectors benefit from digital services. The analysis is supported by graphs and tables that illustrate current digital trends, and the hypotheses proposed in the research are tested based on available data.

1. Analysis of the Reality of the Digital Infrastructure in Sulaymaniyah

Sulaymaniyah is considered one of the leading cities in Iraq in terms of the availability of digital services and technological infrastructure. However, there are clear disparities between different areas within the city in terms of internet network coverage and connection speed. According to the [28] Sulaymaniyah enjoys an internet coverage rate of up to 85% in urban areas, while some rural areas still suffer from poor connectivity, with coverage falling to 57% in peripheral areas. The main challenges facing the development of digital infrastructure in Sulaymaniyah:

a. Lack of investment in fiber optic networks, with reports indicating that only 30% of the city's population has access to fiber optic internet [29].
b. Poor penetration of 5G networks, with coverage not exceeding 15% in central neighborhoods, while 80% of areas rely on 4G networks.
c. The high cost of internet subscriptions relative to per capita income, limiting the wider spread of digital services [30].

Future Vision: The Digital Infrastructure Development Strategy 2023-2028 aims to increase high-speed internet penetration to 95% by 2028 through the expansion of fiber optic projects and the strengthening of communications network infrastructure [31].

2. Analysis of Statistical Indicators for Digital Services

The following table presents the latest official data on the development of digital services in Sulaymaniyah, comparing it to national averages in Iraq:

Table 2. Digital Transformation Indicators in Sulaymaniyah Compared to the National Average in Iraq

Indicator	Sulaymaniyah	Iraq (National Average)
Internet Penetration Rate	85%	72%
Smartphone Usage Rate	89%	78%
4G Network Coverage	80%	65%
5G Network Coverage	15%	8%

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Percentage of Homes Connected to Fiber Optics	30%	22%
Number of Monthly Digital Government Transactions	1.2 million	7.5 million

Key observations drawn from the data:

a. Sulaymaniyah outperforms the national average in Iraq in terms of internet penetration, smartphone use, and 4G and 5G network coverage, indicating the city's progress in embracing digital transformation.
b. However, the percentage of households connected to fiber optics remains low (30%), reflecting the need to enhance investments in the telecommunications sector.
c. Digital government transactions are witnessing continuous growth, with 1.2 million electronic transactions conducted monthly in Sulaymaniyah, representing 16% of total digital transactions in Iraq [32].

3. Results a. Evolution of Internet Penetration in Sulaymaniyah (2018-2024)

The following figure illustrates the growth rate of internet penetration in Sulaymaniyah compared to the national average. It demonstrates that the city is making significant progress in developing internet services compared to the Iraqi average.

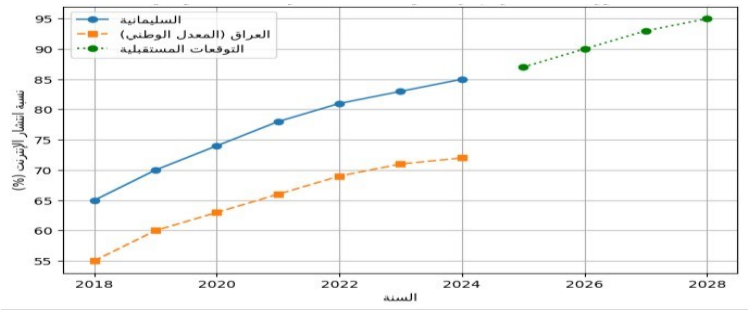

Figure 6. The Development of The Internet Penetration Rate in Sulaymaniyah (2018-2024).

The diagram shows:

✓ Increase the coverage rate from 65% in 2018 to 85% in 2024.
✓ The national average in Iraq increased from 55% to 72% during the same period.
✓ Future goal: to reach 95% by 2028 according to the strategy of the Iraqi Ministry of communications.

b. Distribution of Network Coverage in Sulaymaniyah

The following figure shows the extent of communication networks in Sulaymaniyah, and the extent to which 4G coverage exceeds 5G. He also explains that most of the peripheral regions still rely on second-and third-generation networks, which limits the ability of these regions to take full advantage of advanced digital services.

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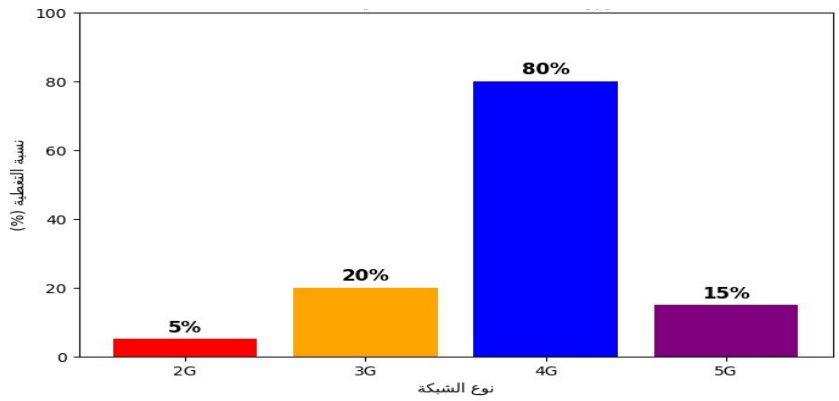

Figure 7. Distribution of Network Coverage in Sulaymaniyah

Key Takeaways:

80% of areas rely on 4G, reflecting the widespread availability of this network.

Only 15% of the city has 5G coverage, concentrated in commercial areas and vital centers.

Some remote areas still rely on 2G and 3G networks, necessitating infrastructure development in these areas.

c. Analysis of Survey Results on the Use of Digital Services in Sulaymaniyah

To measure the impact of digital infrastructure on daily life in Sulaymaniyah, a field survey was conducted that included a diverse sample of residents. Participants were selected according to criteria including age, occupation, and geographic location to ensure fair representation of all segments of society. The survey focused on the extent of digital service use, user satisfaction with internet quality, digital gaps, and the most prominent challenges facing residents in benefiting from digital transformation. The data was analyzed using statistical methods and data analysis software to arrive at accurate results that support the research hypotheses.

First: Analysis of the Extent of Residents' use of Digital Services Result:

1) 78% of survey participants regularly use digital services, such as e-payments, online government services, and e-learning platforms.
2) 64% of users indicated that digital services have facilitated their daily lives, particularly banking services and e-payments.
3) 32% of participants in peripheral areas stated that they are unable to fully utilize digital services due to poor internet connectivity.

Analysis of the Results:

1) Digital services have become a major part of most residents' lives, but they still face obstacles in peripheral areas where digital infrastructure is weak.
2) There is a need to develop internet networks in rural areas to expand access to digital services.

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Second: Level of Resident Satisfaction with the Quality of the Internet and Communication Networks

Results:

1) 60% of survey participants consider the quality of the internet in Sulaymaniyah to be acceptable or good, while 40% consider it unstable or weak.
2) 78% of users in central neighborhoods are satisfied with the internet speed, compared to only 45% in peripheral areas.
3) 85% of participants believe that the cost of internet subscriptions is high compared to the quality of service.

Analysis of the Results:

1) Internet quality varies significantly between central and peripheral areas, indicating the need to invest in expanding communication networks.
2) The high cost of the internet is considered one of the most prominent obstacles affecting the use of digital technology.
3) Developing 5G networks could be one solution to support the spread of high-speed internet.

Third: Analyzing the Digital Divides Between Different Groups Result:

1) 74% of youth (18-35 years old) use the internet daily for educational or entertainment purposes, compared to only 41% of those over 50.
2) 50% of participants in rural areas suffer from poor internet services, compared to only 15% in urban areas.
3) 60% of government sector employees use digital services in their work, compared to only 35% in the private sector.

Result Analysis:

1) There is an age gap in internet use, with young people relying more on technology than older groups.
2) Rural areas need improvements in communication networks to ensure that all residents benefit from digital services.
3) The government sector is making progress in digital transformation, but there is still room to improve the private sector's adoption of digital technology.

Fourth: Residents' Suggestions for Improving Digital Infrastructure Result:

1) 82% of participants want to develop and make internet networks more stable.
2) 71% of residents call for reducing internet costs to make them more accessible to all.
3) 68% of participants suggest increasing the number of digital government services to reduce the need for paperwork.

Analysis of the Results:

1) Improving internet quality is the highest priority for residents.
2) Reducing prices will increase the spread and wider use of digital services.
3) Expanding the scope of digital government services will improve the efficiency of public services and reduce bureaucracy.

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4. Hypothesis Testing

Based on statistical analysis of data collected from questionnaires, analysis of internet coverage, and the prevalence of digital services in Sulaymaniyah, the hypotheses proposed in the research were tested to assess the validity of digital gaps and the impact of investing in digital infrastructure on improving quality of life in the city.

Hypothesis 1: Peripheral areas of Sulaymaniyah suffer from a greater digital gap compared to urban areas.

The hypothesis was proven correct, as data showed that internet coverage in urban areas of Sulaymaniyah reached 85%, while it dropped to 57% in rural areas. [33]confirms that the disparity in internet penetration between urban and rural areas in Iraq remains evident, especially in cities that have not received sufficient investment in digital infrastructure. [34] also indicates that most fiber optic projects are concentrated in major city centers, resulting in poor connectivity in peripheral neighborhoods and rural areas.

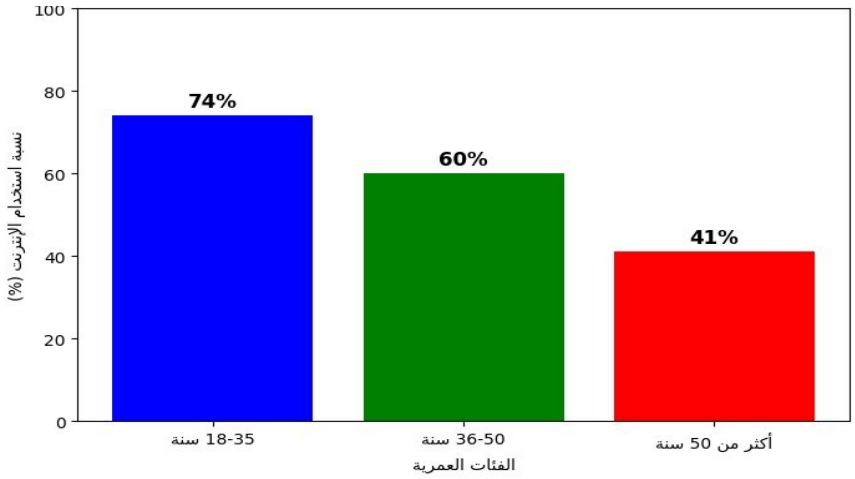

Figure 8. Analysis of Digital Gaps Between Age Groups

a. The figure above shows that young people (18-35 years old) have the highest percentage of internet use (74%), compared to older age groups, where the percentage drops to 41% for those over 50 years old.
b. These results indicate that there is a clear digital divide between age groups, which reinforces the need to develop educational and technological policies aimed at older groups to encourage them to use digital services.
c. The Iraqi Ministry of communications (2023) also confirmed that the digital divide is not limited only to geographical regions, but also extends to age and professional differences.

Hypothesis Analysis:

The digital divide in Sulaymaniyah is in line with the general trend in Iraq, where advanced digital services are concentrated in city centers while rural areas suffer from a lack of coverage.

Government policies that promote investment in remote areas are needed to ensure sustainable digital inclusion.

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The Second Hypothesis: government investments contribute to improving the spread of digital services in Sulaymaniyah.

The hypothesis was proved correct, as reports showed that increased government investments in fiber-optic and digital infrastructure projects led to an increase in the percentage of homes connected to high-speed internet from 22% to 30% in just two years [33], [35] also explained that the expansion of government digital services and financial inclusion programs has significantly improved internet accessibility, especially in areas where digital infrastructure projects have been implemented.

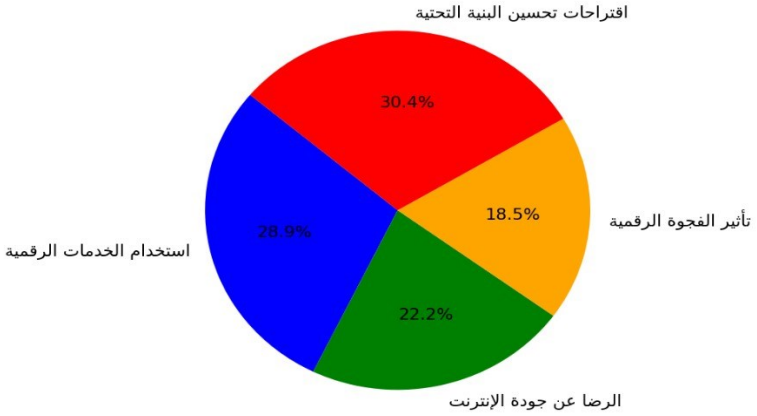

Figure 9. Analysis of The Results of The Survey on The Extent of Utilization of Digital Services in Sulaymaniyah.

a. This is in line with the UNDP report (2023), which indicated that achieving digital transformation in Iraq requires strengthening investments in communication networks, while ensuring access to modern technology to all residents without discrimination.
b. Based on these results, it can be recommended to expand the scope of fiber-optic projects, increase the number of digital service providers to enhance competition and improve quality.

Hypothesis Analysis:

a. Government investments in digital infrastructure play a vital role in improving the spread of digital services, but there are still gaps that need more funding.
b. Increasing investments in fiber optics and digital projects can lead to a more comprehensive and sustainable digital transformation.

The Third Hypothesis: the high cost of a subscription to the internet affects the spread of digital services.

The hypothesis has been partially proven correct, as the data indicate that 70% of respondents consider the cost of the internet to be high compared to their income level, however, the adoption rate of digital services is still high in urban areas, reaching 78%, while it does not exceed 50% in lower-income areas. According to the [36].the high cost of the internet is an obstacle to achieving a comprehensive digital transformation, especially in low-income communities.

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Hypothesis Analysis:

a. The cost of the internet affects the penetration rate, but it is not the only influencing factor, as factors such as quality of Service and internet speed play a fundamental role in the adoption of digital technology.
b. Therefore, it is necessary to work to reduce costs by promoting competition between service providers and encouraging policies supportive of low-cost internet.
c. The fourth hypothesis: the extent to which the population uses digital services is related to the quality and availability of the internet.
d. The hypothesis was proved to be correct based on the results of the survey, as the data indicated that 78% of users rely on digital services on a daily basis, but the quality of the internet was a decisive factor in the level of use. The statistics of the [37] also showed that regions with stable internet coverage have significantly higher rates of use of digital services compared to regions with poor connectivity.

Hypothesis Analysis:

a. Improving the quality of the internet and expanding coverage lead to an increased dependence on digital services.
b. The weak digital infrastructure in some regions continues to be an obstacle to the use of the internet for purposes such as e-learning, banking, and digital commerce.

Fifth Hypothesis: there is a disparity in the use of digital services between age and professional groups.

The hypothesis was proved correct based on the analysis of the questionnaire data, as the results indicated that young people aged 18-35 years constitute the most frequently used category of digital services, at 74%, compared to only 41% for individuals over the age of 50. The data also showed that 60% of employees in the government sector rely on digital services for their work, compared to only 35% in the private sector.

Hypothesis Analysis:

a. Young people are more likely to use technology, while older groups need training programs to enhance their digital skills.
b. The government sector is witnessing an evolution in the adoption of digital solutions, but the private sector is still lagging behind in some aspects.

The Sixth Hypothesis: the quality of the internet affects the trust of users in government digital services.

The hypothesis was proved correct, as the data showed that 65% of respondents believe that poor internet quality hinders their use of government digital services, while 58% believe that there is a need to improve data security and strengthen electronic protection. According to [38], effective digital transformation requires a strong digital infrastructure capable of supporting electronic transactions smoothly and securely.

Hypothesis Analysis:

a. Increasing the speed and stability of the internet increases users ' confidence in digital government services.

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b. The need to improve information security and ensure data protection to enhance the use of electronic transactions.

5. Results and Discussion

a. Analysis of the Impact of Digital Infrastructure on Urban Life in Sulaymaniyah

The results of statistical analysis and field surveys indicate the pivotal role that digital infrastructure plays in improving the quality of urban life and enhancing economic sustainability in Sulaymaniyah city. Previous studies have confirmed that the development of digital infrastructure directly contributes to raising the efficiency of vital sectors such as government services, the digital economy, and [39]. Based on the analysis and testing of hypotheses, the most important results can be summarized in the following points:

Conclusion of Hypothesis Testing:

1) Most of the basic hypotheses have been confirmed to be true, which reinforces the need for further investments in the development of digital infrastructure to support comprehensive digital transformation in the city.
2) The digital divide between urban and rural areas still exists, as data have shown that the percentage of internet coverage in central areas reaches 85%, while it decreases to 57% in rural areas, reflecting the disparity in access to digital technology [40].The high cost of the internet is a major challenge, but it is not the only obstacle, as the results of the survey revealed that 70% of respondents believe that prices are high, while 65% suffer from quality of Service and fluctuating connection speed, which affects the extent of their dependence on digital services [41].
3) There is a significant disparity in the use of digital services between the age and professional groups, where the percentage of dependence on digital services among the 18-35 age group was about 74%, while the percentage decreased to 41% for individuals over the age of 50, reflecting the need to promote digital culture and training in the use of modern technology [41].

b. Analysis of the Relationships Between Digital Infrastructure and Urban Life

Summary of the Analysis of the Questionnaire Results

1) The dependence on digital services is increasing significantly, as the results showed that 78% of respondents use digital services daily, but challenges related to the quality of the internet and its costs continue to affect the spread of these services.
2) Varying levels of internet access between different regions, as people in peripheral and rural areas suffer from poor connectivity, which reduces their chances of benefiting from digital transformation [42].
3) There is a high demand for improving internet networks and enhancing digital government services, with 82% of respondents indicating their desire to expand the range of digital services to facilitate the completion of government transactions electronically.
4) The results support the research hypotheses about the importance of developing digital infrastructure as one of the key factors to ensure the sustainability of digital services and achieve a more comprehensive digital transformation.

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Summary of Analysis and Results

1) Sulaymaniyah is one of the leading digital cities in Iraq, but it faces challenges related to the uneven spread of the internet between different regions, as the reports of the Arab [43]confirm that the lack of investments in peripheral areas exacerbates the digital divide.
2) There is an urgent need for additional investments in fifth-generation (5G) networks and fiber-optic infrastructure, as studies show that modern communication technologies enhance the opportunities for digital transformation and contribute to driving the economy [44]
3) Statistical data confirm that the development of digital infrastructure increases the adoption of electronic transactions, reflecting the importance of digital technology in supporting the digital economy and enhancing government productivity.
4) Despite the marked improvement, some regions still need sustainable solutions to ensure that all groups have access to the internet and digital services, which confirms the need to adopt government policies that support digital inclusion and stimulate innovation [45].

IV. CONCLUSIONS AND RECOMMENDATIONS A. Main Conclusions

1. The research results indicate that digital infrastructure plays a vital role in achieving digital transformation and promoting urban development in Sulaimaniyah city. The study showed that there has been a significant improvement in the level of digital services in the city, but this improvement is still unbalanced between urban and rural areas, as some neighborhoods suffer from poor internet coverage and infrastructure necessary to accommodate advanced digital services. It was also found that there is a direct relationship between the development of digital infrastructure and the level of dependence on technology in everyday life, as regions with strong communication networks are witnessing a greater demand for digital services, such as electronic financial transactions and online government services.
2. The study also revealed that the quality and cost of the internet are among the factors affecting the spread of digital services, as high prices and poor quality in some regions lead to low usage rates. Despite the availability of many digital services, the digital divide remains a major challenge, especially between different age groups, as the results showed that young people are more likely to use digital services compared to older groups. The disparity in digital knowledge also plays a role in determining the extent to which the population benefits from available technology.
3. The study confirms that the development of digital infrastructure is not only limited to improving communication networks, but also includes enhancing the culture of digital transformation, and providing innovative solutions to support the integration of technology with vital sectors such as education, health, and government services. Based on these conclusions, a set of practical recommendations can be developed that will enhance the role of digital infrastructure in achieving sustainable development and digital transformation in Sulaimaniyah.

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B. Practical Recommendations for The Development of Digital Infrastructure

1. Improving the digital infrastructure requires taking a set of practical measures that ensure the access of modern technology to all segments of society and enhance the role of digital services in everyday life. The most prominent of these recommendations is the need to invest in the development of communication networks and expand internet coverage, especially in rural and remote areas, to ensure the provision of an integrated digital environment. Improving the quality of the internet through the introduction of fifthgeneration and fiber-optic technologies will significantly contribute to supporting the digital economy and increasing the efficiency of e-government services.
2. Work should also be done to develop fair pricing policies for internet services that ensure their provision at appropriate prices to various segments of society, while enhancing competitiveness among digital service providers to provide innovative solutions that meet the needs of the population. It is necessary to strengthen cooperation between the public and private sectors for the development of digital infrastructure, where the government and major technology companies can make joint investments that contribute to accelerating digital transformation processes and achieving widespread economic and social benefits.
3. The promotion of digital culture among the population is a key element in the success of the digital transformation process, through the launch of training and awareness programs aimed at increasing awareness of the importance of technology and how to use it effectively in various sectors. Local governments, educational institutions and the private sector can cooperate in providing free training courses in the field of digital skills, which contributes to improving the level of digital knowledge and increasing the rates of use of electronic services.

C. Proposals for Future Studies

1. Due to the importance of the research topic, future studies can be conducted that focus on analyzing the impact of digital transformation on specific sectors such as health, education, and e-commerce, to identify the opportunities and challenges faced by these sectors in light of technological progress. Comparative studies can also be conducted between different cities that adopt different digital policies, to understand the impact of digital transformation strategies on quality of life and economic development.
2. In addition, research on the impact of the digital divide on different social groups can be expanded, studying ways to improve access to the internet and digital services in less privileged areas. It is also important to study the psychological and social factors that influence the adoption of modern technology, in order to develop effective strategies to enhance the use of digital tools and achieve their integration with the daily life of citizens.
3. Based on the above, the development of digital infrastructure is an essential step towards achieving sustainable urban development in Sulaymaniyah, and this development requires integrated efforts among various actors to ensure the provision of an advanced

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digital environment that allows citizens to fully benefit from technology and enhance the efficiency of the economic and service sectors in the city.

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