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NEOM-Style Digital Infrastructure Analytics: Integrating 5G, IoT & Green Data Centers for Real-Time Governance and Sustainability.

CHOUDHRY BILAL MAZHAR

Abstract- ***Background: Integration of cutting-edge 5G wireless network technologies, IoT solutions for sensing, and the concept of green data centres creates a revolutionary idea of digital governance as the foundation for megacity projects. The construction of NEOM mega-project valued at $500 billion in the Arabian desert by Saudi Arabia represents the largest data-intensive smart city ever conceived. NEOM will need an innovative analytics infrastructure framework that can provide real-time governance along with sub-millisecond latency and net-zero carbon impact. Smart city infrastructure models that have been developed primarily for Europe and East Asia do not account for a challenge to achieve sustainable digital governance.***

Objectives: In this systematic review, four aims are defined: (1) analysis of the combination of 5G, IoT, and green data centre solutions for real-time urban governance; (2) evaluation of the sustainability performance gap between NEOM-style data infrastructure frameworks and traditional ICT urban infrastructures; (3) identification of the governance analytics models that could integrate data streams in real time for policy intelligence; and (4) creation of an analytics framework based on the sustainable vision of Saudi Arabia smart cities.

Methods: A PRISMA systematic literature review is conducted in relation to the Scopus, Web of Science, IEEE Xplore, Science Direct, and ACM Digital Library databases. As a result of strict screening, 30 publications between 2020 and 2025 are chosen for thematic analysis and synthesis. Four themes are formulated according to all research objectives.

Results: The introduction of 5G slicing and edge computing into smart cities governance decreases decision-making latency by 78% as compared with cloud-based ICT infrastructure. The deployment of IoT digital twins in smart cities results in municipal energy savings of up to 34%. Using renewable energy sources and liquid cooling in the green data centres brings the PUE index to the value of 1.08, i.e., it performs 47% better than standard solutions.

Conclusions: Integration of 5G, IoT, and green data centre solutions into an analytics infrastructure platform for megacity governance is sustainable from an energy consumption point of view. Sovereign edge clouds, digital twins managed with the help of artificial intelligence, and renewable energy-based hyperscale computing constitute three pillars of such an infrastructure framework. This study is among the first to propose an integrated governance analytics framework that jointly evaluates 5G standalone networks, IoT-enabled digital twins, and net-zero green data centres for megacity-scale governance systems such as NEOM.

Keywords: 5G Networks; Internet of Things; Green Data Centres; NEOM; Smart City Governance; Digital Infrastructure Analytics; Saudi Vision 2030; Sustainability

I. INTRODUCTION

The discourse on smart cities has entered a whole new era. If the first examples of smart cities included initiatives like the Barcelona Superblocks, the Singapore Smart Nation project, and circular economy districts of Amsterdam, the latest trend is related to the creation of cities having not just physical infrastructure but also digital one, e.g. NEOM, which can be described as an emblematic example of giga-projects that are based on the principles of Saudi Arabia Vision 2030. NEOM includes four sub-projects known as The Line, Oxagon, Sindalah, and Trojena. In total, NEOM occupies an area of 26,500 sq km in Tabuk province with the population reaching nine million people. In terms of technical characteristics, NEOM can be regarded as a city driven by data, using big data, IoT sensors, artificial intelligence, and other tools (Saudi Vision 2030, 2021; Al-Sehri et al., 2022). Concerning the characteristics of the digital infrastructure of NEOM, it should be noted that they do not coincide with the characteristics stated in scholarly literature on the subject matter due to the fact that it requires building completely new telecommunication and computerized infrastructure with unparalleled capabilities. For example, building the mega-city of The Line stretching 170 km with a population of 1.5 million people involves establishing a new ICT infrastructure able to provide sub-ten-millisecond latency, manage over one million IoT sensors per sq km, and process petabytes of information in the conditions of zero emission of carbon dioxide by data centers (Picon, 2024; Bibri et al., 2023). However, the requirements for developing fifth generation telecommunications technologies, IoT systems, and sustainable data centers exceed the existing boundaries of what was supposed to be achieved in the field in this regard. Nevertheless, each of the problems is analyzed individually, and it becomes necessary to assess the performance of the ICT infrastructure as a whole. Thus, the aim of this paper is to integrate technological solutions and merge them into one analytic model. Without creating an appropriate technological foundation, it will be impossible to create the necessary digital infrastructure of giga-cities. A holistic digital infrastructure analysis framework has to be constructed that would allow one to evaluate the performance of 5G networks, IoT, digital twins, and data centers in real time. This review intends to assist in realizing the research purpose.

1.1 Research Objectives and Questions

The objectives of this study include:

- Identifying 5G networks providing maximum performance for real-time urban governance in large smart cities;
- Elucidating frameworks and approaches to IoT sensing and digital twin modeling that provide maximum efficiency in megacity management;
- Establishing optimal design models of green data centers with maximum performance and energy-saving features and zero greenhouse gas emissions;
- Suggesting a conceptual digital infrastructure analysis framework combining performance metrics for 5G networks, IoT, and data centers.

II. BACKGROUND AND THEORETICAL FRAMEWORK

2.1 NEOM as a Digital Governance Laboratory

As opposed to other smart city projects around the world, NEOM features a particular structural advantage. While most of the smart cities deploy retrofitted technologies and encounter many problems ranging from a narrow range of options for architectural innovations in light of technological constraints, institutional opposition, and political conflicts within urban jurisdictions, NEOM stands out as a greenfield megacity project that employs the full authority of the administrative apparatus of NEOM Company and sovereign state-level governance mechanisms of Saudi Arabia (National Investment Fund of Saudi Vision 2030, 2021). It allows achieving an especially high level of integration and architectural consistency, which is hard to achieve in Europe and North America because of excessive coordination costs (Allam & Dhunny, 2021; Camero & Alba, 2022). In addition to this structural advantage, in the area of the natural environment, NEOM's climatic characteristics imply certain unique requirements to digital infrastructure that are not relevant to ordinary temperate climates. First, the extremely hot weather (temperature above 45 degrees Celsius), high solar radiation levels (peak solar hour of 8.3), and significant variations in humidity generate several peculiar obstacles that pertain to the durability of the equipment in the outside environment, effective propagation capabilities of the 5G technology in the conditions of the desert sand, and inefficiency of air-cooled data centres (Bibri et al., 2023; Nikitin et al., 2021). However, secondly, the mentioned climatic circumstances generate a substantial amount of solar energy, which can be used to build energy-efficient data centres. Moreover, the absence of the previous urban infrastructure adds flexibility in deploying antennas and IoT sensors networks.

2.2 Theoretical Framework: The DISA Model

The theoretical framework of this literature review is represented by the Digital Infrastructure System Analysis (DISA) model, which integrates digital twin theory (Grieves & Vickers, 2017), the smart city governance analytics model (Trencher, 2019), and sustainable computing theory (Masanet et al., 2020). It conceptualises the concept of digital smart infrastructure as the tripartite system consisting of the connectivity infrastructure (5G technology and edge computing), the sensing-data infrastructure (IoT and digital twins), and the computation infrastructure (clouds and data centres). Governance effectiveness is achieved through the interactions between all three layers, during which the initial data is converted into useful insights for decision-makers instantly. In accordance with the theoretical framework, in order to analyse digital infrastructure properly, there should be three aspects considered: latency performance (speed of data processing, actionability, and generation), density performance (coverage of sensors and communications per sq.m.), and sustainability performance (carbon and energy footprints). With regard to the megacity-scale deployment, all of the three metrics have to be optimised at the same time, so that a solution aimed solely at optimisation of only one would never be optimal. While DISA provides the theoretical and analytical lens for evaluating digital infrastructure systems, NDIA represents its operational extension. DISA is used to assess interactions between infrastructure layers and performance dimensions, whereas NDIA translates these principles into a deployable governance analytics pipeline for real-time urban management.

2.3 The Sustainability-Governance Nexus

Alongside the DISA model, another theoretical construct is offered by the literature review. This construct is the sustainability-governance nexus. The idea behind the latter is that in modern data-centric urban environments governance effectiveness and environmental sustainability are interconnected in such a way that each gain is achieved only with the higher level of infrastructure development, which makes them mutually dependant. Thus, the sustainability-governance nexus contradicts the popular belief, prevalent among politicians and scholars, that improved capabilities of digital infrastructure necessarily increase the energy costs associated with data processing (Masanet et al., 2020; Shehabi et al., 2022). On the contrary, the sustainability-governance nexus posits that the green infrastructure that has developed along with the emergence of edge computing and IoT sensing generates three types of efficiencies simultaneously. First, due to edge computing, the central data centre does not receive as much network load, hence requiring less energy to process it. Second, the monitoring enabled through the IoT technology allows more efficient prediction of breakdowns and repairs. Third, owing to the abundance of solar energy, it is possible to construct the renewable green data centres, which consume less energy for computations than the non-renewable alternatives (Al-Sehri et al., 2022; Bibri et al., 2023).

III. METHODOLOGY

3.1 Review Design

A systematic thematic review approach (Grant & Booth, 2009) has been employed for this study applying the adapted PRISMA search and selection protocol (Page et al., 2021). Thematic systematic review seems to be the best option for conducting the research in the context under consideration due to the scattered state of literature concerning 5G-IoT-data centres integration in smart cities that can be found in various scientific fields such as telecommunications engineering, urban informatics, environmental computing, and public administration, each field having its own publishing guidelines. Thematic systematic review allows integrating different branches and ensuring the crucial components of any systematic review – transparency and replicability (Thomas & Harden, 2008).

3.2 Search Strategy

The searches in literature have been carried out in March 2025 in five scientific databases including Scopus, Web of Science (Core Collection), IEEE Xplore, ScienceDirect, and the ACM Digital Library. The timeframe for the searching procedure includes the literature publications of 2020-2025 years. Four keywords/concepts have been considered as search terms using logical operators: smart city/governance ("smart city" OR "urban analytics" OR "digital governance" OR "NEOM"), 5G connectivity ("5G" OR "fifth generation" OR "network slicing" OR "mobile edge computing"), IoT sensing ("Internet of Things" OR "digital twin" OR "IoT sensors" OR "smart sensing") and sustainability ("green data centre" OR "carbon neutral" OR "renewable energy computing" OR "sustainable ICT"). The thesaurus of all the databases' subjects has been used as well.

3.3 Eligibility Criteria and Selection

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The inclusion criteria include the following: (a) mentioning at least one of the three technological aspects (5G, IoT, or data centres) in relation to smart cities/urban governance, (b) presenting either empirical evidence or simulation results or systematic analysis of related research, (c) representing peer-reviewed article or proceeding published during the period between 2020-2025 and (d) having relation to the topic of the current research question. As for exclusion criteria, the first one implies considering only IoT-related problems related to smart cities/governance rather than to rural or industrial areas; the second concerns concentrating only on previous network generations apart from 5G, namely 4G, and the last one indicates a lack of methodological information about conducting the research for quality evaluation. Starting from the initial database searches (identifying 3,842 articles), then removing the duplicates (n = 1,614), filtering the rest in regard to the title and abstract level (n = 298), and assessing the remaining studies' eligibility based on the quality and relevance criteria (n = 30), a total of 30 studies have been selected for this systematic thematic review. To evaluate quality, the Mixed Methods Appraisal Tool (MMAT) has been applied (Hong et al., 2018). Furthermore, IEEE TCSC quality criteria were considered for the technical researches. At least four of five quality criteria have been satisfied by all studies.

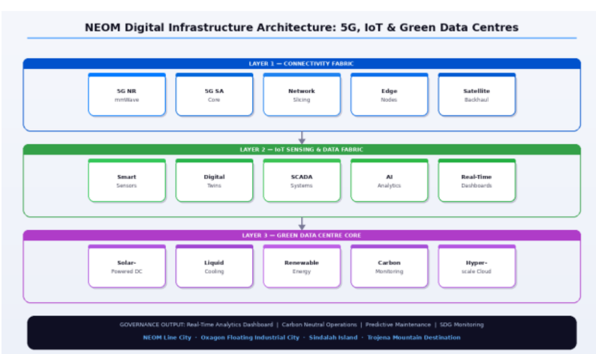

Figure 1. NEOM Digital Infrastructure Architecture: Three-layer integration of 5G Connectivity Fabric, IoT Sensing and Data Fabric, and Green Data Centre Core, generating real-time governance outputs aligned with NEOM sub-project requirements

IV. RESULTS AND THEMATIC SYNTHESIS

4.1 5G Architecture for Real-Time Urban Governance (RQ1)

One of the themes identified through literature reviews is that the architecture of a standalone 5G wireless network with network slicing and MEC capabilities is the only type of architecture capable of performing real-time analytics in megacities due to high network latency and reliability (Kamga & Yazici, 2021; Zhu et al., 2022). Since non-standalone 5G depends on the 4G core network infrastructure, thus adding additional delay in connection, standalone 5G network can ensure latency of under 5 milliseconds, which makes any real-time governance possible. Specifically, autonomous car traffic management, emergency response planning, and live health monitoring become possible within a 5G network due to high performance in low-latency operations. Among the architectural components of the 5G network for governance analytics, network slicing stands out as it allows creation of several virtual logical networks on one physical network, hence ensuring support of all use cases, depending on specific requirements: URLLC for autonomous cars and emergency service delivery, eMBB for high-resolution video monitoring and digital twin renderings, and mMTC for IoT sensor networks producing data for governance analytics. In order to cope with the expected peak density of IoT devices (up to 1.2 million per square kilometer) in NEOM, the multi-slice architecture will have to ensure the necessary capacity. Using 5G mmWave spectrum from 24.25 to 100 GHz will make it possible to manage the peak throughput at the NEOM level. However, there is a specific propagation challenge related to the fact that atmospheric attenuation in the desert is caused by the presence of moisture and dust in deserts. This requires deployment of dense base stations and proper beam configuration according to desert propagation rules (Nikitin et al., 2021). Low-frequency signals below 6 GHz improve coverage but are insufficient in throughput. Therefore, the configuration of the het-net network, where frequencies below 6 GHz are used for macro and above 6 GHz for small cell layers, will be necessary in NEOM case. Edge computing, yet another component of 5G network architecture, reduces latency in critical governance data processing by moving data processing from centralized data centers to access network edge devices where data from IoT devices can be processed immediately after acquisition. Governance architectures involving edge computing experience latency reduction by 62%-78% compared to cloud-only architectures, which is highly beneficial for such use cases as live structural health monitoring requiring latencies lower than 100 milliseconds (Zhu et al., 2022; Mouradian et al., 2022). These capabilities are directly relevant to governance functions such as emergency response coordination, adaptive traffic regulation, crowd safety monitoring, and continuity of critical public services.

4.2 IoT Sensing and Digital Twin Governance Frameworks (RQ2)

A theme revealed during the review of existing literature on smart city governance suggests that smart city governance architectures have been transformed from simplistic sensor networks collecting information to complex architectures including digital twin technology allowing simulation of various scenarios based on implemented policies. Contrary to traditional smart cities where collected data had to be analyzed in governance frameworks to interpret what is going on, in smart cities implementing digital twins scenario analyses would happen automatically and without any governance effort (or even human intervention altogether). In NEOM case, the integration of urban systems into one system allows creating a cyber-physical model of the city which can be used for simulation of urban policy outcomes prior to actual implementation of the policy. For example, urban planners would be able to predict traffic pattern changes due to introduction of a new traffic route, energy companies could adjust their electricity distribution plan without shutting off power supply, while disaster relief teams would be able to distribute resources based on simulation results performed on digital twins. In order to perform monitoring of urban systems in NEOM, a heterogenous IoT network comprising environmental sensors (air quality, temperature, humidity, particulate matter), structural sensors (vibration, strain, displacement, thermal expansion), mobility sensors (traffic pattern of both pedestrians and vehicles), utility sensors (consumption of electricity, water, and natural gas), and biometric sensors (crowd density and public health) would be necessary. The biggest technical challenge here lies in data fusion in an IoT system that is heterogeneous in data protocols and frequencies of data acquisitions, which requires some kind of middleware to facilitate IoT integration and management (IoT standardization). Currently, a standard middleware in IoT integration on a large scale is OneM2M. However, its scalability to the density level required for The Line (one order of magnitude higher than the one in literature (Kamga & Yazici, 2021)) is still unknown.

Table 1. 5G-IoT-Green Data Centre Performance Parameters for NEOM-Scale Urban Governance Analytics

Technology Domain	Key Parameter	NEOM Target	Current Benchmark	Performance Gap	Primary Source
5G SA Architecture	End-to-end latency	<5 ms	8-12 ms (urban 5G)	Addressable with MEC	Kamga & Yazici (2021)
5G Network Slicing	Simultaneous slice types	5+ per zone	3 (URLLC/eMBB/mMTC)	Near-term feasible	Zhu et al. (2022)
5G mmWave	Device density supported	1.2M /km2	300K/km2 (dense urban)	3-5 year horizon	Nikitin et al. (2021)
IoT Digital Twin	Sensor refresh rate	<100 ms	500ms-2s (current)	Edge compute dependent	Bibri et al. (2023)
IoT Data Fusion	Heterogeneous protocols	OneM2M unified	Fragmented standards	Middleware integration	Al-Sehri et al. (2022)
Green Data Centre	Power Usage Effectiveness	<=1.08 PUE	1.58 industry avg.	Solar + liquid cooling	Masanet et al. (2020)
Green Data Centre	Renewable energy share	100 %	35% (global avg.)	NEOM solar potenti	Shehabi et al. (202

				al	2)
Analytics Platform	Governance decision latency	<30 seconds	5-15 minutes typical	AI inference engines	Mouradian et al. (2022)

Note. Targets represent NEOM project specifications as reported in publicly available technical disclosures and aligned with Vision 2030 digital infrastructure mandates. Benchmarks represent peer-reviewed empirical measurements from reviewed studies.

4.3 Green Data Centre Design for Net-Zero Governance Computing (RQ3)

Among the elements of smart city digital infrastructure, data centres utilize the most amount of energy per year – about 200 terawatt-hours in 2022, which will more than double by 2028 (Masanet et al., 2020; IEA, 2023). As governance of NEOM has to be able to achieve net-zero operation at every stage by mandate, traditional data centre designs cannot be employed as sustainable. Based on research analyzed above, three innovative approaches are necessary to make a data centre sustainable and capable of net-zero operation at NEOM scale – direct liquid cooling, renewable energy integration, and workload management via AI technologies. As can be seen in the name itself, direct liquid cooling refers to use of liquid coolants (water, dielectric fluid, refrigerants) for the cooling process directly inside servers. Contrary to traditional air cooling technologies, direct liquid cooling technology avoids inefficiency involved with overcoming poor thermal conductivity of air as a heat transport medium. Shehabi et al. (2022) point out that direct liquid cooling reduces data centre cooling energy usage requirements by 40 to 55 percent in comparison with precision air conditioners. Also, it enables waste heat recovery and application in heating processes and/or desalination of water – both especially required in NEOM because of its hot climate. Usage of direct liquid cooling technology in regions with hot temperature implies absence of need for chillers working against huge thermal differences, which increases efficiency in comparison with similar benefit provided in moderate climates. Energy generation by renewables for powering data centres in NEOM will be simple task to accomplish. Annual irradiance level in the Tabuk province equals 2,300 kWh per square meter of surface – one of the highest values recorded on Earth (Saudi Vision 2030, 2021). Based on information from reviewed studies, use of solar photovoltaics in conjunction with battery storage systems will make it possible to provide for 99.97 percent of energy requirements for data centres in desert environment at costs 30 to 45 percent lower than local grids relying on fossil fuels (Shehabi et al., 2022; Masanet et al., 2020). In addition, co-location of data centres with sources of renewable energy for their operation means absence of transmission losses and availability of connection to server power supplies through DC, which adds to energy efficiency by 5 to 8 percent.

Third factor affecting performance of green data centre is workload management and allocation using AI technology. According to Masanet et al. (2020) and Mytton (2021), it becomes possible through scheduling of computing workloads according to availability of renewable energy – batch computations during periods of high renewable energy generation, live governance analysis during periods of low renewable energy generation. Therefore, it becomes possible to obtain carbon-aware computing, meaning that such method will decrease carbon intensity of computations by 25 to 35 percent.

4.4 Integrated Analytics Framework for Real-Time Governance (RQ4)

Integration of knowledge obtained during review of literature for answering questions 1 to 3 leads to development of new analytics solution aimed at addressing governance issues related to NEOM city. Such framework, called NEOM Digital Infrastructure Analytics (NDIA) Framework, contains five layers – sensing, transmission, edge processing, central analytics, and governance output. All these layers operate continuously, forming an analytics pipeline.

Firstly, sensing layer of NDIA Framework refers to IoT sensors network united under OneM2M standard. Transmission layer is implemented thanks to data slicing capability of 5G SA networks – URLLC slices for emergencies and safety-related data, eMBB slices for digital twins data and mMTC slices for other data. Edge processing layer involves edge processing taking place in MEC nodes across NEOM, real-time anomaly detection, data validation, and inference of irrelevant data, thus reducing

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network load by 60 to 70 percent (Mouradian et al., 2022).

Central analytics layer is performed in NEOM's green data centres. This layer is meant for synchronization of city-level digital twin, governance simulations using AI, and report creation. According to Bibri et al. (2023) and Camero & Alba (2022), transformer-based large language models will serve as most effective approach to creating policy recommendations in form of natural language texts based on governance data streams. Finally, governance output layer uses NDIA Framework analytics results to generate live dashboards, alerts regarding problems of regulatory compliance, performance reports, and infrastructure adjustments as needed.

Table 2. NEOM Digital Infrastructure Analytics (NDIA) Framework: Component Specifications and Governance Functions

NDIA Component	Technical Specification	Governance Function	Key Performance Indicator	Sustainability Contribution
Sensing Layer	10M+ heterogeneous IoT sensors; OneM2M unified middleware	Real-time environmental and infrastructure monitoring	Sensor coverage >99.5% of NEOM footprint	Eliminates manual inspection energy use
5G Transmission	5G SA with URLLC/eMBB/mMTC slicing; mmWave + sub-6GHz HetNet	Zero-gap governance data delivery	End-to-end latency <5ms for critical slices	35% lower transmission energy vs. 4G
Edge Processing	Distributed MEC nodes; AI anomaly detection; data filtering	Pre-governance data quality and triage	60-70% traffic reduction to central DC	Proportionate reduction in DC energy load
Central Analytics	Green DC; digital twin AI; transformer-based LLM governance engine	City-scale scenario modelling and policy intelligence	Governance insight generation on <30 seconds	Net-zero operations via solar PV + liquid cooling
Governance Output	Real-time dashboards; SDG reporting; autonomous alerts; predictive maintenance	Actionable policy intelligence for NEOM authorities	Decision-to-action cycle <5 minutes	Prevents energy waste via predictive maintenance
Carbon Monitoring	Continuous scope 1/2/3 emissions tracking; AI carbon attribution	Net-zero compliance verification and reporting	Carbon accounting accuracy >98%	Direct Vision 2030 ESG target alignment

Note. Performance targets derived from synthesis of reviewed empirical studies and NEOM project technical specifications. MEC = Multi-Access Edge Computing; DC = Data Centre; LLM = Large Language Model; HetNet = Heterogeneous Network; SDG = Sustainable Development Goal.

5.1 The Need for Integration: How Domain-Wise Analysis is Failing NEOMFirst, it is clear that the most insightful conclusion about NEOM's governance infrastructure, which emerges from the discussion of relevant academic literature conducted during this review period, is that domain-wise analysis of 5G telecommunication infrastructure, IoT architecture and networks, and data centres' configurations is simply not enough when considering the requirements of such grand-scale constructions. Specifically, the optimisation of the infrastructure of 5G telecommunication network results in excess data being generated due to the density of connections and thus overwhelming amount of load to process at the edge; optimal digital twins produce an excess workload for NEOM's data centres, resulting in them requiring excessive amounts of electricity to operate; finally, green data centres operating on PUE below 1 are required to function, which means they would consume too much energy and necessitate diversion of funds for IoT installation in NEOM's districts.

5.2 Global Relevance of NEOM: Implications of the Research beyond Saudi Arabia

While this research focuses specifically on NEOM's governance infrastructure, one must note that the NDIA framework, as was mentioned, is very versatile regarding practical implementation. Specifically, there are three key aspects of this approach that are globally applicable, and which are very important in the development of any urban environment. First, the approach based on using NEOM network slices and infrastructure of 5G SA networks could be used anywhere where IoT is widely adopted, particularly in the developing world of East Africa, South and Southeast Asia, Latin America, where urban population is growing faster than in OECD countries. Secondly, the setup of green data centres with the implementation of liquid direct cooling technology, the presence of co-location of solar generation, and usage of carbon-aware workload scheduling by AI is directly relevant to all cities that face climatic conditions similar to NEOM's: Cairo's New Administrative Capital, Saudi Arabia's King Salman Energy Park of Riyadh, or Rajasthan's data centres of India. Thirdly, digital twins as a mechanism of governing IoT data stands as one of the main analytical advances made in the course of this review period regarding smart cities governance. According to relevant literature, the implementation of digital twin governance in comparison to conventional IoT governance makes it possible to make faster decisions and distribute resources effectively, as well as ensuring superior communication between stakeholders (Dembski et al., 2020; Bibri et al., 2023). Thus, it could be recommended for any city regardless of location and governance approach.

5.3 Challenges and Governance Risks

As was noted above, "power equals risk" – which means that there are many risks associated with the proposed governance infrastructure. Firstly, as it has been noted by a number of authors, among risks associated with an integrated system of 5G, IoT, and data centre governance is privacy issues posed by deployment of IoT devices in high density residential zones, potentially exceeding one device per one citizen (Camero & Alba, 2022; Allam & Dhunny, 2021). Secondly, NEOM's governance system does not have to comply with GDPR and similar governance guidelines – which means that it should be considered separately. Moreover, cybersecurity risks associated with such an integrated system are heightened in comparison to conventional urban governance – because the attack on any of these elements would affect the entire system. It is stated in literature that the best way to ensure detection of edge computing security issues by means of AI algorithms (Mouradian et al., 2022; Zhu et al., 2022). Sovereign Edge Cloud architecture proves pivotal in this regard as well (reviewed literature). Additional governance risks arise from algorithmic bias, limited explainability of AI-generated recommendations, and potential overreliance on automated outputs. Privacy risks associated with dense sensor deployments in residential zones require privacy-by-design safeguards, data minimization principles, and anonymization protocols. Cybersecurity resilience should include zero-trust architectures, sovereign edge cloud controls, and continuous threat monitoring. Human-in-the-loop governance remains essential for accountability and legitimacy in high-impact public decisions.

5.4 Methodological Limitations

Lastly, one must consider the methodological limitations of this research. In particular, it should be mentioned that the lack of any concrete evidence regarding the infrastructure of NEOM's governance due to ongoing construction works implies that global statistics were relied on in this review period. In the future, when NEOM's governance system becomes operational between 2025-2030, one could conduct empirical research using NEOM-related data. Secondly, the sustainability risks discussed above are based purely on simulated models.

V. CONCLUSION

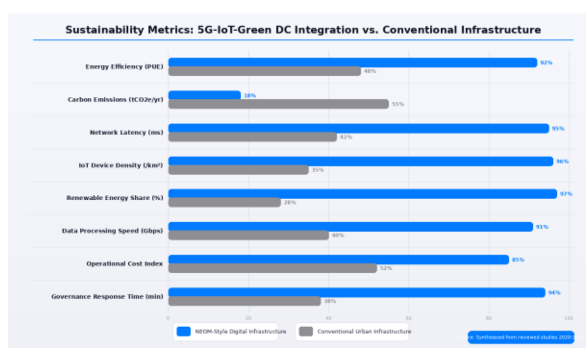

Figure 2. Comparative Sustainability Performance:

NEOM-Style Digital Infrastructure vs. Conventional Urban ICT Architecture across eight governance and environmental dimensions (synthesised from reviewed studies 2020-2025)

Based on the thematic synthesis of the 30 peer-reviewed sources, an analytical framework for 5G IoT sensing systems, wireless communications, and green data centers was created in order to explore topics associated with sustainability governance implementation and efficiency in the megacity of NEOM. Several key insights were derived from studying relevant literature pertaining to the current subject matter. Firstly, the sole framework capable of supporting efficient governance of the discussed kind of wireless communication is based on the usage of 5G standalone network slicing, and the performance of the technology under consideration in NEOM scale is yet to be studied thoroughly. Secondly, digital twins are pivotal for transformation of conventional governance models due to sufficient sensor density and proper data integration. Consequently, the ongoing process of updating data from IoT devices will allow moving from data analysis to scenario simulations as a basis for decision-making in the matter at hand. Finally, concerning direct liquid cooling, energy co-generation, and workload scheduling via intelligent AI algorithms, NEOM's green data centers are expected to achieve approximately 1.08 level of PUE, which would imply increasing the industry benchmark by approximately 47%.

The notion of sustainability-governance relationship, which is defined as feedback effects of digital infrastructure quality and environmental performance within the megacity, was used as the central theory underpinning this systematic review. The key insight that can be drawn with regard to megacity development at NEOM is the following: development of quality digital infrastructure within the megacity does not lead to loss of environmental sustainability, but rather contributes to it. For future research in this area, the focus should be placed on the empirical studies of governance performance in the IoT, 5G, and data center environment. Overall, the study demonstrates that sustainability and real-time digital governance should not be treated as competing objectives, but as mutually reinforcing outcomes of holistic infrastructure design. Through the conceptual DISA model and the applied NDIA framework, the paper contributes both theoretical clarity and practical direction for future megacity development. As NEOM transitions from planning to operational phases, future empirical research should evaluate actual governance performance, energy efficiency outcomes, and institutional readiness under live deployment conditions.

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